

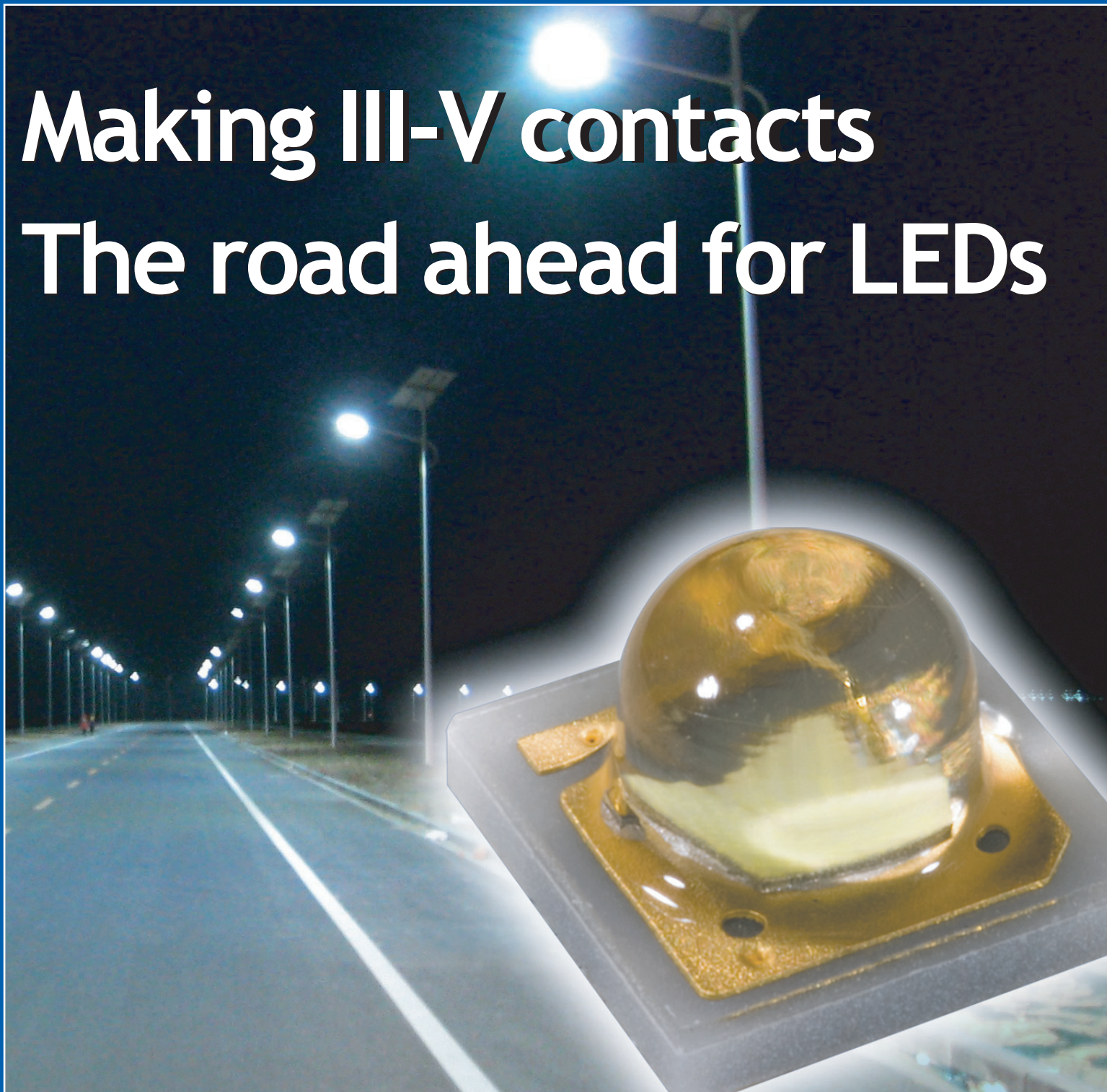
semiconductor **TODAY**

COMPOUNDS & ADVANCED SILICON

Vol. 6 • Issue 3 • April/May 2011

www.semiconductor-today.com

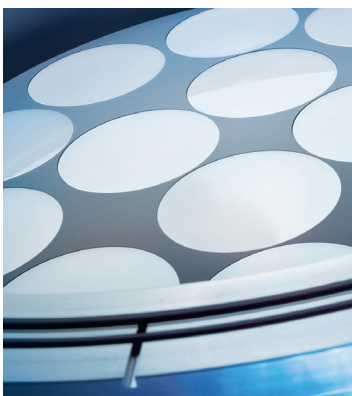
Making III-V contacts The road ahead for LEDs



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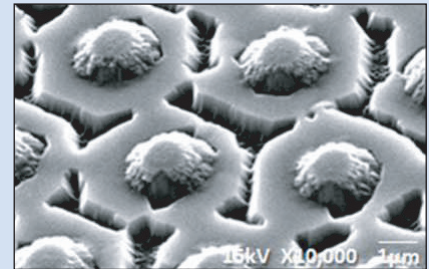
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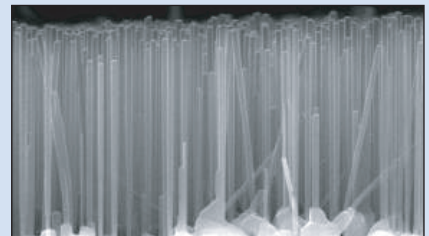
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p60 SolFocus, Bechtel and Sol Orchard have completed installation of a CPV solar plant for a California agribusiness.



p76 SEM of undoped GaN deposited on truncated-cone-patterned sapphire substrate, which can boost short-circuit current in nitride solar cells.



p85 Micrograph of high-density nanowires grown on silicon wafer, which can both boost LED efficiency and cut cost for solid-state lighting, say Leti and HelioDEL.



Cover: GBT's solar-powered street-lamps installed in Ningxia (a central province in China, close to Mongolia). The lamps' OSLOM SSL LEDs can withstand the challenging near-desert climate and provide stable performance and uniform illumination, says LED maker Osram Semiconductors. **p46**

Share prices and market shares

In the run up to May's annual CS MANTECH Compound Semiconductor Manufacturing Technology conference in Indian Wells, Palm Springs, the industry is in good underlying health. As we went to press with this issue, many firms were reporting high year-on-year growth (for details, see www.semiconductor.com) — to be reported next issue. However, many also reported greater-than-seasonal drops in revenue quarter-to-quarter.

In some cases, this can be attributed to company-specific trends such as RFMD still being heavily dependent on Nokia which, during the smartphone boom, has lost market share to Samsung and Apple (see page 9).

In other cases, results are more generally market dependent, such as LED makers Cree and SemiLEDs both reporting revenue below guidance (see pages 42 and 38, respectively). Both blame pricing pressure and (in the case of Cree) lower sales of LED chips and components as inventories are worked through at customers such as LCD TV back-light unit (BLU) manufacturers. Back up the supply chain, Q1/2011 has also seen drops in revenue for MOCVD reactor makers Aixtron and Veeco.

Consequently, the lower-than-forecast Q1/2011 sales and profits of the likes of Cree and SemiLEDs led to drops in the share prices of not only those firms but also otherwise rapidly growing firms like sapphire substrate maker Rubicon Technologies.

Some financial analysts, focused on Cree and SemiLEDs (due to the latter's initial public offering of shares last December) have been speculating whether those firms' results are representative of the LED sector as a whole, and whether the boom in the LED industry is over.

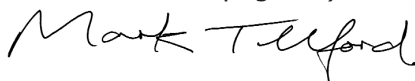
It's true that, driven by solid-state lighting initiatives, Chinese government subsidies have inflated investment in LED fabrication plants and MOCVD reactors. According to SEMIs in its quarterly 'Opto/LED Fab Forecast', 61 new LED fabs are coming online over 2010–2012 (mainly in China), with 50% capacity expansion in 2011 driving 40% growth in fab equipment spending (following a tripling last year) — see article on page 88. IMS Research reckons that MOCVD reactor shipments grew by 250% from 228 in 2009 to 798 in 2010 — see article on page 90. However, IMS forecasts no slowing of the MOCVD market in 2011, with annual shipments rising 37% to possibly exceed 1000 reactors for the first time.

Although some are warning of overcapacity in the LED sector, IMS reckons that, as Chinese uptake and economies of scale drive LED prices down, solid-state lighting will emerge fully. While Cree's revenues are falling, the pricing pressure is not necessarily an indicator of reduced demand but increased (lower-cost) competition. Indeed, just on 2 May, The Korea Times reported that LG Display is terminating its contract with Cree for LED chips for its liquid-crystal display (LCD) panels, partly through diversifying to other suppliers and partly through LG Group's component affiliate LG Innotek improving the yields of its own, in-house produced LED chips.

As well as the prospects for solid-state lighting, other sectors showing both technology and market developments include ultraviolet LEDs (as reported by Yole Développement in the article on page 79).

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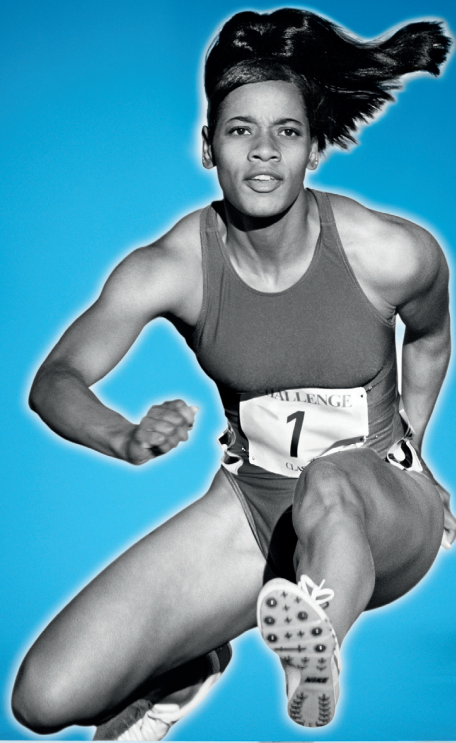
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LED shipments growing 40% to 165bn in 2011

Boom fueling niche market for semiconductor processing tool makers

The light-emitting diode market is expected to explode as unit shipments increase more than 40% in 2011 and double between 2010 and 2013, according to the report 'The Solid State Lighting Revolution: Market Analysis and Insight On Reducing Manufacturing Costs' from The Information Network.

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

Shipments of high-brightness LEDs (HB-LEDs) will grow from less than 100 billion units in 2010 to nearly 135 billion in 2011, forecasts The Information Network. In addition, shipments of LEDs for backlight units (BLU-LEDs) will grow from 20 billion to 30 billion units. Together, LED shipments will grow from 120 billion to 165 billion units.

In 2010, Nichia led the market with a 15% share (down from 16% in 2009). Samsung LED rocketed to second place with a 10.5% share (up from 6.5% in 2009). Cree was in fifth place with a 6% share in 2010, followed by LumiLEDs at 5.5% (in 2009, their market shares were reversed).

In 2010, Aixtron led the market in MOCVD tool shipments with slightly more than a 55% share, followed by Veeco with a 41% share of the total 786 tools sold. In 2009, Aixtron had an almost 70% share and Veeco

MOVCD reactor makers' market shares, 2010 vs 2009.

	2009	2010
Aixtron	70%	55%
Veeco	25%	41%
Other	5%	4%

just a 25% share of 228 tools sold.

Pushing for further growth in MOCVD installations is China, which introduced a MOCVD stimulus program that is expected to result in \$1.6bn in spending on MOCVD tools from 2010 to 2012, notes The Information Network. In 2010, China represented nearly 35% of MOCVD installations.

LEDs currently represent a \$10bn niche market compared to the \$250bn semiconductor market, comments the market research firm. The consensus forecast of 786 MOCVD tools represents a market of nearly \$2bn (based on an average selling price of \$2.5m per tool). MOCVD represents 8% of the typical cost breakdown for a packaged LED. Other front-end tools represent more than 3% of the cost, equating to an additional \$500m market for lithography and metrology tools. The biggest sector (65%) represents back-end processes such as substrate removal, chip separation, and packaging.

The Information Network concludes that backlight sectors will exhibit the fastest growth in the HB-LED market, with an overall compound annual growth rate (CAGR) of more than 40%, led by the LCD TV sector exhibiting a CAGR of 300.3% between 2007 and 2012.

www.theinformationnet.com/led.html

Optical component market grows 35% to \$5.6bn in 2010

The global optical component (OC) market grew by 35% in 2010 to a 10-year high of \$5.6bn, according to 'Market Alert: 4Q10 and 2010 Global OC and Market Share: 4Q10 OC Global Spreadsheet' from telecoms analyst Ovum.

Optical components have led the recovery of the telecom market from the global recession of 2009 through its dramatic gain in 2010. "The 35% year-on-year growth experienced by the OC market in 2010 was the highest since the telecom bubble years, when the market more than doubled in one year," notes Ovum analyst and report author Daryl Inniss. "However, we do not believe the market is experiencing another bubble," he adds.

"Growth in the OC market is the best indicator for the next wave of telecom infrastructure expansion, as the 2010 increase follows the industry-wide contraction of 2009," Inniss predicts. "The OC market will continue to expand in 2011, but at a slower rate."

The OC market grew 5% sequentially in Q4/2010 (the seventh consecutive quarterly gain). This growth was led by reconfigurable optical add-drop multiplexers (ROADMs) and filters, long-distance transmission devices, and transmission discretets. ROADMs and filters comprised the fastest-growing segment, with annual revenue rising 46% from 2009 to \$0.9bn in 2010, including Q4/2010 revenue of \$260m rising 10% sequentially (above the industry average of 5%). Ovum believes the future outlook for this segment is good, as ROADMs are at the heart of all transport networks.

"There were many strong vendor performances in Q4/2010," says Inniss. "JDSU led the pack in terms of growth and increased its revenues by over 75% compared to the previous year and 17% sequentially. The company also grew its market share by 0.6% on the previous quarter."

www.datamonitor.com

Lighting to overtake LCD TVs in LED demand in 2014

LED penetration in large-area backlights to reach 70% in 2011

As demand for LEDs continues to rise, TV applications will dominate the LED market through 2013, accounting for nearly 50% of total LED backlight demand, forecasts market research firm DisplaySearch's 'Quarterly LED Supply/Demand Market Forecast Report'. However, LED lighting will capture the lead by 2014, as demand for LEDs in LCD TV backlights falls due to a decrease in the number of LED packages per set (a result of efficacy enhancements and cost reductions).

"The market for LED backlights continues to grow as manufacturers leverage the technology for large-display applications like notebooks, monitors, and TVs," notes senior analyst Leo Liu. "In addition, there are a growing number of emerging applications for LEDs, such as lighting, signal and automotive."

Currently, LED backlights are used in all small/medium LCDs, and LED penetration in mobile PCs is nearly 100%. Penetration in LCD monitors and LCD TVs continues to grow, while the number of LED packages per set is falling.

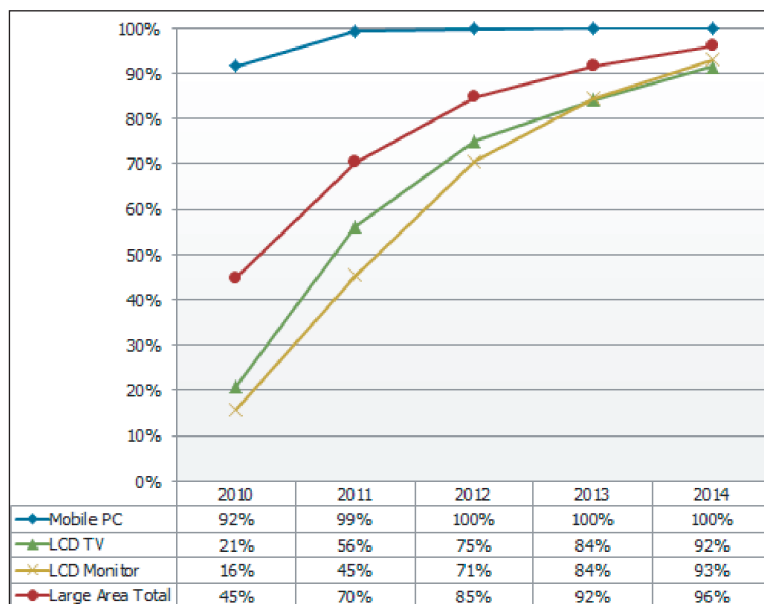
After more than doubling to 12.9% in 2010, the average number of chips per set is rising more slowly, and should peak at 15.1% in 2012. This is driven by the increasing LED efficacy, even as the cost per chip decreases. This virtuous cycle drives LED penetration higher in LCD back-

lights, as well as illumination.

The LED lighting penetration rate in 2010 was 1.4%, and is forecast to reach 9.6% in 2014. Spotlights and LED street lights are forecast to have higher penetration in lighting due to government incentive programs like the 12th Five Year Policy in China, as well as growth in commercial applications. In addition, LED bulbs and fluorescent tubes are growing in Japan due to government incentive programs (Eco-Point) and energy consciousness.

Quarterly chip supply will nearly double from the beginning of 2010 to the end of 2011, as both existing and new suppliers ramp up MOCVD lines. In Q1/2011, Samsung and LG were the top two LED suppliers in terms of 500µm x 500µm chip size. But, led by Epistar in the number-3 position, Taiwan will surpass Korea as largest source of supply in 2011. The tight supply experienced in 2010 has turned into an oversupply, notes DisplaySearch, as chip production has grown while LED TV penetration did not grow as fast as expected, reaching only 21% in 2010.

www.displaysearch.com



Large-area market penetration by application (shipments).

Lamp consumption for general lighting in US to grow at 27.6% to \$1.64bn in 2015

Consumption of LED lamps used in solid-state lighting (SSL) general lighting applications in the USA was \$485m in 2010, and will rise at an average annual growth rate of 27.6% to \$1.64bn in 2015, reckons ElectroniCast Consultants in a market review on 'consumer-level bulbs' used in luminaires in stationary/fixed location (non-vehicle/non-portable) SSL applications.

"PAR lamps are currently the market leader, with over 40% market share; however, the MR- lamp type (especially the MR-16 lamps) used in recessed ceiling/down-lighting and track lighting is on a fast pace to catch-up, pushed by the commercial/industrial sector," says Stephen Montgomery, principal analyst — LED Practice. "General service (especially the A-19 lamp) also is a stand-out in the forecast, especially in potential residential applications, later in the forecast period."

Increased use of LED-based lamps in SSL general lighting is strongly driven by promised savings in maintenance/labor, as well as 'green tech' issues, and several other dynamics. Total cost-of-ownership (TCO) is a key marketing dynamic related to LED lamps, which typically have a premium price point versus other lighting solutions.

"Decorative lamps (such as candle-shapes and globes) is a smaller market segment; however, it is forecast to be a great opportunity for niche-players," says Montgomery. "The linear (tube) lamp, which is eyeing the fluorescent tube market segment, is forecast with the fastest annual growth of over 70% (2010–2015)," he adds. "The street-lamp segment, which also covers parks/campus, tunnels, walkways and parking lots, is poised for 40.5% (value) growth per year, spear-headed by the government sector."

www.electronicast.com

Handset sales increase 20.8% year-on-year to 382.9m in Q1 Nokia, Samsung and LG lose market share to Apple, RIM and ZTE

The global handset device market will grow by 20.8% year-on-year to 382.9 million units in first-quarter 2011 (a growth rate not seen in five years), according to the 'Q2/2011 Global Handset Vendor Sales, Market Share, and Forecast' database of IE Market Research Corp (IEMR).

"Our handset sales data, based on extensive consumer and operator surveys and selected point of sale data, shows a broad-based recovery in the global handset devices space," says Nizar Assanie, VP (Research) at IEMR.

"The winds of change are sweeping the global mobile handset industry," he adds. For Q1/2011, the top-3 global vendors (Nokia, Samsung and LG) will likely announce losses in their market share positions across many key regions and countries. "In Western Europe, for example, data is showing Nokia's market share declining by 595 basis points (year-on-year) in Q1/2011, which is a significant drop for what was once a ubiquitous handset brand in this region," says Assanie.

IEMR's sales data also shows that players such as Apple, Research in Motion and ZTE are gaining traction for their devices globally, with 69.5%, 39.2% and 128.8% growth in unit shipments from these three vendors, respectively.

For full-year 2011, IEMR anticipates total global handset shipments to rise to 1.662bn (up from its forecast made last October of just 1.43bn).

www.iemarketresearch.com

Global handset sales to grow to 1.5 billion units in 2011

Global handset sales will grow to 1.5 billion units in 2011, according to Strategy Analytics' new report 'Handset Sales Forecast by Type: Smartphone, Feature Phone & Basic Phone', which forecasts global handset sales by type from 2003 to 2015 and identifies which categories will grow at above-average rates during the next five years.

The high-value smartphone segment will continue to experience robust growth over the next five years, while feature phones and basic phones will remain a scale play, comments the market research firm.

Strategy Analytics has previously identified a new sub-category of handsets called superphones. This

segment continues to emerge as a super-high-growth market, forecast to expand almost 600% between 2010 and 2015, the firm adds. Android vendors such as Samsung, HTC and Motorola are leading the superphone industry, Strategy Analytics notes.

The high-value smartphone segment will continue to experience robust growth over the next five years, while feature phones and basic phones will remain a scale play

www.strategyanalytics.com

No immediate disruption to GaAs supply chain from Japan quake ...but any big ramp in epi demand could lead to allocation

According to the Strategy Analytics GaAs and Compound Semiconductor Technologies (GaAs) service report 'Japanese Quake Impact on the GaAs Industry' (which provides a preliminary assessment of the impact of the 11 March earthquake and tsunami, as well as subsequent power outages, on the GaAs industry in Japan and worldwide), there is no danger of immediate disruption to the supply of gallium and arsenide raw materials. The supply of SI (semi-insulating) bulk substrates will also be sustained. GaAs device manufacturing facilities were also largely unaffected.

"The primary factors that will impact GaAs device supply out of Japan relate to more generic issues which have an impact on the whole electronics industry," comments Eric Higham, director, GaAs Service. "These include disruption to utilities, logistics and concern for the avail-

ability of materials used in chip packaging and assembly," he adds.

"There is the possibility, however, that any significant ramp in demand for GaAs epitaxial substrates over the next 3-6 weeks may lead to end-users being placed on allocation," observes Asif Anwar, director at Strategy Analytics. "Strategy Analytics analysis shows that the Japanese epitaxial substrate suppliers were running at full production rates, with little to no excess inventory in the supply chain."

In the GaAs RF/microelectronics industry, Japan accounts for 50% of bulk substrate supply, 18-20% of global SI GaAs epitaxial substrate production, and up to a fifth of the global GaAs device market. Japanese firms involved in the GaAs industry include Hitachi Cable, Renesas and Sumitomo Chemical.

www.strategyanalytics.com

Apple overtakes 4th place ZTE in handset shipments

Total handset shipments grow 17% year-on-year to 350m in Q1

Driven by surging smartphones in mature regions and popular multi-SIM models in emerging markets, global handset shipments grew 17% year-on-year from 298.4 million units in first-quarter 2010 to 350 million units in first-quarter 2011, according to market research firm Strategy Analytics. This year will be the first year when every quarter will exceed 300 million units, it forecasts.

In particular, Apple captured fourth place in global handset shipments, rising from sixth position a year earlier and leapfrogging rival ZTE. Both had market share of 2.9% a year ago, but now Apple's is 5.3% and ZTE's is 4.3%. "Apple was a star performer during the quarter, as it shipped a record 18.6 million handsets [up from 8.8 million]," says senior analyst Alex Spektor in the report 'Apple Overtakes ZTE for

Handset vendor shipments (millions) and market share.

Shipments	Q1/10	Q1/11
Nokia	107.8	108.5
Samsung	64.3	68.9
LG	27.1	24.5
Apple	8.8	18.6
ZTE	8.6	15.2
Others	81.8	114.4
Total	298.4	350.1
Growth	19.6%	17.3%

Share	Q1/10	Q1/11
Nokia	36.1%	31.0%
Samsung	21.5%	19.7%
LG	9.1%	7.0%
Apple	2.9%	5.3%
ZTE	2.9%	4.3%
Others	27.4%	32.7%

4th Position in Global Handset Shipments in Q1 2011' published by the Strategy Analytics Wireless Device Strategies (WDS) service.

"It was a mixed quarter for the world's major handset vendors," says Strategy Analytics director Neil Mawston. "Some brands outperformed, such as Apple and ZTE, while others underperformed, such as LG and Nokia," he adds. "LG lost ground due to sluggish feature-phone volumes, while Nokia continued to struggle in 3G smartphones and the important US market."

Samsung shipped 68.9 million handsets in Q1/2011, rising a relatively sluggish 7% from 64.3 million units a year earlier. Its market share has dipped from 22% to 20% over the past year, due to rising competition in 2G and 3G touch-phone markets.

Apple largest vendor by revenue in Q1 ASP of \$638 outweighs Nokia's \$87

In first-quarter 2011 Apple overtook Nokia to become the world's largest handset vendor in revenue terms, according to the latest report from market research firm Strategy Analytics. In revenue terms, Apple is now the world's largest handset vendor, smartphone vendor and tablet vendor.

"We estimate Apple's wholesale revenues for its iPhone handset division stood at US\$11.9bn in the first quarter of 2011," says senior analyst Alex Spektor. "Apple overtook Nokia for the first time, which recorded a lower US\$9.4bn of wholesale handset revenues. With strong volumes and high wholesale prices, the PC vendor has successfully captured revenue leadership of the total handset market in less than four years," he adds.

"Apple's proprietary ecosystem of hardware, software and services has proven wildly popular and hugely profitable," comments Neil Mawston, director at Strategy Analytics. "However, rivals are chasing hard, particularly the Android vendor community, whose global installed base of smartphones we estimate will exceed that of Apple's by the end of 2011," he notes. "Nokia is also investing heavily with Microsoft and Apple will be a key target for them next year."

www.strategyanalytics.com

Handset wholesale revenues in Q1/2011.

Apple	Q1/10	Q1/11
Shipments (millions of units)	8.8	18.6
Wholesale ASP (US\$)	\$606	\$638
Wholesale revenue (US\$bn)	\$5.3	\$11.9
Nokia	Q1/10	Q1/11
Shipments (millions of units)	107.8	108.5
Wholesale ASP (US\$)	\$83	\$87
Wholesale revenue (US\$bn)	\$8.9	\$9.4

IN BRIEF

Nokia, Samsung face low-end threat from Indian OEMs

In India, Nokia is dominant but most low-income mobile users would prefer their next phone to be made in India, so brands such as Lava, Micromax and Spice will benefit, according to Strategy Analytics. International brands without Nokia's brand equity (e.g. Samsung, LG and Sony Ericsson) may face difficulties.

Indian brands have only been on the market for a few years, and only have modest market share, but 63% of respondents (mainly in rural villages and secondary cities with monthly household income of \$130) want lower cost and greater value for money, and greater ease of repair and availability of parts. Affordable mobile phones with an appealing set of features will be key to success.

Anadigics' CEO Rivas and senior VP White resign Michels becomes CEO, Shields COO and Van Sadlers senior VP

RF and mixed-signal semiconductor maker Anadigics Inc of Warren, NJ, USA has announced the resignations of president & CEO Mario Rivas and senior VP Greg White. The firm also says that it remains on track with its first-quarter 2011 revenue guidance of \$42–44m.

Ron Michels (senior VP, chief technology & strategy officer) will assume the responsibilities of CEO, Tom Shields (executive VP & chief financial officer) will assume the additional post of chief operating officer, and John Van Sadlers (VP Advanced Technology) will serve as senior VP RF Products.

"Mario has been instrumental in Anadigics return to profitability during 2010 and we wish him well in his future endeavors," comments Lew Solomon, chairman of the board.

"The board is confident moving forward under the leadership of Ron Michels, a proven Anadigics executive respected by his peers and our customers, and one of the key executives driving our successful turnaround," he adds. "We remain focused and in a strong competitive position given the company's world-class organization, momentum with customers, targeted product fami-



Mario Rivas.

lies, and product roadmap."

Michels joined Anadigics in 1987 and was senior VP/general manager of Broadband Products during 2005–2009.

Previously, he held engineering and management positions in Lockheed Electronics, New Jersey Public Broadcasting, and K & M Broadcasting. Michels earned his Bachelors degree in Electrical Engineering from the New Jersey Institute of Technology. He holds several US Patents, has authored publications in the area of RF communications, and serves on the Lehigh University Electrical & Computer Engineering Advisory Board.

Shields joined Anadigics in 1999. He was senior VP & chief financial officer from July 1999, and has been executive VP & CFO since January 2006. Previously, Shields was VP & controller of Fisher Scientific Company from 1997 to 1999. From 1994 to 1997, he was VP & controller for Harman Consumer Group. From 1986 to 1994, he

served in various positions with Baker & Taylor Inc. Shields received his B.S. and M.B.A. degrees from Fairleigh Dickinson University. He has also been a member of the national Board of Directors for TechAmerica (formerly American Electronics Association) since 2005.

Van Sadlers joined Anadigics in 1990 as a design engineer, serving in several management and executive product development positions. From 2001 to 2006, he was VP, engineering & manufacturing for ASIP, an optoelectronics startup that later merged with T-Networks. But since 2007 he has served as Anadigics' VP Advanced Development. Van Sadlers has a Masters degree in Electrical Engineering (Communication Theory) from NJIT and a Bachelors degree from Stevens Institute of Technology in Optical Physics. He also has several patents in circuit design and optical processing, and has authored a number of technical publications.

"We will work hard to make sure we keep the confidence and trust of our customers during this transition and beyond," comments president & CEO Ron Michels.

www.anadigics.com

China's ZTE names TriQuint 'Best Global Partner' for fourth year running

RF front-end product maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA has received the 'Supplier of the Year' award for 2010 from wireless communication system equipment maker ZTE Corp of Shenzhen, China.

ZTE annually recognizes top suppliers that exhibit superior quality, delivery, cost and service performance. TriQuint has achieved top supplier recognition for the fourth consecutive year and is ZTE's largest provider of power amplifiers

for mobile devices.

TriQuint supplies radio frequency solutions to ZTE including power amplifiers, SAW filters, and multi-function integrated modules for all wireless communication standards including GSM/GPRS, EDGE, CDMA, WCDMA and TD-SCDMA.

"We've developed a solid partnership throughout the years, with close alignment between top management," notes Zeng Zhaoxiang, vice general manager of ZTE Kang Xun. "Again in 2010, TriQuint

exhibited good quality, delivery, cost and service performance (QDCS) with outstanding technical support and service," he adds.

"TriQuint has experienced tremendous growth over the past three years, in part because of strong relationships with key customers such as ZTE," says Tim Dunn, VP Mobile Devices at TriQuint Semiconductor. "We look forward to continuing a mutually prosperous relationship for years to come," he adds.

www.triquint.com

RFMD and Atmel collaborate on ZigBee for smart-energy applications

RF Micro Devices Inc of Greensboro, NC, USA has teamed with semiconductor manufacturer Atmel Corp of San Jose, CA, which provides microcontroller and touch solutions, to deliver ZigBee solutions for a broad range of smart-energy applications.

RFMD's new RF6575 ZigBee (FEM) front-end module has been combined with Atmel's ATmega128RFA1 single-chip solution to create the ATmega128RFA1 reference design. RFMD says that the ZigBee-based solution can provide public utilities and consumers more control over how they monitor and save energy. It is targeted at portable battery-powered equipment, smart-energy advanced metering infrastructure (AMI), high-performance ZigBee, and home-area network (HAN) applications in the 2.4–2.5GHz ISM band. RFMD and Atmel are targeting the need for aggressive size reductions in IEEE 802.15.4 designs with a reduced solution footprint and minimized component count.

"RFMD and Atmel are leveraging each other's expertise to deliver high-performance, highly integrated solutions that reduce design cycle times, lower customer costs, and accelerate product time-to-market," says Bob Van Buskirk, president of RFMD's Multi-Market Products Group (MPG). "Large-scale smart-energy projects are forecasted to grow rapidly, with particularly strong demand anticipated in low-power wireless technologies like ZigBee," he adds.

"The RFMD front-end module combined with the Atmel ATmega128RFA1 single-chip solution offers smart-energy providers better battery life with their lower-power consumption designs without comprising performance," says Magnus Pedersen, Atmel's director of wireless solutions.

RFMD's highly integrated RF6575 features a 2.4–2.5GHz +22dBm power amplifier, Tx harmonic output filter, double-pole double-throw (DPDT) diversity switch, and a low-noise amplifier (LNA). It is housed in a 3.5mm x 3.5mm x 0.5mm package a third the size of rival offerings, RFMD claims, cutting discrete component requirements while minimizing footprint and assembly costs. The transceiver interface is a single-port bi-directional Rx/Tx.

RFMD says its expanding portfolio of ZigBee FEMs enables users to accelerate new ZigBee products to market while reducing component count, size, cost, and power consumption. The RF6575 single-chip ZigBee FEM is specifically optimized for smart-energy applications including smart meters, energy usage control, or 'demand response' and HAN devices. Other RFMD ZigBee FEMs are designed for industrial applications and wireless sensing and control applications requiring low power consumption, high performance and proven reliability.

www.atmel.com
www.rfmd.com

Skyworks first semiconductor firm to receive Samsung's Best Quality Award

Skyworks Solutions Inc of Woburn, MA, USA, which makes high-reliability analog and mixed-signal semiconductors, has received the 2010 Best Quality award from Samsung for "excellence in overall product quality, supply-chain efficiency, and a proactive approach to preventing quality issues". It is the first semiconductor company to be awarded this honor and was selected from over 200 suppliers. Electronics firm Samsung, which makes Android-based mobile devices, uses multiple analog and RF solutions from Skyworks' product portfolio.

"Skyworks' focus on total customer satisfaction and continuous improvement has been instrumental in helping Samsung deliver quality products for today's demanding mobile device market," comments quality management at Samsung.

"This award reflects our ongoing efforts to ensure a quality mindset exists throughout our systems and business processes company-wide," says Nien-Tsu Shen, VP of quality. "Quality is a competitive differentiator and we remain committed to the never-ending quest for perfect quality and complete customer satisfaction."

www.skyworksinc.com

RFMD launches broadband high-power SP4T switch

RFMD has launched the RF1604 single-pole four-throw (SP4T) switch, designed for applications requiring low insertion loss and high power handling capability with minimal DC power consumption. Linearity performance suits multi-mode GSM/EDGE/WCDMA/CDMA and LTE as well as cellular infrastructure applications.

Very high isolation (40dB at 1GHz) between RF ports provides greater RF separation between transmit and receive paths, critical in full-duplex systems. Packaged in a compact 2.5mm x 2.5mm, 12-pin, leadless QFN package, the RF1604 also includes integrated decoding logic, allowing operation from two low-voltage control lines (compati-

ble with low-voltage logic, $V_{HIGH\ min} = 1.3V$). No external DC blocking capacitors are required.

Features include 2kV HBM ESD protection on all ports; low-frequency to >2.7GHz operation covering all standard cellular frequency bands; low insertion loss (0.4dB at 1GHz); and high linearity (IIP2 >120dBm).

Fail-safe bypass LNA modules for cellular infrastructure

Avago Technologies has launched a series of fail-safe bypass low-noise amplifiers (LNAs) for tower-mounted amplifiers (TMA) and base transceiver stations (BTS) applications. The new ALM-11x36 modules can replace large discrete and surface-mount component counts in conventional designs, shortening design cycle time and providing savings in board space.

Operating from a single 5V power supply, the modules have low noise and high linearity through use of the firm's proprietary 0.25 μ m GaAs enhancement-mode pHEMT process. Their bypass isolation eliminates the possibility of oscillation issues, and the modules also feature low bypass insertion loss and high input and output return loss. In addition, the ALM-11x36 LNAs have a fail-safe bypass function, which is especially critical for TMA applications to enable the LNA bi-directional bypass path during

the absence of DC power supply.

All matching components are fully integrated within the modules, and the 50 ohm RF input and output pins are already internally AC-coupled. This makes the modules easy to use, says Avago, as the only external parts required are DC supply bypass capacitors.

The LNA modules perform across a wide range of bands, with the ALM-11036 covering 776–870MHz, the ALM-11136 covering 870–915MHz, the ALM-11236 covering 1710–1850MHz, and the ALM-11336 covering 1850–1980MHz. All share the same compact 7.0mm by 10.0mm by 1.5mm package and pin-out configuration, and hence suit common platform designs.

The wireless infrastructure industry must provide optimum coverage with the best signal quality in a crowded spectrum, comments Avago. Receiver sensitivity is the

most critical requirement in a BTS receiver's design, and LNA selection greatly affects the receiver's performance. For front-end design architectures with a bypass path, low noise figure (NF) and bypass insertion loss (IL) are the key design goals. NF and bypass IL are, respectively, 0.78dB and 0.82dB for the ALM-11036, 0.76dB and 0.85dB for the ALM-11136, 0.67dB and 0.75dB for the ALM-11236, and 0.72dB and 0.78dB for the ALM-11336.

Another key design factor is linearity — specified by input third-order intercept (IIP3) — which affects the receiver's ability to distinguish between wanted and spurious signals that are closely spaced. IIP3 is 21.3dBm for the ALM-11036, 22.0dBm for the ALM-11136, 17.3dBm for the ALM-11236, and 17.9dBm for the ALM-11336.

www.avagotech.com

Avago's highly integrated FEM enables WiFi & Bluetooth coexistence

Avago Technologies has launched a front-end module (FEM) with robust filtering for 802.11 b/g/n WiFi and Bluetooth radios in handsets and mobile routers for tablets and other portable PC devices.

The AFEM-S102 module integrates a film bulk acoustic resonator (FBAR) coexistence filter, SP3T antenna switch and TX path coupler in a small 2.2mm x 2.2mm x 0.55mm package suiting space-constrained applications. The firm claims that the 2.5GHz module delivers superior out-of-band rejection, enabling concurrent operation of WiFi and Bluetooth datacommunication with cellular communication standards.

Avago says that its front-end modules integrate multiple high-performance technologies to reduce PCB board footprint and simplify design for portable electronics applications. The AFEM-S102 in particular exhibits

low insertion loss that combines with high noise rejection to meet stringent coexistence requirements and enable fewer interference issues between WiFi, Bluetooth and other radios. Effectively leveraging Avago's 0.25 μ m GaAs enhancement-mode pHEMT process and its proprietary FBAR filtering technologies, the module delivers 2.6dB maximum insertion loss for the TX path and 35dB rejection at 2110–2170MHz.

"As smartphones and other portable electronics devices add more radio types and bands, coexistence requirements are getting more stringent," says James Wilson, director of marketing for wireless products. "The best-in-class rejection and insertion loss of our proprietary FBAR technology enables OEMs to efficiently address these challenging radio environments," he adds. "The easy-to-use AFEM-S102 front-end module was

designed in conjunction with a leading handset designer for their reference design, specifically to meet the coexistence requirements for WiFi and Bluetooth applications."

Avago claims that its FBAR technology delivers steeper roll-off and lower insertion loss than ceramic or SAW (surface acoustic wave) filters and other competing technologies, and does so in a more compact form factor. Low insertion loss reduces power amplifier current and improves receiver sensitivity and dynamic range, resulting in extended battery life and talk time and better signal quality for handsets. FBAR technology makes ultra-small, high-Q filters possible at a fraction of their usual size, and allows integration with other radio components.

The AFEM-S102 is priced at \$1 each in 10,000 piece quantities.

www.avagotechwireless.com

Agilent ships ADS 2011 for RF and microwave design and simulation

Agilent Technologies Inc of Santa Clara, CA, USA has shipped the latest release of Advanced Design System (ADS), the flagship RF and microwave design and simulation platform of Agilent EEs of EDA, which supplies electronic design automation software for microwave, RF, high-frequency, high-speed digital, RF system, electronic system-level, circuit, 3D electromagnetic, physical design and device-modeling applications. ADS 2011 is claimed to be the industry's most comprehensive multi-technology design platform.

Agilent also says that its work with GaAs/GaN and RF SiGe/BiCMOS/CMOS foundries and relevant surface mount device (SMD) component vendors has resulted in their support for ADS 2011. During the past six months, the majority of existing ADS process design kits and libraries have been upgraded and verified on early access releases, says the firm. These upgraded kits and libraries will be made publicly available to foundry and component vendor customers in the coming days, enabling them to take advantage of new capabilities in ADS 2011, it adds.

The new kits work seamlessly with ADS 2011.01, as well as ADS 2009 Update 1 and prior ADS releases. Users hence need only to download and install the desired kit, independent of which ADS release they are using. Requests for specific kits should be directed to the appropriate component vendor or foundry.

ADS 2011 provides engineers with a multi-technology design environment for designing individual RF and microwave integrated circuits with different technologies (e.g. GaAs, SiGe, GaN, and silicon CMOS). Agilent says that it features electromagnetic technologies for faster, more accurate simulations; a use model that makes electromagnetic simulation easy for all engineers; layout improvements for easier physical design; and dozens of improvements designed to enhance the platform's functionality and usability. Design verification no longer needs to stop at the boundary of a single integrated circuit's or module's technology, the firm adds.

To download ADS 2011, existing ADS customers select the Downloads & Trials tab at:

[www.agilent.com/
find/eesof-ads-latest-downloads](http://www.agilent.com/find/eesof-ads-latest-downloads)

M/A-COM appoints VP of operations

M/A-COM Technology Solutions Inc of Lowell, MA, USA (which manufactures semiconductors, components, and subassemblies for RF, microwave and millimeter-wave applications) has appointed Robert Dennehy as VP of operations, reporting to chief operations officer Bob Donahue.

Dennehy will oversee M/A-COM Tech's global manufacturing operations, and work with his team to establish long-term goals and strategic planning for the firm's global growth strategy.

"Robert's proven leadership skills,



Robert Dennehy.

coupled with his experience with multiple product lines, make him the ideal candidate for his new position," reckons CEO Chuck Bland. Dennehy began with the firm as a test engineer in 1993 and has most recently been serving as managing director of the Infrastructure Group in Cork, Ireland.

www.macomtech.com

IN BRIEF

AWR announces China expansion with third direct office in Asia

High-frequency electronic design automation (EDA) software tool provider AWR Corp of El Segundo, CA, USA plans to open its third direct sales and support office in Asia with a Shanghai, China location. The announcement coincides with the end of AWR's fiscal year, in which it has seen double-digit year-on-year growth in sales for the Asia-Pacific sub-region of Japan, China and Korea.

For the first time, China joined Japan in the top five markets for AWR software ranked by country. During the past fiscal year, AWR's software installations have expanded dramatically in China at multinational firms operating in the region, indigenous Chinese telecoms companies, government research institutions and universities.

AWR's first office in Asia was established in 2006 in Tokyo, Japan, followed by a second office established last year in Seoul, Korea. The firm's third sales and support office in Asia, in Shanghai, is expected to be fully operational by the third quarter of this calendar year.

"AWR is experiencing rapid sales growth in Asia, and we are eager to continue investing resources to support the Asian market by expanding the technical support team currently in place in Japan, Korea and now China," says executive & co-founder Ted Miracco. "AWR China and the Asia-Pacific region are an increasingly significant part of our worldwide revenues, and we expect significant growth in our user base over the next several years," he adds.

www.awrcorp.com

Group4 to site manufacturing facility at UAlbany's CNSE Silicon Valley GaN-on-diamond developer adds plant in NY State

New York State's Governor Andrew M. Cuomo announced that Silicon Valley firm Group4 Labs Inc of Fremont, CA, USA is opening a manufacturing facility at the College of Nanoscale Science and Engineering (CNSE) of the University at Albany — State University of New York (SUNY).

Founded in Menlo Park, CA in 2003, Group4 Labs develops and supplies 'extreme materials' that aim to improve the performance of gallium nitride (GaN) based devices. The firm's technology enables epitaxial GaN layers to be atomically attached (regardless of lattice mismatch) to a free-standing, proprietary chemical-vapor-deposited (CVD) synthetic polycrystalline diamond substrate. The wafer's GaN exterior then presents an atomically smooth finish with a gallium-facing surface that is epi-ready for further epitaxial deposition. Resultant devices exhibit improved efficiency and hence reduced energy consumption, as well as high temperature resilience

and thermal conductivity, for very high-power, high-frequency electronic, solid-state white lighting, military and photonics applications, including in radar systems, smart phones, tablet computers and cellular transmission towers.

Investment of \$1.5m in the new plant is coming from the New York State Energy Research and Development Authority (NYSERDA), whose interest stems from the potential to reduce energy use through more efficient chip designs (reducing the use of fossil fuels as well as greenhouse gas emissions). "Under Governor Cuomo's leadership, NYSERDA remains committed to nurturing innovative clean-energy companies as part of our larger effort to create jobs and build an environmentally friendly economy in the state," says NYSERDA's president & CEO Francis J. Murray Jr. This deal is also expected to leverage an additional \$4m in private funding.

The firm will lease space in CNSE's cleanroom and install its own

equipment there. Group4 Labs New York should start manufacturing by this summer and create 10 jobs initially, rising to a targeted 50 in the Capital Region ultimately by 2015.

The firm previously announced a manufacturing and test facility in Syracuse, NY, which is expected to grow to about 94 jobs by 2015. Group4 already provides its product to Lockheed Martin in Syracuse for use in its radar equipment. "We like New York because of the talent that is available, and the incubation resources at CNSE, and because of the fact that it is close to our customers," comments CEO & co-founder Felix Ejeckam.

"Bringing business to our state and creating jobs is essential to getting New York back on the right path," Cuomo said. "As part of our state's recovery, we must maximize New York's reputation in innovative nanotechnology and we look forward to working with Group4 Labs to bring good jobs to the Albany and Syracuse areas."

www.Group4Labs.com

New NAE members elected include Stanford epi expert

The US National Academy of Engineering (NAE) has elected 68 new members and nine foreign associates for 2011, bringing total US membership to 2290 and foreign associates to 202.

Membership honors those who have made outstanding contributions to "engineering research, practice, or education, including, where appropriate, significant contributions to the engineering literature" and to the "pioneering of new and developing fields of technology, making major advancements in traditional fields of engineering, or developing/implementing innovative approaches to engineering education."

New members include:

● James S. Harris Jr (the James and Ellenor Chesebrough professor of Electrical Engineering, Materials

Science and Applied Physics at Stanford University) for contributions to epitaxial growth of compound semiconductor materials and their applications.

● John A. Rogers (the Lee J. Flory-Founder Chair in Engineering in the Department of Materials Science and Engineering at the University of Illinois, Urbana-Champaign) for novel electronic and optoelectronic devices and systems.

● Mark J. Kushner (the George I. Haddad Collegiate professor and director, Michigan Institute for Plasma Science and Engineering, at University of Michigan, Ann Arbor) for contributions to low-temperature plasmas for semiconductors, optics, and thin-film manufacturing.

● Jacqueline Gail (Berg) Gish (director of special projects,

Northrop Grumman Aerospace Systems in Redondo Beach, CA) for technical and programmatic contributions to high-power diode-pumped solid-state lasers for defense applications.

● David D. Awschalom (the Peter J. Clarke professor, director of the California NanoSystems Institute, and director of the Center for Spintronics and Quantum Computation, at University of California, Santa Barbara) for contributions to the understanding of spin coherence and spintronics.

● Daniel C. Edelstein (IBM Fellow and manager, BEOL Technology Strategy, at IBM T.J. Watson Research Center in Yorktown Heights, NY) for contributions to implementing copper/low-dielectric chip interconnects.

www.nae.edu

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Fairchild buys Sweden's TranSiC

Silicon chip maker adds silicon carbide power device technology

Fairchild Semiconductor of San Jose, CA, USA, which makes silicon chips for power and mobile designs, says that, to meet the need for increasing efficiencies and higher performance for semiconductor applications, it is acquiring silicon carbide (SiC) power transistor maker TranSiC AB of Kista, Sweden.

Fairchild says that the acquisition provides it with bipolar SiC transistor technology with demonstrated industry-leading efficiencies and performance over wide temperature ranges, as well as superior performance over MOSFET and JFET technology approaches. The firm has also acquired a team of SiC engineers and scientists and multiple patents in SiC technology.

"The combination of silicon carbide technology with Fairchild's existing capabilities in MOSFETs, IGBTs and multi-chip modules, along with our global access to customers, positions us to continue to be a leader in innovative, high-performance power transistor technology," says chairman, CEO & president Mark Thompson.

"The performance levels achieved with SiC technology allow for much

higher efficiency in power conversion," notes chief technology officer Dan Kinzer. "It also offers a higher switching speed, a feature that enables smaller end-system form factors," he adds. "Silicon carbide technology is established in the market with a strong lead over alternatives in the wide-bandgap area for applications that require voltages greater than 600V and demonstrates superior ruggedness and reliability."

Fairchild says that benefits over alternative technologies include: lower on-state voltage drop for a given chip size; higher current density; higher-temperature operation; extremely low thermal resistance; ultrafast switching with only majority carrier conduction; easy drive solutions due to normally-off operation with current gain in the range of 100; and easy paralleling due to the positive temperature coefficient of resistance.

Additionally, the device resistance is very near to the theoretical limit for SiC. Turn-on and turn-off times in the 25ns range switching 50A from 800V have been demonstrated. Parametric stability has been demon-

strated under long-term full rated bias and current stress conditions.

The firm says that these high-gain SiC bipolar devices suit high-power conversion applications in down-hole drilling, solar inverters, wind-powered inverters, electric and hybrid electric vehicles, industrial drives, UPS and light rail traction applications. These markets are projected by Yole Development to approach \$1bn by 2020.

Fairchild claims that the SiC devices are capable of industry-leading efficiency, cutting losses relative to established silicon approaches by up to half, or allowing an increase in frequency by up to 4x with similar losses. Overall system cost and value can benefit from much smaller, lighter passive components, the firm says, adding that there is no equal for systems requiring the best efficiency and power density.

Fairchild is sampling initial 1200V products up to 50A ratings in targeted applications. Future offerings are in development to expand the voltage and current range, and to continue to drive improved energy savings.

www.transic.com

www.fairchildsemi.com

CISSOID launches high-voltage 225°C SiC power switch with logic-level gate control

Fabless high-temperature semiconductor firm CISSOID of Mont-Saint-Guibert, Belgium has unveiled JUPITER, which it claims is the first high-temperature silicon carbide high-voltage switch with seamless gate control through a simple logic-level 0/5V.

In particular, CHT-JUPITER is a 600V normally-off switch rated for a drain current of 1A at 225°C, and it is packaged in a hermetically sealed TO-254 metal package, guaranteed for operation from -55°C up to +225°C.

CHT-JUPITER's on-resistance ranges from 0.7Ω at 25°C to 1.25Ω at 225°C. Input capacitance is typically 430pF. The gate leakage and drain off-currents are 160nA and 250μA, respectively, at 225°C.

A key feature of the device is its ability to be driven by a 0/5V logic-level signal, which dramatically reduces the complexity of the driver stage. In particular, CHT-JUPITER simplifies the design of medium-power, high-voltage converters such as switched-mode power supplies (SMPS) and motor

drives that have to operate in extreme environments.

CISSOID says that, with CHT-JUPITER, electronics engineers can decrease the complexity of their electrical schematics, shorten their bill-of-material, and improve the reliability, weight and size of their systems while reducing the need for cooling in their applications.

A data-sheet is available now. CHT-JUPITER can be ordered for sampling and evaluation. Pricing starts at €481/unit up to 200 units.

www.cissoid.com

ROHM launches 600V/20A SiC Schottky barrier diodes

SBDs combine lower VF and faster recovery time than Si fast recovery diodes

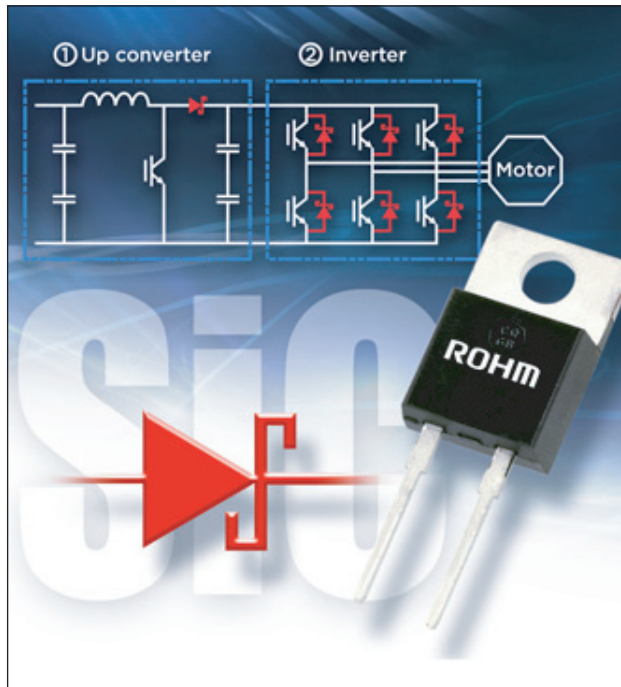
ROHM Semiconductor of San Diego, CA (the US arm of system LSI, discrete components and module product maker ROHM Co Ltd of Kyoto, Japan) has launched the SCS1xxAGC series of silicon carbide (SiC) Schottky barrier diodes (SBD).

The firm says that the new class of SiC diodes offers low forward voltage and fast recovery time, leading to improved power conversion efficiency in applications such as power factor correction (PFC)/power supplies, solar panel inverters, uninterruptible power supplies (UPS), air conditioners and others.

The SCS1xxAGC series maintains low forward voltage (V_F) over a wide operating temperature range, resulting in lower power dissipation under actual operating conditions (e.g. the 10A-rated part has a V_F of 1.5V at 25°C and 1.6V at 150°C). Low V_F reduces conduction loss, while the ultra-short reverse recovery time (15ns, typical) enables high-speed switching and minimizes switching loss.

ROHM Semiconductor says that, with the acquisition of single-crystal SiC wafer manufacturer SiCrystal AG of Erlangen, Germany last year, it possesses total manufacturing capability for SiC semiconductors, from ingot formation to power device fabrication, allowing rapid development of products and complete control of raw materials reliability and quality.

"SiC is the ideal material for power electronics, with its high break-down voltage, low power loss, high



ROHM's silicon carbide Schottky barrier diode.

operating temperature and superior thermal conductivity," says ROHM's senior technical product marketing

We also have 1200V SBDs and MOSFETs, currently in sampling at strategic partners

features such as low V_F and the highest current rating at 600V (a true 600V/20A SBD, not dual 2x10A)," he adds.

"These diodes are but the first in ROHM's SiC product lineup," Doan notes. "We also have 1200V SBDs and MOSFETs, currently in sampling at strategic partners, to address higher-power applications such as UPS and to enable all-SiC power devices."

www.rohm.com/us/silicon-carbide-diode.html

IN BRIEF

Fox signs fifth license for its SiC patents

The Fox Group Inc of Warrenton VA, USA has entered into a license agreement with a non-US company for rights to patents in its portfolio. This is the fifth non-exclusive and royalty-bearing license agreement that Fox Group has signed for its patents related to silicon carbide (SiC), following the fourth (with a US corporation) just in February and the third (with the Wide Bandgap Materials group of II-VI Inc's compound semiconductor business, which manufactures single-crystal silicon carbide (SiC) substrates) in August 2008. Details of the latest patent license were not disclosed.

Founded in 1999, Fox Group is a privately held corporation with technology and patents related to silicon carbide and to high-purity, epitaxial crystal growth for LEDs and lasers.

"Fox Group's key patents are for silicon carbide with low defect density, and our successful licensing activities confirm the value of our intellectual property," says president & CEO Barney O'Meara. "Non-exclusive licenses remain available, and we look forward to the balance of the industry taking licenses," he adds.

Silicon carbide is used in the production of high-performance power semiconductor devices and optoelectronics such as LEDs, lasers, RF transistors, detectors, MOSFETs, HEMTs, JFETs, BJTs, and Schottky barrier and PIN diodes. It is expected to play an increasingly important role in higher-efficiency power conditioning systems for electric vehicles, photovoltaics, wind, and other renewable energy sources.

www.thefoxgroupinc.com

GLOBALFOUNDRIES partners with IMEC

Silicon foundry joins GaN and sub-22nm CMOS R&D programs

GLOBALFOUNDRIES of Milpitas, CA, USA has signed a strategic long-term partnership on sub-22nm CMOS scaling and gallium nitride-on-silicon (GaN-on-Si) technology with nanoelectronics R&D center IMEC of Leuven, Belgium, as well as becoming a full IMEC core CMOS partner.

Launched in March 2009 through a partnership between micro-processor maker AMD of Sunnyvale, CA and the Advanced Technology Investment Company (ATIC) of Abu Dhabi, United Arab Emirates, GLOBALFOUNDRIES claims to be the world's first full-service semiconductor foundry with a global manufacturing and technology footprint. Headquartered in Silicon Valley, the firm has manufacturing operations in Singapore (through acquisition of silicon foundry Chartered Semiconductor Manufacturing in January 2010), Germany, and a new fab under construction in Saratoga County, NY, USA. These sites are supported by a global network of R&D, design enablement, and customer support in Singapore, China, Taiwan, Japan,

the USA, Germany, and the UK.

IMEC's sub-22nm core CMOS program aims to develop processes that can be used in high-volume manufacturing of future logic and memory ICs. The program encompasses material and device studies, tool and process step exploration, integration options and advanced characterization towards process technology platforms for the next generation of ICs, as well as exploring and developing the options for further generations.

The firm will also collaborate on extreme ultraviolet (EUV) lithography, device technology for logic and memory, nano-interconnects and 3D integration together with other integrated device manufacturers (IDMs), foundries, fabless and fablite companies, equipment and material suppliers who are part of the IMEC research ecosystem.

GLOBALFOUNDRIES is also joining the IMEC GaN research program, which targets high-performance, cost-effective GaN devices on silicon. This program brings together IDMs, foundries, compound semiconductor companies, equipment

suppliers and substrate suppliers to develop 8-inch GaN technology on silicon.

"Partnering with GLOBALFOUNDRIES is very important for IMEC and our partners since it strengthens our collaboration with foundries and thus also the ecosystem we offer in our programs to IDMs and the fabless and fablite community," says IMEC's president & CEO Luc Van den hove. "We expect this partnership to give a further boost to our research programs over the coming years," he adds.

"GLOBALFOUNDRIES has long embraced a collaborative approach to R&D innovation based on a model of shared objectives and shared investments with partners around the world," says the firm's VP of alliances, David Bennett. "The mission and capabilities of IMEC are highly complementary to our current collaborative R&D approach and will add another important dimension to our technology pipeline."

www.globalfoundries.com

www.imec.be

Northrop Grumman GaN-based modules set 180-day standard for sustained high-power operation

US defense contractor Northrop Grumman Corp has set a new standard for its gallium nitride-based high-power transmit/receive (T/R) modules by reliably operating them for over 180 days during continuous high-power testing.

In a rigorous evaluation conducted by its Advanced Concepts and Technology Division, the T/R modules were tested by using high-stressing operational long-pulse waveforms, which operated on the modules non-stop for more than six months. These waveforms were designed to simulate the electronic activities of actual radar functions,

in a relevant environment allowing Northrop Grumman engineers to understand how well they would perform in tactical operation.

The tests prove that the next generation of active electronically scanned arrays (AESA) is capable of reliable operation while producing much greater radar sensitivity, at higher efficiency and lower cost, says the firm. With this new threshold established, the T/R modules can serve as critical technology elements for a wide range of future applications.

"By successfully employing the latest advances in high-power

semiconductor technology in a functioning T/R module, we have demonstrated the great performance and reliability of our design approach," says Steve McCoy, VP of the Advanced Concepts business unit in the firm's Electronic Systems sector. "This new level of maturity also supports technology readiness for the next generation of Northrop Grumman's high-performance, low-cost AESA radars, and opportunities for cost reduction and performance upgrades to our current AESA product line," McCoy adds.

www.northropgrumman.com

Keithley launches high-power test instrument

Keithley Instruments Inc of Cleveland, OH, USA has launched the Model 2651A High Power System SourceMeter instrument, the latest addition to its Series 2600A System SourceMeter family.

Designed for characterizing high-power electronics, the Model 2651A provides what is said to be the widest current range available, critical for R&D, reliability and production test applications such as testing high-brightness LEDs (HB-LEDs), power semiconductors, DC-DC converters, batteries, and other high-power materials, components, modules, and subassemblies.

Like each member of the Series 2600A family, the Model 2651A offers a flexible, four-quadrant voltage and current source/load coupled with precision voltage and current meters. It combines the functionality of multiple instruments in a single full-rack enclosure: semiconductor characterization instrument, precision power supply, true current source, DMM (digital multimeter), arbitrary waveform generator, V or I pulse generator, electronic load, and trigger controller, and is fully expandable into a multi-channel, tightly synchronized system via Keithley's TSP-Link technology. Unlike competitive solutions, which typically have limited power, measurement speed and/or resolution, Keithley claims the Model 2651A can source or sink up to 2000W of pulsed power ($\pm 40V$, $\pm 50A$) or 200W of DC power ($\pm 10V@ \pm 20A$, $\pm 20V@ \pm 10A$, $\pm 40V@ \pm 5A$). It can also make precise measurements of signals as low as 1pA and 100 μV at speeds up to 1 μs per reading.

The Model 2651A provides a choice of digitizing or integrating measurement modes for precise characterization of both transient and steady-state behavior. Two independent analog-to-digital (A/D) converters define each mode — one for current and the other for voltage — which run simultaneously for accurate source readback without sacrificing test throughput.



Keithley's new Model 2651A.

The digitizing measurement mode's 18-bit A/D converters allow the capture of 1 million readings per second for continuous 1 μs -per-point sampling, making this mode the most appropriate choice for waveform capture and measuring transient characteristics with high precision. Competing solutions must average multiple readings to produce a measurement result and often do not allow the measurement of transient behavior, Keithley claims.

The integrating measurement mode, based on 22-bit A/D converters, optimizes the instrument's operation for applications that demand the highest possible measurement accuracy and resolution. This ensures precise measurements of the very low currents and voltages common in next-generation devices. All Series 2600A instruments provide integrating measurement mode operation.

Connecting two Model 2651A units in parallel via TSP-Link expands the system's current range from 50A to 100A. This is 2.5–5 times greater than the nearest competing solution, the firm claims. The voltage range can be expanded from 40V to 80V when two units are connected in series. The embedded Test Script Processor (TSP) included in all Series 2600A instruments simplifies testing by allowing users to address multiple units as a single instrument so that they act in concert. The built-in trigger controller in the Model 2651A can syn-

chronize the operation of all linked channels to within 500ns. These capabilities provide what is claimed to be the broadest dynamic range available, suiting a broad variety of high-current, high-power test applications, including:

- power semiconductor, HB-LED, and optical device characterization and testing;
- characterization of GaN, SiC, and other compound materials and devices;
- semiconductor junction temperature characterization;
- reliability testing;
- high-speed, high-precision digitization; and
- electro-migration studies.

To minimize device self-heating during tests (a common problem with high-power semiconductors and materials), the Model 2651A offers high-speed pulsing capabilities that allow users to source and measure pulses with high accuracy. Pulse widths from 100 μs to DC and duty cycles from 1% to 100% are programmable. Competing solutions are typically hampered by limited flexibility for programming the instrumentation's duty cycle, Keithley claims.

TSP Express (Keithley's LXI-based I-V test software utility) is embedded in the instrument, so there is no need for software installation or programming. From basic to advanced tests, TSP Express delivers device data in three steps: connect, configure, and collect. It also simplifies connecting instruments to allow higher pulsing levels. Results can be viewed in either graphical or tabular format and then exported to a .csv file for use with spreadsheet applications. Two other powerful software tools for creating test sequences are also provided: the Test Script Builder application supports creating, modifying, debugging, running, and managing TSP scripts; an IVI-based LabVIEW driver simplifies integrating the 2651A into LabVIEW test sequences.

www.keithley.com

5N Plus grows sales 7% year-on-year to a record \$20.6m Order backlog grows 32% to record \$71.2m, boosted by First Solar deal

For its fiscal third-quarter 2011 (to end-February), 5N Plus Inc of Montreal, Quebec, Canada has reported (in Canadian dollars) record sales of \$20.6m, up 4.6% on \$19.7m last quarter and 7% on \$19.3m a year ago.

Founded in 2000, 5N Plus focuses on specialty high-purity metals such as tellurium, cadmium, selenium, germanium, indium and antimony and also produces related II-VI semiconducting compounds such as cadmium telluride (CdTe), cadmium sulphide (CdS) and indium antimonide (InSb) as precursors for the growth of crystals for electronic applications, including solar photovoltaic, radiation detector and infrared markets. 5N Plus owns four material subsidiaries: 5N PV GmbH (Eisenhuttenstadt, Germany), Firebird Technologies Inc (Trail, BC, Canada), 5N Plus Corp (DeForest, WI, USA) and Sylarus Technologies LLC (St George, UT, USA).

Earnings before interest, taxes, depreciation and amortization (EBITDA) were \$5.98m (29.1% of sales), down on \$6.2m (31.6% of sales) last quarter. EBITDA was adversely affected by (i) SG&A (selling, general & administrative) expenses related to new facilities in Wisconsin and Malaysia as well as the acquisitions of MCP Group SA and Sylarus Technologies LLC (incurred without 5N Plus yet benefiting from the full revenue potential of these four new initiatives); and (ii) a \$536,426 increase in R&D expenses.

During the quarter, cash and cash equivalents fell further, from \$54.7m to \$42.8m, due mainly to a strategic increase in inventories of about \$21m and capital expenditures totalling \$15m related primarily to Firebird's new facility as well as 5N Plus' new plant in Wisconsin.

5N Plus has also completed a \$50m two-year senior secured revolving facility with National Bank of Canada, replacing a \$17.5m

revolving credit facility with another Canadian bank (currently undrawn). It intends to use the new revolving facility for corporate purposes, including capital expenditure and permitted acquisitions.

On 10 January, the US\$3m convertible note previously provided by 5N to Sylarus (a producer of germanium substrates for solar cells) was converted into a 66.67% majority interest that 5N Plus now owns.

"We made great progress in the execution of our growth plan," says president & CEO Jacques L'Écuyer. On 3 February, 5N announced the signing of new long-term supply agreements with cadmium telluride (CdTe) thin-film photovoltaic (PV) module maker First Solar Inc of Tempe, AZ, USA extending until end-December 2015, and plans to build a new recycling facility in Malaysia. The increase in CdTe to be ordered by First Solar will initially be 30% and will reach 60% by 2013, compared to the minimum quantities prescribed in the original agreements. The new Malaysian plant should be operational by mid-2012.

"This has greatly contributed to our record quarter in terms of sales and backlog and provides a firm base for all of our organic growth initiatives, which include — in addition to our other solar and medical-imaging product initiatives — our germanium-related activities, for which investments are still underway," says L'Écuyer. "These initiatives include the construction of our new facility in Trail, British Columbia and investments enabling us to acquire a majority ownership in Sylarus, aimed at allowing us to develop a germanium-wafer manufacturing capability for photovoltaic applications," he adds.

Also, in mid-April, 5N completed the acquisition of MCP Group SA of Tilly, Belgium (announced at the end of February) for \$317m, and closed the associated 'bought deal' equity financing of 13,590,000 common shares at a price of \$9.20 per share (for total gross proceeds of \$125m). The MCP acquisition is a "transformational transaction enabling us to become a global leader in the production and distribution of specialty metals", says L'Écuyer. "This acquisition is both highly strategic, as it provides a means for business diversification and further growth, and financially accretive. It is thus well aligned with our vision of becoming a global leader in the

Initiatives include the construction of our new facility in Trail, BC and investments enabling us to acquire a majority ownership in Sylarus

production of specialty metals for the clean technology markets," he adds. "Together we now form a stronger company that is well positioned to grow and take advantage of opportunities in a number of exciting new markets, including solar, light-emitting diodes and eco-friendly materials."

"Such investments are expected to begin generating significant revenues in fiscal 2012 and should contribute to a further strengthening of our base business, the outlook for which remains very promising," L'Écuyer continues.

5N Plus notes that, at the end of the quarter, its backlog of orders expected to translate into sales over the next 12 months was a record \$71.2m, up 13.7% on \$62.6m last quarter and 32.4% on \$53.8m a year ago (despite changes in currency exchange rates having an adverse impact of about \$5.7m).

www.5nplus.com

5N closes MCP acquisition and \$125m public offering

5N Plus has completed its acquisition of MCP Group SA of Tilly, Belgium (announced on 28 February) as well as its 'bought deal' public offering of 13,590,000 common shares at a price of \$9.20 per share (yielding total proceeds of \$125m).

Formed in September 2007 from the merger of specialty metal firms MCP Aramayo Ltd and Sidech SA, the private company MCP was majority-owned by co-CEOs Laurent Raskin and Frank Fache and Belgian industrial group Floridienne SA. It is the leading producer and distributor of bismuth and bismuth chemicals (with market share estimated to be more than 50%) and a key player in other specialty metals (including gallium, indium, selenium and tellurium), used in products mainly related to industrial and electronic applications. MCP has about 400 staff in nine production sites and 15 commercial offices across Europe, Asia and the USA.

"We look forward to working with MCP in order to expand 5N Plus' product offering and establish a worldwide manufacturing and distribution platform," says 5N Plus' president & CEO Jacques L'Écuyer.

Fache will be appointed to 5N's board, which will consist of six directors. Raskin should join the board at the next annual meeting of shareholders. Fache and Raskin will be appointed executive VPs, reporting directly to L'Écuyer.

5N Plus has acquired all of MCP's issued and outstanding shares for: (i) €105.8m in cash (CDN\$142.8m as of 25 February); (ii) promissory notes to MCP's selling shareholders totaling €46.9m (CDN\$63.3m), payable over a 3-year period; and (iii) 11,377,797 common shares of 5N issued to selling shareholders (subject to lock-up provisions lasting up to 18 months). The purchase price also includes a cash 'holdback' of €14.97m (CDN\$20.2m), payable

by 5N Plus within three years.

Using the closing price of 5N's shares on the Toronto Stock Exchange on 25 February (\$8) and a Euro to Canadian dollar exchange rate of 1.3494, the deal is valued at €235.2m (CDN\$317.3m). 5N has also assumed MCP's net debt (€65.6m as at end-December 2010, mostly short-term debt used to fund MCP's working-capital requirements).

Investors in the public offering received shares in lieu of subscription receipts. The shares were sold to a syndicate of underwriters led by National Bank Financial Inc and including GMP Securities LP, CIBC World Markets Inc, TD Securities Inc, Versant Partners Inc, Cormark Securities Inc, HSBC Securities (Canada) Inc, M Partners Inc and Stonecap Securities Inc. Net proceeds were used to fund part of the cash part of the MCP deal (with the balance paid from cash on hand).

www.mcp-group.com

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IQE's full-year 2010 sales rise 38%, tripling profit

Optoelectronics growth of 46% outpaces 32% growth for wireless

After late January's trading update for second-half 2010 revenue of "at least £38.7m", epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK has reported revenue of a record £39.6m, up 20% on first-half 2010's £33m.

This takes full-year 2010 revenue to £72.7m, up 38% on 2009's £52.7m, driven by higher volumes in all main markets and increased market share.

Although IQE Silicon electronics business was less than 5% of total revenue, wireless sales grew by over 32% (75% of total revenue).

The emerging optoelectronics business grew 46% organically (to 20% of total revenue), albeit from a lower base. However, opto growth was boosted to more than 56% by late September's acquisition of antimony-based substrate maker Galaxy Compound Semiconductors Inc of Spokane, WA (the sole US provider of infrared imaging materials to high-value military and other markets). Complementing IQE's Wafer Technology subsidiary in Milton Keynes, UK, the acquisition positions IQE as the market leader for gallium antimonide and indium antimonide substrates for use in infrared sensing, it is reckoned.

IQE says its optoelectronics sales are already starting to reflect the benefit of pre-production revenues from consumer applications and concentrated photovoltaics (CPV). In particular, sales of VCSELS (critical for finger navigation and optical interconnects) grew by about 120%, while sales of CPV material grew by more than 80%.

"Our core business of high-speed connectivity, including wireless-related products for all forms of mobile device communications, has continued to show very strong growth, whilst new and emerging products for consumer, energy efficiency, industrial and defence applications are generating increased demand across all our key markets," says president & CEO Drew Nelson. "2010 has been an outstanding year for the Group, with record revenues and profits achieved, delivering on key strategic, operational and financial objectives well ahead of the board's expectations," he adds.

Reflecting "strong management of costs and further operating efficiencies", full-year gross margin has risen from 21.9% in 2009 (which was boosted by one-off cost savings in a period of destocking) to 22.8%.

Aided by high operational gearing, pre-tax profit tripled (from £2.1m to £6.3m) and retained profit more than tripled (from £2.1m to £7.5m).

A placing of 65 million new shares at the end of September raised gross proceeds of £20.8m, which was used to repay borrowings, finance capital expenditure and fund the Galaxy acquisition. Capital expenditure rose from £1.7m in 2009 to £5m, as capacity has been added to meet expected continued growth in demand. In particular, IQE invested £3.4m in development expenditure (up on £2.3m in 2009), relating to the qualification of new wireless and optoelectronic products and the development of new solar and gallium nitride materials. Also,

IQE disposed of a property in Singapore for £1.5m, realizing a profit of £0.4m. Overall, compared with net debt of £14.9m at the end of 2009, IQE had net cash of £7m at the end of 2010.

"We continue to make excellent progress in the development and commercialization of key IP that we expect will contribute to revenues during 2011 and help to increase our competitive advantage and leading positions in a number of high-growth markets," says Nelson. In particular, last August IQE was granted two Japanese patents on nanocolumn technology for high-purity GaN substrates (for producing blue and green lasers and LEDs), developed by NanoGaN Ltd of Bath, UK (acquired in October 2009).

"In terms of the four technology 'megatrends' of this decade [high-speed connectivity; sustainable clean energy generation and the efficient use of energy; the explosion of personal consumer devices for enhanced lifestyle, and the increased sophistication and performance of security-related systems] we are helping drive these with our key enabling technologies," says Nelson. In particular, with a number of emerging high-volume and mass-market applications, IQE believes that its optoelectronics business has the potential to eclipse wireless growth on a sustained basis and eventually to evolve into a business with the scale and profitability of the wireless operation.

www.iqep.com

IQE's CEO Nelson elected as new president of EPIC

The European Photonics Industry Consortium (EPIC) of Paris, France has elected IQE's CEO Dr Drew Nelson as its president.

With 80 voting members and over 400 associate members, EPIC promotes sustainable development for European organizations working in

photonics. Members have played a leading role in creating and operating the European Technology Platform, Photonics-21 and European projects such as LIFT for fiber-laser development and Nexpresso, supporting commercial innovation by small and medium enterprises.

Nelson succeeds Jean-François Coutris of Sagem Défense et Sécurité (who has completed serving two terms as second president). He began his term on 5 April, presiding at EPIC's annual general assembly in Paris.

<http://epic-assoc.com>

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Riber's Q1 revenue doubles year-on-year

Diversification into OLEDs and CIGS PV boosts order backlog by 134%

For first-quarter 2011, Riber S.A. of Bezons, France, which manufactures molecular beam epitaxy (MBE) systems as well as evaporation sources and effusion cells, has reported revenue of €5.7m, up 98% on €2.9m a year ago but down on the exceptional €13.1m last quarter (which contributed 63% of full-year 2010's revenue).

In particular, growth is being driven by systems sales, with the delivery of two machines in Q1 boosting systems revenue to €2.1m, almost double (up 92%) on €1.1m a year ago. Revenue for evaporation sources and cells grew nine-fold, from just €0.3m a year ago to €2.6m, reflecting Riber's ongoing diversification to the strongly growing markets for OLEDs (organic LEDs) and copper indium gallium diselenide (CIGS) thin-film photovoltaic panels. Services & accessories revenue was €1m, down 'temporarily' by

34% from the high level of €1.5m a year ago. Riber adds that the positive evolution of revenue is also resulting from its policy of aiming to spread production evenly throughout the year.

At the end of the March quarter, order backlog was €21.3m, up strongly by 134% on €9.1m a year ago. This includes systems orders worth €14m (more than double the €6.9m a year ago), comprising six research systems and four production systems (including an order received in March for a new production machine). Out of these 10 machines, only one system is not scheduled to be delivered during 2011. In addition, backlog includes major effusion cell orders in the OLED sector, boosting total orders for evaporation sources and cells 25-fold from just €0.2m a year ago to €5m. Services & accessories orders have grown by 15% from €2m to €2.3m.

Riber concludes that these trends confirm the relevance of its business strategy, based on:

Evaporation sources and cells grew nine-fold... reflecting Riber's ongoing diversification to the strongly growing markets for OLEDs and CIGS

- continuing to strengthen its market leadership in MBE systems;
- capitalizing on the installed base and growing sales of epitaxy equipment, spare parts and accessories, as well as corresponding services; and
- launching a

range of high-value-added equipment and services for high-growth applications (thin-film solar panels, OLED lighting and flat screens, etc).

www.riber.com

IQE recruits director of global gallium nitride strategy

Epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK has appointed Dr Trevor Martin as director of global gallium nitride (GaN) strategy, responsible for enhancing and delivering IQE's GaN strategy across the group.

IQE says that GaN is becoming an increasingly important material system across a diverse range of markets encompassing defence, industrial and consumer applications, from high-efficiency power switching and high-power radio frequency to advanced optoelectronics in the form of lasers and LEDs. Opportunities for GaN materials will be driven by technology 'megatrends' such as efficient power generation and transmission, efficient energy usage such as solid-state lighting, electric vehicles, and improved wireless infrastructure.



Dr Trevor Martin.

Martin has more than 25 years of experience in compound semiconductor materials and joins IQE from QinetiQ, Malvern, UK where he was responsible for its overall epitaxial capabilities and the development of GaN technology.

Martin received his PhD from the University of Glasgow for work on molecular beam epitaxy (MBE) growth on indium phosphide (InP) and has been involved in the development of a number of key semiconductor technologies prior to his work in GaN, including the on-wafer integration of optical devices and the development of antimony-based devices. He has also had extensive

involvement in large multinational collaborative programs, has served on many academic steering and review panels, has co-authored more than 150 papers, and is co-inventor on a number of patents.

"IQE has established an enviable reputation as a global leader in GaN-based materials and Trevor's appointment complements and further strengthens our technology leadership in this important market sector," reckons business development director

Adrian Meldrum. IQE acquired GaN substrate firm NanoGaN Ltd of Bath, UK in October 2009.

www.iqep.com

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TU Eindhoven to use Aixtron CCS MOCVD reactor for nanowire structures

Aixtron says that in fourth-quarter 2010 it received an order from existing customer the University of Technology (TU) Eindhoven in The Netherlands for a Close Coupled Showerhead (CCS) MOCVD reactor in 3x2"-wafer configuration.

After delivery in third-quarter 2011, the local Aixtron support team will install and commission the reactor in the cleanroom facility within the COBRA Research Institute at TU Eindhoven. It will then be used for the growth of GaAs- and InP-based nanowire structures as well as for nitrides and silicon compounds.

"The new reactor will be used for fundamental research purposes and in particular to synthesize complex semiconducting nanowire heterostructures to be used as active elements in solar cells, (bio)chemical sensors, thermoelectrics and in quantum information devices," says professor Dr Erik Bakkers of TU Eindhoven's Photonics of Semiconductor Nanostructures Department. "For these applications, the electronic (mobility) and optical quality (linewidth and intensity) of the wires must be excellent," he adds.

"This versatile MOCVD system will be the workhorse of our group, providing Dutch research institutes with nanowires and other relevant materials," Bakkers continues. "The CCS system will enable us to achieve control of nanowire properties and enable the manufacture of nanowires from new combinations of materials."

TU Eindhoven's nanowire group began operation in January 2010 and has since been setting up a national nanowire growth facility. The COBRA Research Institute is the National Centre of the Netherlands for Research on III-V semiconductors and optoelectronic devices and systems. COBRA employs more than 100 scientists and technicians.

www.aixtron.com

PARC orders Aixtron CCS MOCVD system for InGaAlN lasers and LEDs

In Q4/2010 Aixtron received an order for a Close Coupled Showerhead (CCS) MOCVD reactor (in 3x2"-wafer configuration) from Xerox subsidiary PARC of Palo Alto, CA, USA, which creates, prototypes, co-develops, licenses and delivers technology and services for government and commercial clients.

The system has a full set of features such as the in-situ multichannel pyrometer ARGUS, high-temperature growth, and gap adjustment for optimum (Al)GaN conditions over a wide pressure range.

After delivery in Q2/2011 and commissioning by a local Aixtron support team, PARC's electronic materials and devices research division will use the reactor for the epitaxial growth of indium gallium aluminum nitride (InGaAlN) LEDs, laser diodes and electronic devices.

"Our ongoing programs require a state-of-the-art MOCVD system with advanced features that enable our team to carry out R&D over a wide range of optoelectronic materials and devices," says Jennifer Ernst,

PARC's director of business development. "The CCS system is widely deployed in industry and well suited to our needs," she adds.

"We can expand our capacity and capabilities to develop and deliver new device technologies. We will be able to develop new processes in a commercial reactor that are compatible with a prospective scale-up to full production scale in due course," Ernst continues. "Working closely with the experienced Aixtron support team, our group expects to, for example, quickly optimize conditions for growth of GaN alloys with a high percentage of Al, as required for deep-UV optical emitting devices."

PARC's R&D optoelectronic materials and devices team has already developed LEDs and laser diodes in the visible and UV spectral regions. It has made contributions to the fundamental understanding of the materials and devices, and demonstrated innovations in the design and realization of InGaAlN devices for optoelectronic applications.

www.parc.com

CRIUS II qualified in Taiwan with Chi Mei

Aixtron's latest CCS MOCVD platform system, the CRIUS II, has been qualified for mass production within the Chi Mei Group, outperforming expected process stability, uniformity, and throughput.

Chi Mei was the first customer in Taiwan to receive the new system. The 55x2"-wafer configuration CRIUS II was installed and commissioned by the local Aixtron service team at facilities near the Southern Taiwan Science Park. Since then the team has been working closely with the firm to speed qualification.

A company representative noted that it has been a seamless transition from the CRIUS to CRIUS II due to its straightforward process transfer capabilities — the unique

CCS reactor chamber technology simply requires the application of area-scaling factors, says Aixtron. The qualified system will soon be fully operational for Chi Mei's family of HB-LED products.

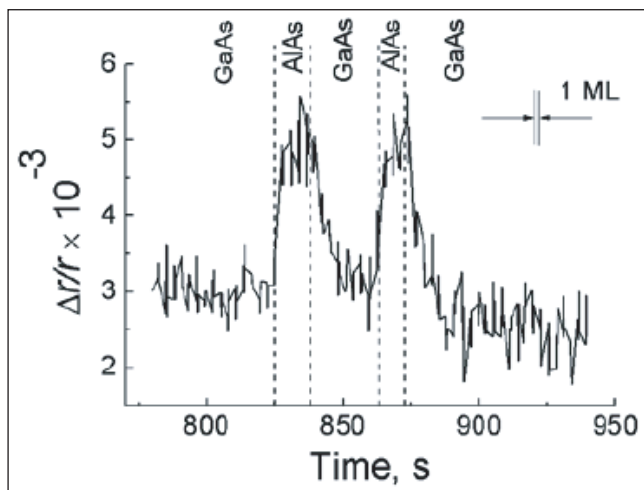
Aixtron says the CRIUS II can be tuned to optimize performance and can further be converted from 2" to 4", 6" or larger wafer size production, a key factor for GaN LED manufacturing. Since larger wafer sizes play a crucial role in reducing LED manufacturing cost, the CRIUS II can boost productivity, says Aixtron. Compared to the CRIUS, the CRIUS II capacity has been raised from 31x2" to 55x2" wafers. Alternatively, the CRIUS II reactor chamber can accommodate as many as 13x4" wafers.

EpiRAS TT used in MBE growth of AlAs/GaAs resonant-tunnel diodes

Igor Kazakov and co-workers at the Lebedev Physical Institute in Moscow, Russia recently reported results of the MBE growth of high-quality resonant tunnel diode (RTD) structures ('In Situ Optical Diagnostics of Growing Surfaces in the Process of Nanoheterostructure Fabrication'. *Semiconductors*, 2010, Vol. 44, No11, p1441).

LayTec AG of Berlin, Germany says that the team used its EpiRAS

TT system for real-time monitoring of all stages of heterostructure growth of the ultra-thin GaAs and AlAs layers (see Figure). "The optical monitoring we used is an efficient monitoring tool at all stages of the growth," the Lebedev



Reflection anisotropy spectroscopy transient (RAS) resolving the RTD's active region (2.3/4.5/2.0nm of AlAs/GaAs/AlAs) during MBE growth.

Physical Institute team concluded. "Reflectance anisotropy (RA) data enables detection of the changes in the material composition at normal GaAs/AlAs interfaces with one-monolayer resolution."

www.laytec.de

LayTec appoints marketing manager

New marketing manager Daniela Sill joined LayTec in January in order to strengthen the firm's marketing team.

Sill has a degree in business economics (focused on marketing) from the University of Applied Sciences Pforzheim (Germany).

LayTec adds that she brings many



years of experience working as product, marketing and exhibition manager as well as a marketing consultant.

www.laytec.de

LayTec hosting in-situ seminars at May's CS Week and July's ICNS

LayTec AG of Berlin, Germany (which provides in-situ optical metrology systems for thin-film processes) says that this year it is organizing two in-situ seminars, each with a different topical focus:

- 'In-situ monitoring of III-arsenide and III-phosphide epitaxial growth', in conjunction with the Compound Semiconductor Week

2011 in Berlin, Germany on 22 May (3–6 pm); and

- 'In-situ monitoring of III-nitride epitaxial growth', in conjunction with the 9th International Conference on Nitride Semiconductors in Glasgow, UK on 10 July (2–4pm).

To register e-mail: info@laytec.de.

www.csw2011.org

www.icns9.org

IN BRIEF

Taiwan LED maker Epistar receives further Aixtron G5 reactors

Deposition equipment maker Aixtron SE of Herzogenrath, Germany has announced further shipments of metal-organic chemical vapor deposition (MOCVD) systems, for delivery in the first and second quarters of 2011, to Taiwan's biggest LED chipmaker, Epistar Corp of Hsinchu Science-based Industrial Park. The contract is for multiple AIX G5 HT reactors in a 14x4"-wafer configuration. Aixtron's local support team is installing and commissioning the reactors, which will be dedicated to the growth of high-brightness LEDs.

Following Epistar's qualification of the AIX G5 HT in 2010, Aixtron says that this latest repeat order is a further endorsement of the G5's very rapid time-to-production and high system-to-system reproducibility (both key factors in a highly competitive market and a considerable driver of cost reduction).

"The new reactors will form the backbone of our planned capacity expansion for our high-brightness LED production program," says Epistar's president Dr Ming-Jiunn Jou. "In particular, we have been impressed by the run-to-run and system-to-system reproducibility the G5 has shown. This makes the G5 the leading MOCVD system in terms of throughput and yield, allowing us to quickly ramp up our capacities and expand our product portfolio even further in the direction of solid-state lighting products," he comments, adding that the G5 also provides an easy, scalable route for the firm's process recipes.

www.epistar.com.tw

www.aixtron.com

IN BRIEF

P+E wins Taiwan purifier orders

Power+Energy Inc of Ivyland, PA, USA, which provides palladium-membrane-based hydrogen purifiers for LED makers, GaN and SiC power and high-frequency devices, photovoltaic manufacturers and polysilicon suppliers, has won orders from customers in Taiwan for four more PE9000MZ purifiers (for delivery and installation this quarter). The firm has also recently shipped systems to the USA, Germany and China.

"We are very pleased to continue to grow our customer base in Taiwan," says president Noel Leeson. "Success of the PE9000MZ product demonstrates that its performance and cost are a good match to the needs of the market and that our partnership with WahLee Industrial Corp is proving successful in winning users over to Power+Energy's products."

In March 2010, P+E announced a partnership for WahLee to exclusively sell and service its purifiers in Taiwan and China.

www.powerandenergy.com

Altatech extends global network with distributor QES Singapore

To extend its reach into Asia's growing semiconductor markets, capital equipment maker Altatech Semiconductor S.A. of Montbonnot, near Grenoble, France has signed QES Singapore Pte Ltd as its sales, installation and field service partner in Singapore. Part of the QES Group, QES Singapore has begun representing Altatech's AltaSight wafer inspection systems and liquid-precursor AltaCVD (chemical vapor deposition) products with prospective and existing customers on the island.

Established in 1991, QES Group is one of the region's leading manufacturers' representatives, says Altatech, as well as a provider of engineering solutions. The 250-person firm is headquartered in Malaysia, where it also operates a manufacturing facility, and has regional offices in Singapore, Thailand, the Philippines, Vietnam, Indonesia and China.

QES Singapore's staff includes 11 sales and service personnel. Two of the field service engineers are currently being trained on the operation and maintenance of the

AltaSight and AltaCVD product lines at Altatech's headquarters. QES Singapore's field personnel have experience with a wide variety of semiconductor-processing systems as well as equipment for the mass storage, petrochemical and life sciences markets, says Altatech.

"QES's solid technical background in semiconductor processing, combined with its track record of excellent customer service, make this an ideal partnership," believes Altatech's president Jean-Luc Delcarri. "Leveraging its established relationships, QES has already begun working to educate local microelectronics companies on the performance and benefits of our technologies," he adds.

"Our marketing work had already begun on Altatech's exciting product line," says QES Singapore's general manager S.C. Pang. "We are working together to address the needs of Altatech's customers in the semiconductor industry while also exploring opportunities in other applications."

www.qesnet.com

www.altatech-sc.com

Applied Seals opens applications and design center

Applied Seals North America Inc of Newark, CA, USA has opened a new applications and design center, boosting its capabilities in troubleshooting customers' problems with o-rings and other seals, prescribing the best application-specific solutions and designing seals for the 22nm technology node of semiconductor manufacturing. Advanced perfluoroelastomer (or FFKM) seals are used throughout semiconductor manufacturing equipment to create and maintain ultraclean environments for ICs manufacturing.

For chip makers and wafer fabrication equipment suppliers, the plant provides a dedicated applications lab for diagnosing and solv-

ing sealing issues. Customers can send their seals for analysis.

"This addition to our Silicon Valley operations allows us to work even more closely with semiconductor industry members to educate them about the wide variety of sealing solutions and their differences," says president & general manager Dalia Vernikovskiy. "Diagnosing the cause of a specific problem and then prescribing the right seal is critical. Now we can provide exact solutions faster."

The center is equipped to precisely measure standard and custom-sized seals and glands and to determine surface roughness to within 50nm. Metrology data is then used to perform finite element analysis (FEA)

to optimize the geometry and composition of sealing components for individual applications. The metrology equipment includes magnifying optical comparators, CCTV-coupled microscopes, calipers and gauges.

The firm can also use the facility to design sealing solutions for leading-edge processes, including immersion lithography and depositing materials like hafnium, with engineers in Silicon Valley sharing insights with Applied Seals' R&D, engineering and manufacturing divisions in Taiwan.

Eventually, the facility may produce small volumes of prototype seals prior to volume manufacturing at Applied Seals' factory in Taiwan.

www.appliedsealsna.com

California awards Applied \$500,000 to improve LED manufacturing

The California Energy Commission (CEC) has awarded \$500,000 to process equipment maker Applied Materials Inc of Santa Clara, CA for a research project to develop an improved and more cost-effective way to manufacture LEDs.

Created by the California Legislature in 1974, the CEC is the state's primary energy policy and planning agency. It has five major responsibilities: forecasting future energy needs and keeping historical energy data; licensing thermal power plants 50MW or larger; promoting energy efficiency through appliance and building standards; developing energy technologies and supporting renewable energy; and planning for and directing state response to energy emergency.

Funding comes from the CEC's Public Interest Energy Research (PIER) program (which supports public-interest R&D that helps to improve the quality of life in California by bringing environmentally safe, reliable, and affordable energy services and products to the marketplace).

Total project cost is \$8,718,911, of which Applied is providing \$4,225,000. It also received a \$3,993,911 American Recovery and Reinvestment Act (ARRA) award in January 2010 from the US Department of Energy for the project 'Advanced Epi Tools for Gallium Nitride LED Devices' to develop a multi-chamber hybrid system for metal-organic chemical vapor deposition and hydride vapor phase epitaxy.

The CEC-funded project aims to cut the costs of LEDs via improvements in manufacturing equipment and processes, particularly MOCVD.

Improving the manufacturing process should cut operating costs, increase LED efficiency, and reduce manufacturing waste since more LEDs will meet target specifications. Improving manufacturing efficiency means that higher-quality LEDs would be fabricated at lower cost, helping to broaden adoption of LEDs in the marketplace.

The project is due for completion by July 2012. The firm expects it to create 1600 jobs in California by 2015.

www.appliedmaterials.com

NuGenTec's seals tested in contamination-critical CVD process

Nugeneration Technologies LLC (NuGenTec) of Emeryville, CA, USA (a producer of high-performance materials and chemicals) says that its Gumlast L8010 — which is 100%-pure perfluoroelastomer (FFKM) — has been successfully tested in contamination-critical chemical vapor deposition (CVD) process. HP Labs tested the L8010 in a roughing pump isolation valve during CVD of germanium and silicon germanium (SiGe) thin films.

Using proprietary pseudo-living polymerization, multiple grades of Gumlast have been formulated to optimize the performance of the molded parts in many different

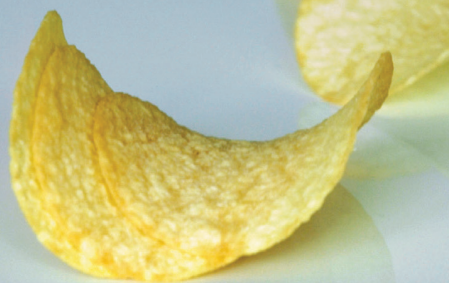
applications. Gumlast L8010 is made in ISO-certified production lines with very high line yield, the firm says, adding that Gumlast L8010 is priced at or near 50% of most other FFKMs on the market.

Due to the critical role of sealing components in semiconductor processing, NuGenTec says this benchmarking status is noteworthy for a US-manufactured product with a significantly lower price point.

"Deposition of high-quality germanium nanowire requires seal purity and performance beyond ordinary," says Fred Pourmirzaie, director of the FloDynamix LLC division.

www.nugentec.com

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OIPT expansion boosts production capacity by 50%

Staffing grows 30% over last 12 months

UK-based etch, deposition and growth system maker Oxford Instruments Plasma Technology (OIPT) says that a major expansion and improvement program at the firm is delivering key benefits to its customers, with investment in a number of key areas of the business resulting in faster and more streamlined manufacturing, better research facilities and more comprehensive customer support.

"Our workforce has grown by over 30% in the past 12 months, enabling us to react quickly to our significantly increased order book and to provide faster product and process development for our customers," comments managing director Andy Matthews. "We have responded to the demands of our industry to ensure we are as competitive as possible, and to retain our reputation for producing world-class products and creating long-term relationships with our customers based on trust and respect," he adds.

The firm has incorporated parallel build and test bays in Manufacturing



(Left to right) Ayres and Matthews in the expanded production facility.

for production of its etch, deposition and growth equipment, enabling it to respond to customer requirements with more flexibility as well as reducing manufacturing lead times. It says that this has resulted in more efficient manufacturing processes for repeat products, for example in supplying equipment to the fast-growing high-brightness light-emitting diode (HB-LED) production market. OIPT reckons that these changes have increased its production capacity by about 50%.

In addition, new R&D and appli-

cations laboratories have been built with expanded capabilities, and the firm has appointed extra process engineers. The applications laboratories house the company's range of etch, deposition and growth equipment, including PlasmaPro, FlexAL ALD and Nanofab nanoscale growth tools manufactured at the firm's facility in Bristol, UK, where customer samples are run and new processes developed.

Dedicated engineering and software development suites as well as a specialist training department have also been created in order to maximize the capacity to deliver tools and support to customers.

"This major investment in both staff and facilities supports our ability to meet the needs of our diverse customer base," says general manager Dan Ayres. "Alongside our global team and supply base, we're able to continually improve our quality and delivery performance whilst innovating our product and process offering," he adds.

www.oxinst.com

Soraa adds Plasma-Therm deposition and etch systems

Plasma process equipment maker Plasma-Therm LLC of St Petersburg, FL, USA says that Soraa Inc of Fremont, CA, USA has recently purchased three of its systems to provide plasma deposition and etch steps in its wafer fabrication process.

Founded by pioneering nitride researchers from the University of California at Santa Barbara (professors Shuji Nakamura, Steve DenBaars and Jim Speck), Soraa is developing a new class of green and blue laser diodes and LEDs for application in general lighting and projection display markets. Led by CEO Eric Kim, the firm is rapidly expanding its US-based manufacturing capacity in preparation for volume production.

Soraa purchased a 790+ RIE (reactive ion etch) system, a VERSALINE PECVD (plasma-enhanced chemical vapor deposition) system and a VERSALINE ICP (inductively coupled plasma) system. By providing dielectric deposition and metal, dielectric, and active material patterning, they collectively deliver key front-end processing technologies that are critical to the development and production of photonic devices. Plasma-Therm says that demand for LEDs and lasers continues to increase as they enter mainstream applications including consumer lighting, displays, biotechnology, defense and industrial markets.

"As engineers apply their skills and knowledge to different semi-

conductor applications, they often keep the knowledge and experience they have from working with different equipment sets," says executive VP of sales & marketing Ed Ostan. "Positive experiences with Plasma-Therm processing systems have repeatedly led to new orders and continued relationships," he adds. "The value previously experienced with Plasma-Therm equipment was instrumental in this manufacturer's decision to purchase Plasma-Therm equipment. Our emphasis on building strong business relationships as well as the proven reliability and support of our systems is a key factor in repeat orders."

www.soraa.com

www.plasmatherm.com

Oxford Instruments receives UK Queen's Award for Enterprise: International Trade

UK-based etch, deposition and growth system maker Oxford Instruments Plasma Technology (OIPT) has been awarded The Queen's Award for Enterprise: International Trade for more than doubling its overseas earnings over six years of sustained growth, and exporting more than 90% of its production.

Oxford Instruments Plasma Technology (part of the Oxford Instruments Group) started trading in 1981 and is the world's largest supplier of thin-film plasma etch and deposition equipment to the R&D market, and is also in the top two in several key production applications. This is the 12th Queen's Award that the Oxford Instruments Group has won.

The firm says that its performance was based on a product range addressing a wide spread of markets combined with an aggressive

strategy of developing new markets, primarily in Asia. This resulted in total exports of £139m in six years and the creation of 29 more full-time permanent UK jobs during the period applicable to the Award selection criteria. This growth has continued as demand for equipment has

increased, **Performance was based on a product range addressing a wide spread of markets**

and the firm has recently undergone an expansion and refurbishment programme, investing more than £2.5m (\$4m) in its factory near Bristol, UK. This has expanded production capacity by more than 50%, and allowed Oxford instruments Plasma Technology to keep up with the significant growth in business seen in the last 12 months.

The firm has also substantially enlarged its Applications Laboratory by extending the R&D area, and installing an additional Class 1000 cleanroom area where another six tools for process development and running customer samples will be installed. This increase in facility size has boosted staffing to over 330 worldwide, with many additions in the front line including process expertise, service and support.

"Our company's continued growth and success is attributable to our strong workforce, continuous R&D, and our belief in listening to our customers and developing the tools and systems that they want," comments managing director Andy Matthews. The award recognizes the skill, commitment and dedication of everyone at Oxford Instruments Plasma Technology over a sustained period, he adds.

www.oxford-instruments.com

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www.oxford-instruments.com/plasma

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EV Group wins Frost & Sullivan's European Nanoimprint Technology Product Innovation Award

EV Group (EVG) of St Florian, Austria, a supplier of wafer bonding and lithography equipment for the MEMS (micro-electro-mechanical system), nanotechnology and semiconductor markets, has received the 2010 European Nanoimprint Technology Product Innovation Award from market research firm Frost & Sullivan, recognizing its accomplishments in addressing industrial needs with nanoimprinting solutions.

Frost & Sullivan implemented a comprehensive research study that ranked multiple nanoimprint lithography (NIL) providers across several categories including advancement of technology, industrial implementation, solution portfolio, fulfilling future market needs, and impact on the end-user. EVG says that it received among the highest marks in every category and ranked significantly higher than the nearest competitor overall.

"With market leadership in wafer bonding, 3D interconnect and MEMS manufacturing tools, EV Group has vast expertise in different areas that synergize with its nanoimprinting solutions,"

comments Frost & Sullivan research analyst Kenneth Chua. "The company is known to provide proven solutions fulfilling the needs of the semiconductor industry. Its NIL equipment continues this legacy and brings about low-cost, high-throughput and reliable solutions to its end-users," he adds.

According to Frost & Sullivan, much of the competition in NIL has been focused on making NIL viable for either mainstream semiconductor fabrication or patterning for future data storage media (bit-patterned media in hard disk drives). In contrast, EVG has leveraged its expertise to focus on key high-growth markets, including optics and microfluidics.

Moreover, as EVG continues to enhance the capabilities and performance of its NIL technology, it periodically evaluates its potential for other markets—and is prepared to realign its development strategies in the event that NIL becomes better suited to the needs of data storage and mainstream semiconductor manufacturers. The firm says that this is evident in its latest development, which is the ability to

pattern features as small as 12.5nm in diameter using ultra-violet-assisted nanoimprinting, compatible with its EVG620, EVG6200 and EVG770 NIL systems.

"With a decade of experience in nanoimprint lithography, this award is testament to the quality and EVG's outstanding achievements in NIL technology innovation, as well as to the company's overall success in aligning its development efforts with market demand," states Dr Thomas Glinsner, EV Group's head of product management.

Nanoimprinting is used to produce patterns on a substrate by mechanical means. EVG's ultraviolet-assisted NIL (UV-NIL), as well as its hot embossing processes, leverages its proprietary soft-stamp technology, whereby a master imprinting stamp is used to generate soft stamps. This method increases the lifetime of the master stamp due to reduced mechanical contact and enables an overall reduction in cost of ownership.

www.awards.frost.com

www.evgroup.com/en/products/lithography/nil_systems

MEI delivers order for 17 wet processing systems

MEI LLC of Albany, OR, USA says that it has completed delivery of a record order for 17 semiconductor wet processing systems for a major semiconductor manufacturer. The primary applications for the wet bench process systems are compound semiconductor etch, wafer cleaning, stripping and plating processes.

MEI says that it was selected as the equipment vendor of choice for duplicating the semiconductor manufacturer's processes of record into a new fabrication facility in Texas.

The compound semiconductor manufacturer requested the custom,



Wet benches in production at MEI's manufacturing facilities.

semi-automated and manual wafer processing tools last September and needed rapid delivery. Both the compound semiconductor firm and

MEI are experiencing rapid growth, the supplier notes.

"The contract is especially challenging and rewarding because of the strict performance requirements that the vendor had, combined with the rapid production schedule," says CEO Dan Cappello. "With our Revolution rotary wet bench and Achiever wet processing platforms, we were able to meet their throughput and quality needs with custom wet benches," he adds. "With our new production facility, we were able to ramp up and meet their schedule without difficulty."

www.meillc.com

MV Products launches vacuum foreline traps for high-brightness LED and solar cell manufacturing

The MV Products division of Mass-Vac Inc of North Billerica, MA, USA is introducing a line of vacuum foreline traps for manufacturing processes that create large volumes of solid by-products.

Specifically, MV Vacuum Inlet Traps are suited to metal-organic chemical vapor deposition (MOCVD), hydride vapor phase epitaxy (HVPE), plasma-enhanced chemical vapor deposition (PECVD) and low-pressure chemical vapor deposition (LPCVD) processes used in manufacturing solar cells, high-brightness light-emitting diodes (HB-LEDs), and Li-ion batteries, which generate high volumes of particulates. Offered in several models to accommodate different manufacturing process applications and volume requirements, they can



MV Products' vacuum foreline traps.

incorporate a wide range of filters for trapping solids, organic solvents

and other contaminants and for protecting vacuum pump systems from oil back-streaming.

Featuring user-selectable filter elements, MV Vacuum Inlet Traps include:

- the MV Multi-Trap, which has a knock-down stage plus two stages of filter elements and is capable of up to 2500 cubic inches (40,968cm³) of solids accumulation, and
- the Posi-Trap for applications up to 50 cubic feet (1,415,842cm³) per minute (CFM).

Both models are offered in several sizes, with stainless-steel, copper gauze, molecular sieve, activated charcoal, pleated polypropylene (2, 5 and 20µm pore sizes) and Sodasorb filters.

www.massvac.com



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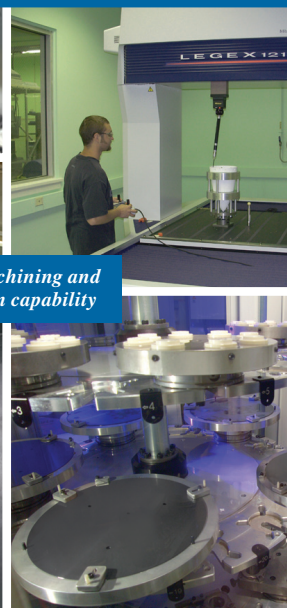
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Entegris adds 150mm Thick Wafer Shipper

At March's SEMICON China 2011 show in Shanghai, Entegris Inc of Billerica, MA, USA demonstrated its new Ultrapak 150mm Thick Wafer Shipper and Aeronex gas purification systems for LED manufacturing.

The Ultrapak 150mm Thick Wafer Shipper is designed for shipping the 1.3mm-thick wafers commonly used in LED chip manufacturing. The polypropylene shipper secures wafers to limit rotation, reduce particle contamination and prevent damage or breakage.

"Through collaboration with leading LED manufacturers, Entegris identified key modifications for its widely used semiconductor shipper that ideally suit the unique needs of the LED industry," says William Shaner, VP & general manager for the Microenvironments Division. "We combined their input with more than 30 years of Entegris' wafer shipping experience to design the most protective shipper for these critical substrates."

Modifications include improving wafer spacing and pitch to fit wafers that are thicker than standard silicon wafers. The design also has a new secondary packaging system to support and protect heavier loads. The shipper expands the current line of LED wafer handling products, which includes a multi-wafer shipper for thin wafers (Ultrapak 100mm Thin Wafer Shipper, launched at January's SEMICON Korea 2011), single-wafer shippers, and multiple wafer carriers for in-fab processing.

At SEMICON China, Entegris also exhibited its Aeronex line of gas purification solutions for HB-LED making. The firm says the systems provide reliable gas purification for maximum uptime, enabling manufacturers to produce HB-LEDs with the highest photoluminescence peaks and luminous efficiencies. The multi-bed design allows continuous supply of purified gas and is available in several flow ranges for nitrogen, hydrogen and ammonia.

www.entegris.com

Sumitomo Chemical & Samsung LED to form \$72m sapphire substrate JV

Sumitomo Chemical Co Ltd of Tokyo, Japan and Samsung LED Co Ltd of Suwon, South Korea have agreed to form a 50:50 joint venture in South Korea for R&D, manufacturing and sale of sapphire substrates for LEDs. Samsung LED says in a regulatory filing that it will invest 40bn won (\$36m), so total investment amounts to \$72m.

Sumitomo Chemical provides materials such as high-purity alumina, which is used as a raw material in sapphire substrates and liquid-crystal polymer used in materials for LED packages. Last year, its subsidiary Dongwoo Fine-Chem of Seoul, South Korea started developing sapphire substrates, and is currently upgrading its production facilities to start commercial production as soon as possible. Samsung LED is a joint venture formed in mid-2009 between Samsung Electronics Co and its affiliate Samsung Electro-Mechanics Co. The firm plans to invest in strategic

expansion of its core business of LED manufacturing.

The joint venture is in response to the demand for sapphire substrates and related materials, which is driven by growth in the market for LEDs in LCD TV backlights, interior lighting, and automobiles. The plan is to set up a production plant this year and to start mass production of substrates from early 2012.

The joint venture partners reckon that, as both firms aim to expand business in the LED sector, they can strengthen their competitiveness by generating synergies in technology development, marketing and other areas. Specifically, Samsung LED wants to benefit from vertical integration of the supply chain of such key components, and to avoid importing the material. Currently, about five firms control 90% of the global supply of sapphire ingots, and Samsung LED wants to secure its supply as global demand rises.

www.sumitomo-chem.co.jp/english

Chinese silicon wafer maker LDK Solar enters sapphire wafer business \$40m invested in 2 million wafer-per-year plant

LDK Solar Co Ltd of Hi-Tech Industrial Park, Xinyu City in Jiangxi Province, China, which is a vertically integrated manufacturer of photovoltaic (PV) products and a manufacturer of solar wafers, has invested about \$40m to establish a manufacturing plant in Nanchang City, Jiangxi Province with the capacity to supply 2 million 2"-equivalent sapphire wafers per year, with the aim of capturing the growing opportunities in the LED industry.

LDK currently makes polysilicon, mono- and multicrystalline ingots, wafers, modules and cells, and also engages in project development activities in selected segments of the PV market. The firm also has a US office in Sunnyvale, CA.

"This new investment in manufacturing sapphire wafers has a great synergy with LDK Solar's crystallization and wafer engineering and manufacturing expertise, and will enhance LDK Solar's product offerings," believes chairman & CEO Xiaofeng Peng. "We also would like to express our sincere appreciation to Nanchang City and Jiangxi Province for the support they have shown."

Other solar silicon wafer firms recently expanding into supplying sapphire substrates for the booming LED industry include China's Jiangsu Jixing New Material and Jiujiang Sapphire Tech, Taiwan's San Chih Semiconductor, and South Korea's OCI Company Ltd.

www.ldksolar.com

BluGlass and SPTS JV establishing UK RPCVD research and demo site

SPTS CVD production tool to be retrofitted with BluGlass' RPCVD technology

BluGlass Ltd of Silverwater, Australia and SPP Process Technology Systems Ltd (SPTS) of Newport, Wales, UK, the plasma etch, deposition and thermal processing equipment subsidiary of Sumitomo Precision Products Co Ltd (SPP), say that their joint venture (formed last August, when SPTS invested AUS\$5.2m in BluGlass) has begun the establishment of a remote-plasma chemical vapor deposition (RPCVD) research and demonstration site in the UK. The facility will include the retrofit of a field-proven SPTS CVD production platform to incorporate BluGlass' RPCVD technology.

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

Focused on commercializing the RPCVD technology, the JV began operation last October and has seen the establishment of a JV team in Silverwater and now in the UK.

BluGlass says that progress is being made on all fronts, with some milestones progressing faster than others. The technology has seen some significant improvements but, due to repair and maintenance issues with the fifth-generation RPCVD tool (leading to machine downtime), there has been some delay in achieving single-crystal material to the standard set by the firm. Despite this, progress has been made on this and other improvements, such as greater growth rates compared to previous generations. The JV is still working towards the achievement of high-quality single-crystal material.

"SPTS believes in the RPCVD technology, firmly supporting the commercial potential of our joint venture with BluGlass," says SPTS president William Johnson. "Having engaged with our LED customers, we are encouraged by their validation of the RPCVD value proposition and level of interest in the outcomes of the joint venture," he adds. "Accordingly, SPTS has further strengthened our commitment to the JV with the allocation of additional resources, budget and the advanced commencement of activity and research here in the UK," Johnson continues. SPTS has started on the design of its RPCVD research and demonstration site and machine in the UK.

"We have been extremely fortunate to find such an expert and well connected partner to bring our technology to the market," comments BluGlass CEO Giles Bourne about SPTS. "The progression of our technology since the commencement of the JV has been very encouraging," he adds.

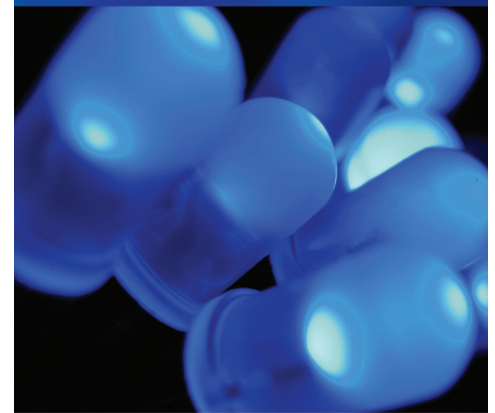
The JV is geared towards the delivery of single-crystal material, a demonstration facility in the UK with access to global customers, and surpassing the benchmark in material quality set by metal-organic chemical vapor deposition (MOCVD) in order to deliver RPCVD to the mainstream LED manufacturing market.

BluGlass says that feedback from customers indicates that the theoretical performance advantages of RPCVD are now recognized as a core value proposition for LED manufacturing. The RPCVD process is increasingly anticipated to be used in conjunction with existing technology, broadening its potential market opportunity.

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www.bluglass.com.au

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IN BRIEF

InnoLas expands to supply laser systems for 300MW of thin-film PV production

Laser processing system maker InnoLas Systems GmbH of Krailling, Germany has won orders for process equipment for thin-film photovoltaic (PV) module manufacturing with a total annual production volume output of 300MW. Several customers worldwide have ordered IMPALA series machines focusing on CIS (copper indium selenium) and CIGS (copper indium gallium diselenide) processing.

The IMPALA is a large-format laser processing system (with a panel size of up to 1600mm). Multi-laser operation and parallel processing ensure especially high-throughput using several tool heads. InnoLas says that innovative handling concepts and the option to apply through-the-glass processing minimize damage and soiling during the structuring process.

To ensure that its production capacity remains sustainable with its continuously growing order volume, InnoLas has opened a further production facility close to its headquarters, adding 400m² for office space and 1500m² for manufacturing (doubles its existing production area, since the main building already houses 1500m² for production as well as a further 1000m² for offices and laboratories).

"In view of full order books and expansive business developments, this step was merely a logical consequence," says sales manager Alejandro Becker. "It guarantees that we can continue to process customer enquiries and implement further technological developments fast, flexibly and reliably," he adds.

<http://innolas-systems.com>

Light measurement firm Pro-Lite takes majority stake in Germany's SphereOptics

Photonics and light measurement equipment distributor Pro-Lite Technology Ltd of Cranfield, UK has acquired a majority stake in SphereOptics GmbH of Uhdlingen, Germany, helping to grow its light measurement business in the German, German-speaking and Eastern European markets.

Formed in 2002, Pro-Lite is a supplier of specialist equipment and services with a technical focus on: instruments for measuring light and the optical properties of materials; lasers and related equipment; opto-mechanics and positioning equipment; and optics & optical materials. Pro-Lite distributes light measurement products made by Labsphere, Radiant Imaging, Ocean Optics and Konica Minolta in the UK and Ireland.

Formed in 2003, SphereOptics serves the German, German-speaking and Eastern European markets with light measurement, near-infrared (NIR) spectroscopic and hyperspectral instrumentation as well as diffuse reflectance materials and optical standards. SphereOptics distributes the products made by Labsphere, Radiant Imaging, ASD and Headwall Photonics. SphereOptics GmbH was originally the German sister of US firm SphereOptics LLC, which was acquired by fellow US firm Labsphere in 2010 (resulting in SphereOptics GmbH distributing the integrating sphere and light measurement products of the combined Labsphere/SphereOptics).

Pro-Lite and SphereOptics share a common focus in serving the lighting, LED, display and automotive markets with photometric, spectroradiometric and goniophotometric test equipment for luminaires, solid state lighting, lamps, displays and LEDs. The combined firm's aim is to become the premiere company providing light measurement and

optical instrumentation to the European market.

To support clients in the LED and solid-state lighting markets, in 2010 Pro-Lite doubled the size of its premises at the Cranfield University Innovation Centre (near Milton Keynes, UK) and invested more than £100,000 (\$160,000, €115,000) in a photometric test & demonstration laboratory. The dark-room facility is equipped with 25cm and 1m Labsphere integrating sphere spectroradiometer systems, a luminaire gonio-photometer system and imaging photometer from Radiant Imaging, a range of luminance and illuminance photometers and colorimeters from Konica Minolta, and several irradiance spectroradiometers from Ocean Optics.

Pro-Lite also provides a rental service for the hire of photometers that are used to measure the 'brightness' and colour of displays and all manner of light sources (lamps, luminaires, LEDs etc). The photometric measurement and equipment hire services will now be available to customers of SphereOptics in Germany, as well as in German-speaking and Eastern European countries.

"There are strong synergies between our two companies which we will exploit to better serve our customers working with LEDs, displays and lighting," says Pro-Lite director Robert Yeo.

SphereOptics' Christina Boehme will continue to serve as general manager and minority shareholder under Pro-Lite's ownership. "We serve similar markets with the same light measurement products from Labsphere and Radiant Imaging," notes Boehme. "Pro-Lite's technical leadership will support the growth of the SphereOptics business in Germany and Eastern Europe," she adds.

www.pro-lite.co.uk



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SemiLEDs revenue drops due to pricing pressure

Yield improvement, 4" transition and 135lm/W ramp to boost margin

For its fiscal second-quarter 2011 (to end February), LED chip and component maker SemiLEDs Corp of Boise, ID, USA (which has chip fabrication facilities in Hsinchu Science Park, Taiwan) has reported revenue of \$9.96m, up 30% on \$7.68m a year ago but down 23% on \$13m last quarter (and down on guidance of \$10.5–12.5m).

After rising from 41% a year ago to 51% last quarter, gross margin has fallen to 23%, impacted by previously announced pricing pressure, lower capacity utilization, change in product mix, and a shortage in metal-organic chemical compound. SemiLEDs said in January that a particular customer (focused on the cell-phone camera flash market) had gone to a high-performance competitor based solely on price, and that SemiLEDs had chosen not to pursue the business as it would have depressed margins further if the contract had been taken up.

On a non-GAAP basis (excluding foreign exchange losses), net loss was \$0.74m, compared to net income of \$3.9m last quarter and \$1.93m a year ago. Nevertheless, cash flow from operations rose from \$1.6m last quarter to \$1.7m.

Also, the initial public offering in December generated net proceeds of \$95.5m (before deducting expenses of \$3.4m), boosting cash and cash equivalents during the quarter from just \$9.9m to \$102.6m. SemiLEDs is using proceeds for expanding production capacity in Taiwan (doubling by August), R&D expenses related to LED chip production based on 6" wafers, and general corporate purposes (including working capital and capital expenditures).

"While we believe the long-term market opportunity of LEDs has not changed, the quarter did not meet our expectations relative to revenue, EPS or gross margin due to the aggressive, competitive pricing environment and our decision to preserve our market share," says chairman & CEO Trung Doan.

"Efforts to improve our gross margin include taking actions to improve our yield, transition to 4" wafers in our Taiwan facility, as well as ramping volume production of our new high-brightness LED chip, I-Do [launched in late March], which delivers up to 135 lumens per watt, enabling us to provide our customers with a very cost-effective lighting solution," he adds.

For its fiscal third-quarter 2011 (to end May), SemiLEDs expects revenue to fall further to \$6–7m, but gross margin should rebound to 25–30%.

Founded in 2005, SemiLEDs' proprietary blue, green and ultraviolet (UV) 'metal vertical photon' (MvpLED) chip design features a vertical LED structure on a patented copper alloy base (after removal of the sapphire substrate) that provides what is claimed to be the best thermal resistance on the market — allowing better heat removal than for LEDs that retain the sapphire substrate — as well as electrical and optical advantages such as greater luminous efficacy and longer lumen maintenance.

The firm fabricates LED chips for sale mainly to chip-packaging customers in China, Taiwan and other parts of Asia such as Korea, or to distributors who sell to packagers. It also packages some of its chips into LED components for sale to distributors and end-customers in selected markets (mainly for general lighting applications, including street lights and commercial, industrial and residential lighting).

www.semileds.com

SemiLEDs launches 135 lumen per Watt LED chip I-Do

SemiLEDs has launched a new chip in its ultra-high-brightness LED product portfolio.

Entering high-volume production in April, I-Do is the second generation of SemiLEDs' I-Core AK series of LEDs, which are designed to provide further improvements in brightness, reliability and overall efficiency.

The firm says that the I-Do LED features a new design with improved reliability, optimized current distribution and lower forward voltages at high current operation of 700mA and 1A. It adds that the

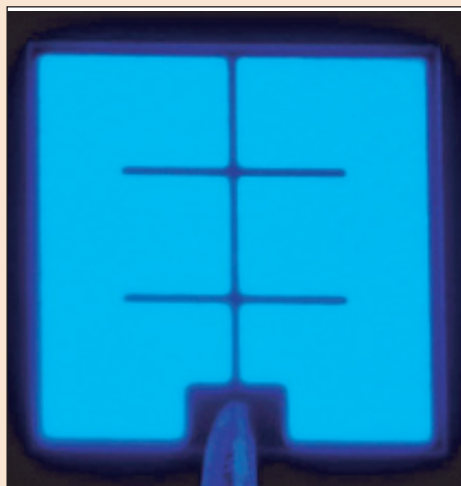


Photo of SemiLEDs' new I-Do chip.

I-Do is not only more reliable but also significantly brighter, as the design produces improved internal quantum efficiency. In a white light package, a 45 mil I-Do chip can deliver up to 135lm at 350mA with a correlated color temperature (CCT) of 5000–7000K, more than a 10% improvement over the previous generation.

With increased efficiency, reliability and what is claimed to be the lowest thermal resistance in the market, SemiLEDs says that the I-Do chip suits small-footprint, high-performance applications.

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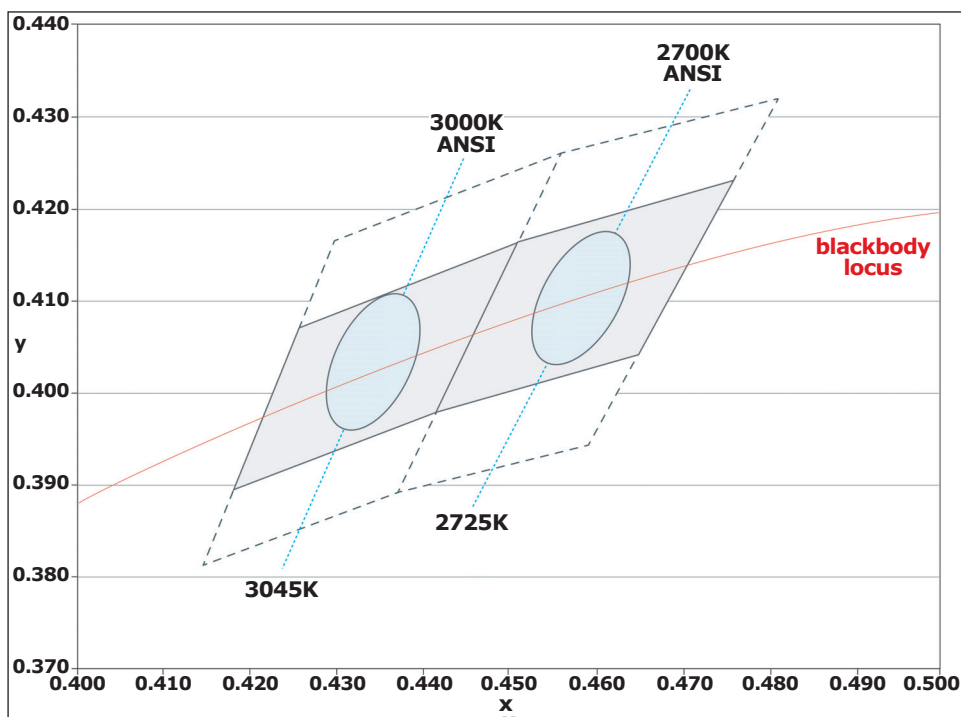
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Lumileds adds hot-tested LUXEON A illumination-grade LED with Freedom From Binning

Philips Lumileds of San Jose, CA, USA says that its latest illumination-grade LED reduces the engineering effort required for new solutions and delivers Freedom From Binning. The LUXEON A shares the LUXEON Rebel ES platform and footprint and incorporates a 2mm² thin-film flip-chip and Lumiramic phosphor technology to deliver what is claimed to be the highest-quality light at correlated color temperatures (CCTs) of 2700K and 3000K with high efficacy (100 lumens/Watt at 350mA) and light output (175lm).

Lumileds says that its unique chip and phosphor technology allows color targeting that ensures all LUXEON A emitters fall within a single 3-step MacAdam ellipse on the black-body curve. The quality, uniformity and consistency of the light from LED to LED relieves luminaire manufacturers and lighting designers of many of their long-held concerns about the suitability of LED technology for illumination applications, adds the firm.

Lumileds says that 'Freedom From Binning' gives confidence in the quality of light, and Lumileds' hot testing pays dividends for engineers designing LED solutions. The LED industry has long tested and specified products at an LED chip junction temperature of 25°C. It is well known that, in applications like down-lights and retrofit lamps, LED junction temperatures are more likely to be near 85°C, so luminaire manufacturers have had to make many complex calculations to determine actual light output, efficacy and color point of their products. In contrast, all LUXEON A LEDs are hot-tested and specified at a junction temperature of 85°C that represents real-world operating conditions. Providing the actual operating condition information means that there's no ambiguity, performance hyperbole or wasted engineering effort, simplifying the process, says Lumileds.



Freedom From Binning delivers the entire LUXEON A distribution within a single 3 MacAdam Ellipse space at each of the targeted color temperatures (2700K and 3000K).

"Our LUXEON LEDs are delivering performance that does not require sacrifices in the quality of light for homes, restaurants, shops, and other applications in pursuit of energy efficiency and reduced operating costs," says Steve Barlow,

Philips Lumileds' senior VP sales & marketing.

LUXEON A is available for sampling and design-in activities now, and will enter high-volume production in early May.

www.philipslumileds.com

Philips Lighting boosted by LED business

Royal Philips Electronics has reported first-quarter 2011 sales of €5.26bn (\$7.48bn), up 6% on a year ago. Of that, the lighting division contributed €1.9bn.

In particular, sales of packaged LEDs have grown strongly, accounting for 7% of the division's revenue of €7.6bn over the past 12 months — equivalent to about €530m, up about 50% on the prior year, and indicating the rapid rate of growth of the industry, as well as the success of the Philips Lumileds subsidiary (which is ranked among the world's top six LED makers).

In addition, Philips' LED-based lamps and luminaires contributed about €600m in revenue over the past 12 months, so total sales of LED-related products were €1.1bn. Since then, first-quarter 2011 sales of all LED-related products were up 27% on a year ago and almost three-fold on 2009.

Philips reckons that the global illumination market was €50–55bn in 2010 and will rise at a compound annual growth rate of 8% over the next five years to €80bn by 2015, due mainly to solid-state lighting (growing to more than half of the market).

Lumileds improves SnapLED array for automotive lighting

Philips Lumileds of San Jose, CA, USA says that it has significantly improved its SnapLED, which it claims is the automotive industry's most widely used LED for signaling applications.

With a continued focus on reliability and performance, engineers have raised junction temperature maximums, narrowed color binning to levels imperceptible by the human eye, dual-binned for drive current to simplify the design process and make it easier to meet critical regulation requirements, and implemented a new Multi-Environment Over Stress Test (MEOST) regimen to ensure that SnapLED is the most reliable automotive LED.

"A 'build out of the box' approach to turn, tail, and stop lighting applications on vehicles is a major step forward for the auto industry and significantly reduces engineering and development costs," claims Scott Kern, strategic & product marketing. "We remove the need for re-testing and screening, which can save our customers more than 5% of operational costs, reduce equipment and manpower needs, speed production, and improve finished goods yields," he reckons.



Lumileds' SnapLED array for a rear combination lamp.

SnapLED's maximum junction temperature has been increased to 135°C (the industry's highest for a mid-power LED, it is claimed), widening the design envelope and giving engineers more flexibility in their design efforts as they create new lighting solutions.

Flux bin sizes (which were already quite small) have been reduced by as much as 67% so that flux variations within a bin are imperceptible to the human eye. Simultaneously, the forward voltage bin widths have been reduced by as much as 50%, making the use of low-cost, resistor-based driver circuits easier to implement. SnapLED is also

designed to operate over a dynamic current range of 30:1, allowing for simplified, yet reliable, designs for both stop- and tail-mode operation.

LEDs in stop-tail signaling lamps tend to operate at the extremes of current limits, and most have difficulty meeting the performance and uniformity requirements without expensive electrical designs. With SnapLED's dual binning, flux ratios between different current levels and uniformity across the entire dynamic range are highly controlled. This precision makes it easier to implement a solution with confidence — without the need for re-testing LEDs prior to assembly — as the uniformity and flux performance are already narrowly defined, says Lumileds.

The new MEOST regime exceeds the testing required by existing standards for automotive signaling LED sources. It exceeds AEC-Q101, including simulations for extreme operational conditions as well as tests that far exceed datasheet guidelines and maximums. SnapLED LEDs should function reliably for the life of the vehicle, concludes Lumileds.

www.philipslumileds.com

Philips accuses Seoul Semiconductor of patent infringement

In March, Philips and its subsidiary Lumileds filed a complaint in federal court in Santa Ana, CA, USA accusing South Korean LED maker Seoul Semiconductor of infringing five patents relating to LED technology and asserting that one of Seoul's 'fundamental' semiconductor structure patents is invalid.

The Philips patents are:

- US Patent 5,779,924, 'Ordered interface texturing for a light emitting device';
- US Patent 6,274,924, 'Surface mountable LED package';
- US Patent 6,547,249, 'Monolithic series/parallel LED arrays formed on highly resistive substrates';
- US Patent 6,590,235, 'High stability optical encapsulation and pack-

aging for light-emitting diodes in the green, blue and near UV range';

- US Patent 6,717,353, 'Phosphor converted light emitting device'.

The accused products include Seoul's Acriche, Top View, High Flux, Side View and Z-Power LEDs.

Philips also seeks a declaratory judgment that its own products do not infringe Seoul's US Patent 5,075,742 ('Semiconductor structure for optoelectronic components with inclusions', directed to a structure with plural layers in semiconductor material), and that this patent is invalid. One of the layers includes stacked sub-layers, with each sub-layer having three-dimensional 'inclusions' — improved electron-hole areas — and a narrow

bandgap. According to the patent, this structure overcomes certain problems in III-V production.

According to the complaint, Philips has a reasonable apprehension of being sued for infringement of the '742 Patent because of press releases and public statements by Seoul calling the patent "fundamental to indium gallium nitride-based light emitting device technology," and characterizing a recent court decision as holding that it would be "impossible for LEDs that use InGaN in their active layers" to avoid infringement of the '742 Patent.

www.greenpatentblog.com/wp-content/uploads/2011/04/Philips-Seoul-Complaint.pdf

Cree's profit halved as revenue falls 15%

June quarter to see rebound as LED component business recovers

For its fiscal third-quarter 2011 (ended 27 March), Cree Inc of Durham, NC, USA (which makes LED chips, lamps and lighting fixtures as well as gallium nitride and silicon carbide power-switching and RF/wireless microelectronic devices and SiC substrates) has reported revenue of \$219.2m. This is down 6% on \$234.1m a year ago and 15% on \$257m last quarter (and 10–17% below the original guidance of \$245–265m).

"Q3 results were in-line with our revised lower targets for the quarter," says chairman & CEO Chuck Swoboda. The drop is attributed mainly to lower sales of LED chips and LED components. "The results reflect both our continued success in LED lighting and the challenges of managing the LED chip and components business through a business cycle with short lead-times and low order visibility," he adds. Cree said in late March that it has taken longer to work through customer inventories than previously anticipated and pricing was lower than forecast, and that the LED chip business was also weaker than targeted due to more aggressive pricing and weaker demand.

On a non-GAAP basis, gross margin has fallen further, from 48.1% a year ago and 47.7% last quarter to 42.4% (below both its revised forecast of

43% and its original forecast of 46%). This is attributed mainly to the increased pricing pressure in the LED chip product line. Likewise, operating margin has also fallen further, from 27.9% a year ago and 26.5% last quarter to 14.9%.

Non-GAAP net income of \$30.1m is down 41% on \$51.3m a year ago and half last quarter's \$60.7m. Cash flow from operations has fallen from \$72.9m a year ago and \$57.2m last quarter to \$41.2m. So, despite capital expenditure being pared further (from \$66m a year ago and \$64.7m last quarter to \$62.8m), free cash flow has declined further, from \$6.9m a year ago and -\$7.5m last quarter to -\$21.7m. This contributed to cash and investments falling by \$37.7m during the quarter, from \$1110.8m to \$1073.1m (although this is still up on \$1066.4m a year ago).

In early March, Cree announced a two-year extension of its strategic agreement with Zumtobel Lighting GmbH (signed in 2008). Since the end of the quarter (in early April) Cree signed a comprehensive, worldwide patent cross-license agreement with Germany's Osram GmbH (designed to accelerate growth of the LED lighting market).

In late February, Cree launched its XLamp MT-G LED (claimed to be the first LED to deliver the performance

required for high-output halogen retrofit applications such as 35–50W MR16 replacement bulbs). Meanwhile, in early April, Cree launched the XLamp XM-L EasyWhite LED (a lower-cost solution for 25W replacement lamps through combining the firm's color mixing technology in a single high-output, small-footprint package). Also, during the quarter, Cree set what is claimed to be a new industry benchmark for color rendering index (CRI) with the commercial release of its LBR-30 LED lamp.

"We continue to be a leader in LED lighting and remain confident we are on the right track as we look forward to further disrupting the market and leading the LED lighting revolution in the years ahead," believes Swoboda.

Swoboda said in late March that the LED components business "appears to be turning the corner... Despite the challenges we faced in Q3, distributor sell-through has improved and we target solid growth". For fiscal fourth-quarter 2011 (ending 26 June), Cree expects revenue to rebound to \$225–245m, but gross margin to fall further to 40%. Non-GAAP operating expenses should rise by \$0.5m to \$61m. Non-GAAP net income is targeted to be \$28–35m.

www.cree.com

LBR-30 LED lamp targeting tracks and recessed downlight fixtures

Cree has announced commercial availability of the LBR-30 LED lamp, which is aimed at replacing incandescent lamps commonly used in tracks, commercial and residential recessed downlights.

Due to its high color rendering index (CRI) of 94, the warm-white LBR-30 is optimized for applications where high color accuracy is essential, including restaurants, retail stores, groceries and museums. Powered by Cree TrueWhite

technology, it delivers 600 lumens, equivalent to a 60W incandescent BR30, while using only 12W of input power. The lamp is designed to last 50,000 hours in open fixtures, which can provide additional savings from reduced re-lamping and maintenance costs.

"The LBR-30 lamp's superior blend of incandescent-like color and efficacy delivers a true no-compromise solution for both general and accent lighting," says

David Turner, Cree director of marketing, LED Lighting. "This high-performance, retrofit lamp quickly installs into track or recessed fixtures and is available in flood or wide flood distributions, giving customers the flexibility to choose the most appropriate solution for their lighting needs."

The Cree LBR-30 is sold through Cree LED Lighting sales channels and is currently shipping in volume.

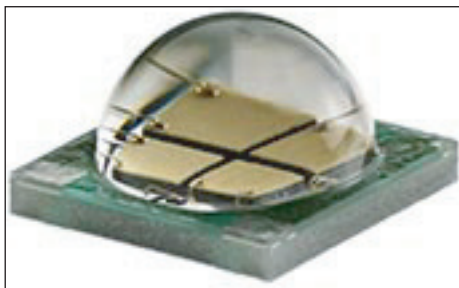
www.CreeLEDLighting.com

Cree's XM-L EasyWhite LED lowers cost for 25W replacement lamps

LED chip, lamp and lighting fixture maker Cree Inc of Durham, NC, USA has announced the first lighting-class LED component that combines the high light output and small footprint of its XLamp XM-L LED package with the firm's unique EasyWhite color mixing technology.

Cree says that its new XM-L EasyWhite LEDs reduce the cost and complexity associated with binning and color mixing, as well as using multiple discrete LEDs. This can enable users to reduce the price and improve the performance of LED solutions for compact directional lighting, such as 20–25W halogen MR, PAR and B10-style (candelabra) replacement lamps.

In these applications, previous single-LED solutions were not able to achieve enough light output to match the incumbent incandescent products, says Cree. Traditional multi-LED configurations complicate the overall system design and have the added disadvantage of not emulating the look of a light bulb's filament. The XM-L EasyWhite LED enables a single-LED component to deliver the performance and design



New XLamp XM-L EasyWhite LED.

simplicity needed for 25W replacement lamps, the firm claims.

At just 4W of power, XM-L EasyWhite LEDs produce up to 340 lumens at an operating temperature of 85°C in warm white (3000K) in a single component. Like the firm's XLamp MT-G LEDs, XM-L EasyWhite LEDs are characterized at 85°C, allowing users to accurately select them at a specific color temperature. They are also available with what is claimed to be the industry's tightest LED-to-LED color consistency, replicating the uniformity of incandescent light bulbs.

"XM-L EasyWhite LEDs give customers the best of both worlds: the color consistency of an

EasyWhite array in the compact size of a discrete component," says Mike Watson, Cree's senior director, marketing and product applications, LED Components. "In 2009, Cree was the first LED manufacturer to eliminate binning for LED components with our innovative EasyWhite color mixing technology," he adds. "XM-L EasyWhite LEDs, along with the recently introduced XLamp MT-G EasyWhite LEDs, accelerate the adoption of LED lighting into applications traditionally addressed by energy-wasting halogen sources."

XM-L EasyWhite LEDs are available in 2-step MacAdams Ellipse color points. They are also available in either a 6V or a high-voltage 12V configuration, enabling the use of efficient, small and low-cost drivers. They also have the same low-profile dome and 5mm x 5mm footprint as the current XM-L LED family.

XM-L EasyWhite LEDs are available in both standard CRI and high-CRI (minimum 85 and 90) versions at multiple color temperatures.

www.cree.com

Cree launches high-lumen LED module for 230V Europe and Asia

Cree of Durham, NC, USA has launched the LMH6, a high-lumen LED module designed to further simplify lighting design, reduce overall cost, and accelerate time-to-market for customers in Europe and Asia.

Featuring Cree TrueWhite Technology, the LMH6 module targets commercial applications where high efficacy, brightness and light quality are critical, such as restaurants, retail, airports, schools and hospitality lighting.

"The LMH6 module is designed with the needs of the 230V European and Asian lighting markets in mind," says Scott Schwab, product line manager,

Cree LED modules. "We are enabling our customers to address the 150mm and 200mm downlight market with beautiful, energy-efficient lighting offering the highest quality and efficacy available in the industry," he claims.

Adding to its existing LMR2 and LMR4 LED modules, the LMH6 is the first high-lumen product in Cree's fully integrated LED module family. Designed to last at least 50,000 hours, the LMH6 delivers 2000 lumens at 74 lumens per watt or 2900 lumens at 78 lumens per watt. It is available in correlated color temperatures (CCTs) of 3000K and 4000K, both with a color rendering index (CRI) of 90.

Fully integrated Digital Addressable Lighting Interface (DALI) dimming allows greater flexibility and control compared to traditional dimming systems, Cree claims. Integrated driver electronics, optics and primary thermal management result in a drop-in ready solution and locking tabs that can simplify the design of additional trim kits, the firm adds.

The 230V LMH6 module complies with multiple international standards and is RoHS compliant. Sample evaluation kits are available now, and production quantities are available with standard lead times.

www.cree.com/modules

Cree and Osram sign LED patent cross-license agreement

Deal covers blue LED chips, white LEDs and phosphors, packaging, luminaires and lamps, and lighting control systems

LED chip, lamp and lighting fixture maker Cree Inc of Durham, NC, USA and LED and lighting manufacturer Osram GmbH of Munich, Germany have signed a comprehensive, worldwide patent cross-license agreement, underscoring "each firm's commitment to speeding the adoption of LED lighting while respecting the value and importance of each other's intellectual property."

The agreement comprises the mutual licensing of patents from both parties (including Osram Opto Semiconductors GmbH of Regensburg, Germany as well as the former LED Light Fixtures Inc of Morrisville, NC, USA, acquired by Cree in March 2008). The agreement addresses all stages of the value chain, including inorganic blue LED chip technology, white LEDs and phosphors, packaging, LED luminaires and lamps, and electronic LED lighting control systems.

"Over the last two decades, we have developed innovative, energy-efficient LED lighting technology and have protected this technology under international intellectual property laws," says Cree's chairman & CEO Chuck Swoboda. "This agreement can enable our customers to accelerate the LED lighting revolution," he adds.

Cree recently announced a similar broad cross-license agreement with Philips and has existing patent agreements with Japanese LED makers Nichia and Toyoda Gosei regarding LED technology.

Osram says that the agreement with Cree continues its own policy of concluding patent cross-license agreements with other large LED makers. In recent years, Osram has entered into similar agreements with other firms in the LED industry including Nichia, Philips and Toyoda Gosei. Osram says that such agreements accelerate the

spread of LED technology in all application fields, and help companies in the development, production and marketing of new products by mitigating the risk of inadvertently infringing other firms' patent rights. Users of Osram's and Cree's LED products hence benefit by being strongly guarded against adverse effects caused by potential patent disputes about these products.

Osram says that, with 8000 patents and patent applications, it holds a strong position regarding intellectual property in LED technology. "For all companies involved, the respectful management of intellectual property is essential for the smooth development of LED technology," comments Osram's chief operating officer Martin Goetzler. "The agreement with Cree is an important step in this process," he adds.

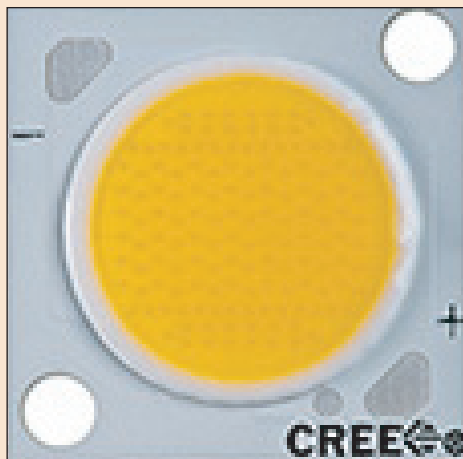
www.cree.com

www.osram.com

Cree claims brightest, most efficient lighting-class LED array

Cree has announced full availability of what it claims is the industry's first lighting-class LED array that helps to reduce overall system cost by combining superior efficacy, ease-of-design and ease-of-manufacture. The XLamp CXA2011 LED array is designed to deliver the smooth light output and consistent color that is needed for applications such as omnidirectional bulbs or directional downlights.

"The CXA2011 LED has been incredibly easy to work with, enabling us to create very high-performance products," says Jason Lee, president of lighting firm Gama Illuminer of Zhongshan City, Guangdong, China. "It gave us a plug-and-play solution with the right combination of brightness, efficacy and color consistency with real-world 85°C specifications.



Cree's new XLamp CXA2011 LED.

Creating a design with CXA2011 was simple, and manufacturing will be underway in record time."

Easy-to-use screw-mounts simplify the manufacturing and design process by eliminating the need for complex design-specific engineering

and reflow soldering. "Combining fast and flexible system design with ease-of-manufacturing, the CXA2011 LED array helps customers quickly create a broad range of LED-based designs," says Mike Watson, Cree's senior director of marketing, LED components. "Lower system cost and quicker time-to-market are keys to accelerating the LED lighting revolution."

The CXA2011 LED array delivers up to 4000 lumens at an operating temperature of 85°C (1A, 5000K) in a single component. It is available in 2-step and 4-step EasyWhite options, delivering what is claimed to be the industry's tightest LED-to-LED color consistency (reducing system complexity and making light source selection as easy as specifying a color temperature).

<http://cxa.cree.com/cxa20.html>

Advertising lighting with 90% maintenance cost reduction

Osram Opto Semiconductors says that, when the advertising light-boxes in Singapore's Changi Airport were to switch away from fluorescent T8 tubes under REVOLITE's energy-saving



REVOLITE's back-light with Golden DRAGON Plus LEDs in an energy saving advertising light-box solution.

program, its Golden DRAGON Plus LEDs were chosen to be the light source by LED back-light application specialist REVOLITE. It was found that over the last five years, after replacing the old tubes and installing REVOLITE's Dio back-lit lightbox system with these LEDs, maintenance costs were reduced by as much as 90%. These environmentally friendly light-boxes also brought about 73% energy savings.

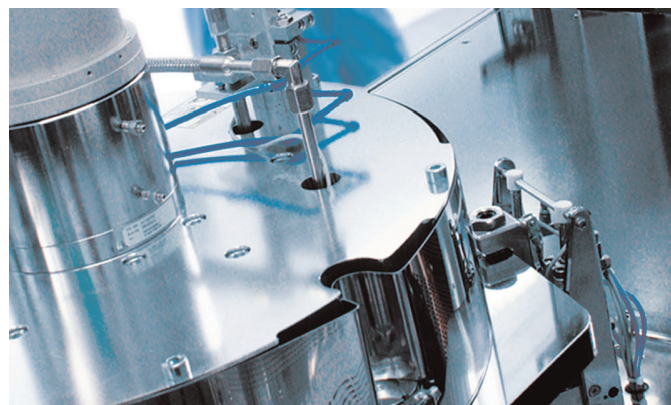
The Changi Airport is a busy hub, with over 98 airlines flying to 205 cities around the world. It is currently handling 5000 arrivals and departures every week and servicing over 37 million passengers a year. The low maintenance requirement of the LED light-boxes is a must for Changi to minimize disruption caused to the Airport's operations.

"REVOLITE has installed and maintained over 200 LED advertising light-boxes in the Airport for over 5 years to date. With Osram's LED technology and our experiences in LED back-light applications, we are able to provide back-light LED modules which can fit into any size configuration, allowing customization of the lighting requirement in a variety of light-box sizes. Furthermore, the thickness of the light-box can be reduced from 30cm to 12cm, which is a lot more aesthetic. We are extremely excited as the great leaps in LED technology in recent years has allowed us to provide an ROI as quick as 1-2 years for our clients today," said Calvin Lim, director of REVOLITE.

"These advertising light-boxes in Changi Airport, equipped with Osram's Golden DRAGON Plus LEDs, prove that the LEDs have exceptionally good quality, high reliability and superior lighting performance. In addition, the LED's uniform brightness and colour meet the requirements of the demanding advertising industry," said Kai-Chong Cheng, marketing director of Osram Opto Semiconductors Asia Ltd.

The retail digital signage market is growing rapidly as public spaces are dotted with advertising and communication billboards. According to iSuppli, this market will grow at a CAGR of 26.8% by 2013. With low energy consumption and low maintenance, the trend is for LEDs to replace traditional light sources. As such, a much higher growth rate for LED retail signage market is expected.

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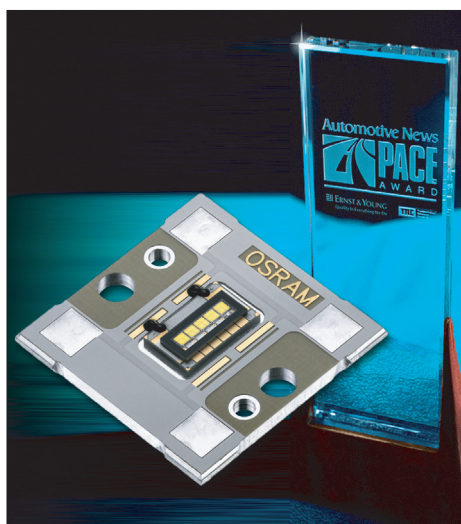
Osram's OSTAR Headlamp LED receives PACE Award for Automotive Innovation in forward headlamp control

On behalf of Osram Opto Semiconductors GmbH of Regensburg, Germany, LED automotive director Peter Knittl has accepted an award for innovation at the 17th annual Automotive News PACE Awards held at a ceremony at the Max M. Fisher Music Center in Detroit, MI.

The PACE (Premier Automotive Suppliers' Contribution to Excellence) Award is presented by Automotive News, Ernst & Young LLP and Transportation Research Center Inc (TRC Inc). Osram's OSTAR Headlamp LED won an award in the Product category, which honors innovation in new products, components or systems that have significant market impact and act as 'game changers' in the automotive industry.

The OSTAR Headlamp LED uses the auto industry's 1st ThinGaN light-emitting diodes with phosphor layer transfer. It was developed with a unique integrated shutter function to control the output of the light, eliminating the need for mechanical shutters and projecting a clearly defined legal beam pattern onto the road without the loss of light commonly associated with mechanical shutters.

Osram Opto claims that the OSTAR LED platform of products provides more styling freedom, reduces energy use, is more reliable and generates more light than conventional headlamps. It is avail-



PACE Award for innovation for Osram's OSTAR Headlamp LED in controlling forward headlamp functions (such as in the Audi A8 sedan, bottom).

Light-emitting diodes already meet all the requirements of modern automobile lighting and are setting new standards in many respects

able in five chip configurations — 1x1, 1x2, 1x3, 1x4 and 1x5 — with precisely packaged chip spacing to achieve a consistent and uniform beam pattern critical to the optical design. Typical light values achieved for each LED chip are 160lm at 700mA. Depending on the variant and operating current, values between 125lm and 1100lm are achievable. An innovative conversion process provides a seamless white color impression at maximum brightness levels.

The firm says that, with its scalable brightness, the OSTAR headlamp suits all headlamp functions. In the top-of-the-line Audi A8 sedan, OSTAR LEDs have advanced headlamp lighting beyond simple low and high beams, it is claimed. They provide all of the forward lighting functions, including LED headlamp for nighttime driving, low-beam light sources for daytime running lights (DRL), and special lighting functions such as motorway beams, cornering lights and all-weather lights. "LEDs already meet all the requirements of modern automobile lighting and are setting new standards in many respects, and the implementation of our latest OSTAR Headlamp LED forward lighting technology into this vehicle is a prime example," comments Knittl.

www.automotivenews.com/pace
www.osram-os.com

Mouser expands Osram Opto distribution into Europe

Mouser Electronics Inc of Mansfield, TX, USA, a design engineering resource and global distributor for semiconductors and electronic components, has announced the European expansion of its agreement with Osram Opto Semiconductors GmbH of Regensburg, Germany.

Agreed at the Embedded World Show in Nürnberg, Germany at the

end of February, the extended distribution partnership strengthens Mouser's European line card by providing its customers with Osram Opto's portfolio of LEDs for diverse applications. Mouser says that the expansion fits its strategic emphasis on supplying innovative solutions to design engineers and small production buyers.

"We have enjoyed great success

with Mouser as our catalog distributor in America, Canada and Mexico," says Stephan Kreuzel, director Distribution Europe and Emerging Markets for Osram Opto. "We support Mouser's strategy of being the one-stop source for design engineers and small production buyers. It fits our own company's mission of lighting the future," he adds.

OSLON SSL LEDs light streets in three Beijing districts

As part of China's '10 cities 10,000 lights' project, three districts in Beijing have been equipped with LED street luminaires made by HBTechnology CAST Group using OSLON SSL LEDs from Osram Opto Semiconductors.

LED modules for street luminaires with an output of 120W or 180W now replace the conventional 250W or 400W sodium vapour lamps, saving up to 50% in energy. This is of great importance for the high energy consumption in Beijing, says Osram Opto. In addition to energy efficiency, light quality also played a major role in the decision for conversion. Since Dong Cheng, Chao Yang and Da Xing are urban districts bustling with life, good illumination was required to increase safety for both drivers and pedestrians.

Osram Opto claims that, among 1W-class LEDs on the market, its OSLON SSL LEDs are the smallest (just 3mm x 3mm) and have the greatest luminous efficacy, working reliably and efficiently at high flux rates.



LED street lighting in Beijing.

OSLON SSL LEDs have a beam angle of 80° (specifically 120° x 80° for this application), suiting street lighting. "The LEDs meet all of our technical requirements, and we have no problems integrating them into the external lenses," says HBTechnology CAST Group's managing director Bing Hu. "The result is homogeneous and powerful illumination of the streets without light pollution," he adds. "The long lifespan of OSLON SSL LEDs also results in lower maintenance requirements, which might otherwise have obstructed the flow of traffic and

generated additional costs."

Osram Opto says that, due especially to their capability for handling high current loads, OSLON SSL LEDs can be used to realize particularly energy- and cost-saving lighting solutions. At an operating current of 350mA, the light source achieves a typical brightness of 110lm in ultra-white (5700 and 6500K). At a color temperature of 3000K it achieves a typical efficiency of 82lm/W and a brightness of 92lm. Also, brightness is as much as 156lm (warm white) at an operating current of 700mA. "This allows us to realize lighting applications requiring a lot of light by using fewer LEDs," says Kai-chong Cheng, marketing director at Osram Opto Semiconductors in Asia. "If, as planned, Beijing converts all of its street lighting to LED, the savings potential is enormous."

China is the leading market in LED street lighting, representing about 50% of applications worldwide. The pilot project in the capital is to be followed by other cities.

Solar-powered LED street lamps for near-desert conditions

Osram Opto Semiconductors says its OSLON SSL LEDs have been installed in solar-powered street lamps in the extreme weather conditions of Ningxia, a central province in China close to Mongolia. LED street lighting is rapidly replacing traditional lighting fixtures since it can be applied in various conditions, says the firm. In particular, OSLON SSL LED lamps withstand the challenging near-desert climate and provide stable performance and uniform illumination, fulfilling the requirements set out by the city and its planners, it adds.

The 174 new street lamps line the 2.6km of Da Xue Road in Shizhuishan City. The city is close to the Gobi Desert, with an average of 28 days of fine weather per month and great temperature difference between day and night, so the local govern-

ment decided to use solar energy to power the new street lamps.

"By using solar energy alone, the street lamps need to be of very low power consumption," says Xin-jun Dang, managing director of street-lamp installer GBT Technologies (Shenzhen) Ltd. "With Osram's OSLON SSL LED as light source, our solar-powered street lamps are estimated to save more than RMB300,000 per year in energy cost alone and reduce CO₂ emission by more than 53 tons annually," he adds. "We are pleased to work with Osram, which provides an excellent application support to us. As the weather conditions are rather extreme, Osram's LED simulation reports also help us make improvements to the designs before the fixtures are installed."

The 1 W LEDs, measuring just 3mm x 3mm, deliver what is said to be outstanding efficiency at all currents. Combined with the thermal management and stable quality of the LEDs, the street lamps can perform well even when the temperature goes down to -20°C.

To further save energy and to provide comfortable illumination to the road, light sensors are installed to control the luminance. On a normal day, the lamps will work in full light for 5 hours and will be turned down to half light (half power) until dawn. On other occasions when light conditions vary, the luminance can be adjusted accordingly. Each lamp will hence consume only 80W, which is only one-fifth of a high-pressure sodium (HPS) lamp.

www.osram-os.com

IN BRIEF

Marktech adds 650nm Point Source LED

Marktech Optoelectronics of Latham, NY, USA, whose capabilities span wafer growth through finished packaging and custom solutions, has added a 650nm-wavelength emitter to its high-accuracy Point Source LED series.

The firm says that an unobstructed, narrow beam of light output and newly improved narrow spectral bandwidth are key features to the Point Source product line, which suits critical sensing applications including encoders, linear or edge-positioning sensors and medical sensing equipment.

The unobstructed, radiated beam pattern is made possible by masking the die and relocating the topside electrode. By eliminating the 'dark spot' typically associated with conventional LEDs, the Point Source LED series yields far more accurate results in sensing applications, Marktech claims.

For applications using thin fiber-optic cable, the unobstructed die and narrow beam allow the fiber to be positioned in close proximity to the chip for improved accuracy. Also, a 'near-parallel' beam of light can be achieved with an internal ball lensing option mounted to the top of the LED die.

In addition to standard product offerings, Marktech has the in-house ability to customize die and component packaging depending on the customer's requirements. Die aperture windows are available up to 200 microns. Standard packaging options include TO-18 and TO-46 metal can types as well as miniature surface-mount ceramic versions. Additionally, a number of lensing options are available depending on the beam output desired.

www.marktechopto.com

Bavarian Ministry of Economic Affairs visits Optogan in St Petersburg

With the aim of expanding and intensifying economic ties between Bavaria and Russia (its largest trading partner in Eastern Europe), as part of 'German week' in St Petersburg a delegation from the Bavarian Ministry of Economic Affairs (focused on sustainable power generation and supply) included a tour of Optogan's LED lamp production plant (which

was opened last November by the Russian Federation's deputy Prime Minister Sergey Ivanov, and visited in March by Russia's President Dmitry Medvedev).

Optogan's chip technology was created by Vladislav Bougrov and Maxim Odnoblyudov, who were PhD students of Nobel prize winner and Russian Academy of Science member Zhores Alferov at the Ioffe Physico-Technical Institute in St Petersburg in the 1990s before working at Finland's Helsinki University of Technology, then in late 2004 (together with Alexey Kovsh) founding Optogan Oy in Espoo, Helsinki to develop GaN-based LEDs.

In addition to Optogan having an R&D facility in Helsinki, since founding Optogan GmbH in Germany in 2005 it has established epitaxy and chip R&D plus a pilot line in Dortmund and, last year, its Fab1 chip fabrication plant in Landshut. After founding CJSC Optogan



Optogan founder Maxim Odnoblyudov and Dr Johann Schleicher, permanent secretary of the Bavarian Ministry of Economic Affairs, Infrastructure, Transport and Technology during the factory tour.

in Russia in 2009, last May it acquired the plant in St Petersburg, where it has established LED packaging as well as luminaire assembly production lines.

During the Bavarian delegation's tour, Optogan Group's founders described recent developments in LED lighting and outlined their development aims for the Russian and global market.

"Optogan is a prime example of a Bavarian-Russian high-tech company," commented Dr Johann Schleicher, permanent secretary of the Bavarian Ministry of Economic Affairs, Infrastructure, Transport and Technology. "The manufacturing plants in Germany's Bavarian Landshut and St Petersburg in Russia are, through Optogan's presence, economically and technologically connected," he added.

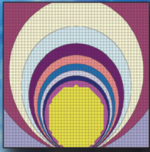
"Our offices complement each other," notes Optogan GmbH's CEO Hans Peter Ehweiner. "Due to a Russian modernization offensive, the primary energy consumption should be reduced by 40% by the end of 2020. With the introduction of LED technology, Optogan is able to make a decisive contribution," he concluded.

www.optogan.com

During the Bavarian delegation's tour, Optogan Group's founders described recent developments in LED lighting

FerroTec

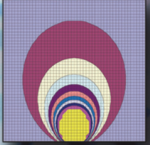
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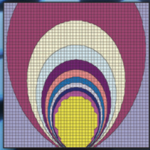
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For more information, visit us at www.temescal.net



Temescal

Sony Shiroishi laser fab partially resumes operation

8 out of 10 Sony plants now re-started after Japan earthquake

Tokyo-based electronics firm Sony Corp has given an update on the status of its manufacturing operations affected by the East Japan earthquake, tsunami and related power outages of 11 March.

As of 14 March, operations at ten Sony Group sites and facilities had been suspended. As announced on 22 March, manufacturing operations at three of these sites had since resumed or partially resumed.

Now, manufacturing operations at five further sites have also resumed or partially resumed. The latter include the fabrication plant of Sony Shiroishi Semiconductor Inc in Miyagi Prefecture (close to Sendai) which makes lasers including blue laser diodes for both Sony's own

Blu-ray Disc and PlayStation3 products as well as external customers.

As also announced on 22 March, operations at five manufacturing sites that were not directly damaged by the earthquake and tsunami have been adjusted in response to planned power outages and the availability of necessary raw materials and components. While the situation varies according to product, Sony is responding to fluctuations in material or component supply by adjusting production levels at these sites, as well as at certain other domestic and overseas manufacturing sites from time to time.

Sony says that it will continue to monitor the availability of raw materials and components, and

endeavor to maintain supplies of any products affected by the adjustments by relying on existing inventory to the extent available. It also plans to take further measures as necessary, including reallocating available materials and components among Sony Group companies, using alternative components and expanding procurement channels in order to restore full production capacity as early as possible.

Sony says that it is continuing to evaluate the full impact of the earthquake, tsunami and related power outages (including the impact of these production adjustments) on its businesses and consolidated financial results.

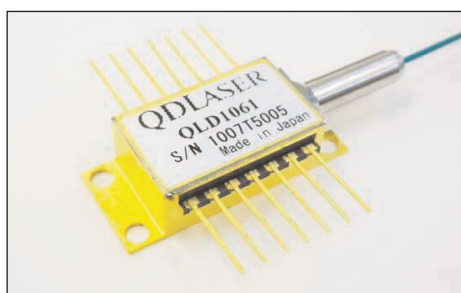
www.sony.net

QD Laser commercializes stable, single-mode 1064nm DFB laser module in butterfly package

QD Laser Inc, which was founded in 2006 based on more than 10 years of research on quantum-dot-based optoelectronic devices by Fujitsu Laboratories Ltd and the University of Tokyo, has announced the commercial release of the QLD1061, a single-mode distributed feedback (DFB) laser module emitting at a wavelength of 1064nm.

The firm says that semiconductor lasers emitting in the near-infrared (NIR) wavelength band around 1064nm have recently attracted much attention for many applications including fiber lasers for material processing, LIDAR, frequency conversion for generating exotic wavelengths, gas sensing etc. To expand the application area, single-mode lasers with stable operation have been needed.

QD Laser says the QLD1061 offers strong fiber output power (>30mW), narrow spectral linewidth (<10MHz) with stable single-mode oscillation. The DFB laser chip is packaged in a standard 14-pin butterfly laser



QLD1061 14-pin laser module.

module with an optical isolator. The module has an output pigtail using a polarization-maintaining fiber.

The design of the laser chip is based on DFB laser technology normally used in telecom applications, where quite high wavelength stability is required. Reliable packaging, including a built-in optical isolator, also contributes to the stability. In continuous-wave (CW) operation, the QLD1061 provides high side-mode suppression ratio (SMSR), even when changing the output power over a wide range of operating temperatures. In pulsed operation, a stable, short pulse train between

50ps and 100ns is generated with low amplitude noise and low timing jitter maintaining high SMSR. These characteristics (claimed to be unique) differentiate the QLD1061 from conventional wavelength-stabilized lasers such as a fiber-grating-based external-cavity lasers.

QD Laser says that it has already received a lot of positive responses from evaluations of prototypes by global companies. The firm adds that the QLD1061 suits a variety of applications in CW or pulsed operation (e.g. an injection seeder of a fiber laser and a wavelength sweeper for sensing), and that it can contribute to an improvement in performance and market expansion of many systems using NIR-wavelength-range semiconductor lasers.

QD Laser exhibited the QLD1061 at April's Photonix Japan 2011 in Tokyo and LaserEXPO in Yokohama, Japan, and will exhibit it at LASER World of PHOTONICS (23–26 May) in Munich, Germany (booth B1-310).

www.qdlaser.com

Opnext's revenue down 1.8% after 10-day module assembly stoppage

Optical module and component maker Opnext Inc of Fremont, NJ, USA says that for its fiscal fourth-quarter 2011 (to end March) it expects revenue of about \$95.3m, up 24% on \$76.8m a year ago but down 1.8% on \$97.1m last quarter.

It is also down on original guidance of \$97–102m, but this is attributed to a 10-day interruption in module manufacturing operations in Japan following the earthquake and tsunami on 11 March.

The module assembly facility in Totsuka suffered minor disruption but, while shipments of subassemblies to contract manufacturers and shipments of finished goods to customers from inventory each resumed on 18 March, production was not reinstated until 21 March.

The chip production facility in Totsuka suffered minor damage which has been repaired, and the firm is in the process of recalibrating and verifying proper operation of the

equipment prior to restarting full production, which was expected by the end of April.

Opnext's industrial and commercial production facility in Komoro was undamaged and production there resumed shortly after the earthquake. The facility is also being used to process pre-existing wafers from the Totsuka chip fab pending the full restoration of operations there.

Opnext says that it is also continuing to work with suppliers affected by the earthquake and tsunami (and related follow-on events) to address component availability and, in certain instances, it is exploring alternative sources of supply. In addition, it continues to be impacted by the planned power outages in the Totsuka area and it is in the process of installing backup power capability to permit continuous operation.

www.opnext.com

ProPhotonix adds blue and violet lasers

ProPhotonix Ltd of Salem, NH, USA, a designer and maker of LED systems and laser modules (as well as a distributor of laser diodes for Opnext, QSI, Sanyo and Sony), is to distribute two new high-power lasers launched at January's Photonics West event by Opnext.

The HL40023MG, a 500mW 404nm-wavelength violet laser, suits applications like biomedical illumination and optical lithography. Biomedical and direct imaging system makers often use large, power-hungry solid-state laser diodes. The HL40023MG offers a cost-competitive option for using a high-intensity diode in a small 5.6mm package. With a typical operating current of just 390mA, it also saves on power, helping to lower overall operating costs.

The HL45023TG is the first in a family of planned blue lasers.

It has been designed to meet the demands of embedded mobile pico-projector applications, but it is also suited to fluorescence and sensing applications. With a proprietary design, the HL45023TG provides 60mW of optical output power at a wavelength of 445nm while consuming 30% less power than blue lasers currently available. A maximum operating temperature of 70°C and small 3.8mm package suit the growing market demand in embedded and mobile device applications.

"The great relationship between our companies, coupled with the market presence of ProPhotonix, will uncover many new opportunities in a variety of applications," says Bob Murphy, Opnext's business development director for North America Sales.

www.prophotonix.com

Mass Spectrometers for advanced research applications

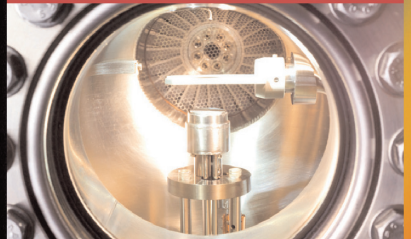
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IN BRIEF

3S grows revenue 40% in fiscal first-half 2011

For its fiscal first-half 2011 (to end-December 2010), 3S Photonics of Nozay, France, which makes laser chips, optical discrete modules and passive components for telecom networks, has reported revenue of €25m, up 40% on a year ago considering the post-divestiture product portfolio.

In February 2010, 3S acquired optical telecom component firm Avensys Inc of Montreal, Quebec, Canada (which — through its Avensys Solutions division — also provides instrumentation and integrated solutions for process and environmental monitoring systems). Nevertheless, with results far outweighing expectations, operating income (which was negative in fiscal first-half 2010) reached €1.05m.

"We are facing the second half of the year in a very comfortable position," comments president & CEO Alexandre Krivine. "This result can, of course, be partially explained by favorable market conditions but it also demonstrates the success of our diversification strategy into the terrestrial pump market and of our cost-reduction efforts."

Krivine adds that 3S now faces two key challenges: increasing output through technological innovation to support the growth of the firm, and continuing to offer the same level of quality and reliability. "These are two important assets that have enabled the 3S Photonics group to become one of the leaders in this market," he reckons.

For its fiscal full-year 2011 (to end June), 3S expects consolidated revenue of €50–55m (doubling from €25.22m in fiscal 2010).

www.3Sphotonics.com

3S names MD of French subsidiary and creates three new board members

3S Photonics Group of Nozay, France, which makes laser chips, optical discrete modules and passive components for telecom networks, has



nominated Jean-Michel Bonard as its managing director for France, and created three new posts on its board.

After acquiring optical telecom component firm Avensys Inc of Montreal, Canada in February 2010, 3S says this announcement illustrates its aim to capitalize on existing synergies between its various entities and to launch a policy of diversification, geographic expansion and strategic partnerships that will reinforce its international position. The aim is to reach consolidated annual revenue of €50–55m by this summer.

3S is reorganizing to meet its goals for the coming months and years, explains president & CEO Alexandre Krivine. "We are pursuing our efforts to further improve profitability within our various subsidiaries, maximize the company's perform-

ance and support our teams through sales development."

To strengthen collaboration between all entities and benefit from their respective expertise, the new structure also involves three new strategic positions on the group's board:

- business development director Jean-Pierre Hirtz;
- chief financial officer Geoffroy Morel; and
- VP of sales Fotis Konstantinidis.

Bonard joined 3S in July 2009 as deputy general manager in charge of company operations, while also taking on responsibility for the finance department. He began his career as an export manager for space equipment provider Katun Corp. In 2001, he joined GE Capital Finance as regional manager for the South. At the end of 2007, he created JMB Conseils, a financial consulting firm for telecom and IT companies. Bonard graduated from ESIAE/EMI in Paris, and he also holds an MBA from the Schiller International University in Florida.

www.3Sphotonics.com

Advanced Photonix promotes CFO to chief operating officer

Advanced Photonix Inc of Ann Arbor, MI, USA (which designs and makes silicon, InP- and GaAs-based photodetectors, subsystems, and terahertz instrumentation for telecom, homeland security, military, medical and industrial markets) has promoted chief financial officer Robin Risser to chief operating officer and member of the board of directors.

"Our rapidly expanding sales pipeline in our fast growth areas of high-speed optical receivers and Terahertz is driving our need to implement organizational changes to best respond to these opportunities," says president & CEO Richard (Rick) Kurtz. "With over 18 years in

the optical field and industry knowledge, combined with his financial and strategic expertise, Rob brings valuable experience and background to the COO position," he adds.

"We need to build on our strong internal management talent pool in conjunction with new external management expertise. Rob will also continue to serve as our CFO while we conduct a search for his replacement," Kurtz continues. "Having worked with Rob for the past six years I know he will be instrumental in helping API grow to the next level in the shortest possible time frame."

www.advancedphotonix.com

GigOptix 40G DPSK modulator passes Telcordia high-temp lifetime testing

GigOptix says that its LX8401 40G DPSK Mach-Zehnder modulator (MZM) has passed pre-qualification assessment, with over 1000hrs of Telcordia's GR-468 demanding high-temperature operating lifetime (HTOL) testing without degradation in operating performance. This is "an important milestone in our commercialization of our TFPS [Thin Film Polymer on Silicon] technology," notes Dr Raluca Dinu, VP & general manager of GigOptix Bothell.

The HTOL test assesses reliability by stressing the MZM at 85°C while it is modulating a 1550nm laser and being driven by a high-speed electrical RF signal. The test simulates an accelerated 25 year lifetime. The performance parameters measured included insertion loss, drive voltage, extinction ratio, and bandwidth. The result builds on previous reliability assessments by GigOptix of its TFPS optical chips, operated over 7000hrs at 85°C to date.

"We are now in the process of running full GR-468 qualification on these devices, including damp heat, mechanical shock and temperature cycling testing to be completed in the third quarter of 2011," says Dinu. "We expect the LX8401 and subsequent modulators addressing both the 40G and 100G markets to be a major vehicle for future revenue growth as we capitalize on the rapid growth of these optical networking markets."

GigOptix's claims TFPS technology enables low drive voltage in the smallest form factor available, reducing power consumption by over 20% versus competing modulator technologies, while enabling smaller 300-pin optical transponders.

The product is being industrialized by contract manufacturing partner Sanmina-SCI, which has provided process development, manufacturing and supply chain services for the LX8401.

Dispute settled with stockholder DBSI

GigOptix has entered into a settlement agreement with the trustees of the DBSI Liquidating Trust and the DBSI Estate Litigation Trust, arising from potential claims related to the bankruptcy of DBSI Inc in November 2008. Affiliates of DBSI were investors in a predecessor of GigOptix, which resulted in them becoming stockholders of GigOptix. DBSI was the beneficial owner of the investment held by its affiliates. DBSI Liquidating Trust now holds its GigOptix shares and warrants to purchase 660,473 shares (with a weighted average exercise price of \$32.35 per share with exercise periods expiring between end-2011 and 23 April 2017).

The affiliate DBSI Estate Litigation Trust was mulling claims against entities including GigOptix and affiliated parties. GigOptix disputed the existence of any claims.

The settlement now resolves the disputed claims and eliminates potential litigation. The trustees have agreed to cancel and return the warrants. GigOptix will issue to the DBSI Liquidating Trust two warrants (each for 500,000 shares) not exercisable for six months from the date of issuance: one with a term of three years and an exercise price of \$2.60 per share; one with a term of four years and an exercise price of \$3.00 per share. The warrants may be exercised on a 'cashless' exercise basis. The trustees also agreed to release their claims against GigOptix, its subsidiaries, directors and staff.

"We were eager to avoid the legal expense, waste of management time and bandwidth, and the risk that is always associated with litigation," says GigOptix's chairman & CEO Dr Avi Katz.

IN BRIEF

GigOptix wins \$750,000 order for 100G DWDM modulator drivers

GigOptix Inc of Palo Alto, CA, USA, which designs modulator drivers, laser drivers and transimpedance amplifier (TIA) ICs based on III-V materials as well as polymer electro-optic modulators for 40-100Gb/s fiber-optic communications, says it has booked a \$750,000 purchase order for its 100G quad-driver from a tier 1 telecom customer for its 100G DWDM networking systems. The order will be delivered in the second and third quarters of 2011.

The GX62450 100G DP-QPSK (dual-polarization quadrature phase-shift keying) driver is designed to be plug-in compatible with industry-available 100G multiplexer and Mach-Zehnder modulators. GigOptix says that the GX62450's GPPO-connectorized form factor ensures optimal RF coupling to the 100G optical modulator inputs and also occupies less board-level real-estate than comparable surface-mounted device solutions.

"100G is quickly becoming an industry reality, driven by increased demand for more bandwidth due to smartphone usage, IPTV and cloud services, as well as other video and data-intensive applications," says VP of marketing Pdraig O'Mathuna. "Next-generation wired and wireless networks will require high-speed optical links to enable the content delivery demanded by consumers," he adds. "In fact, Cisco is predicting a compounded annual growth rate for IP traffic of 34% through 2014. We see robust demand for our 100G products in 2011 and expect the 100G market to be one of the major growth engines for our company going forward."

www.gigoptix.com

ODIS demonstrates laser using POET monolithic optoelectronic fabrication

VCSEL targets on-chip optical connections between electronic devices

OPEL Solar International Inc of Toronto, Canada says that its US affiliate OPEL Defense Integrated Systems (ODIS) of Shelton, CT has demonstrated laser operation for the first time in a new integrated device as part of its Planar Optoelectronic Technology (POET) process.

POET creates high-performance devices by fusing optical and electronic functions together on a single chip. Specifically, POET is a semiconductor manufacturing technology that enables the monolithic fabrication of integrated circuits containing both electronic and optical elements. The firm claims that by offering components with much lower cost, together with increased speed, density and reliability, POET could allow it to fundamentally alter the landscape for a broad range of applications, such as tablet computers and smartphones.

Based on a proprietary III-V materials structure, the pulsed vertical-

cavity surface-emitting laser (VCSEL) operates at 980nm with a 12 μ m-diameter vertical cavity surface and an output power of 1.7mW. In tandem with ODIS' existing integrated detector — a heterostructure field-effect transistor (HFET) device — the laser enables inter-circuit optical connections between electronic devices for on-chip applications.

"This has proven, for the first time, an end-to-end technology for on-chip integration of photonic circuits can manipulate light signals on the same semiconductor framework as electronic signals," reckons OPEL's CEO Leon M. Pierhal. "This technology has the potential to overcome the constraints of copper interconnects in silicon-based chips, and it further validates the years of development invested in ODIS, as reflected in the potential market applications for POET technology, as well as its overall importance to our stakeholders," he adds. "This is

the baseline laser that will serve as the foundation device from which greater enhancements are projected and in the process of development," Pierhal notes.

ODIS has also proven other optoelectronic devices, including HFETs, optical thyristors, oscillators, and super-radiant light-emitting devices, all able to be monolithically fabricated via the POET process. These devices are currently being validated for scale-up by a third-party fabrication facility.

The POET platform is also the basis for other ODIS projects, under various governmental agency grants, to provide next-generation optoelectronic devices. These include 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).

www.opelinc.com

CyOptics launches compact PM-QPSK receivers for 40 and 100Gbps coherent systems

Indium phosphide-based optical chip and component maker CyOptics Inc of Lehigh Valley, PA, USA has launched 40 and 100Gbps polarization-multiplexed quadrature phase-shift-keying (PM-QPSK) integrated coherent receivers for 40G and 100G coherent DWDM transmission systems. The optical receivers expand the firm's growing portfolio of components leveraging monolithic and hybrid photonic integrated circuits (PICs).

The RX-PMQPSK-40 and -100 coherent receivers integrate two matched 90° optical hybrids, four high-speed balanced detector pairs, and four differential linear TIAs with manual and automatic gain control.

The compact surface-mount package (40mm long and less than 7mm high) also integrates the polarization splitters for signal and local oscillator.

The receivers use CyOptics' portfolio of high-speed InP-based balanced photo-detectors (PDs) and silica planar lightguide circuit (PLC) device technology for the 90° hybrid mixers. They also leverage the firm's automated precision-robotic integration platform for mounting the balanced PDs directly onto the PLC chip to provide a highly integrated optical sub-assembly with high performance in a very small footprint. The receivers adhere to the Optical Internetworking Forum (OIF) Implementation Agreement.

"Our new 40G and 100G coherent Receivers address the needs for very compact component solutions of transponder and line-card manufacturers alike," says Stefan Rochus, VP of marketing & business development. "CyOptics is uniquely positioned to combine all of the critical InP and PLC device technologies, together with our automated high-precision manufacturing platform, to deliver a high-performance and low-cost coherent receiver solution," he claims.

CyOptics is ramping production for both the 40G and 100G receivers now, for general availability in June.

www.cyoantics.com

www.oiforum.com

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ISO9001:2000, Certificate No.: FM 26963
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Tera Santa Consortium formed to develop first Terabit OFDM-based optical network

Israeli 3–5 year project targets coherent technology at low-cost, compact Terabit transponder

Seven companies and five universities in Israel have formed the Tera Santa Consortium, whose goal is to develop the world's first Terabit orthogonal frequency division multiplexing (OFDM)-based optical network.

With financial support from the Israeli Ministry of Industry, Trade & Labor's Office of the Chief Scientist (OCS) through its MAGNET program, the founding consortium members include communications system maker ECI Telecom, the Israeli subsidiary of fiber-optic communications component and subsystem maker Finisar Corp of Sunnyvale, CA, USA, network switch provider Orckit-Corrigent of Tel-Aviv, Elisra-Elbit (which provides information warfare solutions based on real-time coherent signal processing), fabless semiconductor firm MultiPhy (which provides DSP-based CMOS ICs for high-speed communications), Optiway (which provides optical multi-service solutions for in-buildings wireless communications), optoelectronic module maker Civcom of Petach Tikva, the Technion Israel Institute of Technology, Ben-Gurion University, the Hebrew University in Jerusalem, Bar-Ilan University, and Tel-Aviv University.

Fueled by ever-growing demand for bandwidth, a low-cost, compact and high-performance Terabit transponder solution will answer this market need with optimized bandwidth utilization and increased capacity for multi-service applications, says the consortium.

The focus of its activity is on the development of OFDM-based optical transmission technology and to research, develop and prototype a Terabit optical networking platform. This technology will be used to develop techniques to handle coherent optical links and will

explore the operational and performance impact that coherent technology's new degrees of freedom will have on optical networking. The research should yield the building blocks for commercial Terabit optical networks for metro and long-haul market segments.

Research topics will include:

- high-speed design using high-order quadrature amplitude modulation (QAM) constellations;
- overcoming optical impairments over long distances;
- maximizing system spectral efficiency;
- novel digital signal processing (DSP) architectures and algorithmic design;
- cost-effective and compact analog and optical components design; and
- design of photonic integrated circuits (PICs) as component-level platforms for the sub-system layer.

The consortium has already initiated activities and will continue for the next 3–5 years. It will work closely with and contribute to the international industry standard organizations involved with this effort, such as the IEEE, ITU and OIF.

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“By applying coherent technology, we enable a new level of cognitive intelligence in the optical network — from digital and optical components,

through transmission sub-systems, and all the way to a fully functioning network,” says consortium chairman Shai Stein (ECI Telecom's chief technology officer).

Cognitive coherent systems are intelligent systems that include unique DSP-based phase modulation techniques, allowing usage of inherent monitoring and self-rate adaptation capabilities as part of the system design and construction

coherent systems are intelligent systems that include unique DSP-based phase modulation techniques, allowing usage of inherent monitoring and self-rate adaptation capabilities as part of the system design and construction.

“By combining the expertise of both industry and academia, the Tera Santa Consortium brings the ideal blend of skills and cross-functionality for a holistic approach,” Stein reckons.

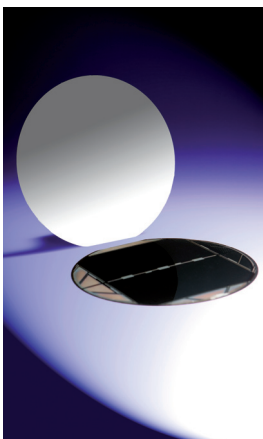
“We have created a consortium structure in which we amplify and leverage the cooperative efforts of major companies and an ensemble of top researchers in our field, supported by generous government funding,” says Technion's professor Moshe Nazarathy (co-founder of Harmonic Inc). “This transcends what any single company alone may accomplish,” he believes. “It also promotes an unprecedented degree of inter-academia-industry cooperation... we have come up with an out-of-the-box concrete approach towards realizing our vision for a Terabit system.”

www.finisar.com



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Emcore acquires assets of CPV system maker Soliant Terrestrial CPV portfolio gains commercial rooftop product line

Emcore Corp of Albuquerque, NM, USA, which makes components and subsystems for the fiber-optic and solar power markets, has acquired certain assets of Soliant Energy Inc of Monrovia, CA. Soliant's concentrated photovoltaic (CPV) systems for commercial rooftop applications combine CPV modules with patent-pending TipTilt Tracking, offering what is said to be a high-energy-density, light-weight, low-profile, and low-cost solution.

The Soliant assets acquired by Emcore include the equipment, inventory, software, licenses, intellectual property, and tooling for the rooftop solar energy product line. The acquisition was completed as part of an Assignment for the Benefit of Creditors process. Emcore did not assume any liabilities of Soliant.

Emcore plans to integrate the former Soliant R&D and pilot-production line into its existing facilities in Alhambra, CA. The commercial manufacturing operation is expected to transfer to Emcore's low-cost manufacturing joint venture Suncore in Huainan, China. Key members of the former Soliant team will join Emcore to facilitate the integration, product development, and business development and customer support.

"The addition of Soliant's rooftop CPV product line [to Emcore's terrestrial CPV portfolio] gives Emcore immediate access to the reportedly multi-billion dollar rooftop PV market, and expands the reach of Emcore's existing ground-mount systems," says CEO Dr Hong Hou. "We are very impressed with the capability of the Soliant team.

With the establishment of our CPV design and customer service center in Southern California, we will be able to develop business opportunities and serve our customer base in the most active region for solar installations," he adds.

"This integration allows us to leverage Emcore's highly efficient solar cell supply and its low-cost manufacturing infrastructure," says Dr Rick Russell, former VP of engineering & operations for Soliant and new VP of engineering for Emcore Rooftop CPV Systems. "Soliant enjoyed a very successful working relationship with Emcore through the development of our system," he notes. "This combined team will allow us to accelerate delivery of the most cost-effective and highest reliable rooftop system to market."

www.emcore.com

Soitec wins contracts from SDG&E for up to 30MW

Subsidiaries of Soitec Solar Development LLC, a firm managed by Soitec of Bernin, France, which makes engineered substrates including silicon-on-insulator (SOI) wafers (as well as III-V epiwafers through its Picogiga International division), has signed three contracts to supply a combined capacity of 30MW of solar energy to Californian public utility San Diego Gas & Electric (SDG&E, a subsidiary of energy services holding company Sempra Energy that supplies 3.5 million consumers in San Diego and southern Orange counties).

The electricity will be generated at three solar power plant sites in San Diego County that will use Soitec Concentrix technology. The concentrator photovoltaic (CPV) modules will be manufactured in a new Soitec factory to be built in the San Diego area.

"Including these three new contracts, SDG&E has signed nine renewable contracts over the past year for more than 1100MW of

green energy, with nearly 520MW from solar power, including a contract for up to 150MW that also uses Concentrix technology [via Tenaska Solar Ventures (a division of energy firm Tenaska of Omaha, Nebraska)]," says James P. Avery, SDG&E's senior VP of power supply. "Combined with another local solar contract we signed last year, these latest solar projects will increase the total amount of solar power generated in San Diego County by about 60%."

These three projects will produce enough solar energy to serve more than 11,200 households a year and further contribute to SDG&E reaching its RPS (Renewable Portfolio Standard) goals. The projects will deploy Concentrix ground-mounted dual-axis tracking CPV solar power systems, which use lenses to concentrate sunlight onto very small, highly efficient solar cells.

"Our CPV systems are perfectly suited for projects close to well-populated areas, as the high system efficiency of CPV minimizes the

amount of land needed for a given amount of electricity production," says Soitec's CEO & chairman André-Jacques Auberton-Hervé. "We are committed to the US market and look forward to increasing our presence in the San Diego community with all of our San Diego operations."

Soitec will implement capacity investments and pursue options for related financing to construct its San Diego area factory. At full capacity, Soitec's San Diego area operations will generate up to 450 direct jobs and more than 1000 indirect jobs. The factory location is expected to be announced this summer, with completion within 18 months of starting construction. Soitec's delivery of the CPV systems for these three new solar energy facilities in San Diego County will begin in 2013 and finish in 2014.

The three power purchase contracts require approval from the California Public Utilities Commission.

www.sdge.com

www.soitec.com

NREL and AIST to compare CPV cells from USA, Japan and Germany

Test sites in sunny, high-altitude Colorado and cloudier, lower-altitude Yokohama

The US Department of Energy's National Renewable Energy Laboratory (NREL) in Golden, CO, USA is partnering with international industrial technology and solar research organizations to test how solar cells from three different manufacturers — in the USA, Japan and Germany — perform under different average lighting conditions characteristic of the study's two test sites in Aurora, CO, USA and Yokohama, Japan.

Concentrator photovoltaic (CPV) solar systems (which use lenses to multiply the sun's intensity, reduce the area of solar cells needed, and improve the efficiency of conventional photovoltaics) have been installed at the test sites partly to measure how well the same cells perform in the high-altitude sunshine of Colorado in comparison with those in cloudier, lower-altitude Japan.

NREL teamed with Japan's National Institute of Advanced Industrial Science and Technology (AIST) — the largest research organization in industrial science and technology in Japan — to install 25kW of CPV systems at the Solar Technology Acceleration Center (SolarTAC) in Aurora. SolarTAC originated in 2008 when six public and private sector entities — original founding member Xcel Energy, Abengoa Solar, the City of Aurora, the Colorado Renewable Energy Collaboratory, Midwest Research Institute (MRI), and SunEdison — joined forces to establish the USA's largest test facility for solar technologies.

Managed and operated by MRI, SolarTAC provides a venue that supports proprietary research, testing, demonstration and validation by member companies (as well as collaborative activities between members) of a broad range of solar technologies at the early commercial

or near-commercial stage of development, at utility scale and under actual field conditions. SolarTAC member NREL plans to host multiple projects there.

CPV systems made by Japanese manufacturer Daido Steel are installed at both the Aurora and Yokohama sites and are designed to compare solar cells made by Spectrolab of the USA, Sharp Corp of Japan, and Azur Space of Germany.

Daido's CPV design uses a dome-shaped Fresnel lens and concentrator solar cells with efficiencies approaching 40%, resulting in module efficiencies of about 30%. By contrast, most existing PV panels on rooftops have an efficiency of 20% or less. The output of the CPV systems will be compared with conventional silicon PV modules.

The study will also test high-efficiency versions of the gallium indium phosphide/gallium arsenide (GaInP/GaAs) solar cells originally invented and developed at NREL, which are now used for space exploration applications such as the Mars rovers. The high efficiencies of these cells, coupled with system designs that greatly reduce the area that needs to be covered by solar cells, have attracted growing interest in recent years, says NREL. In the modules being tested, solar cells cover 1000th of the space covered by similar conventional solar modules.

The project is funded primarily by AIST as a part of the 'R&D on Innovative Solar Cells' project, which in turn is funded by Japan's New Energy and Industrial Technology Development Organization (NEDO), established by the Japanese government in 1980 to develop oil-alternative energy technologies).

www.solartac.org

www.nrel.gov

IN BRIEF

CPV system maker Isofoton's Q1/2011 revenue up 74% year-on-year

Isofoton S.A. of Malaga, Spain has reported revenue of more than €32m in first-quarter 2011, up 74% on a year ago.

Spun off from the Polytechnic University of Madrid in 1981, Isofoton designs, manufactures and supplies solar energy solutions focusing on photovoltaic, thermal, and high-concentration photovoltaics using GaAs-based cells. The firm has been developing concentrating photovoltaic (CPV) systems since 2001.

Isofoton says that its strong performance and substantial improvement in profit margin have also been underpinned by the ongoing cost cutting that was implemented by the new management team, coupled with enhanced production efficiency (less waste) and improved unit power.

After rolling out a new manufacturing line that will double production capacity, the firm expects to grow revenue further in second-quarter 2011, as it sees a recovery in the German, Italian and US markets, along with other markets. It also aims to double full-year revenue from 2010 to 2011. Over the next three years the firm aims to increase its production capacity fivefold.

Isofoton says that its new sales policy, which calls for expansion into new markets, is serving to both further diversify its customer portfolio and ensure stable sales. As part of the policy, the firm is opening or strengthening sales offices in Germany, Italy, France, the USA, South Korea, China and the Middle East. Isofoton has a presence in more than 60 countries in total.

www.isofofon.com

SolFocus completes CPV plant for California agribusiness

Concentrator photovoltaic (CPV) system maker SolFocus Inc of Mountain View, CA, USA, engineering, construction and project management firm Bechtel Power Corp and Sol Orchard LLC (which specializes in ground-mounted, solar projects for land owners to develop underutilized land into revenue-generating or operating-expense-off-setting use) say that a 1MW CPV plant has been completed for Nichols Farms in Hanford in California's San Joaquin Valley.

The installation will produce 2,244 million kilowatt hours (kWh) in the first year (about 70% of the processing facility's electricity demand). Sited on 6 acres adjacent to the pistachio processing facility and consisting of 119 SF-1100S CPV systems (each generating 8.8kW of power), the plant was designed and built by Bechtel, and is now connected to the regional electrical grid serviced by SoCal Edison.

"As an integrated grower, processor, and marketer of pistachios, I appreciate the value of harnessing natural resources in an efficient, sustainable manner," says owner Chuck Nichols. "The high energy yield combined with the superior environmental footprint of the SolFocus systems made it an ideal choice for our facility, which processes pistachios for farmers throughout the Central Valley of California."

California's central valley region has significant solar resources and agricultural businesses that can benefit from solar technology. The Nichols Farms project is delivering lower operating costs, and the impact of future increasing energy costs has been minimized, says SolFocus.

"Helping to advance high-efficiency, large-scale solar energy is a strategic interest for Bechtel," says Ian Copeland, president of Bechtel's Renewable Power division.

"The SolFocus system provides a combination of high-efficiency CPV with rapid installation capabilities that can deliver cost-competitive



SolFocus' CPV arrays powering Nichols Farm.

power very quickly," he adds.

"This CPV agribusiness project with Nichols Farms is the first of its kind in North America," reckons SolFocus' CEO Mark Crowley. "It demonstrates how SolFocus technology can easily accommodate a wide variety of energy demands that farms and other agricultural sites need," he adds. "The CPV industry has announced several large projects that will have a significant impact in upcoming years. However, it is this type of distributed generation solar plant which can immediately impact sustainability across a broad range of applications."

"This new and growing industry is investing in our Central Valley," comments Michael Picker, Special Advisor to the Governor for Renewable Energy Facilities. "By increasing energy and cost efficiency through the deployment of SolFocus CPV solar technology, Nichols Farms demonstrates the next generation of solar technology and sustainable agriculture," adds Assemblyman David Valadao.

Sol Orchard introduced the concept to Nichols Farms, and developed the project from concept to completion. "This is the third project we have developed utilizing SolFocus technology," says president Jeff Brothers. "The high

energy yield and reliable products allow us to move forward on projects quickly and with good financial results," he comments. "Bringing Bechtel in as the contractor gave us assurance that, when the switch was flipped, we'd have a robust power plant capable of delivering on all of its expectations."

SolFocus' CPV technology uses a system of patented reflective optics (curved mirrors) to concentrate sunlight 650 times onto small gallium arsenide-based solar cells (on germanium substrates) that have high solar energy conversion efficiency. The SF-1100S system deployed at the farm features dual-axis tracking for consistent energy delivery, offers environmental benefits including no water usage for energy production, a small land footprint with dual-use potential, and no permanent shadowing or wildlife corridor disruption. SolFocus claims that its CPV technology provides the shortest energy payback and lowest greenhouse gas (GHG) intensity of any solar technology. In solar-rich regions it also yields significantly more energy than other technologies, with an extremely light environmental footprint, the firm adds.

www.bechtel.com
www.solorchard.com
www.solfocus.com

Solar Junction hits record 43.5% efficiency for CPV production cell

Rise from 40.9% in January tops Spire's 42.3%

Solar Junction of San Jose, CA, USA, a manufacturer of III-V multi-junction solar cells based on lattice-matched 1eV materials for concentrated photovoltaics (CPV), has set a record of 43.5% energy conversion efficiency for a commercial-ready production cell.

The 5.5mm x 5.5mm production cell tops the existing 42.3% record (achieved last October by Spire Corp) by 1.2% and is much higher than the average efficiency gain achieved by previous record holders. Solar Junction's cell has a peak efficiency of 43.5% at more than 400 suns but still maintained an efficiency as high as 43% out to 1000 suns, as measured by the Measurement and Characterization Laboratory of the US Department of Energy's National Renewable Energy Laboratory (NREL).

Over the past four years, record CPV cell efficiencies have averaged improvements of 0.4% annually. By contrast, over the past nine months Solar Junction has been on a steep efficiency trajectory. This 43.5% achievement comes after the firm reported just in January achieving an NREL-verified 40.9% efficiency, followed in mid-February by 41.4%. These achievements were, in part, supported under the DOE's PV Incubator Program, managed through NREL.

"In the time I've been on Solar Junction's board, the company has hit all of its aggressive efficiency milestones on target," says Dr Forest Baskett, general partner at New Enterprise Associates. "That ability to deliver and execute sets it apart from the pack and positions it for swift market gains," he reckons.

"There's no question that we've been on a nine-month tear," says Solar Junction's CEO Jim Weldon. "We've delivered on milestone after milestone and attribute this to our superior performing technology platform, driven by our dedicated,



Wafer of Solar Junction CPV cells.

hard-charging technical team, supported by our integrated in-house manufacturing line that has enabled, and will continue to enable, multiple iterations of product improvement on an accelerated timeline," he adds.

Founded in 2007 with investors including New Enterprise Associates, Draper Fisher Jurvetson and Advanced Technology Ventures, Solar Junction says that its cell, which incorporates proprietary adjustable spectrum lattice-matched A-SLAM technology, enables it to more optimally partition the solar spectrum for maximum efficiency and greater reliability. "With A-SLAM, we have a highly extensible technology that is actually delivering a clear and continued path to higher efficiencies in both the short and long term," says Weldon. "That bodes well for CPV," he adds. The firm says that increases in CPV cell efficiencies are a key driver for improving CPV economics, with each cell efficiency gain leveraged and multiplied in value by the components that account for the remaining 80% of total system costs.

In February, Solar Junction made the short-list of finalists selected for post-selection due diligence within the DOE Loan Guarantee Program (LGP). The firm plans to scale in-house manufacturing to 250MW capacity and ship commercial cells within the year.

www.sj-solar.com

IN BRIEF

COO's role expands to president for commercial ramp

SolFocus' chief operating officer Bob Legendre has been promoted to president & COO, reporting to CEO Mark Crowley and overseeing a broad range of activities including manufacturing, supply chain, engineering, deployment, field support, and product quality.

"Bob has done an excellent job of building a supply chain and manufacturing capability that puts SolFocus in a leadership position in the CPV marketplace," reckons Crowley. SolFocus has deployed systems around the globe, now operating in Arizona, Colorado, California, Hawaii, Italy, Portugal, Greece, Spain, Australia, South Africa, and Malaysia. Systems are certified to the IEC 62108 standard, and are backed by Munich Re performance insurance. "As our business has matured, the benefits of consolidating all product-related activities under Bob's leadership will result in seamless customer service," says Crowley.

As COO, Legendre led SolFocus' engineering organization to drive cost out of the product and improve product quality. He also finalized product realization and product certification for deployment in EMEA, Australia and North America.

SolFocus says that Legendre has 25 years of global experience in all aspects of operations management including supply chain, operations, captive and contracted offshore manufacturing, NPI (new product introduction) operations, research and engineering development. Prior to SolFocus, Legendre was executive VP of PowerWave. He also had senior roles with InFocus and Western Digital (managing operations in South East Asia).

www.solfocus.com

China provides first order for OPEL Solar Asia

OPEL Solar International Inc of Toronto, Ontario, Canada, which makes high-concentration photovoltaic (HCPV) panels (and both roof- and ground-based solar tracker systems), says that, little more than 90 days after its formation, OPEL Solar Asia (OSA) — the joint venture between its US subsidiary OPEL Solar Inc and Ecotech Environmental Technology Ltd of Hong Kong — has secured an initial order: a blanket purchase order for 5MW of both HCPV panels and dual-axis trackers. The purchase order more than doubles the initial 2MW of orders originally forecasted when the JV was formed.

OPEL says that this initial order represents rapid progress in its long-term objective to penetrate

the HCPV market in East Asia. Many experts believe East Asia, and especially China, will be the fastest-growing CPV solar market in the world, adds the firm.

The initial systems will be delivered to one of China's five major electric power companies, starting in Q2/2011 and completing in 2012.

"This initial purchase order, in excess of tens of millions of dollars for our HCPV solar system, reinforces our decision to form OPEL Solar Asia with our partner Ecotech," says OPEL Solar Inc's CEO Leon M. Pierhal. "Our decision to form the JV significantly increases shareholder value for OPEL Solar in the form of accelerated growth and more profit from

diversified geographies," he adds. "Early indications are that our optimistic outlook in the Asian market may be well justified. It is refreshing to receive this Asian order at this time, given the turmoil in the North African and Middle Eastern regions of the world could impact solar growth there," Pierhal comments.

"Because Ecotech has an established network of local manufacturers, we expect to transition to more local manufacturing by OSA as volumes ramp," Pierhal notes. "As manufacturing processes attain full efficiency, OSA is expected to assume full responsibility for manufacturing and installing complete HCPV utility-grade solar farms."

www.ecotech-hk.com

OPEL to provide tracker systems for water treatment plant

OPEL Solar International has signed a definitive agreement with Aquarion Water Company of Bridgeport, CT, USA to install a tracker-based CPV solar system at its D.W. Loiselle Water Treatment Plant at Trap Falls Reservoir in Shelton, CT.

The plant will use both the TF-800 single-axis tracker and the SF-45 dual-axis tracker. The project is forecasted to produce about 43MWh of energy per year (about 22% more energy than would be expected from the same panels in a fixed installation, it is reckoned).

The plant will be used to offset the energy required to operate the Aquarion water treatment facility. The site will also provide a demonstration site for Aquarion to confirm the effectiveness of implementing this type of system at other sites. As part of the agreement, OPEL will build and operate the plant, which will also demonstrate to other OPEL customers the benefits of solar trackers in climates such as in New England.



OPEL Solar tracker CPV systems.

"This is the first installation for OPEL Solar at a private or municipally owned water plant," says CEO Leon M. Pierhal. "Typically, water and waste water plants provide a great opportunity to utilize clean solar energy to reduce power purchases. Our Solar tracker installations can be an ideal, cost-effective model for private utilities and municipalities nationwide," he adds.

"We have been working diligently on a series of measures to reduce

the company's 'carbon footprint,'" says Aquarion's president & CEO Charles V. Firlotte. "This agreement with OPEL Solar for our Shelton facility is one of the many projects we are undertaking," he adds. "By using OPEL Solar's advanced tracker technology, we will be able to generate much more energy than we could have expected from fixed technologies."

www.aquarionwater.com
www.opelinc.com

OPEL poised for growth after revenue dip in Q4/2010

OPEL Solar International Inc of Toronto, Ontario, Canada, which makes high-concentration photovoltaic (HCPV) panels (and both roof- and ground-based solar tracker systems), has reported revenue of \$375,747 for fourth-quarter 2010 and \$1,647,638 for full-year 2010 (both up year-on-year). However, Q4/2010 was down 22% on Q3's \$479,141.

OPEL notes however that, in response to difficult economic times in the marketplace, in 2010 it cut expenses by more than \$540,000 while increasing annual revenue by \$1m. At the end of 2010, the firm had \$6,934,107 in cash and short-term investments and no debt.

In Q4/2010, OPEL received a purchase order to install a 446kW

solar plant for Toray Plastics in Rhode Island. The firm also agreed a joint venture with Ecotech Environmental Technology Ltd of Hong Kong to form OPEL Solar Asia Ltd and install its HCPV panels and dual-axis solar trackers in China. OPEL Solar Asia's initial purchase order was for 2MW of panels and trackers, but this has recently been increased to 5MW.

At the Solar Power International show in Los Angeles last October, OPEL launched two new products: a prototype of its next-generation Mk-1X HCPV solar module (with performance 20% better than the firm's prior module designs); and a wireless network controller communications capability for its single- and dual-axis trackers

(which can lower installation cost and ongoing operations and maintenance costs for solar fields).

"With our recent bookings OPEL will be well positioned for growth in 2011," says chief financial officer Michael McCoy. "I am also pleased by the recent endorsement for our POET [planar optoelectronic technology] by third parties and the possibilities that the enhanced POET intellectual property portfolio has provided the company [via its US affiliate OPEL Defense Integrated Systems (ODIS) of Shelton, CT, which designs communications transceivers, optoelectronic integrated platforms and infrared sensor type products for military, consumer and industrial applications]."

www.opelinc.com

Single-axis trackers for Greenlight

OPEL Solar is supplying TF-850 single-axis trackers to Greenlight Power Company (a full-service solar energy development firm) for the launch of a 125kW project to be installed at a solar farm in a business park in Kent County, MD. This is the first phase of a 1.4MW solar development at the site.

The trackers should increase the project's energy production by about 24% over what would be expected from the same solar panels using a fixed installation. Output will be sold to Choptank Electric, a Touchstone Energy Cooperative, which is a member-owned electric distribution utility with headquarters in Denton, MD that serves more than 52,140 residential, commercial and industrial accounts in parts of all nine counties of Maryland's Eastern Shore. This first phase of the project will produce about 182MWh annually.

"The boost in energy production from our tracker can improve the economics of any solar project that has an energy-production-based solar renewable energy credit (SREC) program like Maryland's,"

says OPEL's CEO Leon M. Pierhal. "The choice of the TF-850 tracker validates our recent strategic decision to supply clean, solar energy directly for industrial structures." OPEL says its tracker product line can be used with any type of solar panel technology, providing greater layout flexibility for integrators and engineering firms choosing a tracker for a solar field.

"Adding the OPEL Solar tracker made both business and energy sense for this important first phase of our Maryland project," comments Greenlight's president Greg Brown. "Based upon the advice from David Schroeders of Blue Sky Solar [a consulting/EPC provider of Venice, FL, USA], we decided OPEL Solar's single-axis trackers are a great addition to this project that we believe will also benefit many future projects."

Blue Sky Solar Group's founder Schroeders is a civil engineer with more than 20 years construction and engineering experience. The firm is currently building projects in nine states in the USA.

www.greenlightpowercompany.com

Incentives stock options granted

Subject to the provisions of its stock option plan (approved by shareholders in June 2009) as well as the TSX Venture Exchange policies and applicable securities laws, OPEL has granted additional incentive stock options to certain directors, officers and key consultants to purchase up to an aggregate of 750,000 common shares (0.86% of the outstanding voting shares of the firm).

Options granted to the company's officers represent 56.7% of the total grants, and options to the independent members of the board of directors represent 26.7%. The remaining options were granted to key consultants.

Expiring end-February 2021, the stock options are exercisable at a price of CA\$0.76 per share (the closing market price on 3 March, when there were 11,562,500 options outstanding and 86,940,514 voting shares outstanding). The options are exercisable on the basis of 25% on the date of grant and 25% every six months thereafter.

First Solar breaks ground on Vietnam factory

\$300m, 250MW module-making plant to employ 600 staff

First Solar Inc, which makes thin-film photovoltaic (PV) modules based on cadmium telluride (CdTe) as well as providing engineering, procurement and construction (EPC) services, has officially broken ground on its four-line photovoltaic module manufacturing plant in the Dong Nam Industrial Park (a 342 hectare business development zone about 25km north of Ho Chi Minh City) in a ceremony attended by Vietnamese Deputy Minister of Industry and Trade Tran Tuan Anh.

The \$300m plant is due to begin commercial production in second-half 2012 and employ about 600 associates. Up to 2000 people will be involved in the construction. The plant will produce more than 250MW of modules per year from the four manufacturing lines, with the flexibility for future expansion. First Solar also plans to install 3MW

of modules on the factory's roof.

"Our Dong Nam factory will play a key role in our plan to nearly double First Solar's capacity by 2012 and further reduce the cost of solar electricity," says president Bruce Sohn. "We look forward to working closely with the Vietnamese authorities in the months and years to come."

The factory will use First Solar's continuous manufacturing process, which transforms a sheet of glass into a

The plant will produce more than 250MW of modules per year from the four manufacturing lines. Our Dong Nam factory will play a key role in our plan to nearly double First Solar's capacity by 2012

complete solar module in less than 2.5 hours, contributing to what is claimed to be the industry-leading energy payback time and low carbon footprint of First Solar's thin-film modules.

The factory also will include a recycling plant, which First Solar says is a key feature of its commitment to cradle-to-cradle life-cycle management and extended producer responsibility. The process currently recovers up to 90% of a module's semiconductor materials and glass, by weight, for use in new solar modules and glass products.

All of First Solar's factories worldwide are certified under the ISO14001 system for environmental standards, ISO9001 for quality, and OHSAS 18001 for occupational safety and health.

www.firstsolar.com

First Solar announces departure of president of operations Sohn

First Solar's president of operations Bruce Sohn was due to leave the firm at the end of April.

He is not being replaced, and his direct reports will continue in their current responsibilities with new reporting lines: senior VP of operations Tymen DeJong, VP of supply chain Doug Duval, senior VP of plant replication Heinrich Eichermueller, and senior VP of engineering, procurement and construction (EPC) Jim Lamon will report to CEO Rob Gillette.

"Bruce has been an important part of First Solar's history and growth, and his dedication to our vision has been unwavering. His leadership in establishing and building our manufacturing capabilities on a global scale has been a key driver of our success," says Gillette. "This is a natural time for him to pursue new opportunities outside the company," he adds.



"Not only have we achieved our cost and manufacturing milestones, but we also have positioned a new generation of

leaders to take First Solar into the next phase of growth," says Sohn.

Sohn has been an integral part of First Solar's early history, working as an engineering, operations and managerial consultant and serving on the firm's board of directors from 2003 to 2009. He joined the executive team in 2007 as president, and has since been responsible for technology, operations and supply chain for module production, as well as for the EPC and Operations and Maintenance groups.

DeJong joined First Solar in 2010 as VP of manufacturing from Numonyx Corp, where he worked since 2008 (most recently as a VP

of Assembly/Test Manufacturing). Before that he worked for 25 years at Intel Corp in Fab and Assembly/Test Manufacturing. Duval joined as VP of Global Supply Chain Management in 2008 from Spansion Inc, where he was VP, Global Supply Chain Management. He previously worked in procurement at Advanced Micro Devices and Westinghouse Electric Corp. Eichermueller has been with First Solar's manufacturing team since 2006 and has run the Plant Replication team for the past year. Before that he held roles as VP of operations for NanoNexus, FlexICs and Siemens Solar Industries. Lamon joined First Solar's EPC group in 2008. He has more than 25 years of experience in engineering and construction management, including leadership positions at Shaw Power, Aker Kvaerner Power, Clark Construction and the US Army Corps of Engineers.

First Solar launches modules for 10–30kW commercial power systems Small- and medium-sized commercial and industrial rooftops targeted

First Solar has announced the availability of its cadmium telluride thin-film photovoltaic modules for use in 10–30kW solar systems.

Since its market debut in 2002, First Solar and its business partners have focused on commercial PV systems larger than 30kW (DC). The firm says that, with the introduction of its latest, high-efficiency Series 3 modules, as well as increasing demand for commercial systems below 30kW, it is responding to demand by serving this growing market segment.

“Commercial rooftops in the 10–30kW range represent a multi-gigawatt market globally,” says TK Kallenbach, president of First Solar’s Components Business Group. “This expansion gives our customers additional flexibility to serve smaller- and medium-sized commercial and industrial rooftops. It is a natural extension of our thin-film module capability and allows our customers to continue to learn and apply innovative technology and installation techniques to a growing market,” he adds.

“The combination of economic and environmental attributes of First Solar modules will prove just as attractive to customers of 10–30kW PV systems as they have to customers of bigger systems,” believes Stephan Hansen, managing director of First Solar GmbH of Mainz, Germany, the firm’s European sales and marketing organization. “This offering is open both to existing First Solar customers and to new customers.”

More than 3GW of First Solar modules are already installed worldwide, displacing more than 1.5 million metric tons of CO₂ emissions per year. About one-third are installed in commercial rooftop systems. Typical 10–30kW PV systems installed consist of 125–375 First



Solar modules, requiring 90–270m² of roof space and displacing 4–12 metric tons of CO₂ per year.

First Solar claims that systems using its modules typically have high annual energy yields under real-world conditions (producing more energy than competing systems with the same power rating) and offer environmental benefits including a prefunded module collection and recycling program that enables the recycling of all modules at no additional cost.

First Solar does not sell directly to the public. A list of partners authorized to sell its modules as well as design, install and sell systems using its modules can be found at:

www.firstsolar.com/en/developers_integrators.php

IN BRIEF

First Solar certifies SolarMax inverters for its FS 2 and FS 3 CdTe PV modules

First Solar Inc of Tempe, AZ, USA, which is the world’s largest manufacturer of thin-film photovoltaic (PV) modules, has officially certified that the SolarMax grid-connected inverters made by Sputnik Engineering AG of Biel/Bienne, Switzerland are compatible with the cadmium telluride (CdTe) modules of its FS 2 and FS 3 series.

While crystalline modules can normally be combined with all inverters, this is not necessarily applicable to thin-film modules, particularly when you combine these with transformerless inverters.

In order to guarantee its modules, First Solar subjects all PV systems used in combination with its modules to its specifically developed system design and application (SDA) process. Along with the location, it also checks the installation plan, the proper design, and the operating conditions. Within this process, the interaction between modules and electrical components such as inverters plays an important role. The results of this quality control are high system efficiencies and economically working, optimally designed solar systems, says First Solar.

Sputnik’s inverters have been installed with First Solar modules for years. The official approval (covering all SolarMax inverter types) now accelerates the SDA inspection and assures right from the design stage that the warranty will cover the system, notes Sputnik’s head of Product Management Hans-Georg Schweikardt.

www.solarmax.com
www.firstsolar.com

GE reports record 12.8%-efficient thin-film solar panel; plans 400MW US manufacturing plant

GE completes acquisition of CdTe PV firm PrimeStar and Converteam

General Electric (GE) says that a full-size, thin-film solar panel developed by the firm has been independently certified by the US Department of Energy's National Renewable Energy Laboratory (NREL) as the most efficient ever publicly reported, with an energy conversion efficiency of 12.8%.

GE intends to manufacture the panels at a new US factory that will be larger than any existing solar panel factory in the country. When complete, the factory will highlight an expected investment of more than \$600m made by GE in solar technology and commercialization, and will be complemented by its acquisition of power conversion technology firm Converteam (announced at the end of March).

In addition, GE has completed its acquisition of PrimeStar Solar Inc of Arvada, CO, USA. PrimeStar was founded in Golden, CO in June 2006 to develop cadmium telluride (CdTe) thin-film photovoltaic modules using technology from NREL (which is based in Golden). After acquiring a minority stake in September 2007, GE's power generation division GE Energy of Atlanta, GA, USA took a majority stake in PrimeStar in June 2008.

GE says that photovoltaic solar is the next step in growing its renewable energy portfolio and is part of the firm's 'ecomagination' commitment to drive clean energy technology through innovation and R&D investment. "Over the last decade, through technology investment, GE has become one of the world's major wind turbine manufacturers, and our investment in high-tech solar products will help us continue to grow our position in the renewable energy industry," says Victor Abate, VP of GE's renewable energy business. "We are addressing the biggest barrier for the mainstream adoption of solar technology — cost — and the NREL certification proves

that we are on track to deliver the most affordable solutions for our customers," he adds. Demand for photovoltaics is expected to grow by 75GW over the next five years, with utility-scale solar power plants comprising a significant part of that. With its technology and manufacturing investments recently announced, GE says that it is positioning itself to capitalize on this trend.

The record panel was produced on the PrimeStar 30MW manufacturing line in Arvada. It was measured by NREL at a 12.8% aperture area efficiency, surpassing previously published records for CdTe thin film (the most affordable solar technology in the industry, GE says). GE says that continually increasing solar panel efficiency is a key component of its goal to reduce the total cost of electricity for utilities and consumers (a 1% increase in efficiency is equal to a cut in system cost of about 10%, it notes).

"It's great to see technology that started at NREL ready to move into the market," comments Ryne Raffaele, director of the National Center for Photovoltaics at NREL. NREL transitioned the technology to PrimeStar through a cooperative research and development agreement (CRADA) signed in 2007.

GE plans to build a thin-film solar panel factory in the USA that, at capacity, will produce enough panels per year to power 80,000

homes annually. The 400MW facility will be larger than any existing US solar panel manufacturing plant and will employ 400 people. Multiple locations are being considered, with the final location to be announced soon. This is just the first phase in a global, multi-gigawatt roadmap, says Abate.

The firm also announced more than 100MW of new commercial agreements for solar thin-film products, including panels, inverters and total solar power plants. Its largest solar agreement to date is with NextEra Energy for 60MW of thin-film panels. Once deployed, they will help to grow NextEra's solar power portfolio, solidifying its position as the largest generator of solar energy in the USA.

GE has also signed a 20MW solar agreement with Chicago-based clean energy generation firm Invenergy LLC for the supply of thin-film solar panels and GE Brilliance inverters. Invenergy will install the solar products at a project site in Illinois. It recently executed a power purchase agreement for the project which, upon completion, will be one of the largest solar installations in the state.

GE also offers power electronics and pre-designed utility-scale solar power plants for use in multi-megawatt applications. The \$3.2bn acquisition of Converteam will add that firm's energy conversion technologies to GE's solar offerings, broadening its portfolio. GE says that power electronics are critical to bringing renewable sources such as wind and solar into the mainstream, delivering economies of scale and providing stable connection to the grid. By adding Converteam technology, GE aims to be well positioned to bring a broad range of integrated generators, converters and inverters to the wind turbine and solar plant sectors.

www.gepower.com

The 400MW facility will be larger than any existing US solar panel manufacturing plant and will employ 400 people. Multiple locations are being considered, with the final location to be announced soon

Abound partners with Solarsis for Indian PV market

First project is 1MW ground-mount array in Andhra Pradesh

Cadmium telluride (CdTe) thin-film photovoltaic (PV) solar module maker Abound Solar of Loveland, CO, USA has announced a long-term sales agreement with Solar Integration Systems India Pvt Ltd (Solarsis) of Hyderabad to serve project developers in the Indian market.

Solarsis will also establish a test facility to optimize balance of system (BoS) designs around Abound's modules that will lower total system costs for customers. The first project under this agreement will be a 1MW ground-mount array in Ananthapur in the state of Andhra Pradesh.

Abound Solar recently closed on a \$400m loan guarantee from the US Department of Energy (DOE) to fund the expansion of its manufacturing capacity and help cater to demand for its products in emerging markets such as India. As a

solar system integrator with more than 150 years of combined management experience, Solarsis undertakes design, installation and project management of photovoltaic solar solutions using a five-step integration process that includes comprehensive financing with debt and equity support.

"Abound Solar's thin-film modules are ideally suited for environmental conditions found across India: high temperatures and diffuse light conditions," says Solarsis' CEO Venkat Rajaraman. "The combination of thin-film technology and high performance in a low-cost module and our experience in integrating BoS components allow us to deliver strong financial returns to our customers," he adds.

"We are extremely excited to work with Solarsis as a preferred system integration partner for India," says Julian Hawkins, senior VP of sales

& marketing for Abound Solar. "The company's position as a leader in the Indian solar market represents a great opportunity for Abound Solar as we work to develop our presence in the quickly growing market."

According to a recent report published by Research and Markets, India promises to become one of the world's largest photovoltaic solar energy markets, partly because the country has some of the best solar resources in the world. In November 2009, the Indian government announced the National Solar Mission, targeting 20,000MW of cumulative installed solar power by 2022. Average year-on-year growth of 68% will be needed to reach this target, mostly from grid-connected projects. Solar Mission should also create tens of thousands of jobs.

www.abound.com

Apollo-NJIT Solar Energy Research Center files US Patent for Cd vacancy theory

Apollo Solar Energy Inc of Chengdu, Sichuan Province, China says that professor Ken Chin, director of the Apollo-NJIT Solar Energy Research Center, has filed the US patent application 'CdTe Solar Panel Processing Technology based on Cd Vacancy Theory' (application number 61/357,058).

Through its subsidiary Sichuan Apollo Solar Science and Technology Co Ltd, Apollo Solar Energy is a vertically integrated firm primarily engaged in mining, refining and producing high-purity tellurium (Te), tellurium-based compounds and other metals for the thin-film solar photovoltaic (PV) industry as well as for segments of the electronic materials market including radiation detection and infrared detection.

The firm's products include

ultra-high-purity metals and commercial-purity metals (such as selenium, antimony, bismuth, cadmium and zinc), cadmium telluride (CdTe) thin-film compounds, and copper indium gallium diselenide (CIGS) thin-film compounds.

In March 2010, Apollo Solar awarded a three-year \$1.5m grant to establish the Apollo CdTe Solar Energy Research Center at New Jersey Institute of Technology (NJIT) in Newark, NJ, USA, focused on improving the applications of CdTe materials for use in thin-film solar cells. In exchange, Apollo receives first refusal and exclusive rights to use all patents filed by the Apollo-NJIT Solar Energy Research Center.

"Despite its commercial success, CdTe photovoltaic is still often called a 'mystery'," says Apollo's

CEO Dr Jingong Pan. "While many critical processing steps in current CdTe solar panel manufacturing were developed empirically through the years, their mechanisms remain controversial and not well known. Our new invention, however, is based on fundamental understanding of the CdTe solar cell's materials, structure, and device physics," he adds.

"Our new invention may lead to a significant improvement in energy conversion efficiency and reduction of production cost of CdTe thin-film panels," Pan continues. "As a result, we believe that our invention may significantly promote the development of the CdTe thin-film PV industry, and increase market share for our products worldwide," he concludes.

www.apollosolar.com

IN BRIEF

Sputtering materials

At the 54th annual Society of Vacuum Coaters Technical Conference (SVC TechCon) in April, Elmet Technologies Inc of Lewiston, Maine, USA exhibited its molybdenum and tungsten sputtering materials as part of its portfolio for PVD, including copper indium gallium diselenide (CIGS) and cadmium telluride (CdTe) thin-film photovoltaics.

As a fully integrated supplier, Elmet makes products starting from molybdenum and tungsten powder and does all the necessary processing. Powder metallurgy expertise allows it to meet specific application needs (semiconductor or solar grade, planar or rotary). Its portfolio of geometries and sputtering materials includes standard and high purities as well as material compositions.

Elmet serves downstream sputtering target production needs through its machining and finishing operations, providing both sputtering materials and the machined backing plates.

Also at SVC, Dr Martin Schlott, global head of R&D of the Thin Film Materials Division (TMD) at Heraeus of Hanau, Germany, spoke about high-efficiency, rotatable sputtering targets developed for CIGS photovoltaics.

Heraeus has made targets tailored to CIGS (Cu, In, Ga, S/Se) PV technology since the 1990s. It says that achieving the appropriate material properties is critical for yielding uniform film deposition and high-sputter-rate processes enabling formation of a high-quality, low-cost absorber layer.

Schlott presented sputter data and results from the development and testing of targets in Heraeus' sputter applications lab. Rotatable targets discussed included CuGa, pure indium, and ternary alloy CIG.

www.elmettechnologies.com
www.heraeus-targets.com

Q-Cells hits record 13.4% efficiency for mass-produced CIGS PV module

Fraunhofer ISE confirms aperture area efficiency of 14.7%

Q-Cells SE of Bitterfeld-Wolfen, Germany claims to have achieved record efficiency for mass-produced copper indium gallium diselenide (CIGS) thin-film solar modules manufactured via monolithic integration.

In February, the Fraunhofer Institute for Solar Energy Systems (ISE) of Freiburg, Germany measured a Q-Cells Q.SMART UF module made by Freiburg-based Q-Cells' subsidiary Solibro GmbH and confirmed a power output of 100.3Wp Watt peak under standard test conditions, and a total area efficiency of 13.4% for the 0.75m² (119cm x 63cm) module. Moreover, with an aperture area of 0.684m², its aperture area efficiency is a record 14.7% (based on 'Solar cell efficiency tables (version 37)' compiled by Green MA, Emery K, Hishikawa Y and Warta W in Progress in Photovoltaics: Research and Applications 2011; 19: 84-92). "In June 2010, Q-Cells achieved the previous efficiency world record of 13% with the same type of CIGS solar module out of series production," notes chief operating officer Gerhard Rauter.

Q-Cells' CIGS modules are currently taking part in a number of reference installations and are exhibiting stable energy yields (kWh/kWp). Even after one year of operation, Q.SMART systems in different European regions of irradiation show improved performances, claims the firm. The Q.SMART UF is currently among the top performers in a benchmark at a test field in Alice Springs run by the independent, Australian government-financed Desert Knowledge Australia Solar Centre (DKASC), having achieved peak performance under extreme climate conditions. So far, the Q.SMART UF is the highest-performing solar module in this international comparison.

The unframed Q.SMART UF module is self-cleaning, suiting flat roofs and façade solutions. Due to its homogenous black surface it is appropriate for visual aesthetics and building-integrated installations and suitable for private and small- to medium-sized commercial and industrial rooftop and in-roof installations.

The modules are designed for good response to temperature and low light, ensuring high energy yields. This is supported by the positive sorting +5/-0W, allowing deviations only to higher-than-expected levels, says the firm. Advantageous cell geometry makes the modules especially efficient in the event of partial shading or a less-than-optimal positioning of the roof. The module also features durable glass encapsulation with a proven edge seal for long-term stability, ensuring protection and resistance to environmental influences.

Q-Cells currently offers two different CIGS thin-film formats: Q.SMART (framed); and Q.SMART UF (unframed) and Q.SMART UF L (unframed large). The latter is 25% wider than the former two in order to reduce the associated balance of system (BoS) costs on large rooftop and free-field installations.

● For 2010, Q-Cells returned to profitability (EBIT operating income of €82.3m, versus a loss of €362.5m in 2009). Sales rose by 70% from €790.4m to €1.35bn due to strong demand driving an 84% rise in production volumes, from 551MWp to 1014MWp (exceeding 1GW for the first time): i.e. 940MWp of silicon solar cells and 74MWp of CIGS modules. Total production capacity expanded from 830MWp to 1235MWp during 2010.

www.q-cells.com/qsmart

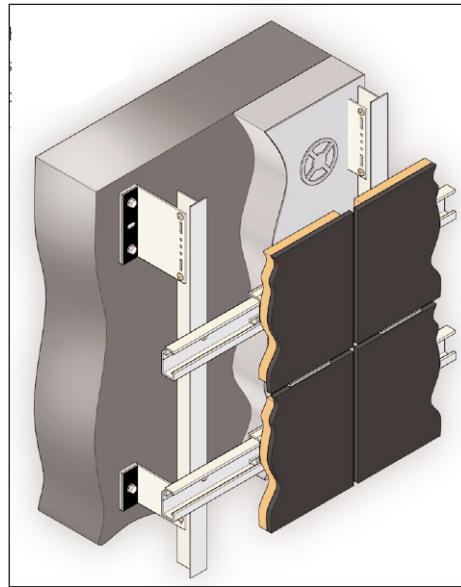
CIS PV firm Odersun co-operates with Lithodecor on solar façades

Odersun AG of Berlin, Germany, which designs and makes flexible thin-film solar modules using proprietary CISCuT (copper indium disulfide on copper tape) reel-to-reel manufacturing technology, and Lithodecor, which produces ventilated curtain wall systems, are co-operating on solar façades.

Odersun is supplying custom-made CIS solar modules for Lithodecor's Airtec system. Apart from classic materials such as glass and natural stone, Airtec façades are now available with multi-functional façade components integrating photovoltaics. Solutions already provided by Lithodecor can be individually combined with the new solar components. Odersun manufactures system-compatible as well as project-specific solar modules for building integration, so Lithodecor is able to provide system standard sizes as well as individual made-to-measure solutions.

The integration of renewable energy into the building envelope is the next logical step for Lithodecor in upgrading its product portfolio. "Energy-efficient building is not a 'nice-to-have' anymore but a mandatory requirement to meet low-carbon goals," says Dr Clemens von Trott zu Solz, managing director of Lithodecor's façade division, which lately emerged from well-known Alsecco following an internal brand conversion. "As an established manufacturer of building systems, we want to provide our customers with materials which help them to meet these new standards. With Odersun we have found the right partner with the technology and products to enable innovative and aesthetic façades solutions," he adds.

Solutions already provided by Lithodecor can be individually combined with the new solar components



Lithodecor's Airtec façade system with integrated photovoltaics.

Odersun is able to adapt its modules in size and design to fit into the respective façade system. "Odersun modules have become a scalable building material thanks to our flexible technology and customizable product design, making it an ideal fit for the various parts of the building envelope," claims the CIS module maker's CEO Dr Hein van der Zeeuw. "We are happy to have Lithodecor as an experienced system partner who shares our vision of energy-efficient building with photovoltaics."

The new solar façade system is designed to support builders striving to meet the tightening standards of energy conservation regulations and energy-efficient refurbishment. Solar components replace alternative façade elements with full functionality and provide payback through the façade-generated electricity, says Odersun.

Both firms showed the first samples of the Airtec Photovoltaic system at January's BAU 2011 building and construction industry trade show in Munich, Germany earlier this year. Reference projects are in the setup phase.

www.odersun.com

IN BRIEF

Sono-Tek launches ultrasonic spray system for CIGS

Sono-Tek Corp of Milton, NY, USA has launched a new ultrasonic spray system for inline copper indium gallium diselenide (CIGS) photovoltaic cell manufacturing. The high-speed reciprocating HyperSonic system is scalable to high-volume production. The firm claims its ultrasonic systems such as the HyperSonic represent lower capital investments and cost savings compared with vacuum-based systems.

Sono-Tek says that non-vacuum deposition methods are becoming more popular in thin-film PV manufacturing as alternatives to chemical vapor deposition (CVD) and sputtering. It also notes that such methods require smaller capital investments compared to vacuum deposition.

Sono-Tek also states that its ultrasonic systems offer up to 95% transfer efficiency of rare-element CIGS suspensions.

Sono-Tek says that its ultrasonic nozzles use high-frequency vibrations to break up agglomerations in solution and hence assure spray uniformity during coating. This is particularly valuable when depositing cadmium-based suspensions, where such agglomerations can result in the non-uniform distribution of particles and a lower cell efficiency.

The HyperSonic system provides independent control of drop size, flow rate and deposition. Sono-Tek states that such features contribute to high uniformity and the ability to optimize morphology characteristics.

The HyperSonic system is available in 61, 97 or 122cm coverage. It includes product sensing capability, and the system can be retrofitted with existing conveyor systems for high-volume lines.

www.sono-tek.com

Hyundai-Avancis breaks ground on Korean CIGS plant HHI-Saint-Gobain JV to complete construction by January

Hyundai-Avancis, a joint venture formed last October between South Korea's Hyundai Heavy Industries Co Ltd (HHI) and Saint-Gobain of Courbevoie, France (which designs, makes and distributes building materials and electronic materials), has held a ground-breaking ceremony for Korea's largest copper indium gallium diselenide (CIGS) thin-film solar module plant.

Held in Ochang Foreign Investment Zone, Chungcheongbuk-do, the ceremony was attended by Saint-Gobain chairman & CEO Pierre-André de Chalendar, Hyundai Heavy chairman Min Keh-sik, and 250 government officials and business people.

Saint-Gobain, said to be the world leader in the habitat and construction markets, and 'green' energy provider Hyundai Heavy each

invested KRW110bn in Hyundai-Avancis, bringing total investment in the joint venture to KRW220bn (\$200m). Hyundai-Avancis plans to complete the 231,000m² plant by January and start production from second-half 2012.

Starting with construction of this first 100MW CIGS solar module plant, using technology from Avancis GmbH of Torgau, Germany (a subsidiary of Saint-Gobain since autumn 2009), Hyundai-Avancis may expand annual production capacity to 400MW by 2015 after considering market conditions.

Hyundai Heavy, Korea's biggest solar cell maker (with a 600MW solar cell and solar module factory at Eumseong, Chungcheongbuk-do), says that it is the only Korean firm with a complete solar power production chain. The new plant

will also make Hyundai Heavy a manufacturer of a full range of solar power products such as polysilicon, ingot/wafer, solar cells, solar modules, and solar power systems. The firm aims to be one of the world's top five CIGS solar module manufacturers by 2015.

With more than 190,000 employees in 64 countries, Saint-Gobain designs, manufactures, and distributes building materials, providing solutions to meet growing demand for energy efficiency and environmental protection. In addition to its first 20MW facility in Torgau, the firm is currently building a second Avancis plant on the same site, with a future annual output of 100MW, to begin operation at the end of 2011.

www.avancis.de/en
<http://english.hhi.co.kr>

Ascent re-focusing from building-integrated/applied PV markets to high-value, emerging markets Cut in European subsidies prompts re-sizing and new CEO

Ascent Solar Technologies Inc of Thornton, CO, USA has announced a change in strategy that will focus its lightweight, flexible thin-film copper indium gallium diselenide (CIGS) solar module technology on applications for emerging and specialty markets.

In the past, Ascent has dedicated much of its resources to establishing a position in the building-applied and building-integrated photovoltaic (BAPV/BIPV) markets. The firm reckons that the new focus provides a clear path for the future and leverages its unique strengths.

Ascent says that producing solar modules that are lightweight and flexible gives it the ability to meet specialty needs for markets such as: military and defense; custom near-space applications; off-grid charging solutions in developing countries; power for portable elec-

tronics; and custom and standard products for rooftop integration on buses, trucks and trains. Ascent believes that it can sell its products in these markets at more attractive margins than currently possible for ground-mount applications or BIPV and BAPV markets.

"Ascent's various BIPV/BAPV products are still important to our long-term growth and success... we will continue selective business development, testing and certification for those products," notes chairman Dr Amit Kumar.

"A number of economic considerations, including the serious reduction of government subsidies in major markets in Europe, indicate that these markets will be under some near-term pressure," Kumar adds. "Therefore, in the near term, we will focus our manufacturing and sales activities

on emerging, high-value, specialty market applications," continues Kumar.

"Although our cash position is strong, we are taking steps to reduce staffing and operating costs that will minimize the company's current cash burn rate."

With the change in strategy, CEO Farhad Moghadam is stepping down to pursue other interests and opportunities, and Ron Eller (a board member for the past two years) has been appointed president & CEO.

Eller is a technology executive and management consultant with more than 25 years experience. This includes, most recently, running various divisions in the enterprise businesses of Hewlett Packard and Compaq Computer Corp.

www.ascentsolar.com

Nanosolar efficiencies hit 13.9% for printed CIGS cells; 11.6% for panels

Nanosolar Inc of San Jose, CA, USA, which makes copper indium gallium diselenide (CIGS) thin-film photovoltaic panels using the industry's first roll-to-roll solar cell printing factory together with a panel-assembly plant in Luckenwalde, Germany, has announced new efficiency benchmarks of 11.6% for its Nanosolar Utility Panel (its first product, which started shipping in late 2007) and 13.9% for its printed CIGS solar cells, as measured by Germany's Fraunhofer Institute for Solar Energy (ISE) and the US National Renewable Energy Laboratory (NREL).

"Our mission is to produce the most cost-efficient solar power possible," says CEO Geoff Tate. "We are doing this through our printed CIGS technology, innovative panel design and sound manufacturing decisions that lower panel costs in tandem with balance of system costs," he adds.

Nanosolar prints its proprietary CIGS and nanoparticle inks directly onto low-cost aluminum foil, both faster and more cost-effectively than with traditional high-vacuum manufacturing equipment, it is claimed. Leveraging robotic manufacturing practices, the firm assembles the electrically matched, all-back-contact thin-film solar cells into uniform solar panels using its cost-effective metal wrap through process at assembly factories that can be located at the point of panel demand.

Nanosolar says that it will reach an annual manufacturing capacity of 115MW by fall 2011. The firm is currently shipping 10%-efficient, 200W panels in volume, with plans to reach 11% and 12% efficiencies in volume within the next 12 months.

The firm says that a unique design enables the Nanosolar Utility Panel to significantly reduce mounting hardware costs, wiring cable volume, and required installation labor in multi-megawatt installations.

The panel has two pieces of durable, tempered glass (versus one tempered glass sheet for most thin-film panels), uses two edge connectors (as opposed to a standard junction box), and produces more power and operates at a far lower voltage than standard thin-film panels, Nanosolar claims. In addition, it is the first solar panel to be certified by TUV to operate at up to 1500 system volts. These system design features allow for balance of systems cost savings of up to 30% over competing thin-film solar panels in utility-scale power plants, the firm adds.

Nanosolar recently signed a panel warranty insurance policy with Munich Re in preparation for future multi-megawatt installations and panel bankability. The policy covers 2011 factory production and serves as a backstop to the firm's 25-year limited performance panel warranty. "Through our extensive due-diligence process, we were impressed with the quality and controls in the Nanosolar manufacturing process," says Christian Scharrer, head of Green Tech Solutions, Special Enterprise Risks at Munich Re. "We are confident in standing behind the Nanosolar Utility Panel as a credible and bankable technology for low-cost utility-scale solar installations."

As part of its commitment to an effective waste management and recycling policy for the firm and its partners, Nanosolar has joined Brussels-based PV Cycle, the European organization committed to responsibly recycle solar panels. The Nanosolar Utility Panel has one of the industry's lowest CO₂ and toxic emissions lifecycle footprints, and its energy payback time is less than 8 months, claims Nanosolar.

"We will soon announce strategic supply agreements with a number of solar power plant developers and installers that will leverage Nanosolar's ability to drive down the cost of solar power," notes Tate.

www.nanosolar.com

IN BRIEF

XsunX's CIGSolar users gain back-end process equipment & support from MAG

XsunX Inc of Aliso Viejo, CA, USA, which is developing hybrid copper indium gallium (di)selenide (CIGS) thin-film photovoltaic solar cell technologies and manufacturing processes, is teaming with MAG Industrial Automation Systems (MAG IAS LLC), which supplies industrial manufacturing systems, assembly and engineering services, to provide 24/7 global service and parts support for users of its CIGSolar cell manufacturing lines.

XsunX and MAG will also work on specific requirements for the back-end process equipment for those customers requesting a complete turnkey solar module assembly line. The CIGSolar system is designed to deliver the front-end process (to make the solar cells). MAG will now work with XsunX to provide a module assembly line (i.e. back-end process equipment) that can assemble the cells into modules for a complete turnkey factory to produce CIGSolar modules.

"As a technology development company, we need to stay focused on our core competency, that of empowering our customers with breakthrough technology that incorporates the best systems and designs to address product market needs, rapid time to market to stay ahead of the competition, and pricing to make solar affordable for our partners and their clients," says XsunX's president & chief operating officer Joseph Grimes. "Teaming with MAG supports that goal and helps to provide our target customer group with confidence that their systems are backed by a proven installation and support infrastructure."

www.xsunx.com

www.mag-ias.com

1MW Solyndra CIGS project to be installed in Bulgaria

Solyndra LLC of Fremont, CA, USA, which makes cylindrical copper indium gallium diselenide (CIGS) photovoltaic (PV) systems consisting of panels and mounting hardware for large commercial rooftops, and Interservice Uzunovi plc solar division (a project management affiliate of Interservice Uzunovi plc of Sofia, Bulgaria) have signed an engineering, procurement and construction (EPC) agreement for a 1MWp Solyndra installation on the rooftops of logistics firm Biomet Co Ltd of Sevlievo, Bulgaria. Solyndra says that the project highlights the continued adoption of its rooftop solar PV systems in Bulgaria and in South Eastern Europe.

The installation consists of about 6000 Solyndra solar panels, which will produce more than 30,000MWh of electricity. This should reduce

CO₂ emissions by more than 140,000 tons over the next 25 years (equivalent to powering 500 households, according to the EPA carbon calculator). The installation is planned to be connected to the grid by mid 2011.

"Solyndra's proven and bankable technology allowed us to complete the planning process in a very short time," comments Interservice Uzunovi's general manager Ralitzia Uzunova. "We were looking for a solution that was designed to partner with the roof, and Solyndra's performance on flat rooftops, combined with the lightweight, non-penetrating design, proved to be the ideal choice."

"This logistics company rooftop is a perfect application for our product and demonstrates Biomet's commitment to the environment as well as

the strong government support for distributed power in the region," says Clemens Jargon, president of Solyndra International AG, describing the installation as an "important showcase project in Bulgaria".

Interservice Uzunovi PLC solar division was founded by the entrepreneur Krasimir Uzunov at the beginning of 2009 following Bulgaria's commitment to meet the requirements of the EU Directive 2001/77/EU, which promotes electricity produced from renewable energy sources in the country's energy market. Its first PV project (with an installed capacity of 5MWp) is situated in Ravna Gora village, in the municipality of Avren. The plant has been operational since March 2010 and sells electricity to local distributor E.ON.

www.solyndra.com

PSE&G completes installation atop HQ as part of Solar 4 All program

Public Service Electric and Gas Company (PSE&G) has completed a rooftop solar installation at its Central Division Headquarters in Somerset, NJ, USA. The 0.9MW system is one of six large solar systems PSE&G is erecting on company-owned properties as part of its \$515m Solar 4 All program.

"By building these systems on PSE&G-owned property, leveraging our knowledge of the electric system and putting our project management skills to work we have installed a large amount of solar capacity in a very short time and in a very cost effective way with little impact to customers," says Al Matos, PSE&G's VP – Renewables and Energy Solutions.

"Through our Solar 4 All program, we have added over 35MW of solar capacity in the state in a little more than a year," Matos adds. "These projects have helped provide stability to the state's solar market and have made New Jersey a center for renewable energy in the USA," he claims.

Financial benefits of Solar 4 All — federal tax investment credits, sale of the energy and capacity to PJM, and solar environmental credits (SRECs) — are returned to PSE&G electric ratepayers, reducing the cost of the program.

The Central Division Headquarters solar system consists of 648 traditional crystalline solar panels and 4180 Solyndra panels. They cover over 101,000ft² of roof space and are connected directly to the grid for the benefit of all PSE&G electric customers. The system will produce enough power for about 155 average-size homes.

Solyndra is among the leading solar panel manufacturing companies that PSE&G is using to deploy solar systems across the state. Solar energy project developer Solis Partners of Manasquan, NJ is responsible for the design, engineering and deployment of both the white cool roof and solar PV systems.

"This turn-key solar rooftop PV system is an important project for

PSE&G and for New Jersey residents," says Solis Partners' managing director Jamie Hahn. "It exemplifies PSE&G's commitment to transform under-utilized rooftops in New Jersey into clean renewable energy sources while reducing greenhouse gases and creating new jobs," he adds.

State regulators approved the Solar 4 All program in July 2009, requiring the utility to install 80MW of solar power. The first phase involves installing up to 40MW of highly distributed pole-attached smart solar units in neighborhoods on utility poles in PSE&G's electric service territory, which includes the state's six largest cities and about 300 rural and suburban communities. This is the world's largest pole-attached solar installation.

The second phase focuses on 40MW of centralized solar facilities, such as the headquarters system and other sites on PSE&G owned or leased properties connected directly to the grid.

www.pseg.com

DOE awards CNSE CIGS project \$57m Veeco to be key partner to new PVMI facility

The US Department of Energy (DOE) has awarded \$57m to The College of Nanoscale Science and Engineering (CNSE) of the University at Albany — State University of New York (SUNY) as part of its SunShot Advanced PV Manufacturing Partnerships Program. Epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA, which provides web coating systems for manufacturing CIGS (copper indium gallium diselenide) solar cells, says that it is a key partner for CNSE on the project as part of the US Photovoltaic Consortium (PVMC), which is coordinating an industry-driven R&D initiative to accelerate the development, manufacturing and commercialization of next-generation CIGS thin-film PV manufacturing technologies (with the aim of driving down the cost and risk of bringing them to the market).

The DOE's SunShot Initiative aims to reduce the total costs of photovoltaic solar energy systems by about 75% so that CIGS solar is cost competitive with other forms of energy by the end of the decade. Achieving this goal — equivalent to about \$1 per watt (about 6 cents per kilowatt-hour for utility systems) — would allow solar energy systems to be broadly deployed across the USA.

"Driven by the world-class innovation at CNSE, the PVMI CIGS consortium will provide a full-scale CIGS center enabling the whole PV supply chain to work together to deploy new technologies, and enable the transition to commercial production," comments Veeco's CEO John Peeler. "Bringing together end-users, module manufacturers, suppliers and technologists is the most efficient way to rapidly advance technology. This center has all the elements to speed the progress of CIGS commercialization," he adds. "In addition to acknowledging the Department of Energy for this funding and their support of CIGS technology

advancement, Veeco would like to take this opportunity to thank our Congressman, Steve Israel, who has been instrumental in helping get the PVMI project off the ground," Peeler notes.

"Investments in our growing clean technology industry are critical to both our economic recovery and our national security," Israel comments. "This latest Department of Energy funding and support of the CNSE PVMI project will bolster our efforts to compete globally as a clean energy leader," he adds.

"CNSE and SEMATECH [which co-manage PVMC] have a proven model demonstrated in the semiconductor industry," notes David Bruns, senior VP, Veeco Solar.

"By leveraging this model, we are confident the same success can be achieved in solar. The DOE's commitment to CIGS and Veeco has been strong and we are appreciative of their continued support," he adds. Veeco received a \$4.8m DOE R&D grant in February to help speed its development of CIGS equipment technology. Veeco Solar currently has a small-scale pilot production line for CIGS development in the Greater Albany region.

"On behalf of the UAlbany NanoCollege, we applaud the leadership and support of New York's federal delegation, led by Senior Senator Chuck Schumer along with Congressmen Paul Tonko, Chris Gibson and Steve Israel, in helping to secure this investment by the DOE," says CNSE senior VP & CEO Dr Alain E. Kaloyeros. "Building on investments made by New York State and coupled with the pioneering model established by CNSE, this will infuse critical capital to position New York and the US as world leaders in 21st century photovoltaic technologies," he adds. "We look forward to working with Veeco as a key partner in our new PV Manufacturing Center."

www.veeco.com
<http://cnse.albany.edu>

IN BRIEF

Manufacturing expertise from Intel to speed MiaSolé's ramp to 150MW

MiaSolé of Santa Clara, CA, USA, which was founded in 2001 to make copper indium gallium diselenide (CIGS) thin-film photovoltaic panels, has entered into an agreement with Intel's Technical Manufacturing Services practice.

Santa Clara-based Intel will provide customized manufacturing services and systems, strategic consulting, operational knowledge and training to MiaSolé as it ramps its manufacturing facilities in 2011 and 2012.

"The engagement is part of Intel's broader strategy to partner promising high-tech innovation with Intel's world-class manufacturing and Copy Exactly methodology," says Brian Krzanich, senior VP & general manager of Intel's Manufacturing and Supply Chain. "This will enable companies like MiaSolé to scale to high-volume manufacturing cheaper, faster, and better," he adds.

MiaSolé has increased its annualized production capacity to more than 50MW in just over a year, and is on-track to triple capacity to over 150MW by the end of 2011. However, the agreement with Intel — which now has more than 40 years of manufacturing experience — should accelerate the production ramp with the improved repeatability and consistency required for high-volume manufacturing, further reducing the overall cost of solar energy and broadening its worldwide adoption, it is reckoned.

"This contribution will strengthen our goals to achieve manufacturing scale at our California factory this year," comments MiaSolé's CEO Dr Joseph Laia.

www.MiaSole.com

Probing vacuum-deposited copper-zinc-tin-chalcogenide kesterite anneal process

Supplying tin during anneal to block decomposition increases solar cell efficiency.

University of Luxembourg researchers have been studying the feasibility of creating low-cost, manufacturable copper-zinc-tin-chalcogenide kesterite-based solar cells using vacuum processing [Alex Redinger et al, *J. Am. Chem. Soc.*, vol133, p3320, 2011]. The team found that introducing tin (Sn) into the post-deposition annealing box prevented decomposition of copper-zinc-tin sulfide ($\text{Cu}_2\text{ZnSnS}_4$) and selenide ($\text{Cu}_2\text{ZnSnSe}_4$) materials (CZTS(e)). High-temperature annealing is required to control film composition and homogeneity.

Last year, a record efficiency of 9.7% was achieved by an IBM team using a liquid deposition process of such materials. The constituents were dissolved in hydrazine (N_2H_4) solution. The deposition was onto molybdenum-coated glass, followed by a short anneal at 540°C. The IBM process has since been the subject of joint development agreements with Solar Frontier of Japan (www.semiconductor-today.com/news_items/2010/OCT/SOLARFRONTIER_191010.htm) and DelSolar of Taiwan (www.semiconductor-today.com/news_items/2010/SEPT/IBM_280910.htm).

The main attraction of these materials is the use of high-abundance, low-cost elements (Figure 1, e.g. no indium). The resulting semiconductor layers have a tunable bandgap in the range 1–1.5eV that is suitable for creating solar cells.

Although a liquid-based process has its attractions in terms of low production costs, the use of hydrazine solution is a safety concern. Hydrazine is a highly toxic and dangerously unstable compound, particularly when out of water. The instability of hydrazine has been used to make rocket fuels, first with German rocket planes in World War II.

The vacuum process alternative to liquid CZTS(e) deposition has achieved efficiencies up to 6.8%. Normally, one would expect a vacuum process to result in better-quality material (e.g. less defects/dislocations) and hence enhanced solar cell performance. Also, vacuum processes are attractive for depositing a wide range of other materials with high quality.

The researchers explain the failure to deliver better-

quality CZTS(e) cells by saying that the annealing step used to improve the crystal structure after deposition results in loss of tin from the vacuum-deposited CZTS semiconductor material, reducing conversion efficiency.

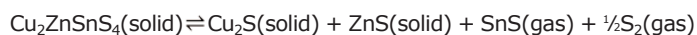
The Luxembourg team produced solar cells annealed in an excess sulfur atmosphere (process A) or in sulfur/tin (process B). The process A annealing atmosphere was created by using sulfur pellets and forming gas (hydrogen/nitrogen). Process B was achieved by also placing 1mg of tin in the graphite annealing box. The 2-hour annealing was carried out at 560°C.

Without tin being present during annealing, the resulting solar cell had a conversion efficiency of 0.02%, and poor short-circuit current and open-circuit voltage characteristics (0.72mA/cm² and 80mV, respectively).

The effect of having tin in the annealing box was to boost efficiency to 5.4%. The short-circuit current and open-circuit voltage were 20mA/cm² and 497mV, respectively. The researchers have previously produced a 3.2%-efficient cell with just sulfur annealing; they therefore believe that the result of process B can be further optimized.

Since the publication of these results, Luxembourg's kesterite solar cells have improved to 6.1% efficiency, certified by Fraunhofer ISE as a European record.

The researchers understood their results in terms of the decomposition reaction:



Although the presence of sulfur in the anneal box might be thought sufficient to block the decomposition reaction to the right-hand side of the equation, the partial pressure needed is high. This is because most of the elemental sulfur in the annealing atmosphere comes in the form of sulfur rings of eight atoms, rather than the S_2 needed. The presence of tin in the box leads to SnS on heating, which is much more effective in blocking decomposition.

The researchers further studied the decomposition process by first electro-depositing copper and zinc onto molybdenum-coated glass. The thickness of the Cu/Zn layers can be used to control the composition of the

final CZTS material.

The team then performed three anneals in sequence in various atmospheres. Between each stage a series of material analyses were carried out (grazing incidence x-ray diffraction, energy- and wavelength-dispersive XRD). The first anneal was in sulfur, the second with a SnS/S atmosphere, and the third in vacuum. All anneals were at 560°C. The duration of the first two anneals was two hours; the final vacuum anneal was six hours.

Analysis (Figure 2) of the first anneal revealed the presence of grains ZnS and Cu₉S₅ (copper-poor Cu₂S). The two materials do not intermix.

The second anneal created CZTS and the Cu_xS signal disappears. Unfortunately it is not possible to separate the ZnS and CZTS signals to say whether there is any remaining material with the former composition. However, the copper, zinc and tin are mixed near the optimum ratios needed for high-performance solar cells.

The researchers comment: "This shows that the incorporation of Sn via SnS does not proceed in a random way but is self-limiting. As long as enough Cu_xS and ZnS is present, SnS and S from the gas phase are incorporated in the film to form CZTS."

Experiments were also carried out where the annealing was carried out with a Se/SnSe₂ atmosphere, which also showed a self-limiting behavior. One must remember here that selenium is not a particularly common element (Figure 1).

The researchers say that their work "can be used to simplify the four-dimensional parameter space (spanned by the four different elements) to an easy and robust two-dimensional process". They

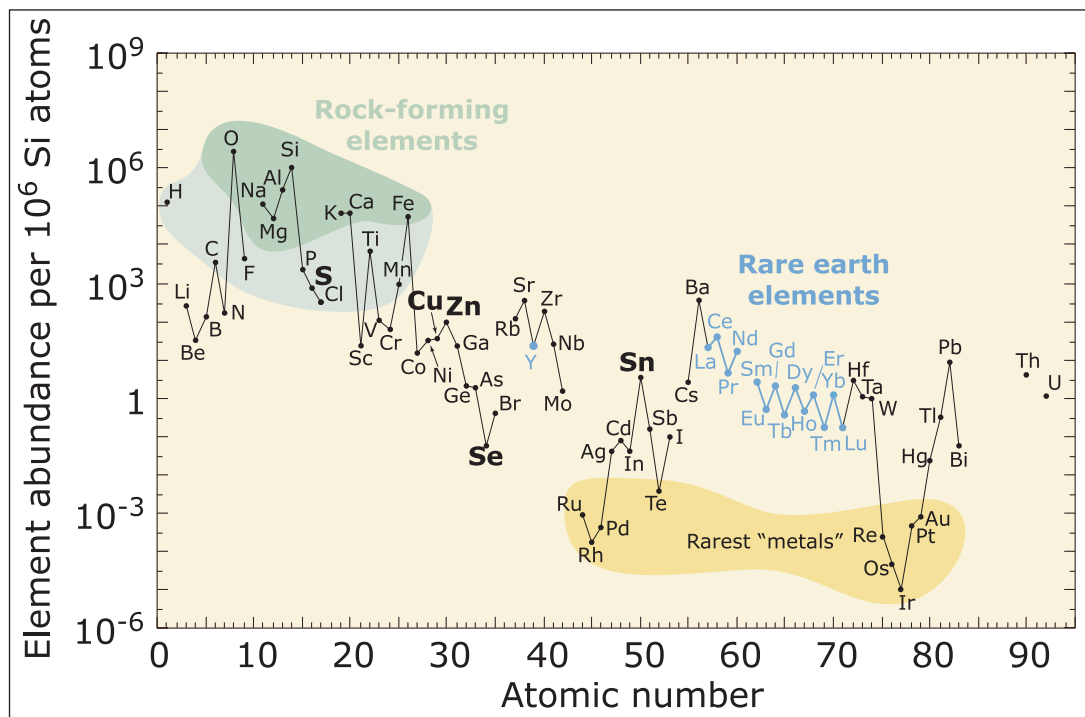


Figure 1. Relative abundance (atom fraction) of the chemical elements in Earth's upper continental crust as a function of atomic number. Of course, deposits exist where the proportions are much different from these averages, making for economic extraction.

From <http://pubs.usgs.gov/fs/2002/fs087-02>.

add that their study of the decomposition reaction "enables us to simplify the precursor to a film containing only Cu and Zn, whereas Sn and S(e) are introduced from the gas phase by a self-regulating process." ■

<http://pubs.acs.org/doi/abs/10.1021/ja111713g>

Author: Mike Cooke

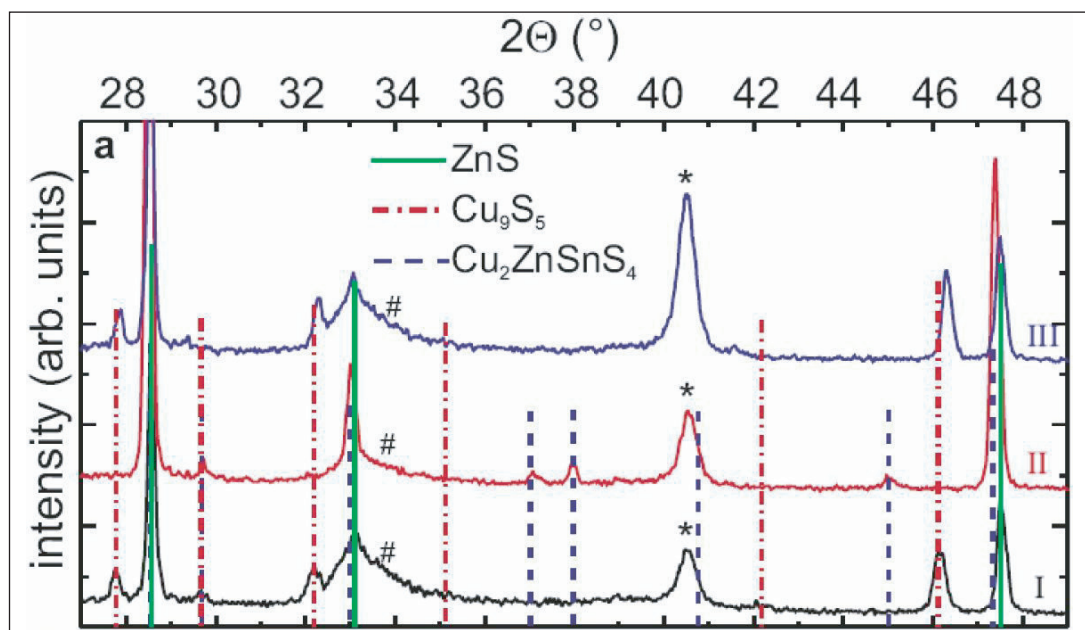


Figure 2. Grazing incidence x-ray diffraction pattern of Luxembourg's annealing experiments, elucidating the equilibrium proposed in equation 1. Scan (I): after annealing of a Cu/Zn stack in sulfur. Scan (II): after annealing of a mixed Cu₉S₅ and ZnS film in sulfur and SnS(g). Scan (III): after annealing CZTS in vacuum. Identified phases include S, Cu₉S₅, Cu₂ZnSnS₄, Mo substrate (*) and MoS₂ (#).

Improving photovoltaic material quality with patterned sapphire

Short-circuit current raised by 26% by growing photovoltaic cells on patterned substrates rather than flat substrates.

Researchers in Taiwan have been using patterned sapphire substrates to improve the performance of nitride semiconductor solar cells [C.C. Yang et al, IEEE Electron Device Letters, published online 24 February 2011]. The team was based at National Cheng Kung University, National Chiao Tung University, and Southern Taiwan University.

While patterned sapphire substrates are mainly used in light-emitting devices to increase light output by reducing the reflection at the air interface, here the patterning is used to improve the material quality of the nitride semiconductor. The improvement comes from reducing the area from which the nitride semiconductor crystal is seeded in a similar manner to that of epitaxial lateral overgrowth (ELOG) techniques. The aim is to reduce the threading dislocations that can act as paths for leakage current, reducing conversion efficiency.

The researchers used flat and patterned sapphire substrates on which layers of nitride semiconductor were deposited using metal-organic chemical vapor deposition (MOCVD). The patterned substrates had truncated cone structures created using photolithography and etch. The cones were put in a triangular array with 1.5 μm spacing between cones (Figure 1). The cones were 1.5 μm high, with top and bottom diameters of 1.0 μm and 3.0 μm , respectively.

The nitride growth began with a thin undoped GaN nucleation low-temperature layer, followed by 4 μm of

u-GaN. The process was controlled to achieve coalescence over the cones and a smooth surface.

The p-i-n structure of the photovoltaic device was begun with 1 μm silicon-doped n⁺-GaIn; continued with a short-period superlattice of 14 pairs of undoped Al_{0.14}Ga_{0.86}N/In_{0.21}Ga_{0.79}N (3nm/4nm); finishing with 0.1 μm of magnesium-doped p-GaN.

Improvement comes from reducing the area from which the nitride semiconductor crystal is seeded in a similar manner to that of epitaxial lateral overgrowth (ELOG) techniques. The aim is to reduce the threading dislocations

Silicon dioxide was applied on top of the whole epilayer sequence as an anti-reflective layer. The PV devices measured 1mm x 1mm with 11.4% electrode coverage.

The performance of the PV cell on patterned substrate (PV-B) was enhanced relative to a device grown on a flat substrate (PV-A): at illumination of global 1.5 air-mass (AM1.5G), the short-circuit current was 26% higher

and the open-circuit voltage was 2% higher (Figure 2). The conversion efficiency of the patterned device was 1.71%, compared with 1.34% for the flat cell. A conversion efficiency of 2.95% for nitride-based PV cells was achieved by Texas Tech University researchers last year (www.semiconductor-today.com/news_items/2010/

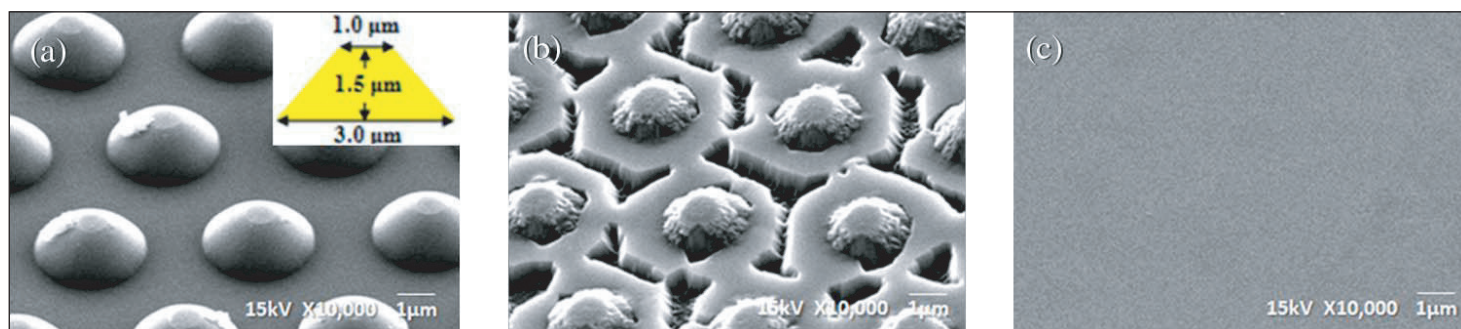


Figure 1. Typical 45°-tilt scanning-electron-microscope images of (a) the surface morphology of truncated-cone patterns on sapphire substrates, (b) u-GaN under 500 torr, and (c) the coalesced quasi-2D growth of u-GaN.

AUG/TEXAS_240810.htm).

Photoluminescence studies on the Taiwan epitaxial material showed a slightly red-shifted peak for the patterned epitaxial material at a 'blue' photon energy of 2.780eV (446nm), compared with 2.793eV (444nm), due to compressive strain in the non-flat material.

The researchers warn: "Although this red-shift could be beneficial for broader solar-spectrum absorption, it should be carefully considered because the excess strain would eventually relax, generating additional threading dislocations to result in leakage paths in the PV devices."

Although this red-shift could be beneficial for broader solar-spectrum absorption, it should be carefully considered because the excess strain would eventually relax, generating additional threading dislocations to result in leakage paths in the PV devices

In the present case, the slightly longer wavelength did make the patterned device more sensitive to the solar spectrum. The researchers estimated that this factor would give the patterned device a 10% current boost over the flat cell. As seen above, the actual figure was 26%, showing that improved material quality must also play a role. ■

<http://dx.doi.org/10.1109/LED.2011.2107725>

Author: Mike Cooke

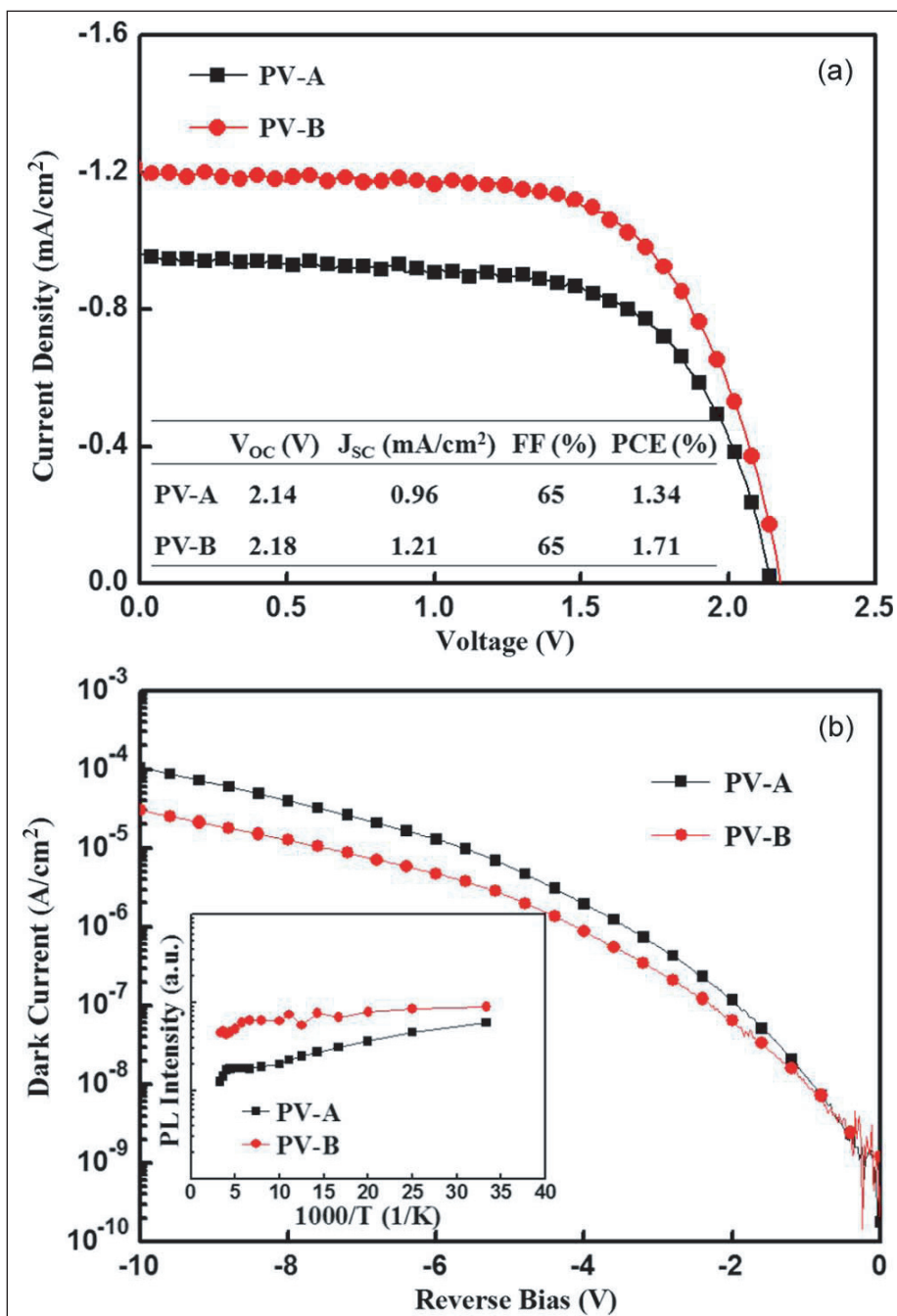


Figure 2. (a) Typical current density vs voltage (J-V) characteristics of devices taken from PV cells illuminated under AM1.5G spectrum. Inset: measured PV parameters. (b) The measured dark current density with the reverse bias. Inset: Arrhenius plots of integrated photoluminescence intensities for PV-A (flat) and PV-B (patterned).

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Self-organized process for nitride LED output boost

Nanotextured p-GaN contact layer boosts output by 46% at 100mA

Researchers at the USA's Rensselaer Polytechnic Institute (RPI) and South Korea's Pohang University of Science and Technology have used a 'self-organized' silver mask to create nanotexturing and boost the output by 46% from a nitride LED at 100mA, compared with a device that has a flat nitride-air interface [Sameer Chhajed et al, Appl. Phys. Lett., vol98, p071102, 2011]. The nanotexturing reduces light reflection back into the device at the p-type gallium nitride (GaN) surface.

A planar GaN surface has a refractive index of 2.5, resulting in 18% normal incidence reflection at an air interface (refractive index 1). Also, the critical angle for total internal reflection is only 23°, restricting light output. In total, a planar GaN-air interface gives the LED an extraction efficiency of about 26%.

Oblique angle deposition of silver on the p-GaN surface created nano-island masking for a short etch process that roughened the surface of the contact layer, improving light extraction. A self-organized process is attractive for reduced complexity and higher throughput.

GaInN LED epitaxial structures (Figure 1) were grown on sapphire substrates using MOCVD. This epi material was used to create 'reference' and 'nanotextured' LEDs after annealing for 1 minute at 800°C to activate the p-GaN layer.

In both cases the epi material had mesa structures defined using lithography and etched down to the n-GaN layer using reactive-ion etch with inductively coupled plasma (ICP-RIE) generated from a chlorine and boron trichloride mix (Cl_2/BCl_3). The mesas were 1mm square. The n-type ohmic contact metal structure was titanium-aluminum-titanium-gold, deposited by electron-beam evaporation. Non-p-contact regions were then masked off by lithography.

Nanotexturing (if any, Figure 2) came before applying the p-contact (10nm semi-transparent palladium).

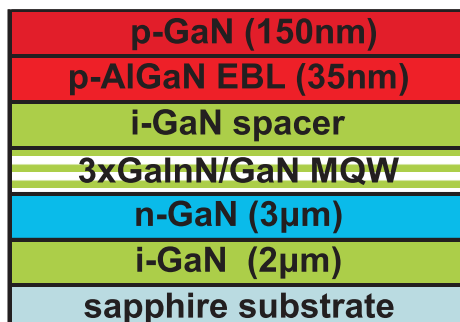


Figure 1. Epitaxial structure of GaInN-based LEDs used by RPI.

The mask for the nanotexture comprised a 5nm silver layer deposited by e-beam evaporation at a 60°

Output power with pulsed drive current (1% duty cycle, pulse width 0.5ms) is enhanced by 46% for the nanotextured LED over the reference at 100mA (Figure 3). The current vs voltage dependence shows that the nanotextured LED has higher series resistance, attributed to contact resistance and current crowding effects. These may result from the reduction in effective contact area by the nanotexturing. Future work aims to mitigate the high resistance.

http://apl.aip.org/resource/1/applab/v98/i7/p071102_s1

Author: Mike Cooke

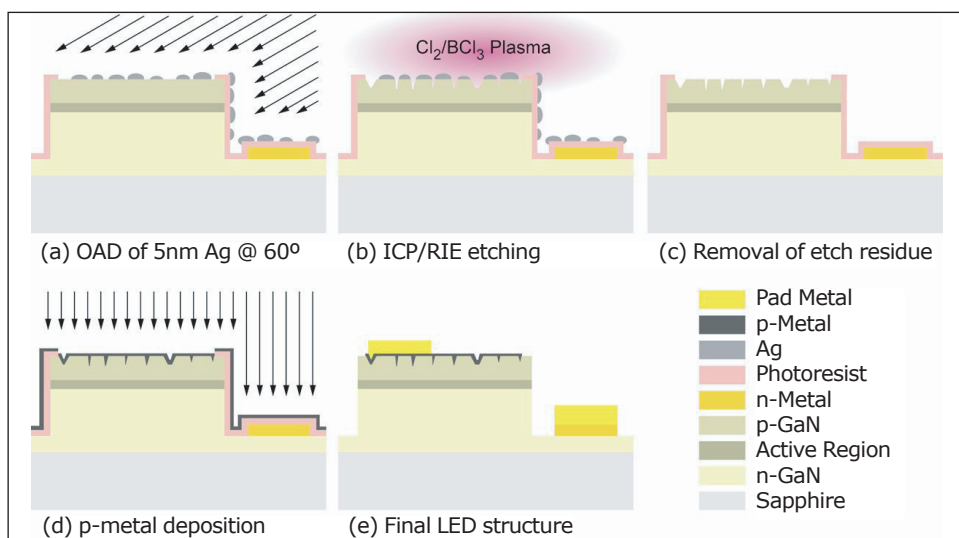


Figure 2. Fabrication process for nanotextured p-type GaN mesa of GaInN LED.

oblique angle, which creates 'self-organized' islands of silver on the surface of the p-contact (and also the litho-mask). The p-contact surface was then exposed for 15s to Cl_2/BCl_3 ICP-RIE. The silver mask was removed using a 70% nitric acid solution. The method does not involve deposition of sacrificial layers or high-temperature annealing, which could damage previous work.

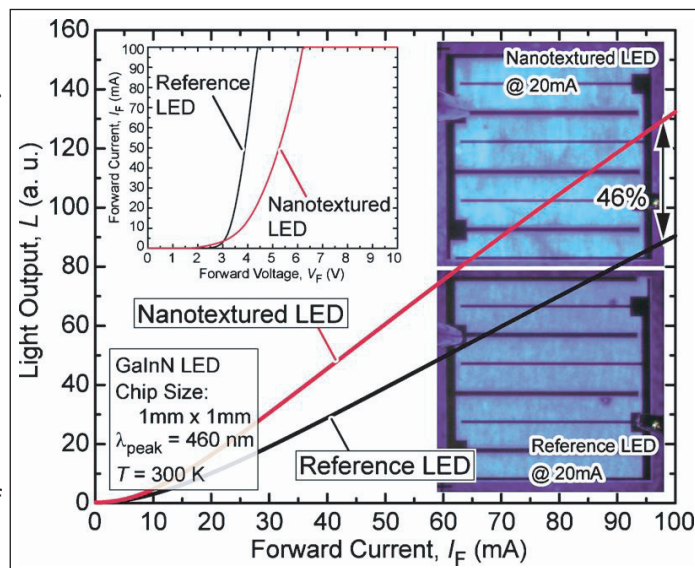


Figure 3. Output power vs forward current of reference and nanotextured LEDs. Inset: forward current vs voltage. Background: illuminated LEDs at 20mA.

UV LED market to grow at 30% to over \$115m in 2016

UVA LEDs still dominate due to UV curing boom

Due to their compactness, lower cost of ownership and environmentally friendly composition, UV LEDs have started and will continue to replace traditional mercury lamps in current applications, and will also open up many new applications (especially portable ones), according to market research firm Yole Développement in its new 'UV LED report', which provides an analysis of the UV LED industry along with major market metrics of the current traditional UV lamp business. The UV LED market is hence expected to increase at an annual growth rate of almost 30% from \$25m to more than \$100m in 2016.

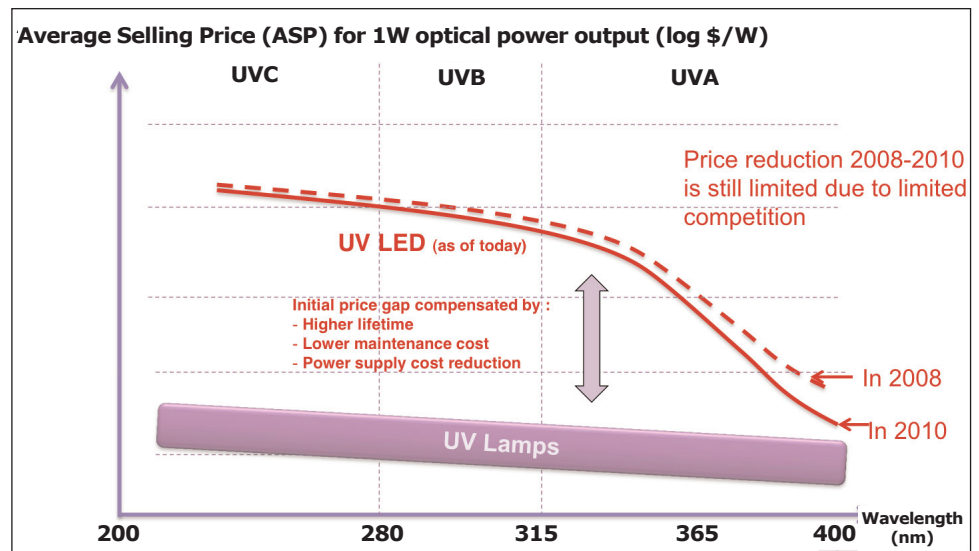
In 2010, most UV LEDs that were sold continued to be those emitting at UVA/B wavelengths (especially in the upper wavelength range of 365–400nm). More than 90% of the UV LED market (outside of R&D) consisted of UV curing, counterfeit detection, medical and instrumentation applications, requiring UV A/B sources. In contrast, UVC LEDs are currently mainly sold for R&D and scientific instrumentation purpose.

UVA (400–315nm light wavelength) business is currently the main UV LED market and will remain so for at least the next 5 years, forecasts Yole, comprising about 90% of the market in 2010 and about 85% in 2016.

Key applications for UVA lamps are UV curing, document/banknote verification, and photocatalyst air purifiers. Of these, the most dynamic and important is clearly UV curing, where UV LEDs can certainly compete with traditional mercury lamps.

Firstly, the market is large (\$120m) and growing at about 10% annually due to the advantages for UV curing technology over traditional technology (speed, green coating).

Secondly, over the past five years many new players have emerged throughout the value chain. Among traditional mercury lamps suppliers, Heraeus Noble light launched a UV LED product line in 2010. Of pure



ASP for UV lamps and current LED commercial products in \$/W.

UV-LED curing system players, Phoseon leads the UV curing market. Meanwhile, traditional UV curing system market leaders (including IST Metz, Hoenle, and Nordson Baldwin) have also adopted UV LEDs.

Finally, between 2009 and 2011 the available power output has doubled to 16W/cm², and the emission source width is now up to 2m, which is comparable to the performance of mercury lamps.

"This booming market attracts well known visible spectrum LED manufacturers from Taiwan and China, who see that UV LEDs have added-value complementary products: SemiLEDs has greatly increased its sales, Tekcore has introduced its first products and Huga is developing UV LEDs," says Dr Philippe Roussel, senior project manager at Yole. "This will help to reduce significantly the cost of the products," he adds.

Potential high-volume applications for UVC LEDs are water and air purification. Yole had assumed that these markets would start up in 2010, but no new commercial UVC LEDs have been released in the last two years. However, numerous research results have been published during this period that show impressive improvements in optical power output: up to 30-fold compared to 2008. Yole hence expects

that, after having solved the efficiency, lifetime and cost challenges, the UVC LED will arrive in 2014 for those key applications.

A key enabling substrate for UVC LEDs is single-crystal aluminum nitride. The first results for AlN-based UVC LEDs were released by Crystal IS Inc of Green Island, NY, USA in 2010, and these show that AlN will improve the lifetime of the devices. This substrate dynamic is confirmed by the arrival of new players such as Nitride Solutions of Wichita, KS, USA and CrystAl-N of Erlangen, Germany, concludes Yole. Several players expect to provide AlN 2" wafers in volume in 2012–2014, so the time to market for UVC applications based on AlN is probably 2013–2015.

Yole also sees a strong trend where AlN suppliers are now extending their activities to UV-LEDs to capture more added-value along the supply chain, e.g. HexaTech, Acerde and Crystal IS.

New entrants into the UV-LED chip-making sector in 2009–2010 also include (for UVA-LED die) Japan's Dowa, Taiwan's Tekcore and China's Huga and (for UVC-LED die) Dowa, Japan's Nichia (which was previously focused on UVA-LEDs) and Crystal IS (via partners Sanan in China and Asahi Kasei in Japan).

www.i-micronews.com/reports/UV-LED/198

Lateral conduction, substrate-free deep UV nitride semiconductor LEDs

South Carolina demonstrates first lateral-conduction substrate-free flip-chip 276nm LEDs grown on thick-AlN/sapphire templates.

Nitek Inc of Irmo, SC, USA and University of South Carolina (USC)

have reported the first successful fabrication and characterization of lateral conduction, substrate-free aluminum gallium nitride (AlGaN) deep ultraviolet (DUV) LEDs grown on thick-AlN/sapphire templates [Seongmo Hwang et al, Appl. Phys. Express, vol4, p032102, 2011].

LEDs emitting in the deep ultraviolet (DUV, wavelengths <300nm) are being widely developed for air/water/surface/food purification/sterilization. Short wavelengths disrupt DNA molecules, killing microbiological organisms. Other possible applications include biomedical instrument- tion and polymer curing.

Researchers are seeking to replace fragile, poisonous mercury lamps with a robust, safe alternative. Presently, the wall-plug efficiencies of DUV LEDs are at best about 2%, and operating lifetimes are only 1000hr at 20mA pump current. Being a first demonstration of a new technique, the Nitek/USC device falls short of the wall-plug efficiency of the best devices by an order of magnitude. Operation lifetime is not reported.

The Nitek/USC researchers began with grooved (0001) sapphire substrates on which an AlN layer was grown using metal-organic chemical vapor deposition (MOCVD). The AlN layer was deposited using maskless pulsed-lateral overgrowth (PLOG) to reduce threading dislocation densities (particularly in the 'wings'). Another effect of the PLOG material was reduced thermal impedance. Apart from improved material quality

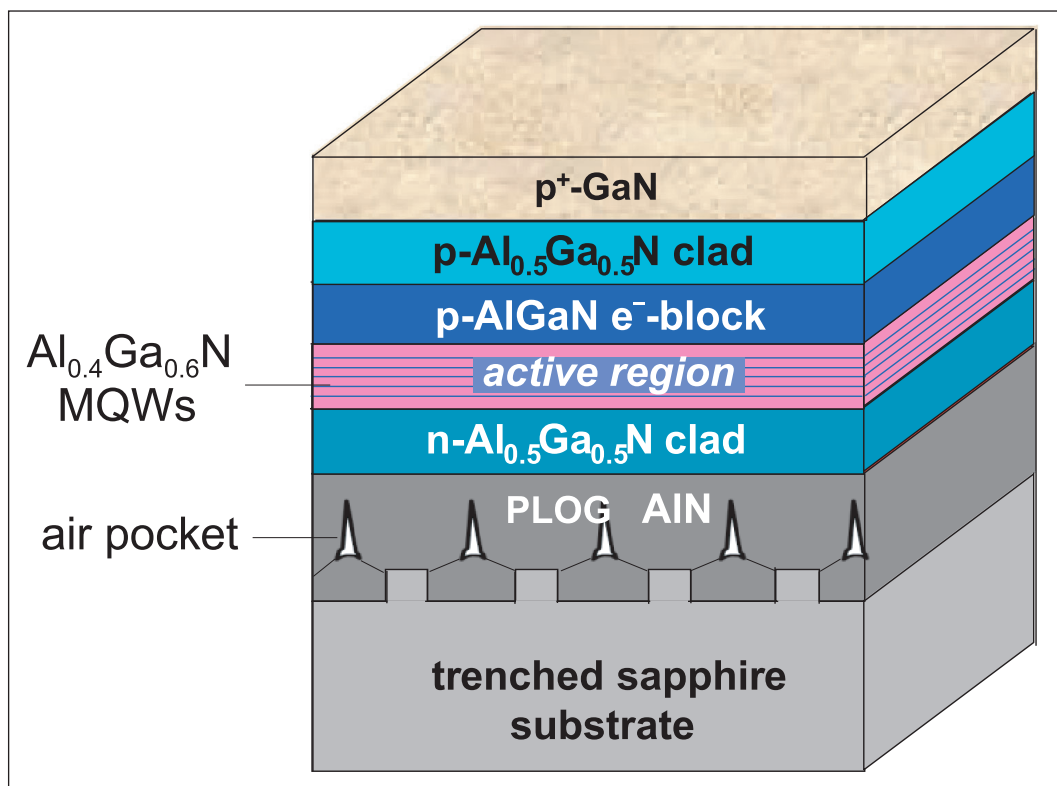


Figure 1. Schematic of epitaxial structure of Nitek/USC 276nm LED.

in the subsequent epitaxial layers, the reduction in dislocations and thermal impedance also determine long-term lifetime reliability of devices. X-ray diffraction analysis gave the (102) ω -scan rocking curve a full-width at half maximum (FWHM) of 377arcsec.

The epitaxial layers were grown using a combination of pulsed atomic layer epitaxy and low-pressure MOCVD. The LEDs (Figure 1) consisted of an active region with $\text{Al}_{0.4}\text{Ga}_{0.6}\text{N}$ multi-quantum wells with $\text{Al}_{0.6}\text{Ga}_{0.4}\text{N}$ barriers. The cladding layers consisted of $\text{Al}_{0.5}\text{Ga}_{0.5}\text{N}$.

An electron-blocking layer of p-AlGaN was included to reduce overshoot and recombination in the p-type GaN layer. Unfortunately there is no good way to produce thick p-AlGaN with high hole densities, so p-GaN is used for the p-contact. However, the p-GaN layer

tends to absorb ultraviolet light. This is the main reason that flip-chip mounting is used for UV LEDs where the chip is turned over and the last-grown p-GaN layer is bonded to the submount.

The resulting epitaxial structure was formed into 100 μm square shaped mesas using lithography and reactive-ion chlorine etching through to the n-type AlGaIn layer. The n-contact consisted of ohmic titanium-aluminum-nickel-gold layers. These metals were then annealed at 950 $^{\circ}\text{C}$. The nickel-gold p-contact was annealed at 550 $^{\circ}\text{C}$.

A lateral-conduction scheme is used with the contact pads on the same side of the LED chip. Although lateral conduction has disadvantages in terms of current bunching effects, it has the advantage of clearing the emission surface of contact pad obstructions, as needed for vertical conduction (contact pads on top and bottom of chip).

The LEDs were diced into 2x2 arrays and flipped on silicon carbide submounts and bonded with gold-tin solder bumps. The sapphire was removed by separation and lift-off using high-energy excimer laser pulses directed through the substrate. Electrical measurements before and after the lift-off showed no noticeable change in behavior. This means that the potential for damage of the laser process had been avoided. The resulting substrate-free flip-chip LED array was then bonded into a transistor outline package header (TO-39).

The turn-on voltage of the device was 6V. Unfortunately, the resistances of the device were higher than expected: the series resistance was about 90 Ω , and both contact resistances were more than one order of magnitude higher than the researchers' typical values. The group comments: "These results are indicative of the need to systematically optimize the doping parameters for LED structures grown on PLOG-AIN templates."

In terms of emission spectrum, there was a main wavelength of 276nm (full-width half-maximum 12.4nm), along with a broader parasitic radiation band around 410nm (violet, photon energy $\sim 3.02\text{eV}$). The main peak was around 250x higher than that of the broad parasitic emission.

The researchers also believe that dramatic increases in output power would result from "eliminating the light scattering mechanisms together with the implementation of backside roughening and the collection of waveguided light"

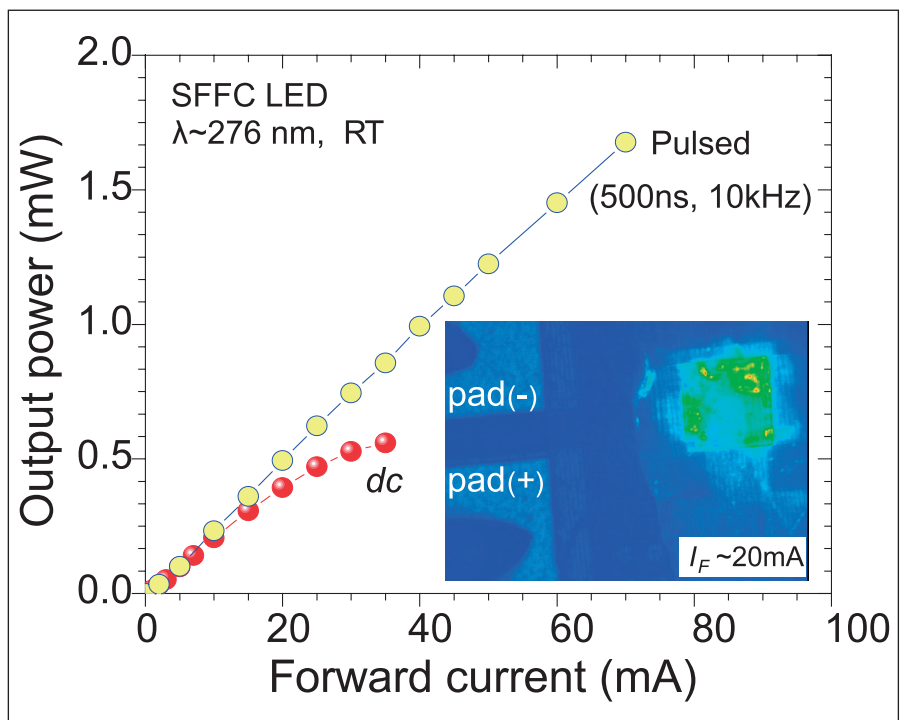


Figure 2. Light output power vs pump current (L-I) characteristics of a 100 μm x 100 μm substrate-free flip-chip single LED measured under direct current and pulsed operation. Inset: plan-view CCD image of LED biased at 20mA forward current.

Light output power (Figure 2) of one 100 μm square devices was measured in both pulsed (0.5% duty cycle) and direct current operation using an integrating sphere and calibrated silicon detector. In direct current mode, the output power was limited to less than 0.6mW (reached at 30mA current, 0.4mW @ 20mA, a quick calculation from graphs in the paper give a wall-plug efficiency of about 0.4mW/20mA/8V = 0.25%).

Pulsed operation, avoiding self-heating effects, enabled an output power of 1.7mW at 70mA. The self-heating seen in direct-current mode was particularly strong due to the high-resistance problem mentioned above. This would also impact wall-plug efficiency.

The researchers report that some improvement has been seen in light extraction through thinning the exposed surface of the LEDs. They attribute the improvement to the reduction of light scattering from the air pockets of the PLOG AIN process. The researchers also believe that dramatic increases in output power would result from "eliminating the light scattering mechanisms together with the implementation of backside roughening and the collection of waveguided light". Such techniques have been successful in enhancing the performance of visible LEDs (e.g. a 50% boost from surface texturing). The 'waveguided light' effect refers to light transmitted along the planes of the epilayers and emitted at the edge of the device. ■

<http://apex.jsap.jp/link?APEX/4/032102>

Author: Mike Cooke

Liquid phase pushes deep UV LEDs to higher efficiency

Boston University develops MBE process for 273nm LEDs using material with high internal quantum efficiency of 32%.

Boston University has produced deep ultraviolet light-emitting diodes from epitaxial nitride semiconductor material that demonstrates a high internal quantum efficiency (IQE) of 32% under photoluminescence (at 300nm wavelength) at room temperature [Yitao Liao et al, Appl. Phys. Lett., vol98, p081110, 2011].

The Boston research group has previously developed aluminum gallium nitride ($\text{Al}_{0.7}\text{Ga}_{0.3}\text{N}$) epitaxial quantum well (QW) structures with AlN barriers that emitted at 220nm and 250nm in very low-temperature (11K)

photoluminescence experiments with IQEs of 5% and 50%, respectively [A. Bhattacharyya et al, Appl. Phys. Lett., vol94, p181907, 2009]. The difference between the two IQEs was explained as being due to the lower III/V ratio (~ 1) for the 220nm material growth, as opposed to the 250nm ($\gg 1$, achieved through higher Ga flux), despite the fact that the compositions of the wells should have been the same ($\text{Al}_{0.7}\text{Ga}_{0.3}\text{N}$). At that time (May 2009), the researchers did not produce LEDs but, since high IQE has now been achieved at room temperature, device demonstrators become feasible.

The researchers believe that their plasma-assisted molecular beam epitaxy (PAMBE) growth with high Ga-flux converts the deposition process from being vapor phase epitaxy (VPE) to liquid phase epitaxy (LPE), with the Ga atoms forming a thin liquid layer on the surface of the growing crystal. The Boston group believes that one effect of LPE is to create AlGa_N layers with lateral compositional inhomogeneities and thus deep band-structure potential fluctuations.

Professor Theodore D. Moustakas, leader of the Boston group, comments: "As a result, the injected electron-hole pairs form excitons localized in these

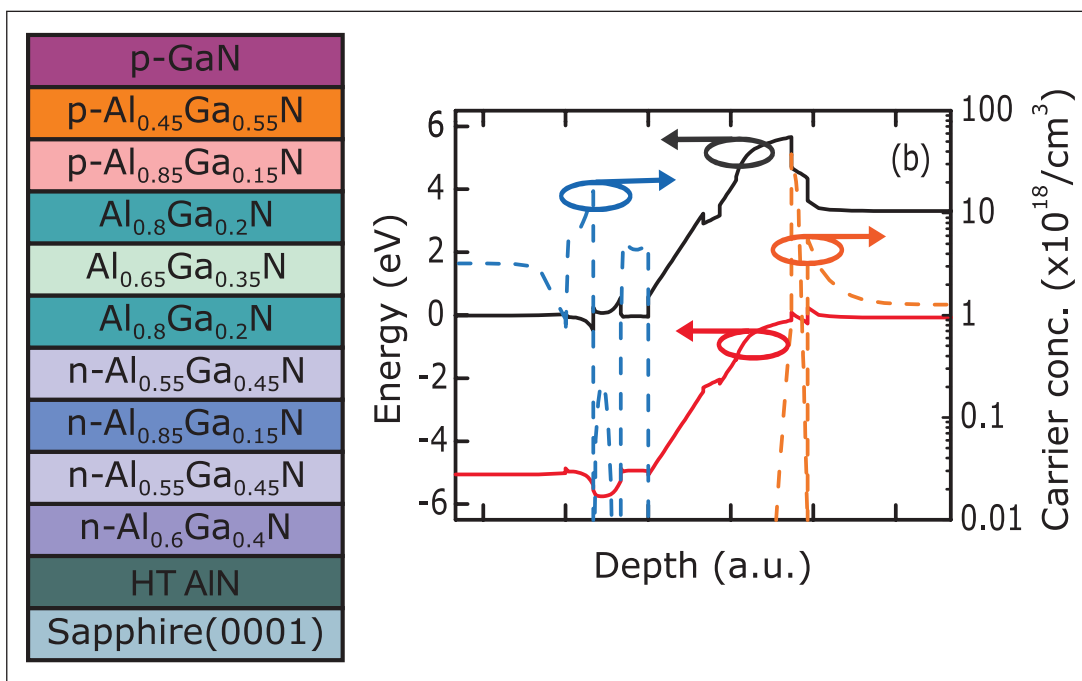


Figure 1. Schematic of the investigated deep UV LED structure (left), with thermal equilibrium band diagram and carrier densities of the structure (right).

potential fluctuations, which prevents them from migrating and recombining non-radiatively at point or line defects. Such phenomena occur automatically in indium gallium nitride (InGa_N) QWs because of the tendency for phase separation due to the 11% difference in the size of In and Ga ions. On the other hand such phase separation is not expected in AlGa_N since the Al and Ga atoms have near identical ionic radius."

Moustakas adds: "A further advantage of our LPE growth mode is that it prevents the incorporation of oxygen, which is always present in the process gases as a major impurity, and introduces states in the middle of the gap in high-Al% AlGa_N alloys. This is to be contrasted with InGa_N alloys in which oxygen introduces shallow states which act as donors."

According to Moustakas, MBE is also much simpler and potentially more economical than the traditional metal-organic chemical vapor deposition (MOCVD) process, which is traditionally used for the growth of this family of materials and devices.

The active region of material used in the latest research consisted of a 3nm single quantum well

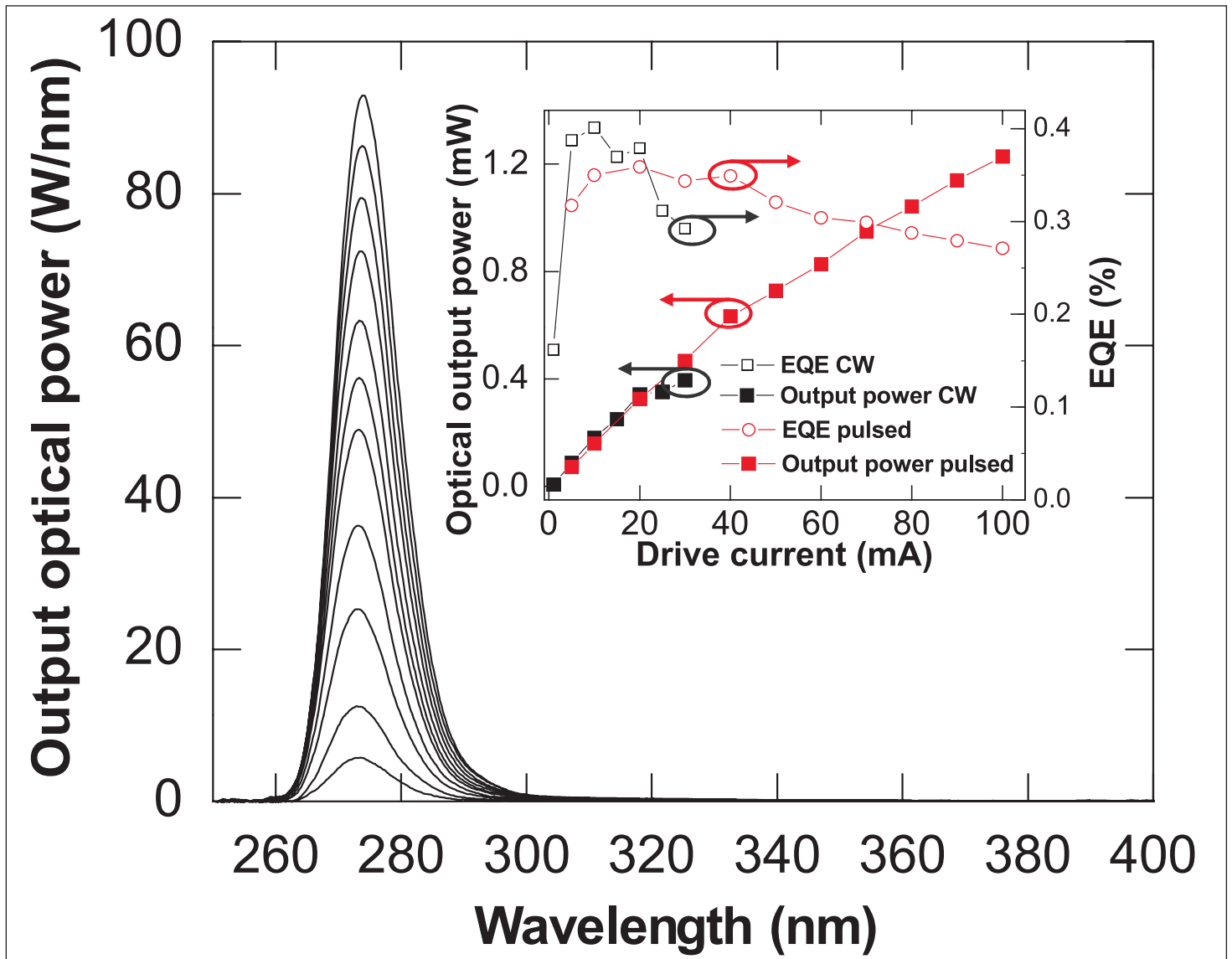


Figure 2. Electroluminescence (EL) spectra of 273nm UV LED measured under pulsed mode. Inset: integrated output power and the EQE under cw and pulsed injection.

between asymmetric barriers (Figure 1). The barrier on the n-side was 10nm and that on the p-side 5nm. The purpose of this was to balance the numbers of holes and electrons in the well, since holes find it harder than electrons to diffuse over barriers.

A complex n-side sequence was designed to avoid nucleation and propagation of cracks through subsequent layers, and to improve electron injection into the well. The initial AlN layer was 2 μ m thick. The n-Al_{0.6}Ga_{0.4}N layer had a doping profile that increased in three steps from the mid 10¹⁷/cm³ range to a final layer that was doped to give a free-electron concentration of more than 10¹⁹/cm³, for a good n-contact. The polarization profile of the uniformly doped n-type AlGaIn layer sequence with 55%, 85% and 55% Al was designed to boost electron injection. A similarly enhanced injection of holes was expected from inserting 45% Al-content p-AlGaIn between the p-GaN contact and the p-Al_{0.85}Ga_{0.15}N electron-blocking layer.

The epitaxial material was processed into 300 μ m

square DUV LEDs using standard processes (lithography, etch). The chip was flip-chip bonded onto a silicon submount. The emission consisted of a single peak at 273nm (Figure 2). The full-width at half-maximum (FWHM) was 9nm. Under continuous-wave (cw) operation, optical output power saturated at 0.38mW with 25mA drive current, due to self-heating effects. Pulsed operation allowed the output power to increase to 1.3mW at 100mA. The maximum external quantum efficiency was 0.4%.

Moustakas draws the conclusion from his group's work that AlGaIn QWs can be made to have the same IQE as that of InGaIn QWs and that therefore the poor external quantum efficiency (EQE) of current-generation LEDs is the result of poor injection and/or extraction efficiencies.

Some of the funding for the work was derived through a Boston University-US Army Research Laboratory (ARL) research co-operation agreement. ■

<http://link.aip.org/link/doi/10.1063/1.3559842>

Author: Mike Cooke

NanoLEDs, a new breakthrough for the LED industry

Xavier Hugon and Philippe Gilet of HelioDEL and Patrick Mottier of Leti explain how nanowire-based LEDs can improve LED efficiency and cost reduction for solid-state lighting applications.

With close to 20% of worldwide electricity consumption currently devoted to lighting, switching to high-efficiency light sources presents a major opportunity to reduce the production of harmful greenhouse gases.

Long-term electricity consumption models show that the widespread use of LED light sources capable of producing up to 200 lumens per watt (lm/W), could decrease worldwide electricity consumption for lighting by more than 50%, and total electricity consumption by more than 10% (see 'Solid-state lighting: lamps, chips, and materials for tomorrow', Jeff Y. Tsao, IEEE Circuits & Devices Vol 20 No 3 (May/June 2004) pp28–37).

However, a dramatic improvement is needed for LED-based light sources to reach this level of performance.

Significant cost reductions also are needed to facilitate the widespread use of LED light sources. Packaged white LEDs that now cost more than \$10 per 1000 lumens (klm) must be lowered to \$1/klm. Concurrently, the so-called 'efficiency droop' — a tendency for LEDs' energy efficiency to fall at high drive currents — has to be eliminated if the industry is to achieve its goal of producing LED packages that can sustain 200lm/W in operation.

This seems to be difficult to achieve with conventional gallium nitride (GaN) LEDs, mainly because of the lack of high-quality, high-diameter and low-price bulk GaN substrates. Instead, many manufacturers are relying on GaN epitaxial layers grown onto sapphire substrates. However, due to the physical mismatch between sapphire and GaN crystals, the GaN layers are inherently stressed, which induces dislocations into the epitaxial layers and decreases LED efficiency and lifetime, as well as manufacturing yields.

For similar reasons, large-diameter sapphire substrates also have been difficult to industrialize. Moreover, sapphire substrates' poor thermal properties require them to be removed before LEDs are assembled and packaged. It should be possible to re-use these larger,

more expensive sapphire substrates after LED assembly. However, the substrate recovery process is complex and, at least thus far, suffers from low yield. That, in turn, reduces the cost advantage of processing more LED dies at a time.

All these reasons combine to slow the industry's efforts to reduce LED manufacturing costs.

Looking ahead, the task of combining high efficiency and large injection current density also remains challenging, and will pose a further obstacle to the widespread use of LEDs in general lighting.

Those difficulties generate other system-level drawbacks, since the most-likely cost-reduction route is focused on increasing LED brightness enough to allow the use of fewer square mm of material to produce the necessary lumens. As a consequence, thermal extraction and management have become major issues, and are contributing to increased lamp costs. Moreover, from a usage point of view, LEDs' extreme brightness can become so dazzling so that it requires additional optics to diffuse that brightness at the lamp level.

A disruptive technology

To overcome these limitations, the French research institute Leti is developing a disruptive new technology called nanowire-based LEDs (NW-LEDs), or nanoLEDs. Nanowires are thin crystalline structures that emit a broader spectrum of light than conventional LEDs when electrically charged, and can be grown on industry-standard silicon substrates.

Leti has successfully demonstrated the operation of a first NW-LED, as well as the ability to grow nanowires on silicon substrates using metal-organic vapor phase epitaxy.

Each of these nanowires acts as a nanoLED with an axial symmetry (Figure 1). Starting from its axis, this so-called core-shell nanoLED heterostructure consists of a GaN core surrounded by indium gallium nitride (InGaN)/GaN radial quantum wells, covered by a GaN shell. ►

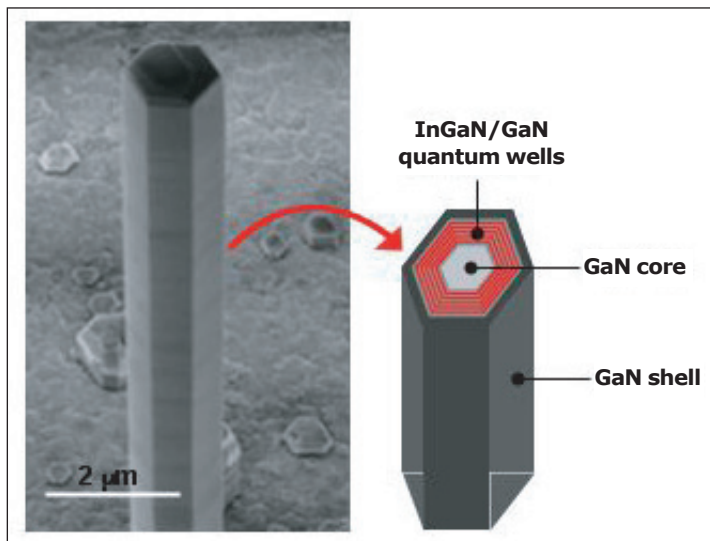


Figure 1. Schematic view of a cross-section of one of Leti's nanowire structures (right), as shown in the SEM image on the left.

► After processing substrates to create an extremely high number of nanowire structures (Figure 2), Leti researchers diced the wafers into devices measuring a few mm², which were then characterized. The devices presented macroscopic electroluminescence coming from multiple quantum wells, with the emitted light centered in the blue spectral range (425nm) and clearly visible with the naked eye.

Single-wire emission measurements led researchers to expect several tens of optical watts emission per cm², an output level that already is comparable to conventional LED levels. As will be explained later, the route toward fulfilling general lighting needs could be achieved without increasing brightness. Nonetheless, no physical limitation has yet been identified that would prevent an increase in NW-LED performance above the level of current high-brightness LEDs. As far as we know, this is the first time that such impressive electroluminescence results have been reported.

In summary, these nanowire structures appear to overcome all of the previously mentioned limitations encountered with conventional LEDs.

Substrate cost and size

Due to their small footprint, nanowires can be grown on a wide variety of substrates. GaN nanocrystals, for example, can easily be grown on 8-inch silicon wafers, opening the door to actual mass production, which is a prerequisite if solid-state lighting is to become the world's dominant lighting technology.

In addition, nanowires' high crystalline quality is largely independent from mismatch between materials. Indeed, the strain induced by the lattice mismatch and differences of thermal expansion coefficients between nanowire material and substrate is localized at the base of the nanowires, and thus able to avoid cracks

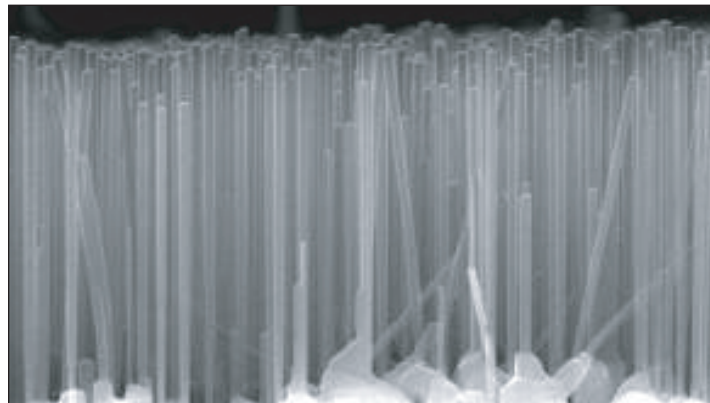


Figure 2. High-density nanowires grown on Si wafer.

and wafer bowing — a major concern for conventional LEDs. As a consequence, the wafer size possibilities for NW-LED manufacturing are only limited by the handling capability of the epitaxial tool used.

New epitaxial technologies could even allow manufacturers to consider using non-silicon, non-monocrystalline substrates, which could potentially be produced using large-volume, roll-to-roll technology, as is already being done with some photovoltaic products.

A simpler process flow

In addition to their wide substrate compatibility, the three-dimensional structures of these new-generation nanoLEDs should allow manufacturers to avoid several process steps that are normally required to produce conventional LEDs. Light extraction from high-index GaN layers, for example, requires additional substrate or LED nanostructuring that comes naturally with NW-LEDs. As a result, NW-LED production is expected to require at least 30% fewer process steps, reducing tool investment as well as processing time and cost.

Solving the efficiency droop issue

The efficiency of GaN-based LEDs decreases when current density increases, resulting in the phenomenon known as efficiency droop. At high current densities, let's say 100 amps per square-centimeter (A/cm²), conventional LED efficiency decreases by as much as 30–40% compared with the maximum value obtained at low current density (say 35A/cm²). Specialists don't fully agree on the physical cause of this phenomenon, although the Auger effect is often mentioned as a probable cause.

However, experimental results show that increasing the active area thickness tends to decrease the efficiency droop. Again, due to the large free surfaces of nanowire LEDs, it should be possible to elastically relax the strain in the quantum well and then increase their thickness, which in turn should decrease the efficiency droop. Moreover, thanks to the much larger emitting area than actual die size in the NW-LED core-shell structure, effective current density through the active

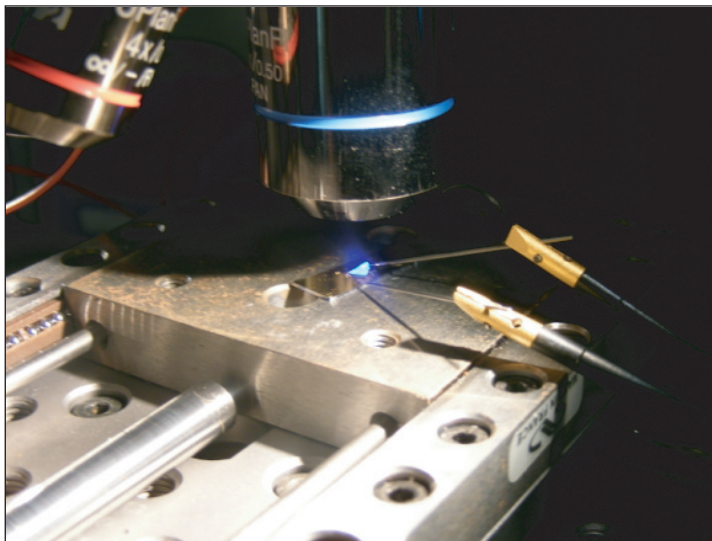


Figure 3. A nanowire LED in operation.

zone is lowered, allowing LEDs to operate in their highest efficiency domain, which should further contribute to reducing the efficiency droop effect.

The green gap issue

For LEDs to emit green light, their indium content must be increased above 20%. However, such a concentration provokes indium clustering or phase separation. In addition, high indium concentration is usually thermally unstable and tends to degrade during the end of the growth cycle. Furthermore, increasing the indium content in InGaN alloy increases its lattice parameter mismatch with GaN, resulting in internal mechanical strain. The strong piezoelectric field induced at the interface between the InGaN quantum wells and the GaN barrier along the c-axis promotes a separation between electrons and holes, decreasing the recombination rate. And that significantly affects the quantum efficiency. Consequently, green LEDs have typically been limited, up to now, to half the quantum efficiency level of blue LEDs. This is the so-called 'green gap' issue.

In nanoLEDs, however, elastic strain relaxation at their free surfaces prevents the quantum well from degrading when the indium content is increased. Furthermore, in the NW-LED core-shell geometry, heterostructures are now grown along m-planes, which are non polar and are therefore free of piezoelectric effects. So, even though it has not been demonstrated yet, core-shell nanowire-based LED technology could offer a way to overcome the green gap issue.

Cost reduction

Besides their substrate quality and size advantages, various other factors are expected to help lower the overall cost of light produced by NW-LEDs. First, because of their three-dimensional structure, the effective light-emitting surface available from a given

chip area is significantly larger than that of conventional LEDs. And because manufacturing costs are directly related to the area of chip surface used, NW-LEDs' higher light quantity per chip should contribute directly to lower costs. Second, while current LED technologies require expensive sapphire substrates, the silicon wafers used to fabricate NW-LEDs are much cheaper, especially when used in large diameters. Silicon also is an excellent electrical and thermal conductor, and easier to dice or to remove for re-use. Thus, assembly and packaging costs should be reduced as well.

Novel LED lighting paradigm

Thanks to the great cost-reduction potential shown by NW-LEDs, the high-brightness approach may not be the only route available to the production of more efficient light sources. Depending on the actual cost per cm^2 of die that can be achieved, lower brightness, larger source size and even higher lumen/watt devices may be possible within an acceptable price range for mass-market lighting buyers. That's especially the case when NW-LEDs' drastically reduced thermal management costs are taken into account, as well the decreased need for optics at the lamp level to avoid dazzling users. For many domestic applications, NW-LEDs may be an ideal answer.

Conclusion

The promising results reported here open the way to the development of a new breakthrough in lighting. Indeed, even after the initial LED breakthrough that occurred at the beginning of the century with the emergence of high-brightness white LEDs, and the amazing improvement in performance since then, the general lighting market is still not widely open to LEDs.

NW-LEDs have the potential to greatly extend the performance limits of solid-state lighting. Moreover, the added potential for lower costs will almost certainly help this new technology to make significant market inroads. NW-LEDs are the only credible technology demonstrating sufficient performance at present, as well as the potential for dramatic further improvement needed to meet future market demands.

The implementation of this remarkable technological breakthrough promises to accelerate the process of cost reduction, and to improve LED energy efficiency. ■

Authors:

Xavier Hugon and Philippe Gilet (CEO and CTO of HeliODEL) and Patrick Mottier (Solid State Lighting Business Development at CEA-Leti).

Leti (www.leti.fr) is an applied R&D institute of the French Atomic Energy Commission (www.cea.fr), focused on micro- and nano-technology and located on the MINATEC campus (www.minatec.com), in Grenoble, France.

Hugon and Gilet left Leti to form the start-up HeliODEL.

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LED fab equipment spending triples in 2010, driven by China

Fab capacity expansion of 50% to drive 40% equipment spending growth in 2011, according to SEMI's Industry Research and Statistics group.

With the wide adoption of LED technology in LCD backlight applications, the LED industry has now advanced into the growth stage of its life cycle, reckons global industry association Semiconductor Equipment and Materials International (SEMI) in its quarterly 'Opto/LED Fab Forecast', which tracks more than 250 opto/LED fabs activities worldwide (with detail information on fab construction and equipment spending, key milestone dates, capacity and ramp-up schedule). To better serve the soaring demand, the industry has attracted a huge amount of capital pouring into the LED supply chain, from equipment and materials to epitaxy/chip fabrication and packaging capacity.

Last year, SEMI recorded three-fold growth in equipment spending for LED fabs, from \$606m in 2009 to \$1.78bn in 2010. It expects this spree to continue this year, growing 40% to \$2.5bn. However, if some of the projects do not ramp up as quickly as planned, there may be some spending 'delay' to 2012. Still, SEMI says that it remains optimistic about investment in 2012 exceeding \$2.3bn worldwide.

Regional equipment spending shows an aggressive investment trend from China, notes SEMI (see Figure 1). Supported by subsidy programs from local governments, new LED fab projects have blossomed in the past two years in different cities in China with investors from various backgrounds. The country hence accounts for almost 50% of overall equipment spending.

Regarding new LED fabs, SEMI recorded 19 new fabs that started operation in 2010 and it expects to see another 27 begin operation this year (see Table 1). Their geographic distribution is mostly in Asia, especially

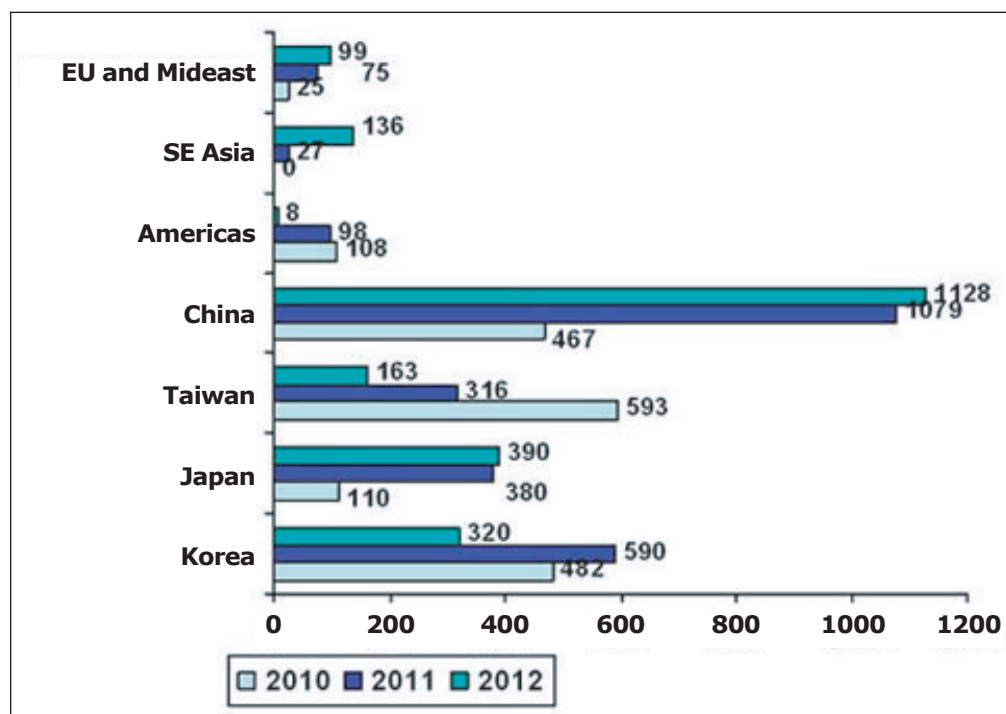


Figure 1: LED equipment spending by region (in \$USm). Source: SEMI Opto/LED Fab Forecast March 2011.

China, Taiwan, and Korea. For 2012, with current information on hand, SEMI counts 15 new fabs coming online, mostly in China. So, in total over 2010–2012,

Country/Region	2010	2011	2012
Europe & Mideast	2	2	
China	12	18	13
Americas	1	1	
SE Asia			2
Taiwan	2	3	
Korea		2	
Japan	2	1	
Grand Total	19	27	15

Table 1: LED fabs starting operation.

61 new LED fabs should have become operational globally, it is reckoned.

Global LED fab capacity reached 4.35 million wafers per month (wpm, 2"-wafer equivalent).

"We expect strong demand from LCD back-light to continue to drive the capacity growth in 2011, with a 50% increase to 6.51 million wpm (2" equivalent)," says the market research report's author Clark Tseng.

Taiwan and China are the two leading regions by LED epi/chip capacity in 2011, followed by Japan and Korea.

However, in view of the upcoming fabs from China, China's LED capacity is expected to

grow from 1.4 million wafers per month in 2011 to 2.3 million wafers per month in 2012 (2" equivalent), becoming the capacity leader.

Current investment momentum is clearly driven by strong demand from LCD backlighting in the short and medium term, and by anticipation of LED adoption in the general lighting market in the longer term, comments SEMI. However, there is one other important factor that came into play — government subsidies, it adds. "We may see some cutback on metal-organic

chemical vapor deposition (MOCVD) subsidy from local governments in China, and this certainly will have some impact on the scale of LED investments," says Tseng. "However, with the announcement of the China government's 12th Five Year Plan, it is believed that the China government will continue to foster the LED market as a whole, which will help the LED market in a more balanced approach," he concludes. ■

www.semi.org/en/Store/MarketInformation/OptoLEDFabForecast

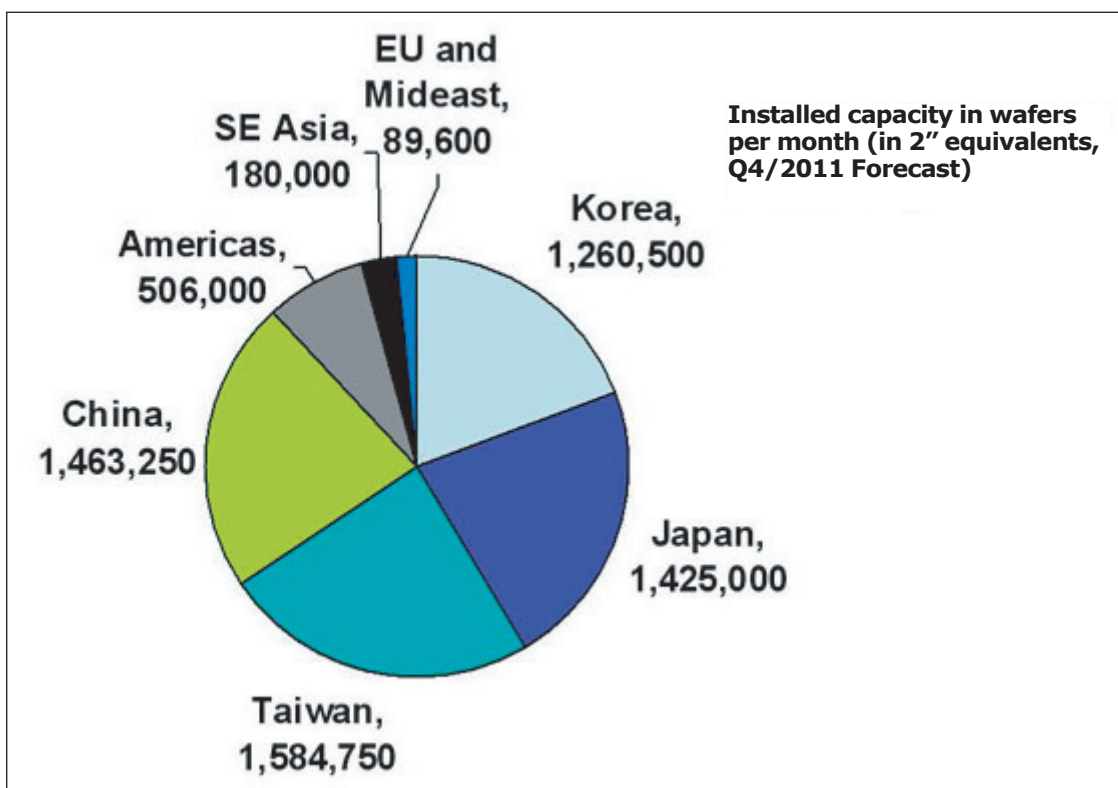


Figure 2: LED fab capacity by region, 2011. Installed capacity in wafers per month (2" equivalents, Q4/2011 forecast). Source: SEMI Opto/LED Fab Forecast March 2011.

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2010: a tremendous year for MOCVD suppliers, but will it continue in 2011?

Ross Young of IMS Research forecasts that, driven by demand from China, emerging solid-state lighting, and continued penetration of LED backlighting, the metal-organic chemical vapor deposition market may exceed 1000 tools in 2011.

A record fourth-quarter 2010 capped a remarkable eight quarters for leading MOCVD reactor makers Aixtron and Veeco. MOCVD shipments to produce blue/green LEDs from suppliers Aixtron, Applied Materials, Jusung, Veeco and Taiyo Nippon Sanso rose for seven consecutive quarters (as shown in Figure 1). Tool shipments were up a remarkable 250% from 228 in 2009 to 798 in 2010.

Aixtron and Veeco continued to dominate this market (see Figure 2), accounting for a 97% share in 2010 despite a number of new entrants. As one of the early players in this space, Aixtron has many more tools installed than Veeco, offering both horizontal and vertical approaches and multiple platforms of each approach and consuming less gas than the latest Veeco tools. Also, until recently Aixtron had a healthy advantage in tool capacity in the form of the CRIUS II and G5. As a result, Veeco must often unseat Aixtron to win business, which has

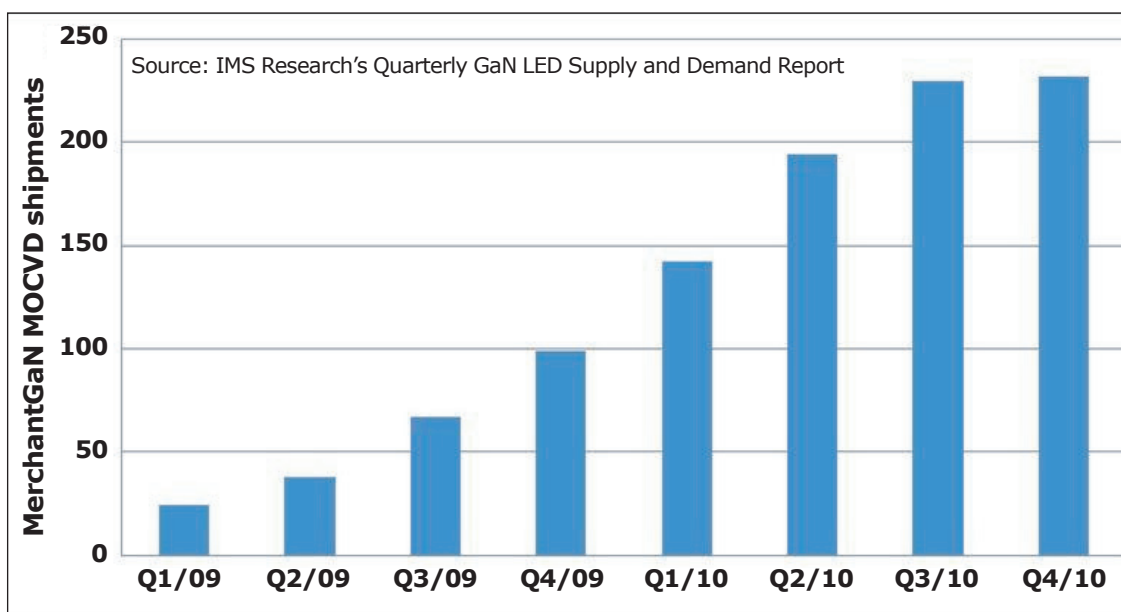


Figure 1: Q1/2009–Q4/2010 GaN MOCVD shipments.

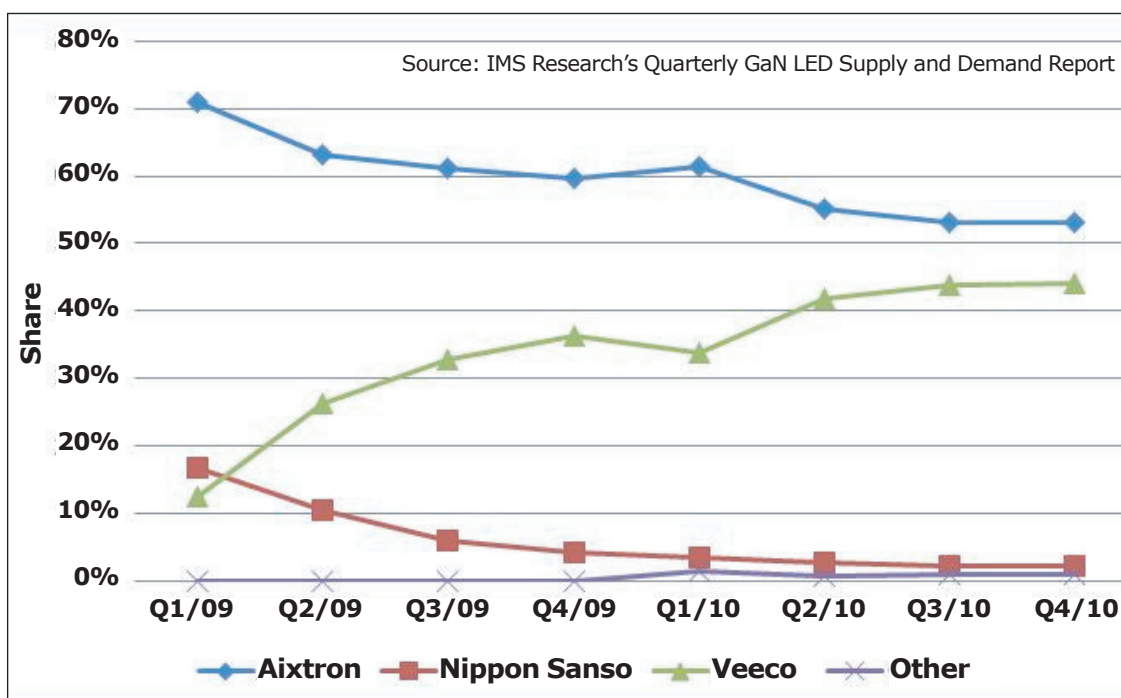


Figure 2: Q1/2009–Q4/2010 GaN MOCVD supplier share.

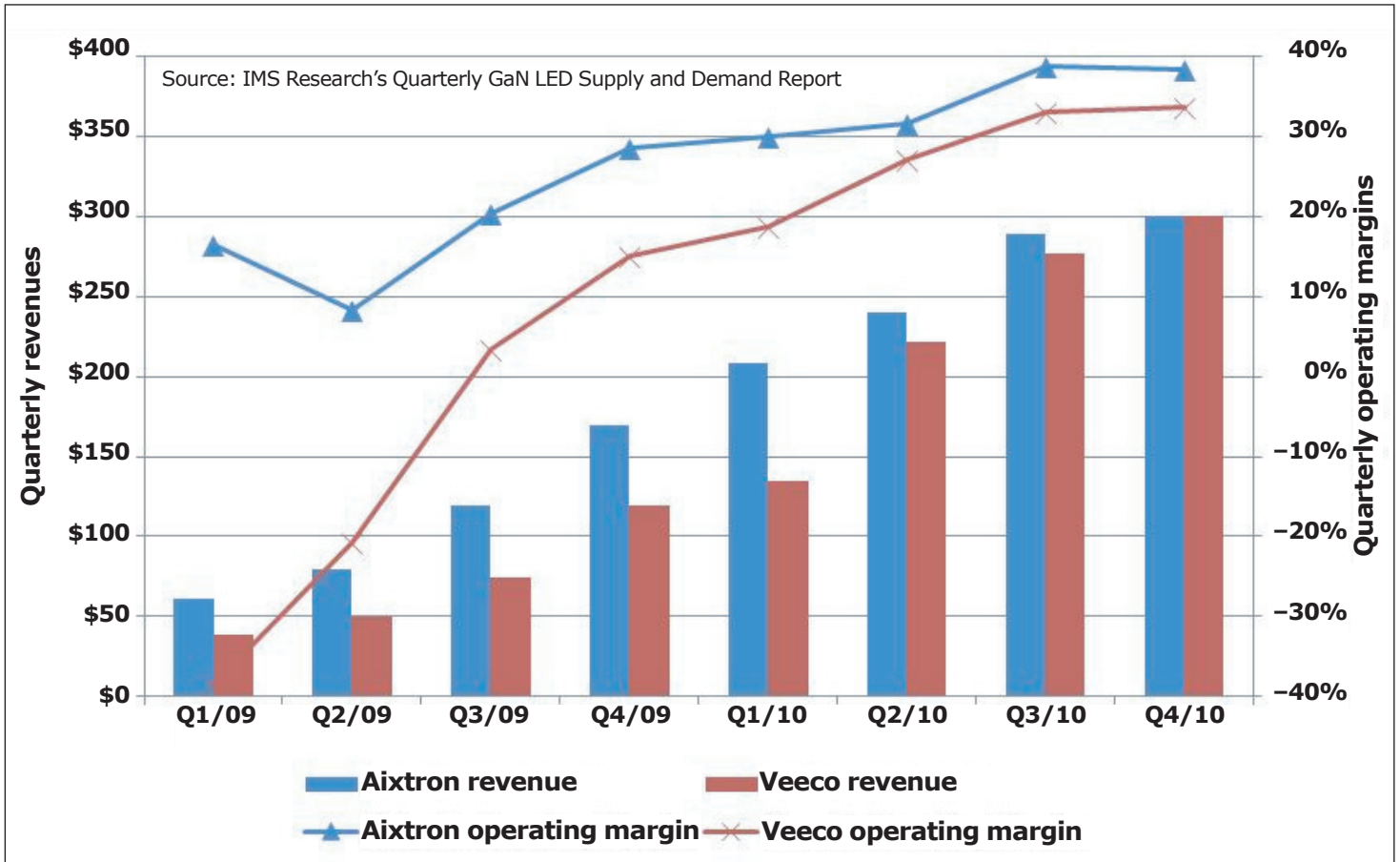


Figure 3: Aixtron's and Veeco's quarterly revenues and operating margins.

not been easy given existing players' familiarity and acceptance of Aixtron tools and their capacity advantage.

However, Veeco has proven it can take share from Aixtron, as shown in Figure 2 with its unit share rising from 31% to 42% from 2009 to 2010 on the acceptance of the K465i (which is believed to generate fewer contaminants in the process chamber, resulting in less maintenance and higher uptime). Veeco has won significant business in China and Korea over this period and has also started improving its share in Taiwan, where Aixtron has long been dominant. As a result, for the past two quarters, the K465i was the LED industry's best-selling tool. In addition, in early 2011, Veeco scaled the process chamber to sizes comparable to the CRIUS II and G5, mounted 2-4 process

chambers on a central transfer chamber, and accelerated its temperature settling time capabilities, setting a new standard for industry throughput in its new MaxBright GaN MOCVD 'cluster' system. With just a 13% share in Q1/2009, Veeco has made significant progress. ▶

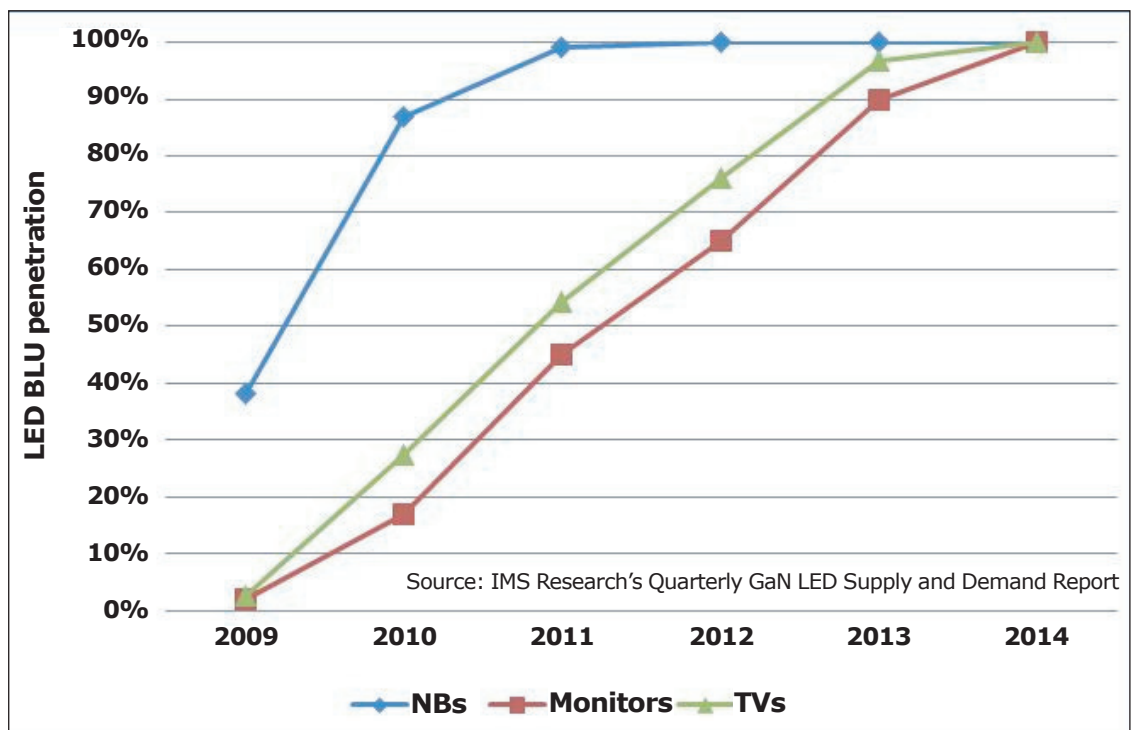


Figure 4: LED backlight penetration by application.

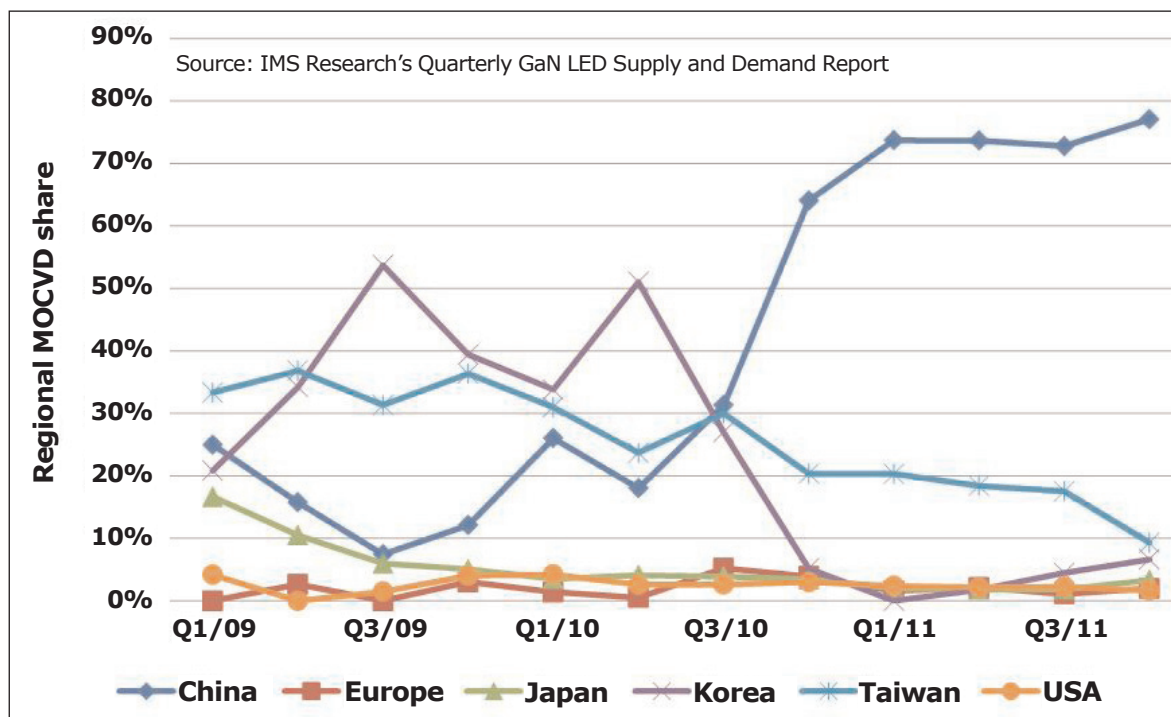


Figure 5: Regional MOCVD demand.

► If you look at each company's financials, you can see that both have come a long way very quickly, as shown in Figure 3. Aixtron's revenues rose 142% in 2010 to over \$1bn, while Veeco's revenues grew even faster, up 230% to \$933m. In addition, the firms also became highly profitable, with Aixtron's operating margins rising from 21% in 2009 to 35% in 2010 and Veeco's growing from -2% to 30%, a dramatic improvement.

Of course, the reason for all of this sudden growth is the rapid adoption of LEDs into backlighting (as shown in Figure 4) and the potential for widespread adoption of LEDs into general lighting. In backlighting, LED costs have come down to similar levels to the incumbent cold-cathode fluorescent (CCFL) technology, up to panel sizes of 15–17". In addition, with premiums and costs continuing to fall at larger sizes while offering numerous advantages (including thinner form factor, lighter weight, increased portability, no mercury, faster turn-on times etc), penetration will continue to increase. For general lighting, LEDs are priced at much higher premiums and will require continued cost reductions before seeing a similar uptake. However, general lighting represents an enormous replacement market. The combination of these two and other smaller opportunities

With subsidized demand from China, solid-state lighting beginning to emerge as prices fall, and LED backlighting continuing to gain ground, we do not see the MOCVD market slowing down in 2011. The merchant MOCVD market may exceed 1000 tools

has existing LED manufacturers significantly expanding capacity while also attracting numerous new entrants. In fact, we show over 30 new players receiving MOCVD tools in 2010 and 2011, excluding JVs in China (which would easily grow this figure closer to 40). With more than 90 firms now buying MOCVD tools, it has created a much larger market.

This rapidly growing market has also produced significant changes in regional demand. As shown in

Figure 5, Korea and Taiwan dominated MOCVD installations in 2009 and through first-half 2010, but in second-half 2010 China became the leading region and dominated Q4/2010 installations. We expect China's share to remain dominant in 2011 as well for a few reasons. First, the Chinese government has established significant incentives to make LEDs in China, resulting in large tool subsidies, tax breaks, and discounted or free land, among others. Second, with the incentives administered at the provincial level, some provinces are ending their subsidies ahead of plan due to other priorities leading to accelerated deliveries in those areas. Third, a number of provinces are competing to attract more investment in their regions and are offering additional incentives which are expected to continue beyond the original MOCVD subsidy plan. Fourth, the Chinese government has created a large street-lighting program (resulting in strong domestic lighting demand) and is expected to continue to foster a domestic LED lighting industry and eventually include domestic content requirements supporting LED manufacturers based in China.

With subsidized demand from China, solid-state lighting beginning to emerge as prices fall, and LED backlighting continuing to gain ground, we do not see the MOCVD market slowing down in 2011. Based on our survey of LED manufacturers worldwide, we believe the merchant MOCVD market may exceed 1000 tools for the first time in 2011, up 37%, producing another excellent year for MOCVD manufacturers. ■

Author: Ross Young, senior vice president, Displays, LEDs and Lighting, IMS Research.

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Market trends in GaAs RF ICs

Strategy Analytics summarizes how the gallium arsenide radio-frequency IC market will see \$3.7bn of power amplifiers being consumed by 1.7 billion handsets in 2014 as multi-band, multi-mode smartphones drive demand.

After global events put a damper on the economy for the start of 2009, the gallium arsenide (GaAs) device market is in the midst of a strong recovery. After a slow start, the market surged toward the latter part of 2009 and revenues finished essentially flat with 2008 levels. The growth that began in the latter part of 2009 continued throughout 2010.

To gain a better perspective of the trends that will drive the GaAs market in the future, it is instructive to look at what has happened to the market over the past decade. As the global economic crisis deepened, it was easy to draw parallels to the 'telecom bubble' of the early 2000s.

Figure 1 shows our analysis of the yearly growth rate for GaAs devices over the last decade. Following the dramatic growth at the end of the 1990s, the chart clearly shows an equally spectacular contraction that drove the GaAs market lower by nearly 35% over the next two years. During the growth period at the end of the 1990s, the drivers were Internet connectivity and 2G wireless networks. Companies responded by building high-capacity networks and enormous quantities of handsets for demand that never materialized. It subsequently took the GaAs industry several years to work through this excess inventory.

The difference now is the seemingly insatiable consumer demand for data services across both fixed and mobile platforms. Figure 2 shows results and estimates from Cisco's Virtual Networking Index initiative. This report categorizes the amount and type of internet protocol (IP) data that consumers and businesses are using. By their estimate, users transmitted nearly 14,700 petabytes (10^{15} bytes) of IP traffic per month in 2009. They believe this number will increase by slightly more than a factor of four to 63,900 PB by 2014. To put this into context, they claim that it will take more than two years to watch the amount of video that will cross global IP networks every second in 2014. While it represents the smallest segment of this estimate, they expect mobile data to have the fastest growth, increasing by a factor of 39 between 2009 and 2014.

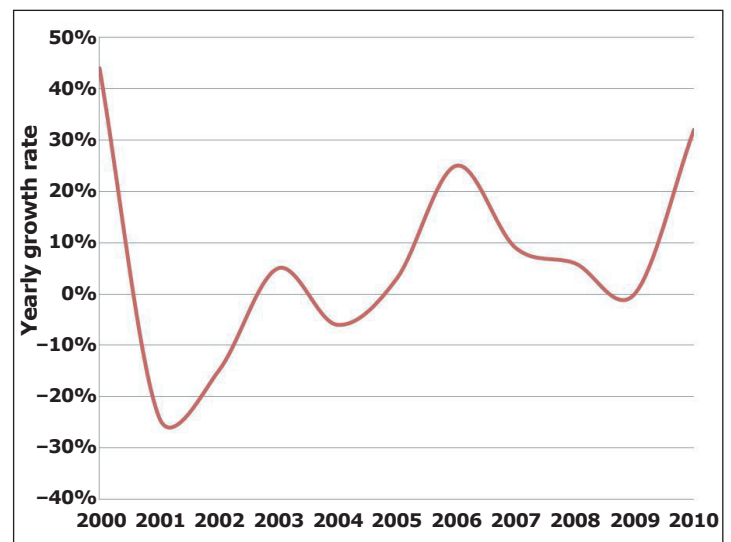


Figure 1: Yearly GaAs device market growth.

The biggest enabler of the mobile data increase and the most important driver of the GaAs RF IC market is the handset segment. The number of handsets sold each year dwarfs devices sold in other market segments. As the use of feature-laden smartphones increases, mobile data consumption will continue to rise quickly. To meet these growing data needs, next-generation networks like LTE, HSPA+ and WiMAX make use of newly available spectrum, wider channel bandwidths and more sophisticated modulation schemes to increase data transmission rates and capacity. Figure 3 shows our estimate of the total number of handsets sold and the growth of smartphones.

Much of the content of a handset is silicon-based, but power amplifiers (PAs) and switches in the front-end of the phone use GaAs devices. We believe that the additional frequency ranges and the desire of operators to supply a 'world-phone' covering many standards and geographical areas will increase the number and complexity of multi-band, multi-mode GaAs PAs and the switching networks used to select the proper amplifiers. In addition, newer handsets also include Bluetooth, GPS and Wi-Fi radios that also increase the use of GaAs components. We estimate that 1.7 billion hand-

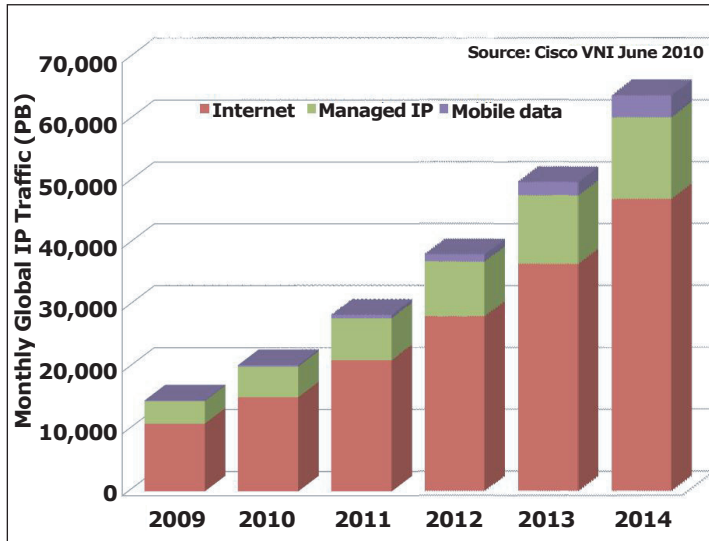


Figure 2: Monthly IP data traffic in Petabytes.

sets will ship in 2014, with GaAs PAs accounting for nearly \$3.7bn in revenue. This will represent 60% of all the GaAs device revenue for the year.

The rapidly expanding demand for data influences developments in many of the other GaAs RF IC markets.

We have become a mobile society transmitting much of our data wirelessly. This means that the entire 'ecosystem' of wireless infrastructure, backhaul, consumer devices and even satellite-based networks will grow and become more sophisticated as a result of the data explosion. These applications will result in amplifier, control and signal generation demand for GaAs RF ICs.

Looking more closely at the profile of the data traffic, video is the predominant source. The Cisco VNI report states "video will continue to exceed 91% of global consumer traffic by 2014". With rapid adoption of faster broadband, video on demand (VOD) and high-definition television (HDTV) by consumers and 3D television gaining traction, bandwidth requirements for wireline broadband networks are also increasing.

As data usage increases, the optical networks that aggregate and transport traffic from metro areas are running at higher capacities with more sophisticated modulation schemes. Portions of several networks currently have 100Gbps capabilities, and higher data rates are moving deeper into the entire network. Several service providers are taking advantage of the inherent high capacity of fiber-optic cables by running them directly to the customer premises to supply internet and video services. Even the operators who do not have all-fiber networks are using fiber deeper into their hybrid fiber coax (HFC) transmission networks. In conjunction with this 'fiber-deep' architecture, they

We estimate that 1.7 billion handsets will ship in 2014, with GaAs PAs accounting for nearly \$3.7bn in revenue

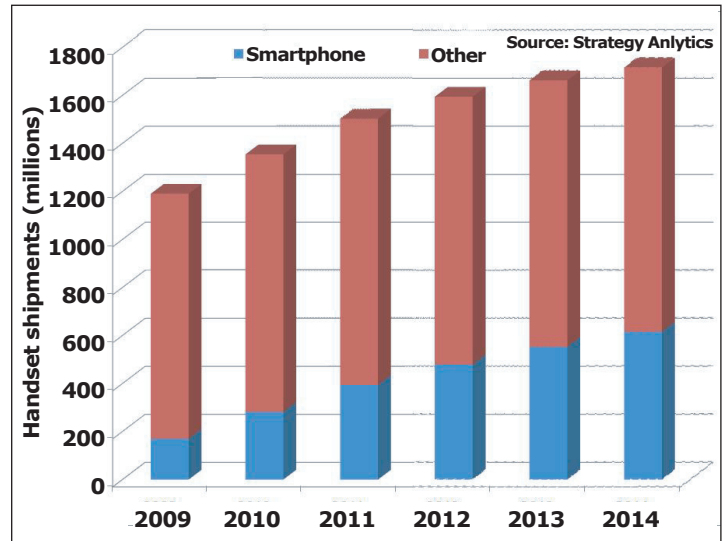


Figure 3: Handset sales and segmentation.

are increasing frequency bands and implementing variants of standards such as DOCSIS to boost data rates and capacity on the portions of the broadband CATV network that remain coaxial.

Both types of networks have opportunities for GaAs devices. In the fiber networks, some signal conditioning occurs in the electrical domain. Transimpedance amplifiers (TIA), laser drivers and various control components use GaAs and other compound semiconductors in these optical-electrical-optical (OEO) transitions. In the coaxial portions of the HFC network, the higher transmission loss requires multiple stages of amplification as the signal travels to the customer premises, where there are also opportunities in the modem and set-top box.

In summary, seemingly insatiable consumer demand for data applications, whether it is text messaging or high-definition video, will be at the root of future growth for GaAs RF IC devices. While market segments like backhaul, fiber transport, CATV and broadband will see good growth, the handset segment drives the overall market value for GaAs devices. Increasing

Increasing number of bands and complexity should allow GaAs devices to remain firmly entrenched

number of bands and complexity should allow GaAs devices to remain firmly entrenched in future market applications.

Strategy Analytics is finalizing our analysis, but preliminary results indicate

that the GaAs market recorded revenue growth of 32% in 2010 to reach slightly more than \$5.4bn. We anticipate that this growth will taper somewhat but still remain strong, and that the GaAs device market will close 2011 with growth in the 15–20% range. ■

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Back-barrier to InAlN HEMT short-channel effects

MIT and IQE RF have used an AlGaN back-barrier to increase the cut-off frequency of an InAlN HEMT by 8% from 195GHz to 210GHz.

Researchers at Massachusetts Institute of Technology (MIT) and IQE RF LLC in the USA have used an aluminum gallium nitride (AlGaN) back-barrier to improve the frequency performance of indium aluminum nitride (InAlN) high-electron-mobility transistors (HEMTs) [Dong Seup Lee et al, IEEE Electron Device Letters, published online 3 March 2011].

The MIT/IQE researchers say that their work is the first use of AlGaN as a back-barrier in an InAlN/GaN device. The aim of the back-barrier is to maintain the performance of smaller ('scaled') devices. In particular, the researchers wanted to reduce 'short-channel effects' such as drain-

induced barrier lowering (DIBL). These effects arise due to the reduced charge density in the two-dimensional electron gas (2DEG) channel and increased gate leakage current arising from the use of thinner barrier layers. With an AlGaN back-barrier, it is hoped to maintain performance with thicker InAlN top-barriers.

Unlike the AlGaN alternative, InAlN layers can be grown lattice matched to GaN if an In fraction of 17% is used. Also, with $\text{In}_{0.17}\text{Al}_{0.83}\text{N}$ there is a large polarization discontinuity with GaN, leading to higher charge densities in, and larger band offset to, the GaN channel, compared with AlGaN/GaN. These features allow sheet resistances for InAlN/GaN structures to be less than $300\Omega/\text{square}$.

The barrier thickness of the InAlN in HEMT devices also tends to be thinner (less than 10nm) than with the corresponding AlGaN HEMTs. A thinner barrier layer removes the need to etch the top-barrier to bring the gate electrode closer to the channel (recessed gate),

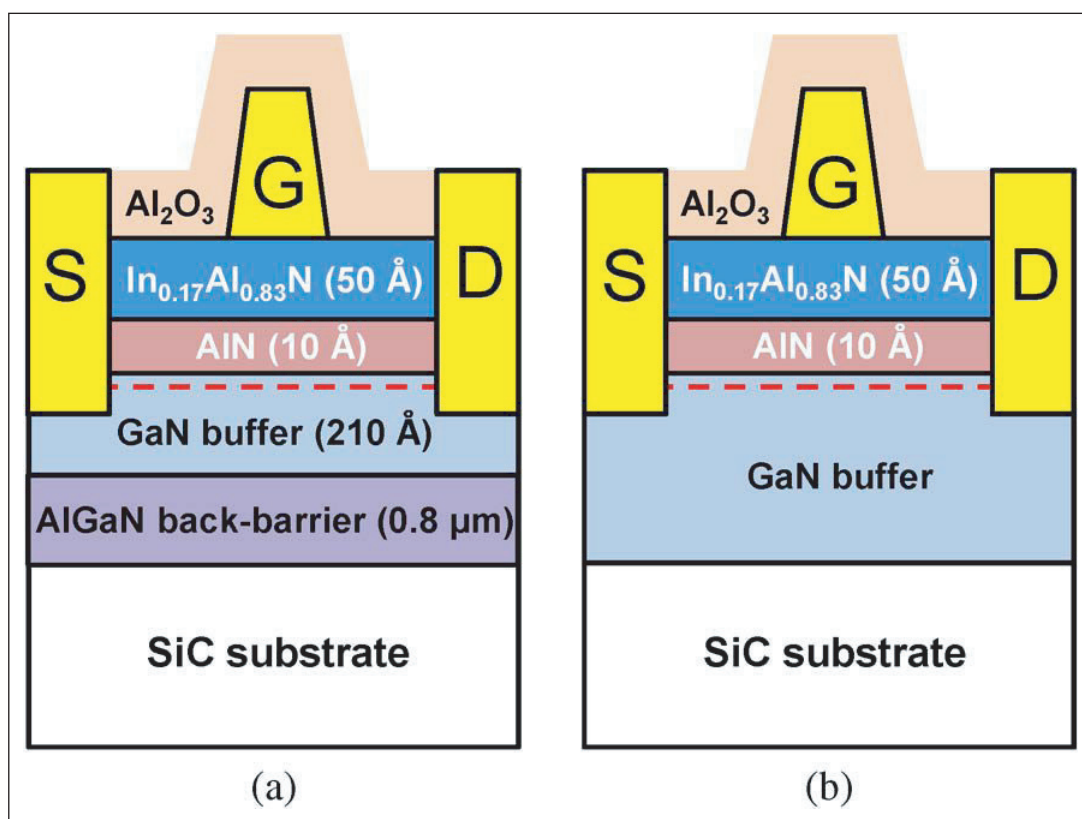


Figure 1. Schematics of InAlN/GaN HEMTs with and without an AlGaN back barrier.

as is commonly done in making smaller AlGaN HEMTs. Avoiding etch processes is desirable in terms of reducing plasma damage of the device, which can

Their work is the first use of AlGaN as a back-barrier in an InAlN/GaN device. The aim of the back-barrier is to maintain the performance of smaller ('scaled') devices. In particular, the researchers wanted to reduce 'short-channel effects' such as drain-induced barrier lowering

adversely affect performance.

These features have enabled InAlN devices with current densities up to $2.5\text{A}/\text{mm}$ and cut-off frequencies (f_T) up to 245GHz. A further feature of nitride semiconductor devices is the potential for operation in harsh environments. On this line, one group has reported InAlN/GaN HEMT

operation at temperatures up to 1000°C.

The MIT/IQE HEMT structures (Figure 1) were grown on silicon carbide (SiC) substrates using metal-organic chemical vapor deposition (MOCVD). The further processing of the epitaxial material into transistor structures (mesa isolation etch and metal contact deposition/anneal) was carried out at the same time with the standard and back-barrier HEMTs. The ohmic source-drain contacts consisted of titanium-aluminum-nickel-gold and the Schottky gate consisted of nickel-gold. A final aluminum oxide layer was (deposited by atomic-layer deposition) acts as passivation.

Although the epitaxial material with back-barrier has a higher mobility ($1635\text{cm}^2/\text{V}\cdot\text{s}$ vs $1369\text{cm}^2/\text{V}\cdot\text{s}$ without), the carrier density is lower ($1.1\times 10^{13}/\text{cm}^2$ vs $1.7\times 10^{13}/\text{cm}^2$) and the sheet resistance higher ($310\Omega/\text{sq}$ vs $260\Omega/\text{sq}$). These factors lead to reduced maximum drain current ($1.49\text{A}/\text{mm}$ vs $2.05\text{A}/\text{mm}$ at 2V gate potential) and higher threshold voltage in DC operation for 65nm gate-length devices. Higher access resistance reduces the extrinsic transconductance (g_m) to $539\text{mS}/\text{mm}$, which is 9% lower than the standard device without back-barrier ($592\text{mS}/\text{mm}$).

At high biases, the back-barrier device also suffers from self-heating effects such as low saturation current. This is caused by the relatively low thermal conductivity of the AlGaN back-barrier material.

One good DC feature of the back-barrier device is smaller drain-induced barrier lowering (DIBL) at shorter gate lengths due to the smaller output conductance.

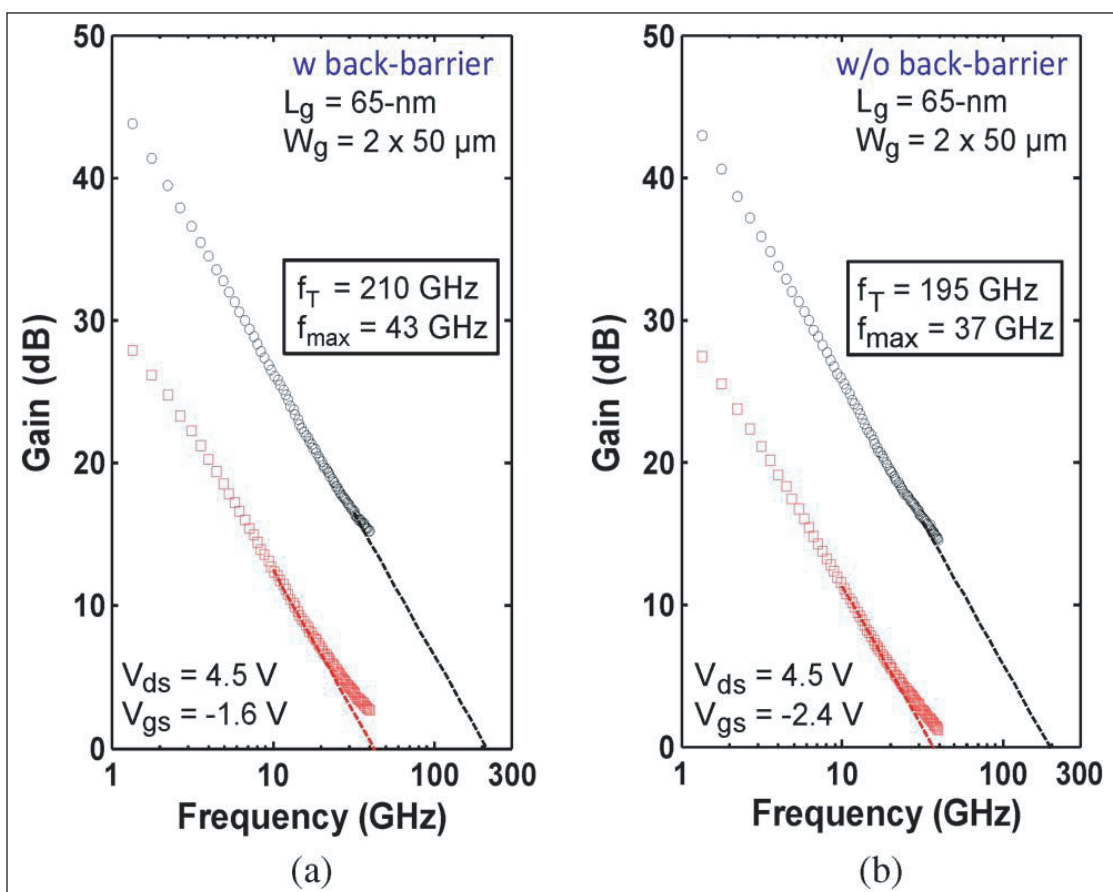


Figure 2. RF performance of 65nm-gate-length InAlN/GaN HEMTs (a) with and (b) without AlGaN back barrier.

The measured maximum cut-off frequencies (f_T s) were 210GHz and 195GHz for the back-barrier and standard HEMTs, respectively. The researchers attribute this 8% gain in f_T as being due to the high output resistance of the back-barrier HEMT

Above a gate length of 100nm, the DIBL of both devices are less than 50mV/V. Below 100nm, the DIBL of devices without back-barrier increases sharply, while that of back-barrier HEMTs remains in the 50–60mV/V range.

Operation at microwave frequencies from 450MHz up to 40GHz was also tested (Figure 2). The maximum cut-off frequency (f_T) conditions were a drain bias of 4.5V and a gate potential of -1.6V for the back-barrier HEMT, and 4.5V and -2.4V , respectively, for the standard device without back barrier. The measured maximum f_T s were 210GHz and 195GHz for the back-barrier and standard HEMTs, respectively. The researchers attribute this 8% gain in f_T as being due to the high output resistance of the back-barrier HEMT.

"It is expected that the improvement becomes even more important as the gate length scales below 50nm," the researchers comment.

The maximum oscillation frequency (f_{max}) was relatively small in both devices due to high resistance of the thin rectangular gate.

Financial support for the research came from the US Defense Advanced Research Projects Agency NEXT, a National Science Foundation CAREER Award, and the Office of Naval Research DURIP program. ■

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www.iqep.com

Author: Mike Cooke

Polarization junctions increase nitride transistor breakdown voltage

University of Sheffield and Japan's POWDEC demonstrate first polarization junction super HFETs.

Researchers from the UK's University of Sheffield and Japanese firm POWDEC K.K. have demonstrated super heterojunction field-effect transistors (HFETs) based on polarization junctions "for the first time" [Akira Nakajima et al, IEEE Electron Device Letters, published online 14 February 2011]. One super HFET that was produced had a breakdown voltage in excess of 1.1kV without the use of the field plates that are often used to massage the electric field distribution in such devices.

The researchers are aiming to develop technology for next-generation ultra-low-loss power devices beyond the GaN material limit. They see lateral devices as being "ideally suited for ultra-high-efficiency power ICs with small chip size".

The new Sheffield/POWDEC device applies a polarization technique to create two-dimensional gases of both electrons (2DEG) and holes (2DHG), reported by the researchers in late 2010 (www.semiconductor-today.com/news_items/2010/DEC/SHEFFIELD_241210.htm). The concept has also been applied to nitride semiconductor diodes, where operation was maintained up to 9kV.

Often the polarization fields resulting from the ionic nature of III-nitride materials can impede device performance in light-emitting devices. However, in HFETs these polarization electric fields that arise from the different polarization properties of the heterostructure layers also create the 2DEG channels on which conduction between source and drain depends. When the conduction is solely through electrons, these devices can also be referred to as high-electron-mobility transistors (HEMTs).

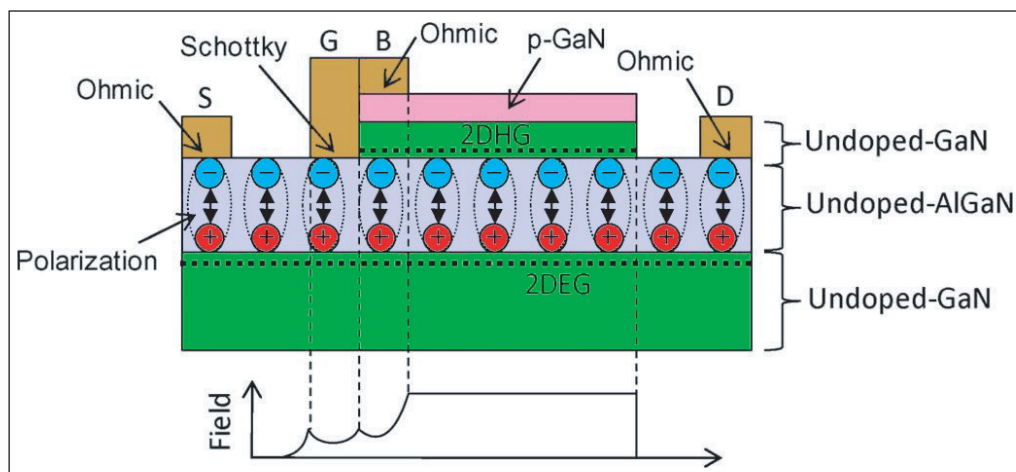


Figure 1. Schematic of Sheffield/POWDEC super HFET and the electric field distribution in OFF-state. There are four electrodes of source (S), gate (G), base (B), and drain (D). The base is electrically connected to the gate. The 2DHG is charged and discharged during the switching cycle through the base electrode.

In the Sheffield/POWDEC device (Figure 1) the polarization fields arise at the interfaces between undoped aluminum gallium nitride (AlGaN) and gallium nitride (GaN) layers. By having two compensating interfaces in the GaN/AlGaN/GaN sequence, the OFF-state can be maintained to higher source-drain bias. "During the OFF state, these positive and negative charge quantities balance each other to result in a flat electric field distribution to maximize the breakdown voltage," the researchers write.

In the turn-off stage, the 2DEG is removed through the drain and the 2DHG through the base electrode. The drift region between the base and drain electrodes is thus depleted. On increasing the drain bias a flat field is maintained in the drift region, improving the breakdown capability

The ON-state flow occurs through the 2DEG, as in conventional HEMTs. However, in the turn-off stage, the 2DEG is

removed through the drain and the 2DHG through the base electrode. The drift region between the base and drain electrodes is thus depleted. On increasing the drain bias a flat field is maintained in the drift region, improving the breakdown capability of the device.

The researchers see their structure as being analogous to the reduced surface field (RESURF) technique used in silicon high-power devices. RESURF uses a 'drift' region between the gate and drain to reduce the field in lateral devices, allowing higher voltages to be applied before the critical electric field is reached.

The researchers produced both conventional and the new super HFETs on the same sapphire wafer, using metal-organic chemical vapor deposition (MOCVD). For the conventional HFETs, the p- and undoped-GaN layers were completely removed by using inductive coupled plasma etching. The ohmic source drain contacts consisted of 800°C annealed titanium-aluminum-titanium-gold layers. The Schottky gate and ohmic base contact consisted of 600°C annealed nickel-gold on AlGaN and p-GaN, respectively. A 300nm silicon dioxide layer provided passivation.

The gate-source distances were 3μm for both devices. The gate-drain distance for the conventional device was 10μm; two gate-drain distances of 10μm and 22μm were produced for the super HFET. The base contact measured 4μm. The distance between the GaN layers and the drain of the super HFET was 3μm.

The 10μm gate-drain devices had similar performance in terms of ON-resistance. The longer 22μm gate-drain distance increased the ON-resistance of the super HFET from an $R_{ON.A}$ value of $2.2\text{m}\Omega\text{-cm}^2$ (10μm value) to $6.1\text{m}\Omega\text{-cm}^2$. There is generally a trade-off between specific ON-resistance and breakdown voltage. The maximum drain current of the 10μm device was 0.29A/mm at a gate voltage of +2V.

The breakdown voltage of super HFETs is significantly enhanced due to charge compensation effect between the positive and negative polarization charges. Since the $R_{ON.A}$ is almost comparable with previously reported conventional HFETs with field-plates, further improvement can be expected by optimizing the device structure

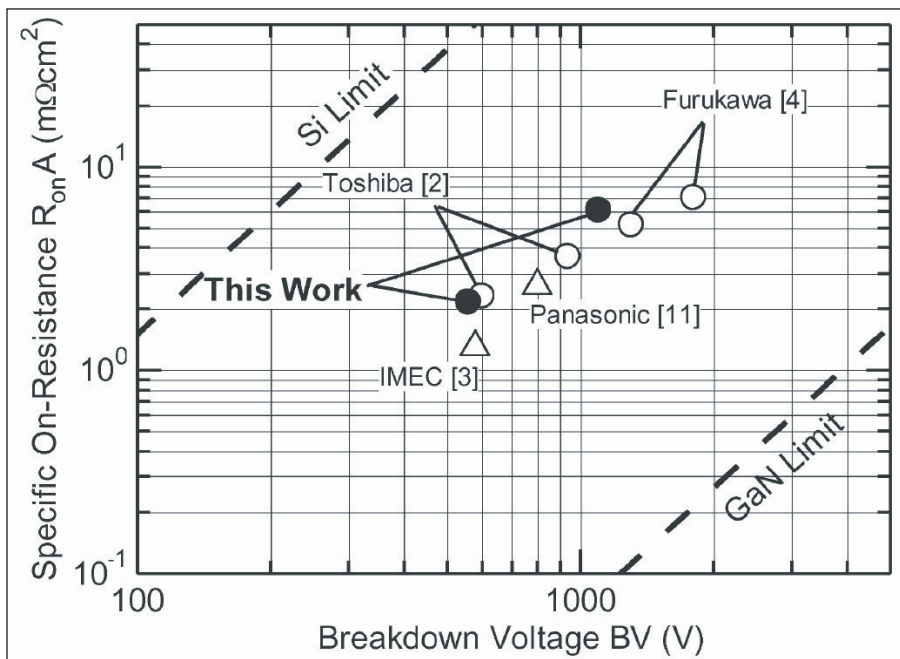


Figure 2. Specific ON-resistance versus breakdown voltage of GaN devices with D-mode (circle) and E-mode operation (triangle). The dashed lines are theoretical material limits of Si and GaN unipolar devices.

The peak transconductance of the super HFET (62mS/mm) was depressed relative to the conventional device (81mS/mm) due to the effective gate length being longer in the super HFET since the base contact was electrically connected to the gate.

The breakdown performance (Figure 2) was demonstrated at a gate voltage of -15V (OFF-state) with a drain current of 10μA/mm indicating breakdown. The form of the breakdown curves suggested an avalanche mechanism between the gate and drain.

The conventional device breakdown voltage (BV) occurred at 100V, lower than the results found with HFETs using field-plates. Without the field-plate, the breakdown tends to occur at the gate edge of the drain side due to electric field crowding. The researchers also suggest that damage from the plasma etch used to remove the p-/u-GaN layers not wanted for the conventional devices may have contributed to increased leakage current effects.

The 10μm super HFET had a breakdown of 560V, and that of the 22μm device exceeded that of the measurement system (1.1kV).

The researchers comment: "The BV of super HFETs is significantly enhanced due to charge compensation effect between the positive and negative polarization charges". Since the $R_{ON.A}$ is almost comparable with previously reported conventional HFETs with field-plates, "further improvement can be expected by optimizing the device structure." ■

<http://dx.doi.org/10.1109/LED.2011.2105242>
www.powdec.co.jp/e/index.html

Author: Mike Cooke

InGaAs tunnel FET with ON current increased by 61%

University of Texas at Austin uses n-type doping to reduce tunneling width and increase field in InGaAs tunneling field-effect transistors.

University of Texas at Austin researchers have developed indium gallium arsenide (InGaAs) tunneling field-effect transistors (TFETs) with ON current increased by up to 61% [Han Zhao et al, Appl. Phys. Lett., vol98, p093501, 2011]. This was achieved by changing the tunnel junction layers, consisting of heavily p-type and intrinsic material (p^{++}/i), to heavily p-type and n-type (p^{++}/n^+).

The effect of using an n-type layer in the tunneling diode is to reduce the tunneling width and increase the tunneling field, which in turn should allow for increased ON currents and better sub-threshold behavior.

Logic transistors need a high ON current and low OFF current to operate effectively. This becomes difficult when the threshold voltage is low, and particularly so for devices with large subthreshold swing (SS). Low threshold voltages are desired to reduce power consumption and heat generation.

Theoretical work suggests that inter-band tunneling field-effect transistors (TFETs) are not subject to the SS limitation of 60mV/dec at room temperature for conventional MOSFETs. Application of these ideas in silicon or germanium has resulted in devices with low ON current, resulting from the high tunneling barrier.

Recently InGaAs has been proposed as a channel material for high-performance, high-density logic, due to its much higher mobility value. InGaAs tunneling structures might allow higher ON currents due to a low carrier effective mass and narrow bandgap.

Pennsylvania State University with Cornell University demonstrated the first InGaAs TFETs in 2009, but the saturation/ON current was low ($20\mu\text{A}/\mu\text{m}$) and the SS was more than 150mV/dec. Texas-Austin managed to double the ON current and cut SS to 96mV/dec last year. These results have to be compared with 65nm strained silicon technology that has achieved ON currents of

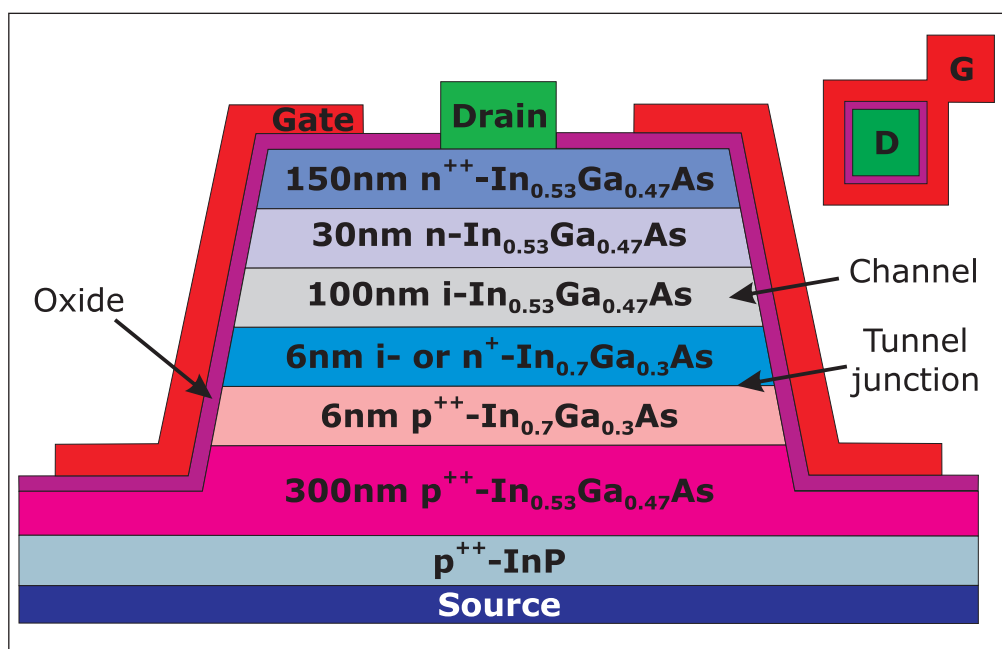


Figure 1. Cross section and top view (inset) of ring-type $\text{In}_{0.7}\text{Ga}_{0.3}\text{As}$ TFETs using p^{++}/i or p^{++}/n^+ tunneling junctions with HfO_2 gate oxide and TaN gate electrode.

1.62mA/ μm (1620 $\mu\text{A}/\mu\text{m}$) with SSs of 105mV/dec.

The latest Texas-Austin TFETs have a vertical structure, using molecular-beam epitaxial layers to form the different regions needed to make the channel and tunnel injector (Figure 1). Conventional CMOS manufacturing tends to favor lateral/planar structures.

The tunnel junction consisted of either a p^{++}/i (undoped) or p^{++}/n^+ junction of $\text{In}_{0.7}\text{Ga}_{0.3}\text{As}$. The p-type material was achieved using beryllium (Be , $2 \times 10^{19}/\text{cm}^3$) and the n-type using silicon (Si , $2 \times 10^{18}/\text{cm}^3$) doping. The doping in the n-type layer must be low enough to ensure that it is fully depleted by the p^{++} layer. Without the depletion, the injection mechanism into the undoped channel layer would be thermionic emission, as in conventional MOSFETs.

The etching to create the 'ring-type' TFET used a citric acid/hydrogen peroxide solution in water. The etch stopped about 100nm into the 300nm $p^{++}\text{-In}_{0.53}\text{Ga}_{0.47}\text{As}$ layer (leaving 200nm). The gate insulator consisted of 5nm of hafnium dioxide (equivalent to a silicon dioxide thickness of 1.2nm) applied using atomic layer deposition (ALD) at 200°C. The gate electrode was sputtered tantalum nitride.

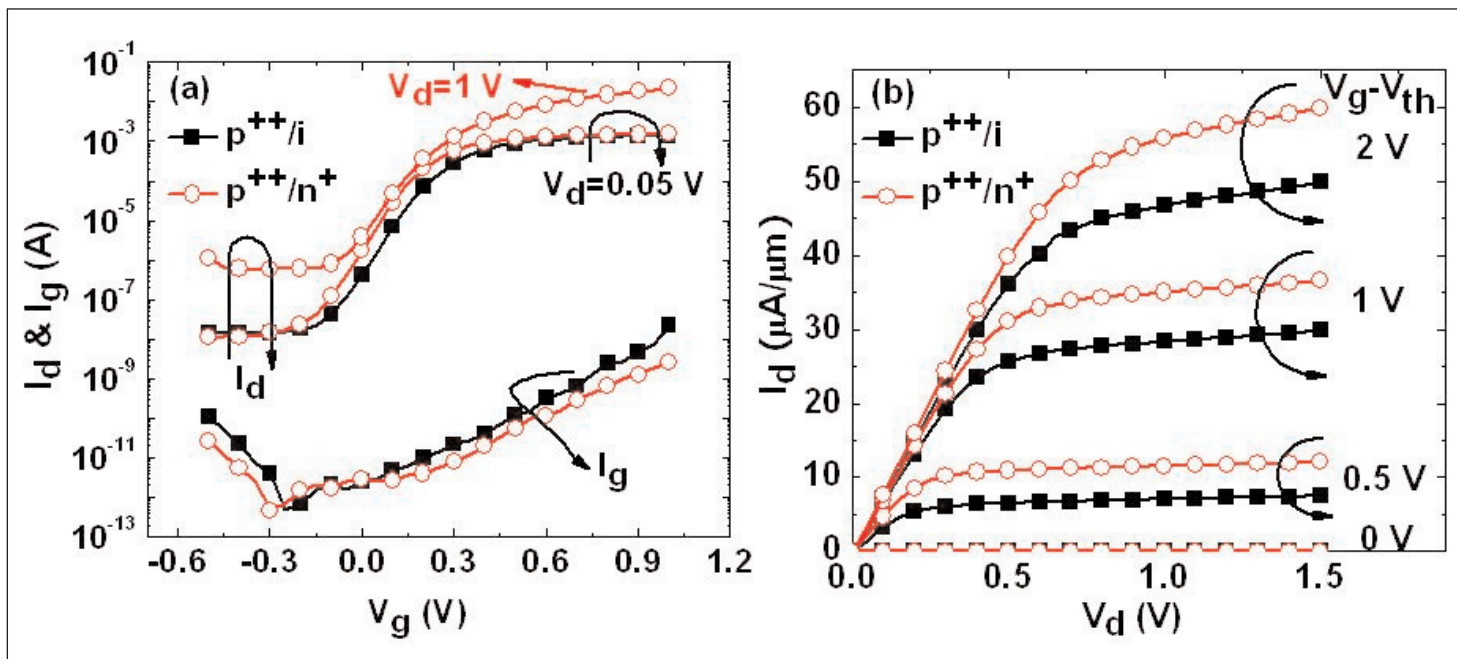


Figure 2. (a) Drain current (I_d - V_{th}) and gate current (I_g - V_{th}) vs gate voltage characteristics of $\text{In}_{0.7}\text{Ga}_{0.3}\text{As}$ TFETs using p^{++}/i or p^{++}/n^{+} tunneling junctions and 5nm HfO_2 gate oxide. (b) Drain current-voltage (I_d - V_d) curves at different gate voltages over threshold ($V_g - V_{th}$) for the same devices (gate width $560\mu\text{m}$, gate length 100nm).

► The drain contact consisted of gold-germanium/nickel/gold and the source was a back contact of chromium and gold; both contacts were applied with electron-beam evaporation. The wafer was then annealed at 300°C in nitrogen to create ohmic source/drain contact behavior.

The minimum sub-threshold swing was $84\text{mV}/\text{dec}$ at a drain bias of 0.05V for both types of tunneling junction. The similarity of the SS for these devices is thought to result from two competing factors: the shorter tunneling width for p^{++}/n^{+} tunneling junctions reduces SS relative to p^{++}/i tunneling; and, higher doping concentration in the n^{+} layer gives weaker coupling between semiconductor and gate in the MOS structure, increasing SS.

The SS was higher than $60\text{mV}/\text{dec}$, the researchers believe, due to a poor III-V/oxide interface and,

Gate leakage was less than $0.2\text{mA}/\text{cm}^2$ at gate voltage of 1V . The drive current of the p^{++}/n^{+} device was enhanced above that of the intrinsic device by 61% and 20% at 0.5V and 2V gate voltage over threshold, respectively. The 2V p^{++}/n^{+} drive current was $60\text{mA}/\text{mm}$. The researchers comment "This improvement is believed to be due to a shorter tunneling width and a higher tunneling electric field for TFETs using p^{++}/n^{+} tunneling junctions"

possibly, dopant diffusion in the tunneling junction (as shown in secondary-ion mass spectroscopy analysis). The interface trap density at the III-V/oxide interface was estimated to be $\sim 4 \times 10^{12}/\text{eV}/\text{cm}^2$.

Gate leakage was less than $0.2\text{mA}/\text{cm}^2$ at gate voltage of 1V . The threshold voltages of the p^{++}/i and p^{++}/n^{+} tunnel junction devices were 0.21V and 0.15V , respectively. The drive current of the p^{++}/n^{+} device was enhanced above that of the intrinsic device by 61% and 20% at 0.5V and 2V gate voltage over threshold, respectively. The 2V p^{++}/n^{+} drive current was $60\mu\text{A}/\mu\text{m}$.

The researchers comment: "This improvement is believed to be due to a shorter tunneling width and a higher tunneling electric field for TFETs using p^{++}/n^{+} tunneling junctions."

The researchers carried out simulation using Sentaurus Device @ Synopsis software to find the performance trends for varied n^{+} doping of the tunnel junction. The simulations suggested that an n^{+} doping of $8 \times 10^{18}/\text{cm}^3$ might be optimum: above this, the off-current is too high; below this and the on-current degrades. Since the simulation was not calibrated, the researchers stress that this result is only a guideline, and hence suggestive that optimization in actual devices could lead to improved performance.

Funding came from Intel Corp, the Texas Advanced Research Program, the US National Science Foundation Integrative Graduate Education and Research Traineeship (NSF IGERT) program, SEMATECH, and Micron Foundation. ■

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Author: Mike Cooke

Tantalum-based ohmic contacts for nitride semiconductor transistors

Ohmic contacts developed with resistance as low as $0.06\Omega\text{-mm}$.

Sweden's Chalmers University of Technology and United Monolithic Semiconductors (UMS, a joint venture between Thales and EADS with production facilities in Orsay, France and Ulm, Germany) have been developing an alternative ohmic metal contact scheme based on tantalum (Ta) for use with aluminum gallium nitride (AlGaN) for high-electron-mobility transistors (HEMTs) [A Malmros et al, *Semicond. Sci. Technol.*, vol26, p075006, 2011]. Overall, the minimum contact resistances (R_c) found for ohmic contacts with low- and high-potential-barrier epitaxial materials were $0.06\Omega\text{-mm}$ and $0.28\Omega\text{-mm}$, respectively.

GaN HEMTs have potential applications for devices operating at high temperature, frequency and power density. Low-resistance contacts are needed for such devices to reduce losses and self-heating.

Conventional ohmic contacts in GaN HEMTs use titanium (Ti) and aluminum (Al), along with a cap to avoid oxidation of the Al layer. The cap often consists of nickel (Ni) or Ti with gold (Au). These structures require annealing at about 800°C , which can damage the performance of the semiconductor heterostructure on which the HEMT action depends. These temperatures can also melt Al, creating unwanted surface roughness of the contact.

Alternative ohmic metals for use with nitride semiconductors are being sought using molybdenum or Ta, for example, which can be annealed at lower temperatures.

The Chalmers/UMS researchers used transmission line method (TLM) structures, which are commonly used to determine the contact resistance of metal-semiconductor junctions. The TLM structures were placed on two particular epitaxial materials grown using metal-organic chemical vapor deposition (MOCVD) on silicon carbide substrates (Table 1). Such epitaxial structures are used for HEMT development.

The wafers were diced into pieces measuring $16\text{mm} \times 16\text{mm}$ before the contact metal deposition. The surfaces were prepared by degreasing, cleaning and etching into mesas. The contacts were created using photolithographic patterning and metal evaporation.

Table 1. Epitaxial heterostructures used in the experiments.

	Epi I	Epi II
Cap	GaN, 3 nm	–
Barrier	$\text{Al}_{0.14}\text{Ga}_{0.86}\text{N}$, 22 nm	$\text{Al}_{0.25}\text{Ga}_{0.75}\text{N}$, 25nm
Buffer	GaN	GaN

The metalized samples were diced further before different anneal treatments were performed.

A variety of sample structures were produced (Table 2) in two main groups with Ta/Al/Ni/Au (samples 1–4) and Ta/Al/Ta (6–17) metallization schemes. The second group (samples 6–17) was produced with the aim of creating a simpler structure and facilitating better understanding of the contact formation. The final Ta layer in the second group is used to prevent oxidation of the Al. A traditional Ti/Al/Ni/Au (sample 5) scheme was also produced for comparison purposes.

The annealing of samples was performed in an AG Heatpulse 610 rapid thermal processor (RTP) in nitrogen. Optimization of the anneal temperature was first carried out with a constant duration of 60s.

The minimum contact resistance of $0.41\Omega\text{-mm}$ for the first group of samples (1–4) occurred with sample 3 at an annealing temperature of 550°C . These results are very sensitive to the Al layer thickness, which makes process control, and hence manufacturing, difficult. The comparison stack (sample 5) became ohmic at 625°C with a minimum contact resistance of $1.63\Omega\text{-mm}$.

Ohmic contacts in GaN HEMTs use Ti and Al, along with a cap to avoid oxidation of the Al layer. The cap often consists of Ni or Ti with Au. These structures require annealing at about 800°C , which can damage the performance of the semiconductor heterostructure on which the HEMT action depends

Table 2. List of fabricated samples and the minimum R_c achieved.

Sample	Layer thickness (Å)						Thickness ratio t_{Al}/t_{Ta}	Epi	Min. R_c (Ω -mm)
	Ti	Ta	Al	Ta	Ni	Au			
1	-	100	700	-	400	400	7	I	1.36
2	-	100	1200	-	400	400	12	I	1.75
3	-	100	1400	-	400	400	14	I	0.41
4	-	100	2800	100	-	500	28	I	2.23
5	200	-	1100	-	400	400	-	I	1.63
6	-	100	700	200	-	-	7	I	0.63
7	-	100	1400	200	-	-	14	I	0.26
8	-	100	2100	200	-	-	21	I	0.65
9	-	100	2800	200	-	-	28	I	0.06
10	-	100	700	200	-	-	7	II	0.47
11	-	100	1400	200	-	-	14	II	0.54
12	-	100	2100	200	-	-	21	II	0.42
13	-	100	2800	200	-	-	28	II	0.28
14	-	50	2800	200	-	-	56	I	0.25
15	-	200	2800	200	-	-	14	I	0.49
16	-	50	2800	200	-	-	56	II	0.42
17	-	200	2800	200	-	-	14	II	1.45

These results were all obtained with the 'epi I' structure with a 14%-Al AlGaN barrier and 3nm GaN cap layer.

The same epi I structure with Ta/Al/Ta metallization (samples 6–9) showed much less sensitivity to the Al layer thickness. The best value of contact resistance of 0.06 Ω -mm for sample 9 was achieved with an annealing temperature of 550°C.

Samples 10–13 on the epi II structure, with 25%-Al AlGaN barrier and no GaN cap, exhibited the lowest contact resistance of 0.42 Ω -mm at 600°C. In the last sequence of samples (14–17), where the bottom Ta layer thickness was varied, the minimum contact resistance was also achieved at 600°C.

The minimum contact resistance of 0.41 Ω -mm for the first group of samples (1–4) occurred with sample 3 at an annealing temperature of 550°C. These results are very sensitive to the Al layer thickness, which makes process control, and hence manufacturing, difficult. The comparison stack (sample 5) became ohmic at 625°C with a minimum contact resistance of 1.63 Ω -mm. The same epi I structure with Ta/Al/Ta metallization (samples 6–9) showed much less sensitivity to the Al layer thickness. The best value of contact resistance of 0.06 Ω -mm for sample 9 was achieved with an annealing temperature of 550°C

From this point, the researchers focused on the stack without Ni-Au, seeing the use of these metals as being an 'unnecessary, complicating factor'.

The anneal duration was then varied at a temperature of 550°C (Figure 1). The results suggest that the epi II structure requires longer duration to anneal the Ta/Al/Ta stack.

On the basis of comparing the minimum contact resistances with the thickness ratios for the Ta and Al ratios, the researchers comment: "Both heterostructures exhibited the minimum R_c at a t_{Al}/t_{Ta} of 28, which may indicate that this value is close to optimum". However, they also believe that more work is needed to confirm this.

The researchers also studied the sheet resistance of the epitaxial material, which needs to be maintained for transistor performance. The value remained stable at 980 Ω /square for epi I up to 575°C. Epi II maintained its sheet resistance to higher anneal temperatures — sample 11 had an increase in sheet resistance from its normal value of 420 Ω /square to 500 Ω /square after annealing at 650°C for 60s.

SEM and optical analysis showed smooth surfaces of the metal layers up to 600°C. At higher temperatures the surface morphology became rougher. Smoother morphology would facilitate lateral scaling/size reduction of devices.

Further work involved transmission electron microscopy (TEM) and energy-dispersive x-ray (EDX) spectroscopy. These studies suggested that interdiffusion of metals with Ta/Al/Ni/Au metallization caused the poor performance of this sequence. On the basis of their analysis, the researchers believe that the contact

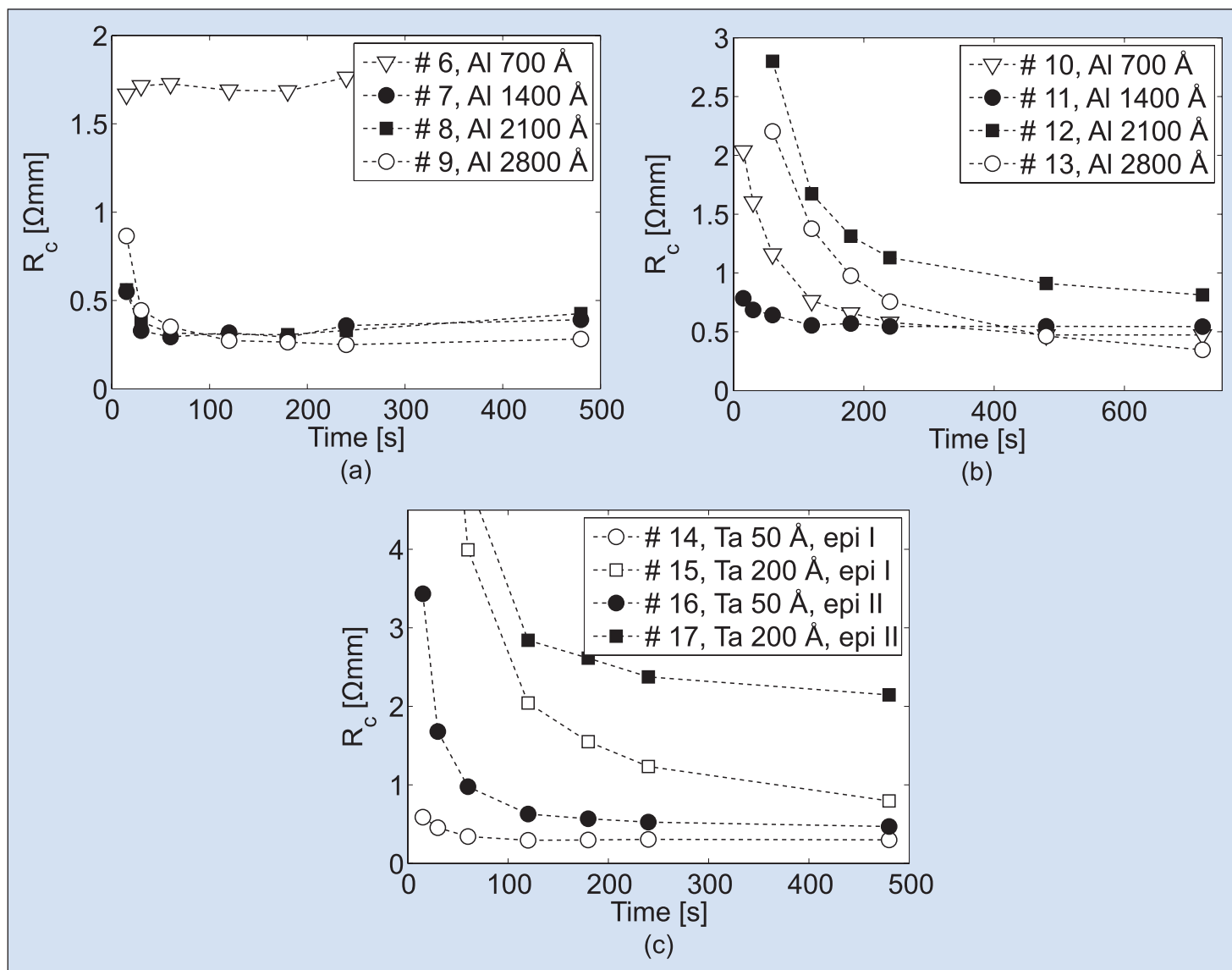


Figure 1. R_c versus time of annealing at 550°C for samples 6–17: (a) Ta/Al/Ta metallization on epi I, (b) Ta/Al/Ta metallization on epi II and (c) Ta/Al/Ta metallization on epi I and II with different Ta layer thicknesses.

mechanism is due to the formation of a metal-nitrogen compound at the metal–semiconductor interface, causing donor-like nitrogen vacancies in the semiconductor.

Thermal stability of the contacts was studied by storing samples 7 and 9 in air at 300°C. They maintained their initial contact resistance values for more than 400

Further work involved TEM and EDX spectroscopy. These studies suggested that interdiffusion of metals with Ta/Al/Ni/Au metallization caused the poor performance of this sequence... the researchers believe that the contact mechanism is due to the formation of a metal-nitrogen compound at the metal–semiconductor interface, causing donor-like nitrogen vacancies in the semiconductor

hours. However, there was an increase in the epitaxial structure's sheet resistance of 6–8% over the test period.

The research was carried out as part of Sweden's Microwave Wide Bandgap Technology project financed by Swedish Governmental Agency of Innovation Systems (VINNOVA), the Swedish Energy Agency, Chalmers University of Technology, Ericsson AB, Furuno Electric Co Ltd, Infineon Technologies Nordic AB, Norse Semiconductor Laboratories AB, Norstel AB, NXP Semiconductors BV, and Saab AB. United Monolithic Semiconductors (UMS) and the Fraunhofer Institute for Applied Solid State Physics (IAF) supplied materials for the study. ■

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Making III-V contact with silicon substrates

High-speed logic, high-frequency/high-power transistors and photonics systems could benefit from marrying with silicon substrates. One impediment to this is contact formulations that use gold. Researchers are working to find a way to union through gold-free contacts. Mike Cooke reports.

There has been a recent push to integrate III-V materials with silicon complementary metal oxide semiconductor (CMOS) field-effect transistor (FET) logic. This push is aimed in three directions: high-mobility channels for logic transistors, high-frequency/high-power nitride semiconductor devices, and photonics systems.

Indium gallium arsenide (InGaAs) is the main material being developed with a view to enhancing the performance of the CMOS logic circuits that are at the base of present day electronics. In particular, as these devices become smaller, the electronic properties of silicon are insufficient to overcome a series of 'short-channel effects'. InGaAs is attractive because it has a much higher mobility than silicon. InGaAs could also be used to produce photonic devices that detect and emit light into silicon-based waveguides with CMOS-controlled elements such as optical attenuators.

Further, since the development of gallium nitride (GaN) layers on silicon, researchers have considered the possibility of developing integrated devices combining the high-frequency/power/temperature capabilities of nitride semiconductors with the logic versatility of high-performance silicon electronics. A particular attraction is the commercial availability of 6-inch (150mm) GaN-on-silicon wafers that could be used in fabrication facilities originally designed for silicon devices such as silicon-based power transistors.

The road to such integration is not straightforward but has many problems that are being intensively worked on by researchers. One hurdle to overcome in this is the use of gold in producing ohmic connections to the source and drain (S/D) regions of III-V field-effect transistors, both for InGaAs (Table 1) and for nitride semiconductors.


The problem is that gold is 'banned' in silicon device fabrication, since gold produces acceptor and donor levels in silicon that poison device performance. Copper is another CMOS poison. However, copper has

Table 1. Possible contact materials for InGaAs devices.

Material system	$N_c(\text{cm}^{-3})$	$\rho_c(\Omega\text{-}\mu\text{m}^2)$	Type
Mo	3.6×10^{19}	1.3	n
Ni/Au-Sn/Ni	2.2×10^{18}	4	n
AuGe	2.2×10^{18}	8	n
Au-Ge-Ni	1×10^{17}	50	n
Au/Pt/Ti	3×10^{19}	20	n
Pd/AuGe	2.3×10^{19}	40	n
Au/Sn/Au	3×10^{19}	30	n
Ni/Au-Zn/Ni	1.5×10^{18}	2000	p
Au/Pt/Ti	2×10^{19}	1100	p
Pt/Ti	5×10^{18}	900	p
Pd/AuGe	4×10^{19}	400	p
AuBe/Pt/Au	2×10^{19}	750	p

found use in CMOS wiring in high-performance and/or low-power devices, although the metal has to be carefully separated from the CMOS layers with barriers consisting of materials such as tantalum or tantalum nitride.

The presence of gold in the typical nitride semiconductor ohmic metal layer stack titanium/aluminum/XY/gold (Ti/Al/XY/Au) is thought to improve the contact resistance by creating gallium vacancies in the nitride semiconductor material and by preventing oxidation of the stack by the atmosphere. The XY-layer is a diffusion layer (typically nickel, palladium or molybdenum). On the negative side, long-term gold diffusion has also been associated with degradation of the ohmic contacts. This latter possible effect gives another motivation for developing gold-free set-ups.

For nitride devices, selective doping of the S/D contacts has been attempted in creating gold-free processes, but these methods tend to reduce breakdown voltages and increase leakage currents. Complicated regrowth methods have also been tried — however, these would be expensive to implement in manufacturing. 

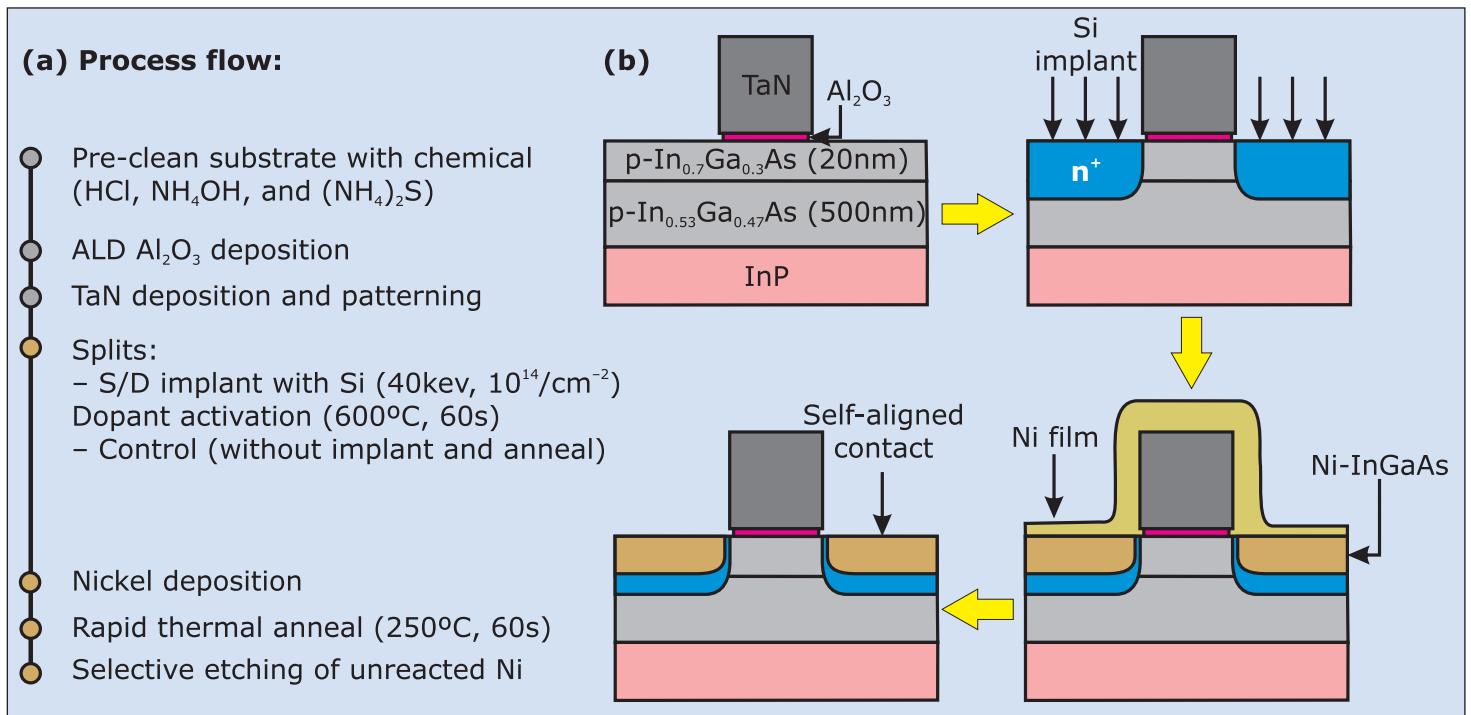


Figure 1. (a) Process flow for fabrication of In_{0.7}Ga_{0.3}As n-MOSFETs with self-aligned Ni-InGaAs contacts and metal S/D. (b) The salicide-like metallization process comprises a reaction of Ni with In_xGa_{1-x}As and a selective removal of excess Ni using a wet etch.

► Self-aligned InGaAs

With InGaAs MOSFETs, it is hoped to mimic silicon CMOS processes that presently use a self-aligned silicide ('SALicide') S/D process. The self-alignment uses previously patterned structures rather than a separate lithographic process (that would require precise alignment) to form the S/D contact regions.

National University of Singapore (NUS) and Taiwan Semiconductor Manufacturing Company (TSMC) claim the first demonstration of self-aligned nickel (Ni) source/drain contacts for InGaAs n-MOSFETs [Xingui Zhang et al, *Electrochemical and Solid-State Letters*, vol14 pH60, 2011, published online 19 November 2010].

Ideally, source/drain contacts should be ohmic. The reaction of the Ni with InGaAs during rapid thermal annealing creates a material with sheet resistance of 20Ω/square. The contact is found to be ohmic in the case of Ni annealed with n-InGaAs, while a Schottky (rectifying) contact is formed with p-InGaAs.

"This work (and that of others along similar lines) suffered from high off-state leakage current and a relatively low on-state to off-state current ratio," says one of the leaders of this research, Dr Yee-Chia Yeo.

"This problem has been resolved in our follow-up work [Xingui Zhang et al, *International Symposium on VLSI Technology Systems and Applications*, Session 2, T24, 25 April 2011]. In this new work, an n⁺ implanted region is introduced beneath the self-aligned Ni-InGaAs regions to suppress the off-state leakage current."

NUS/TSMC's salicide-like metallization process for Ni-InGaAs contacts (Figure 1) begins with surface

preparation and atomic layer deposition (ALD) of aluminum oxide (Al₂O₃) gate dielectric/insulator on the epitaxial InGaAs layers on indium phosphide (InP) substrates. The gate electrode consisted of tantalum nitride (TaN). A spacer was not used.

The application of a silicon implant step before the source/drain metallization was found to reduce the OFF-state current by a factor of 10 (Figure 2). The

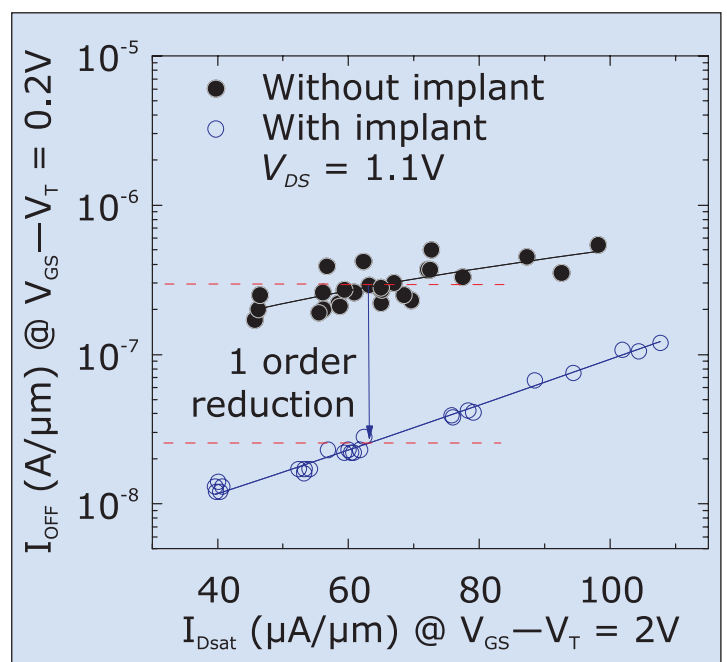


Figure 2. Devices with a source/drain (S/D) implant show a reduction of over one order of magnitude in the OFF-state current (I_{OFF}) in the saturation regime.

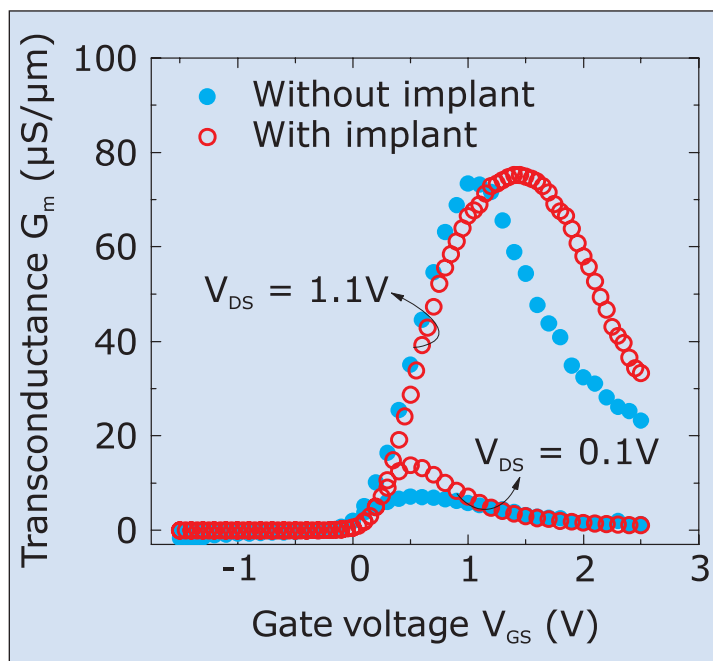


Figure 3. Transconductance-gate potential (G_m - V_{GS}) curves for devices with and without silicon implant of S/D regions. Slight G_m enhancement was observed for device with S/D implant.

implant also gave a slight enhancement to the transconductance (Figure 3) due to a 16% reduced S/D resistance (median values). The median sub-threshold swing was also reduced by 19% for the implanted devices (from a high value of ~ 250 mV/dec).

The n-MOSFETs reported last year had a gate length of $1\mu\text{m}$ and demonstrated an on-state/off-state drain current ratio of $\sim 10^3$ and peak transconductance G_m of $74\mu\text{S}/\mu\text{m}$. Earlier last year some of the same researchers used a nickel germanium formulation to produce the first CMOS-compatible III-V n-MOSFET with self-aligned contacts [reported at www.semiconductor-today.com/news_items/2010/JUNE/VLSI_180610.htm and *Semiconductor Today*, June/July 2010, p83].

Scientists variously based at University of Tokyo, National Institute of Advanced Industrial Science and Technology (NAIST), Sumitomo Chemical Co Ltd have also developed a self-aligned Ni-InGaAs alloy S/D process for application in InGaAs nMOSFETs [SangHyeon Kim et al, *Appl. Phys. Express*, vol4, p024201, 2011; reported www.semiconductor-today.com/news_items/2011/FEB/NAIST_040211.htm and *Semiconductor Today*, February 2010, p104]. With an $\text{In}_{0.7}\text{Ga}_{0.3}\text{As}$ channel, the device achieved an on/off current ratio of 10^4 and subthreshold slope of 147 mV/dec (a low figure indicates a desirable sharp turn-on of current). Other III-V devices have achieved 120 mV/dec and better. Silicon CMOS can achieve about 70 mV/dec, near to the theoretical limit of 60 mV/dec for planar structures.

In work presented at IEDM [*Semiconductor Today* Dec/Jan 2010/2011, p100], the US-based SEMATECH

industry research consortium reported on Al/TiN contacts, obtaining a source-drain resistance value of $1880.8\Omega\text{-}\mu\text{m}$, which the researchers believe is consistent with a sheet resistance of $300\Omega/\text{square}$ and a contact resistance $10^{-6}\Omega\text{-cm}^2$. An improved contact resistance of $10^{-8}\Omega\text{-cm}^2$ ($1\Omega\text{-}\mu\text{m}^2$) has been achieved in experiments, the details of which have yet to be published by SEMATECH.

For InGaAs photonics, the European Union framework 7 (FP7) projects Wavelength Division Multiplexed Photonic Layer on CMOS (WADIMOS, www.wadimos.eu) and pHOTONICS ELectronics functional Integration on CMOS (HELIOS, www.helios-project.eu) have supported work on gold-free contacts for InP-based photonics devices on silicon. In one France-based study [L. Grenouillet et al, 'CMOS compatible contacts and etching for InP-on-silicon active devices', Group IV Photonics conference, San Francisco, 9-11 September 2009], Ni/Al and Ti/Al were used as ohmic contacts on n-InP, giving contact resistance values of $2\times 10^{-5}\Omega\text{-cm}^2$ and $5\times 10^{-5}\Omega\text{-cm}^2$, respectively, without annealing. A CMOS-style Ti/TiN/AlCu stack was also investigated, giving contact resistances of $1\times 10^{-4}\Omega\text{-cm}^2$ on n-InP and $6\times 10^{-5}\Omega\text{-cm}^2$ on p-InGaAs, again without annealing.

Gold-free nitrides

For nitrides, Massachusetts Institute of Technology (MIT) has recently developed gold-free ohmic contacts on high-electron-mobility transistors (HEMTs) on silicon substrates with performance close to that of traditional contacts containing gold [Hyung-Seok Lee et al, *IEEE Electron Device Letters*, published online 20 March 2011].

The gold-free contact (Ti/Al/W) was much smoother, due, it is thought, to the absence of AuAl₄ alloys...

These results enable the fabrication of high-performance GaN power devices in silicon fabs without the risk of contaminating the silicon wafers

The MIT researchers used 4-inch (111)-oriented silicon wafers (100mm diameter) on which nitride semiconductor layers had been grown (Figure 4) using metal-organic chemical vapor deposition (MOCVD): the undoped GaN buffer layer was $1.8\mu\text{m}$ thick; the aluminum gallium nitride (AlGaIn, with 26% Al) barrier and undoped GaN cap layers were 17.5nm and 2nm, respectively.

The mesa isolation and recessing were carried out using electron cyclotron resonance (ECR) etching with boron trichloride/chlorine plasma. The metal contact stack was deposited using electron-beam evaporation. The gold-free stack consisted of titanium (Ti), Al and tungsten (W). The final tungsten layer forms a barrier to prevent oxidation of the Al. ▶

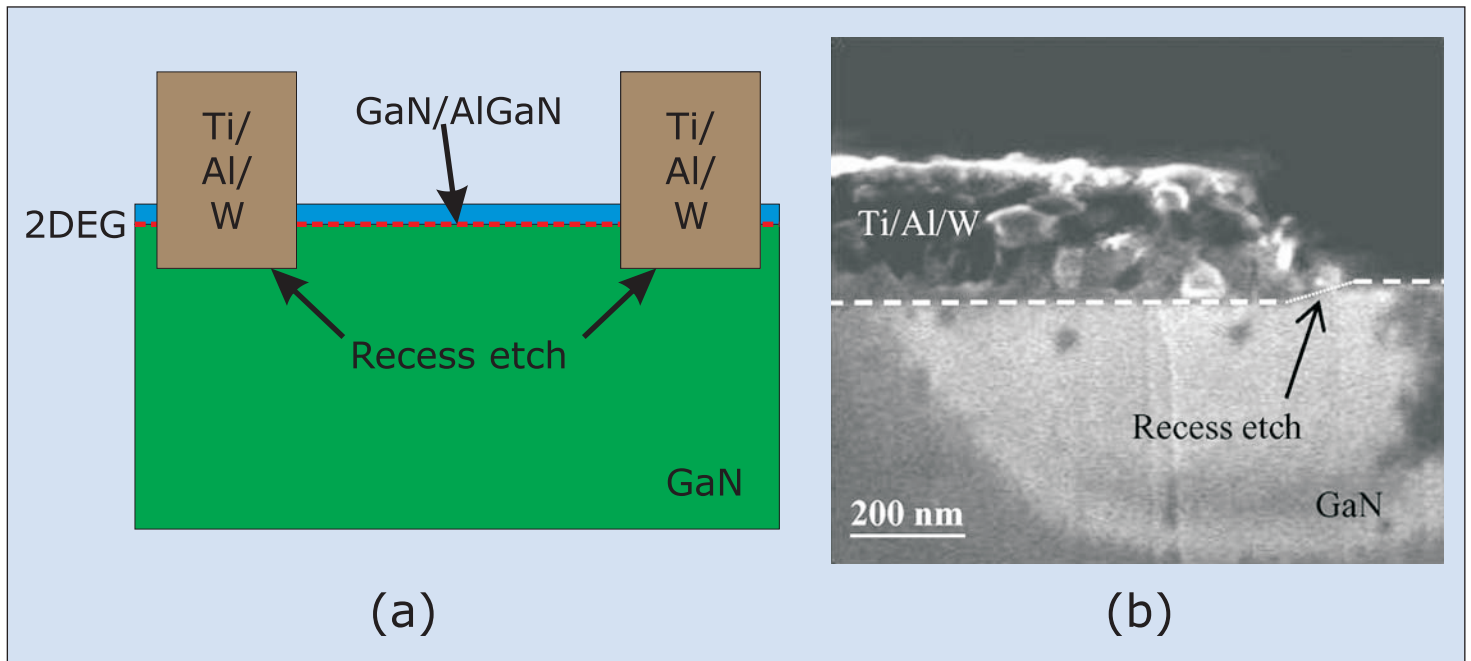


Figure 4. (a) Schematic cross section of the fabricated undoped AlGaIn/GaN HEMTs with S/D ohmic recess. (b) SEM image of the cross section of a Ti/Al/W contact after annealing. Before metallization, the ohmic contact region was recessed $\sim 30\text{nm}$.

► Rapid thermal annealing was used with a temperature of 600–1000°C. It was found that annealing at more than 800°C (900°C for samples without recess) was needed to give linear ohmic behavior.

Various recessing depths were tried: 0nm (i.e. no recessing), 15nm and 30nm. A gold-based stack (titanium-aluminum-nickel-gold) was also produced as a control sample. The lowest contact resistance for the gold-free set up was obtained with 30nm recessing: $0.49\Omega\text{-mm}$ with 870°C anneal. The best results for no- and 15nm-recessing were $2.02\Omega\text{-mm}$ (950°C anneal) and $1.71\Omega\text{-mm}$ (870°C). The anneal times for these results were 30 seconds.

The full recessing of 30nm puts the ohmic metal stack in contact with the two-dimensional electron gas (2DEG) that forms the channel of the nitride semiconductor HEMT. It is also thought that formation of nitrated Al and Ti after annealing reduces the energy barrier between the contact metal and 2DEG.

Specific contact resistances were measured using linear transmission line method (LTLM) structures (Figure 5a). The Ti/Al/W stacks with (30nm) and without recessing had specific contact resistances of $6.5 \times 10^{-6}\Omega\text{-cm}^2$ and $8.7 \times 10^{-5}\Omega\text{-cm}^2$, respectively. The value for the control Ti/Al/Ni/Au contact annealed at 870°C was $3.1 \times 10^{-6}\Omega\text{-cm}^2$. The contact resistance for the control was $0.38\Omega\text{-mm}$.

The researchers also studied the surface smoothness (Figure 5b) of the various contacts (morphology). The gold-free contact (Ti/Al/W) was much smoother, due, it is thought, to the absence of AuAl₄ alloys. Such smoothness is an advantage in highly scaled (i.e. ultra-small) devices.

Apart from the source–drain ohmic contact structures, all samples underwent nominally the same epitaxial and fabrication processes.

After the source–drain contacts had been formed, the gate structure (3nm Ga₂O₃ dielectric, Ti/Al/W metal electrode stack) was formed and 20nm Al₂O₃ passivation was applied using atomic layer deposition. The Ga₂O₃ dielectric was formed by exposing the gate region to oxygen plasma.

The produced transistors had gate lengths of 3 μm . The gate–source and gate–drain distances were both 1.5 μm . All the devices had a threshold voltage of about -2.2V (depletion-mode, normally-on), gate leakage less than 10mA/mm and 87V three-terminal breakdown (at a gate potential of -6V).

However, the 100mA/mm on-current behavior was much improved through recessing with a source–drain voltage drop of only 0.78V, rather than the 1.31V needed for the non-recessed sample. The traditional gold-based contacts had a 0.68V drop at the same current level. The recessed contacts therefore have only a 15% increased voltage compared with the traditional ohmic structure. Since the devices are ‘normally-on’, the gate potential in these measurements is zero.

The researchers conclude: “These results enable the fabrication of high-performance GaN power devices in Si fabs without the risk of contaminating the Si wafers, which enables the large-scale production of GaN power electronics.”

The MIT research was financially supported in part by the Advanced Research Projects Agency—Energy (ARPA-E) Agile Delivery of Electrical Power Technology (ADEPT) program. ►

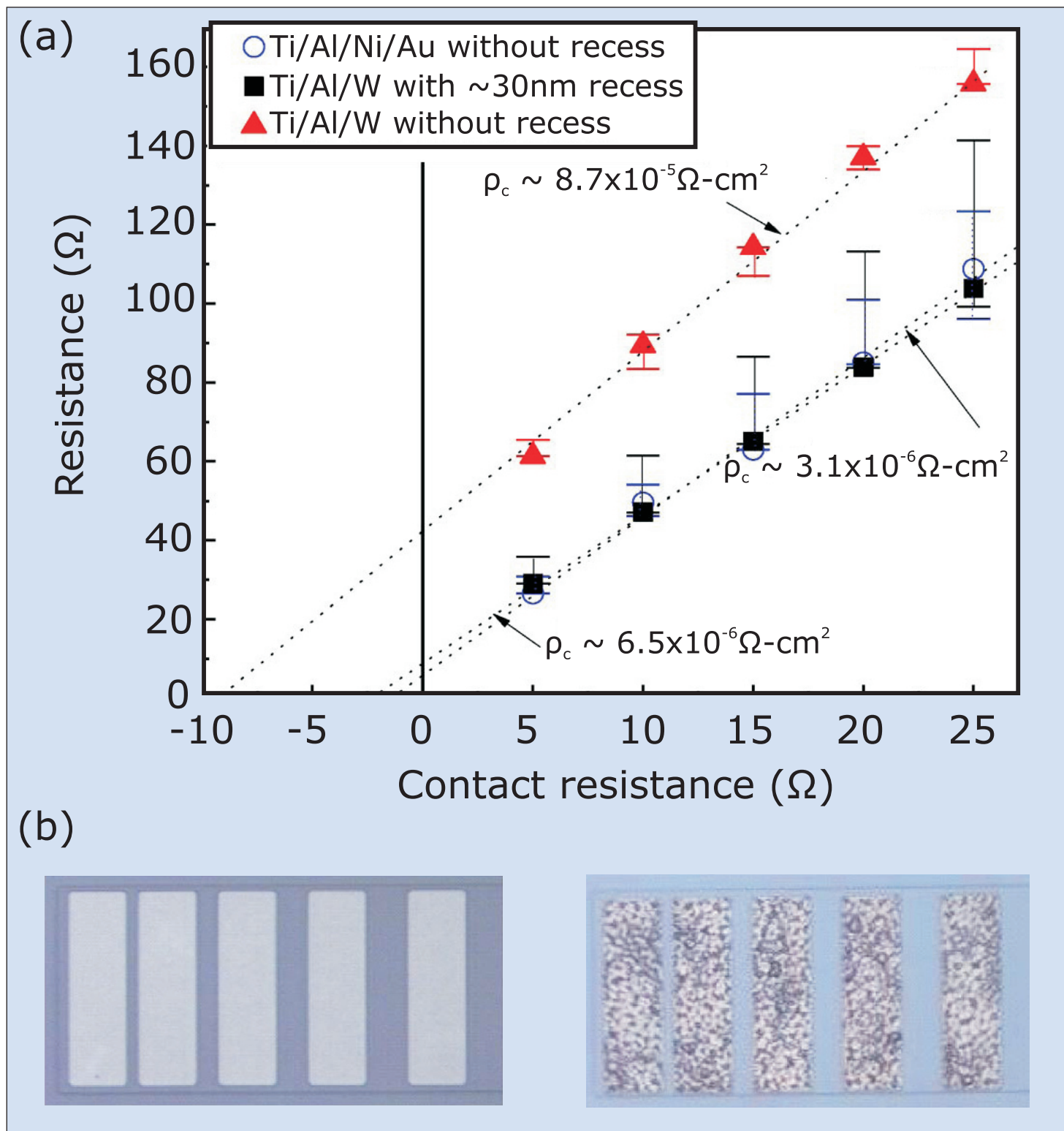


Figure 5. (a) Total resistance for different ohmic metallization processes as a function of contact distance. (b) Optical micrograph images of the surface for (left) Ti/Al/W recessed contacts and (right) standard Ti/Al/Ni/Au contacts.

▶ Another recent report of gold-free source-drain contacts for nitride HEMTs comes from Sweden's Chalmers University of Technology and France/Germany-based United Monolithic Semiconductors (UMS) [A Malmros et al, *Semicond. Sci. Technol.*, vol26, p075006, 2011; see separate report this issue]. Although this research was not directed towards

nitride HEMT integration with silicon, the researchers compared a traditional Ta/Al/Ni/Au metallization scheme with a gold-free Ta/Al/Ta formulation that might be of interest in such work. ■

Mike Cooke is a freelance technology journalist who has worked in semiconductor and advanced technology sectors since 1997.



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Connie Chang-Hasnain - University of California, Berkeley: „Novel Nanophotonic Devices“

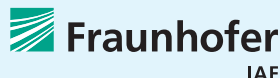
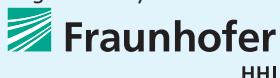
Meint Smit - Technical University Eindhoven: „A new era for InP-based photonics“

Rump session:

Semiconductor Quantum Dots for Electronics and Photonics: Promises and Accomplishments
organized by Dieter Bimberg, Technical University Berlin

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 UK
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 Fax: +44 1933 227814
www.MCP-group.com

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50 Simms Avenue,
 Providence, RI 02902,
 USA
 Tel: +1 401 456 0800
 Fax: +1 401 421 2419
www.thinfilmproducts.umicore.com

United Mineral & Chemical Corp

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 Lyndhurst,
 NJ 07071,
 USA
 Tel: +1 201 507 3300
 Fax: +1 201 507 1506
www.umccorp.com

2 Bulk crystal growth equipment

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 NM 87199-1687,
 USA
 Tel: +1 505 899 8183
 Fax: +1 505 899 8172
www.mrsemicon.com

3 Substrates

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 CA 94538,
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www.axt.com



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 Canada
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www.thefoxgroupinc.com

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 Fax: +86 755 89724120
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 Germany
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 Fax: +49 3731 280 106
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Kyma Technologies Inc

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sp3 Diamond Technologies

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Fax: +1 408 492 0633

www.sp3inc.com

**Sumitomo Electric
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www.sesmi.com

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The Fox Group Inc

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Fax: +33 1 45 10 69 53

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5 Deposition materials

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Dow Electronic Materials

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www.mathesontrigas.com

Mining & Chemical Products Ltd

(see section 1 for full contact details)

Power + Energy Inc

(see section 8 for full contact details)

Praxair Electronics

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Fax: +1 845 398 8304

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www.safchitech.com

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6 Deposition equipment

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E-mail: sales@microchem.com

www.microchem.com

Power + Energy Inc

(see section 8 for full contact details)

Praxair Electronics

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8 Wafer processing equipment

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9 Materials & metals

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www.cambridge-fluid.com

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USA

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Fax: +1 805 541 9399

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11 Process monitoring and control

k-Space Associates Inc

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MI 48103,
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USA

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Fax: +1 734 668 4663

www.k-space.com

k-Space Associates Inc specializes in in-situ, real-time thin-film process monitoring tools for MBE, MOCVD, PVD, and thermal evaporation. Applications and materials include the research and production line monitoring of compound semiconductor-based electronic, optoelectronic, and photovoltaic devices.



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USA
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www.suss.com

15 Assembly/packaging materials**ePAK International Inc**

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United Monolithic Semiconductors

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www.ums-gaas.com

19 Facility equipment**MEI, LLC**

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Fax: +1 412 471 9427
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www.crosslight.com

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www.semitech.us

22 Used equipment

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www.ClassOneEquipment.com

23 Services

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www.mw-zander.com

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24 Consulting

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France
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E-mail: jean-luc.ledys@neuf.fr

25 Resources

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E-mail: lubah@pennwell.com

www.sil-ledchina.com

10–12 May 2011

SEMICON Singapore 2011

Suntec, Singapore

E-mail: cchan@semi.org

www.semiconsingapore.org

15–19 May 2011

LIGHTFAIR International (LFI 2011)

Pennsylvania Convention Center, Philadelphia, PA, USA

E-mail: info@lightfair.com

www.lightfair.com

16–18 May 2011

International Symposium on Photonics and Optoelectronics (SOPO 2011)

Wuhan, China

E-mail: sopo@scirp.org

www.sopoconf.org/2011

16–19 May 2011

2011 CS MANTECH (International Conference on Compound Semiconductor Manufacturing Technology), plus

2011 Reliability Of Compound Semiconductors Workshop (ROCS, formerly GaAs REL Workshop)

Palm Springs Hyatt Grand Champion Hotel, CA, USA

E-mail: csmantech@csmantech.org

www.csmantech.org

www.jedec.org/home/gaas/default.htm

22–26 May 2011

Compound Semiconductor Week (CSW 2011): 38th International Symposium on Compound Semiconductors (ISCS 2011) and 23rd International Conference on Indium Phosphide and Related Materials (IPRM 2011)

Berlin, Germany

E-mail: hatice.altintas@vde.com

www.csw2011.org

22–27 May 2011

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Telchac, Mexico

E-mail: fsutara@fis.cinvestav.mx

<http://ldsd.cinvestav.mx>

23–26 May 2011

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www.world-of-photonics.net/en

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23–26 May 2011

23rd International Symposium on Power Semiconductor Devices and ICs (ISPSD '11)

Paradise Point Resort, San Diego, CA, USA

E-mail: ispsd@maxpowersemi.com

www.ispsd2011.com

23–26 May 2011

2011 International Conference on Frontiers of Characterization and Metrology for Nanoelectronics (IC-FCMN 2011)

MINATEC Innovation Campus, Grenoble, France

E-mail: fcmn2011@insight-outside.fr

www.nist.gov/pml/semiconductor/conference

25–26 May 2011

Imec Technology Forum 2011

Sheraton Brussels Airport Hotel, Brussels, Belgium

E-mail: Annouck.Vanrompay@imec.be

www.itf2011.be

29 May – 1 June 2011

35th Workshop on Compound Semiconductor Devices and Integrated Circuits (WOCSDICE 2011)

Catania, Italy

E-mail: info@wocsdice2011.org

www.wocsdice2011.org

5–10 June 2011

IEEE Microwave Theory and Techniques Society (MTT-S) International Microwave Symposium (IMS 2011)

incorporating 2011 IEEE Radio Frequency Integrated Circuits (RFIC) Symposium

Baltimore Convention Center, MD, USA

www.ims2011.org

8–9 June 2011

euroLED 2011

Ricoh Arena's Jaguar Exhibition Hall, Coventry, UK

E-mail: info@euroled.org.uk

www.euroled.org.uk

8–10 June 2011

Intersolar Europe 2011

New Munich Trade Fair Center, Munich, Germany

E-mail: sraithel@semi.org

www.pvgroup.org/intersolareu

12–16 June 2011

Advanced Photonics Congress

The Westin Harbour Castle, Toronto, Canada

E-mail: ustserv@osa.org

www.osa.org/Meetings/optics_and_photonics_congresses/Advanced_Photonics_Congress

14–16 June 2011

Photonics Festival in Taiwan

Taipei World Trade Center, Taiwan

E-mail: exhibit@mail.pida.org.tw

www.optotaiwan.com/en

15–16 June 2011

SEMICON Russia 2011

Expo Center Moscow, Russia

E-mail: semimoscow@semi.org

www.semiconrussia.org

19–24 June 2011

37th IEEE Photovoltaic Specialists Conference (PVSC)

Washington State Convention Center, Seattle, WA, USA

E-mail: Registration@ieee-pvsc.org

www.ieee-pvsc.org/PVSC37

21–22nd June 2011

S2K 2011

The University of Surrey, Guildford, UK

E-mail: jemi-enquiries@see.ed.ac.uk

www.semiconductor2k.com

21–24 June 2011

LED Tech Korea 2011 & Optical Expo 2011

Seoul, Korea

E-mail: led2100@naver.com

www.korealed.org

28 June 2011

3rd Concentrated Photovoltaics Summit US

San Diego, CA, USA

www.cpvtoday.com

3–8 July 2011

13th International Conference on the Formation of Semiconductor Interfaces (ICFSI-13): From semiconductors to nanoscience and applications in biology

Prague, Czech Republic

E-mail: icfsi13@fzu.cz

<http://pc220.fzu.cz/icfsi13/icfsi-13-1.html>

6–7 July 2011

UK Semiconductors 2011

Endcliffe Village, University of Sheffield, UK

E-mail: info@uksemiconductors.com

www.uksemiconductors.com

10–15 July 2011

9th International Conference on Nitride Semiconductors (ICNS-9)

SECC, Glasgow, Scotland, UK

www.icns9.org

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