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COMPOUNDS & ADVANCED SILICON

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Focus on silicon carbide LED plants set up in Asia

Osram & First Solar grow in Malaysia • Soitec buys Concentrix
Taiwan LED makers build in China • 3S Photonics buys Avensys

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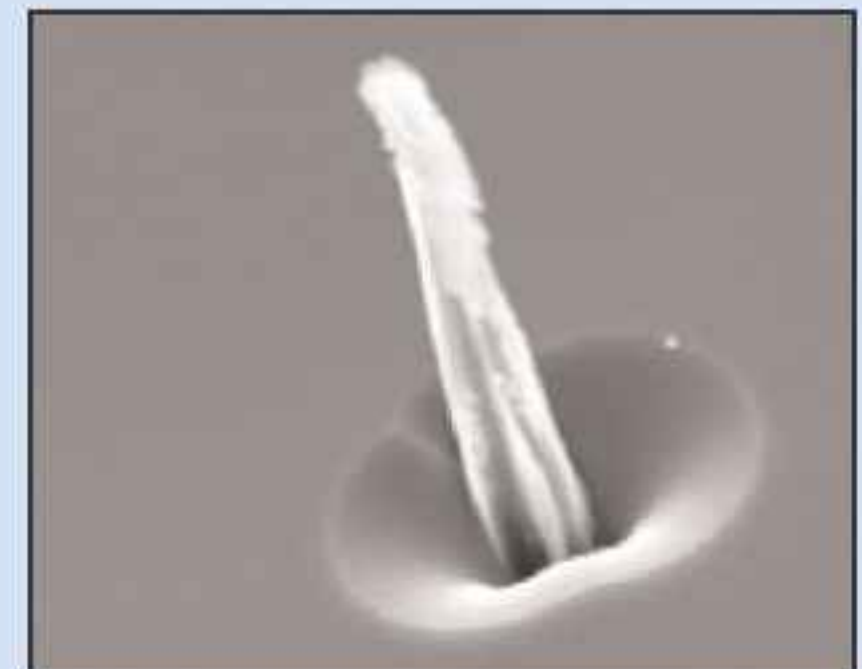
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p28 Osram's second LED chip plant, which has now started production operations in Penang, Malaysia.



p50 Solyndra's CIGS photovoltaic arrays on alwitra's roofing.



p54 Example of pillar formation during the etching of a via hole in silicon carbide.



Cover: Inside the cleanroom of Osram Opto Semiconductors' second LED chip plant, which has begun operation in Penang, Malaysia.

Two years after breaking ground in July 2007, the plant complements the firm's main LED chip fab in Regensburg, Germany (which was expanded in 2008). **p28**

LED light (& PVs, SiC etc) at the end of the tunnel

After last issue reporting how US-based LED makers Cree and SemiLEDs had announced that they were to establish LED chip fabrication plants in mainland China, this issue we report more investments in new LED plants in China, this time by Taiwanese LED chip makers Epistar, Arima Optoelectronics and Neo-Neon (see page 27).

Apart from the market prospects in China, the boom in demand for LEDs is being driven by both display backlighting (e.g. for TVs) and solid-state lighting (see data on pages 6–8, forecasting eight-fold growth in shipments of LED-backlit TV next year, a doubling in overall LED revenue by 2013, and a doubling in sales of MOCVD reactors by 2011).

Indeed, in addition to investments in China, the Korean LED maker Seoul Semiconductor has just received \$248m from Singapore's sovereign fund (page 26). Meanwhile, German LED maker Osram is starting production at its second LED chip fab, in Malaysia (page 28). Malaysia is also to see the addition of eight more production lines at the plant in Kulim of CdTe photovoltaic module maker First Solar (now the largest single PV manufacturing firm of any type, with demand boosted partly by its huge 2GW deal with China for a plant in Inner Mongolia) — see page 48.

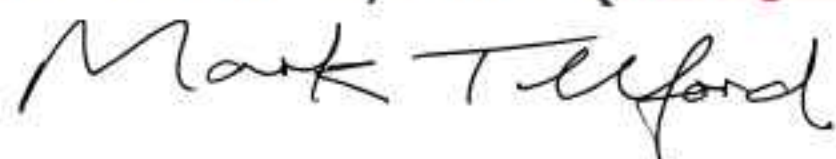
While the benefits of compound semiconductors such as energy efficiency and generation are driving the current resurgence in demand for products like LEDs, an unintended consequence of one of their virtues is ironically being exposed by the current unusually cold weather in the USA and Europe: LEDs waste so little energy in the form of heat that they can't melt the snow off traffic lights! While this should hardly sound the death knell of the LED, maybe — on 1 April perhaps (in the 'wake' of the UN Climate Change Conference in Copenhagen) — we will see a proposal to re-engineer a heating filament back into LED traffic lights...

The cold weather has also thwarted the electric-powered trains entering from snowy France into the warm Channel Tunnel to the UK, with the ensuing condensation overwhelming the onboard electrical equipment. While not necessarily connected, such eventualities may be relevant to the use of future technology such as silicon carbide transistors for power switching in the motors of hybrid electric vehicles, as well as the inverters of photovoltaic systems and, possibly, power electronics devices in smart grid infrastructure (applications of compound semiconductors that are set to be boosted by climate change concerns) — see market forecasts on pages 4–5 (and 51, where thin film is forecast to more than double from 14% to 31% of all PV module production by 2013).

In this issue in particular, we focus on silicon carbide, including the sometimes unique demands of processing the material, such as etching back-side through-substrate via holes (see the report on developments by both Fujitsu and TriQuint on pages 54–55) as well as proposals by Fuji Electric for two-step annealing of U-shape trenches in SiC MOSFETs.

Next issue we will detail the latest developments on other materials (GaN and III-V-on silicon) reported at early December's IEEE IEDM 2009 meeting.

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

Regular issues contain:

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

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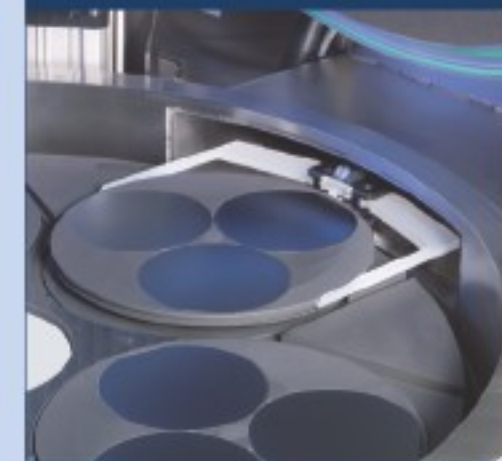
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GaAs integration to stave off silicon challenge

The GaAs industry is creating innovations designed to stave off the dual challenges of integration and low-cost silicon technologies, but heterojunction bipolar transistor (HBT) and high-electron-mobility transistor (HEMT) processes will continue to underpin the commercial market for GaAs devices, which will be worth \$4–5bn by 2013, according to the study 'GaAs MMIC Process Technology Roadmap' from Strategy Analytics.

Bipolar field-effect transistor (BiFET) and bipolar high-electron-mobility transistor (BiHEMT) processes enable GaAs device makers to integrate HBT power amplifiers onto a single die with HEMT-based

switches and other functions. Meanwhile, the use of optical lithography for the production of smaller-geometry processes will enable more cost-effective production of millimeter-wave integrated circuits.

"BiFET and BiHEMT technologies will enable the development of a future class of products, providing integrated solutions that retain the industry-leading performance offered by GaAs and necessary for next-generation wireless markets," notes Steve Entwistle, VP of Strategy Analytics' Strategic Technologies Practice.

"GaAs is still erroneously perceived by many as an exotic, expensive technology," says Asif Anwar,

director of the Strategy Analytics GaAs and Compound Semiconductor Technologies Service. "The reality is that GaAs technologies continue to meet the requirements from cost-sensitive markets, such as cellular handsets, and is the most cost-effective technology for markets that require millimeter-wave performance," he adds.

"The application of optical lithography for millimeter-wave IC production will significantly enhance the cost-effectiveness of GaAs compared to silicon technology-based offerings, while retaining the benefits of performance and faster time-to-market," Anwar concludes.

www.strategyanalytics.com

Smart grid market creating opportunities for GaN & SiC

Smart grid infrastructure requirements will create significant opportunities for advanced materials suppliers ranging from compound semiconductors including gallium nitride (GaN) and silicon carbide (SiC) to the latest nanomaterials, according to a report from analyst firm NanoMarkets.

The report 'Opportunities for New Materials and Devices in the Smart Grid: 2010 to 2017' also claims that new smart grid infrastructure products will create a \$12bn revenue opportunity for suppliers of components, wires, cables, storage devices and insulators.

The use of composite materials will allow the smart grid to carry much larger currents and voltages than today, forecasts NanoMarkets. These materials are already making a difference in the form of composite cabling that offers 2–4 times the capacity of conventional transmis-

sion cabling. But within a few years nanocomposite dielectrics will be used as fillers in grid insulators, with dramatic improvements in voltage endurance, breakdown strength, component size, and aging characteristics. By 2017, such nano-dielectrics are expected to account for more than \$500m in revenues.

Silicon carbide is already beginning to replace silicon in grid power electronics devices, and gallium nitride, zinc oxide and industrial diamond may also in the future, reckons NanoMarkets. Using devices made with these materials, electricity grids will be able to carry more electricity and fewer switching devices will be needed than in existing grid infrastructure; switching losses are said to be half of those for equivalent silicon devices. By 2017, more than \$400m in non-silicon

power electronics devices will be sold into grid applications, the market research firm projects.

By 2017 about \$350m will be spent on superconducting cables and fault current limiting (FCL) devices for the smart grid, NanoMarkets adds. Initially, superconductive cabling will be used in short lengths in strategic areas such as grid interconnects, but expected price declines will eventually drive superconductors into long-haul transmission systems.

Deploying superconductors in smart grid cabling will reduce line losses, assure stable voltage, and expand current carrying capacities. Only carbon nanotube wires promise higher conductivity than superconductors, but nanotube wire deployment lies many years in the future, concludes NanoMarkets.

www.nanomarkets.net

Solar cells to return to high growth in 2010

This year marked the solar industry's first cycle, with end-market demand shrinking 14% year-over-year, according to DisplaySearch's Q4/2009 'Quarterly PV Cell Capacity Database & Trends Report'.

Contraction was due to changes in Spain's generous incentive policy, and was severely aggravated by the global economic crisis and tight credit markets, explains the market research firm. Excess manufacturing capacity has helped push average PV system prices down by more than 25%. However, these lower prices, diversification of the demand base, and positive incentive movement in multiple regions are now expected to drive substantially higher demand in 2010.

"Despite the long-term bright outlook for solar, 2009 demonstrated the industry's cyclical nature and that it is still highly dependent on incentives," states Charles Annis, VP of manufacturing research. "During 2009, there has been nearly 60% over-supply in cell capacity, which means that average fab utilization rates have only been around 40% industry-wide," he adds.

"In the first half of 2009, most solar cell manufacturers were under severe pressure and were losing money," he continues. "However,



Solar cell end-market demand, showing dip in 2009.

because the PV industry is so broad-based and diverse, many of the leading producers have already returned to profitability and are running factories at high utilization and moving forward with expansion plans." Demand in second-half 2009 is proving to be robust and setting the stage for 38% growth next year.

DisplaySearch predicts that solar cell manufacturing capacity will grow 56% to more than 17GW in 2009, then slow in 2010–2011 as demand starts catching up to capacity.

Due to the current cell overcapacity, some firms are shuttering older lines and delaying ramp-up and new investments. Q-Cells is shutting down its first four lines in Germany, as they are not as productive as newer fabs, and adjusting ramp-up

at newer Malaysian lines. This leaves it with 836MW of ramped capacity, causing it to slip to fourth place in 2009 behind First Solar (the dominant CdTe-based PV manufacturer), Suntech and Sharp, with cell capacities of 1,092MW, 950MW

and 870MW, respectively.

However, many firms clearly believe in the long-term, high-demand growth scenario and going forward with large-scale capacity projects, says DisplaySearch. In Japan, Showa Shell Solar is due to start construction next year on a 900MW copper indium gallium diselenide (CIGS) PV product factory in Miyazaki, and Sharp has just reiterated its plans to begin ramping its 480MW thin-film line in Sakai by March, producing triple junction amorphous silicon (a-Si) modules with a conversion efficiency of 10%.

DisplaySearch concludes that by 2012/2013 cell makers will likely need to be adding more capacity to keep up with forecast demand.

www.displaysearch.com

SiC power transistors to impact PV inverter market

Many PV inverter manufacturers are investigating the option of using a silicon carbide Schottky diode within low-power inverter designs, since this can increase overall system efficiency by nearly 0.5%, according to IMS Research's report 'The Global Market for SiC & GaN Power Semiconductors – 2009'. Also, the Fraunhofer Institute for Solar Energy Systems new record of over 99% efficiency for a PV inverter using SiC JFETs has raised eyebrows in power electronics.

SiC has been on the verge of making a big impact on power semicon-

ductors for many years. Compared to silicon, it offers the advantages of low switching and conduction losses, and higher temperature and frequency capability. However, higher cost and device limitations at higher currents remain the largest barriers to mass adoption.

Many supporters of SiC within the PV industry argue that cost is already comparable. Manufacturers still have to pay a premium for the SiC diodes themselves, but inverter systems using the devices can be run at higher frequencies, leading to cost savings in other areas of the

inverter, such as the inductors. There are also other advantages to running the system at higher frequencies, including the reduction of system noise.

"The jury is still out on the implementation of SiC power transistor within PV inverters," says analyst Josh Flood. "Nevertheless, the strong likelihood of a SiC MOSFET being commercially available on the market within the next 4–6 months, and power modules integrating SiC JFETs, will add another dimension to SiC artillery against silicon."

www.imsresearch.com

HB-LEDs to drive doubling of annual MOCVD sales from 208 systems in 2009 to 415 systems in 2011

The high-brightness light-emitting diode (HB-LED) market is expected to explode as unit shipments more than double between 2009 and 2012 according to market research firm The Information Network in its report 'The Solid State Lighting Revolution: Market Analysis And Insight On Reducing Manufacturing Costs'.

"The rapid increase in the market for HB-LEDs used in various applications such as notebook backlights and automobile headlights is also spurring heavy capital investments by LED makers," says president Dr Robert Castellano. "LEDs are creating a niche market for conventional suppliers of semiconductor processing tools and a lucrative market for MOCVD suppliers."

In particular, MOCVD reactor maker Veeco Instruments Inc of Plainview NY, USA notes that a consensus from six sell-side analysts forecasts a doubling in MOCVD demand, from 208 tools in 2009 to 415 tools in 2011.

The Information Network's analysis indicates that in 2009 each MOCVD tool was capable of processing about 30 million LEDs. In 2011, based on the same throughput, there will be a cumulative supply deficit of 15.5 million LED units, unless MOCVD equipment suppliers increase throughput and yields to reduce cost of ownership (CoO). The US Department of Energy's Solid State Lighting Manufacturing Roadmap targets a factor of two improvement in CoO for manufacturing equipment every five years. If suppliers are successful, then enhancements in processing time, uniformity, repeatability, temperature control, and flow geometries will mitigate the supply deficit, says the market research firm.

"Clearly it is not within the best interests of MOCVD tool suppliers to improve CoO as it will reduce sales," adds Castellano. "But competition is the key enabler, which will force suppliers to enhance their tool capabilities," he adds.

HB-LEDs are currently a \$5bn niche market compared to the \$250m semiconductor market. The consensus forecast of 415 MOCVD tools represents a market of greater than \$1bn (based on an average selling price of \$2.5m for each MOCVD tool). MOCVD therefore represents 8% of the typical cost breakdown for a packaged LED. Other front-end tools represent more than 3% of the cost and equate to an additional \$500m market for lithography and metrology tools. The biggest sector, 65%, consists of back-end processes such as substrate removal, chip separation, and packaging.

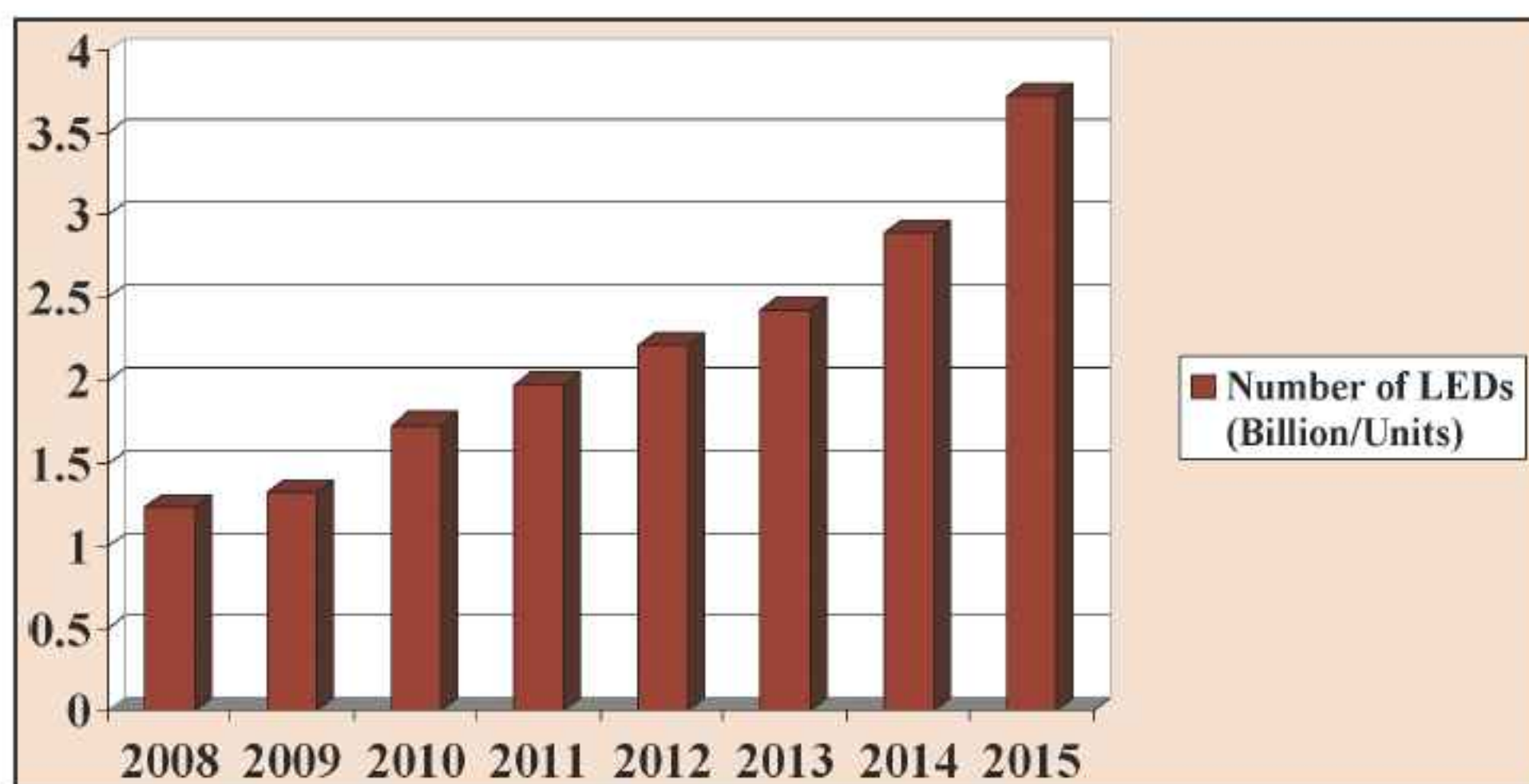
The Information Network notes that backlight sectors will exhibit the fastest growth in the HB-LED market, with an overall compound annual growth rate (CAGR) of more than 40%, led by the LCD TV sector with a CAGR of 300.3% between 2007 and 2012.

www.theinformationnet.com

LED consumption in general lighting to triple from 1.2 billion units in 2008 to 3.7 billion units by 2015

Global consumption of component-level LEDs used in general lighting applications reached over 1.2 billion units in 2008 and will more than triple to 3.7 billion LEDs by 2015, reckons market analyst ElectroniCast Consultants in its forecast of the worldwide consumption of single- and multiple-chip packaged LED 'component-level bulbs' used in selected solid-state lighting (SSL) general lighting applications.

"The Asia Pacific region (APAC) will show a huge 'hockey-stick' growth pattern, especially in the years 2013 to 2015 for both the exterior and interior general lighting applications," says Stephen Montgomery, president of International Business at ElectroniCast.



LEDs used in solid-state general lighting (billion units).

"We expect the worldwide use of white HB-LEDs in solid-state general lighting systems to exceed

1 billion units by 2015," adds Montgomery.

www.electronicast.com

LED market to nearly double to \$14.3bn by 2013

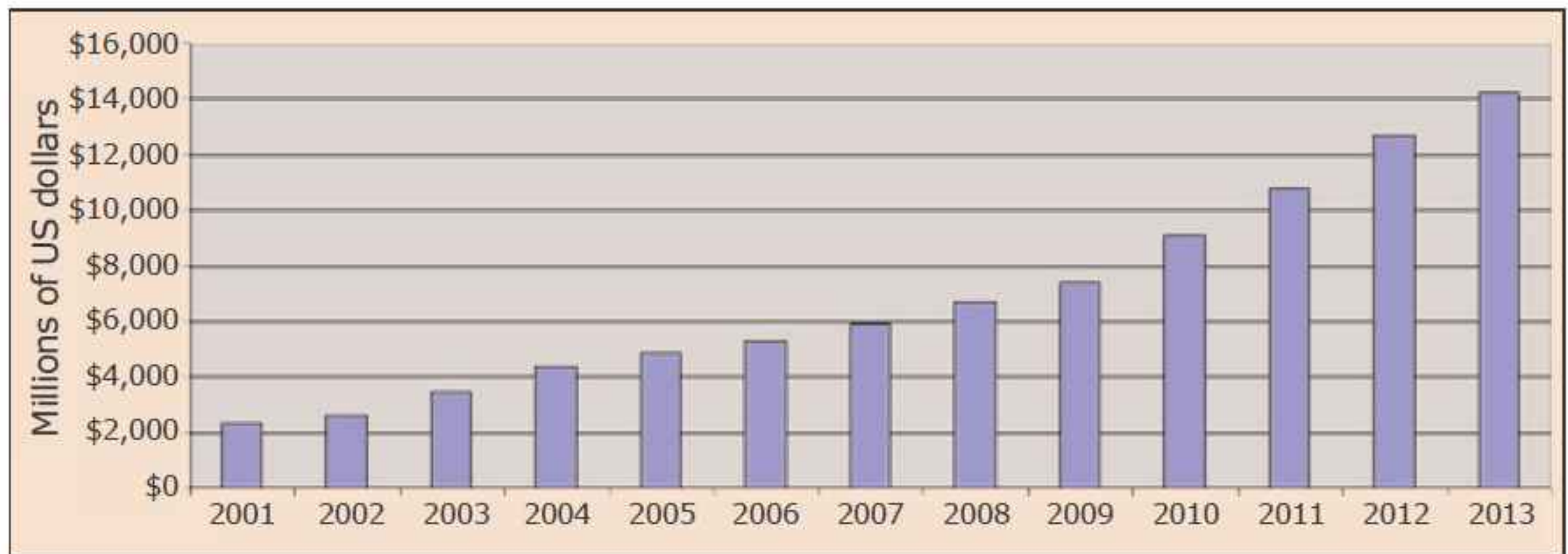
The use of LEDs for general illumination in the coming holiday season is paving the way for double-digit LED market growth in 2009 followed by a near doubling in revenue by 2013, according to iSuppli Corp in its report 'Solid State Lighting: Backlighting of LCD TVs and General Illumination

Drive a Bright Market for LEDs'.

Multiple retailers around the world are actively promoting LED lights for indoor and outdoor decorative illumination applications. Meanwhile, LED lights with Edison sockets used for replacing conventional light bulbs are starting to appear on the shelves of many of these stores, making them a viable choice for general illumination applications, iSuppli says.

"The LED industry is on the threshold of a new expansion phase — a phase that will be characterized by growth rates in the high double digits during the next three years," says Dr Jagdish Rebello, director & principal analyst. "This growth will be driven by the increased adoption of high-brightness (HB) and high-flux [high-power or ultra-high-brightness (UHB)] LEDs into a new range of next-generation lighting applications," he adds. LED revenues were \$6.7bn in 2008, and will grow by 10.9% in 2009 to \$7.4bn (in stark contrast to the overall semiconductor market, which is expected to contract by 12.4% because of the slowdown in the global economy). By 2013, the LED market will reach \$14.3bn, nearly double from 2009.

Beyond general illumination, this growth is being driven by the rising penetration of LEDs as the lighting source of choice for many existing lighting applications, including automotive, traffic and street light-



Global LED market revenue forecast (millions of US dollars).

ing, the backlighting of small LCD displays and keypads in mobile handsets, personal navigation devices, digital picture frames and cameras. The market is also being boosted by the emergence of new applications, such as backlighting of large-sized LCDs in TVs, notebooks and computer monitors and personal illumination.

As predicted by iSuppli in 2007, LEDs have now started to penetrate the general illumination market for residential dwellings and enterprise offices. Also, while the retail prices for LED light bulbs are still about an order of magnitude higher than those of traditional incandescent lamps, customers are increasingly becoming aware of the power savings and long-life benefits of solid-state LED lights, says the market research firm.

As expected, the solid-state lighting market for HB and high-flux devices will outpace overall LED market growth through 2013. Over these next three years, the traditional market for standard-brightness

LEDs will fall by about 2.5%, while the market for HB-LEDs will grow by 6.7% to about \$5.4bn and the market for high-flux LEDs will grow by almost 53% to reach \$7.8bn.

The solid-state lighting market for HB and high-flux devices will outpace overall LED market growth

For general illumination, the development of high-flux LED light bulbs with luminous efficacy exceeding 100 lumens per watt — and designs that allow LEDs to run on AC current without the need for an inverter — are pushing LEDs closer to adoption in the mainstream general illumination market, says iSuppli.

LEDs are already being used in various indoor and outdoor decorative illumination applications and are just starting to target the market for general lighting in homes and enterprises, the firm continues. In addition to the performance advantages offered by solid-state lighting, legislation around the world is increasingly seeking to ban the use of incandescent light in favor of more energy-efficient light sources, pushing LEDs rapidly into mainstream general illumination.

Even in the near term, the advantages of solid-state lighting are beginning to outweigh the cost differential between LEDs and compact fluorescent lamps (CFLs), says iSuppli. As progress is made in LED performance, the cost differential will continue to narrow.

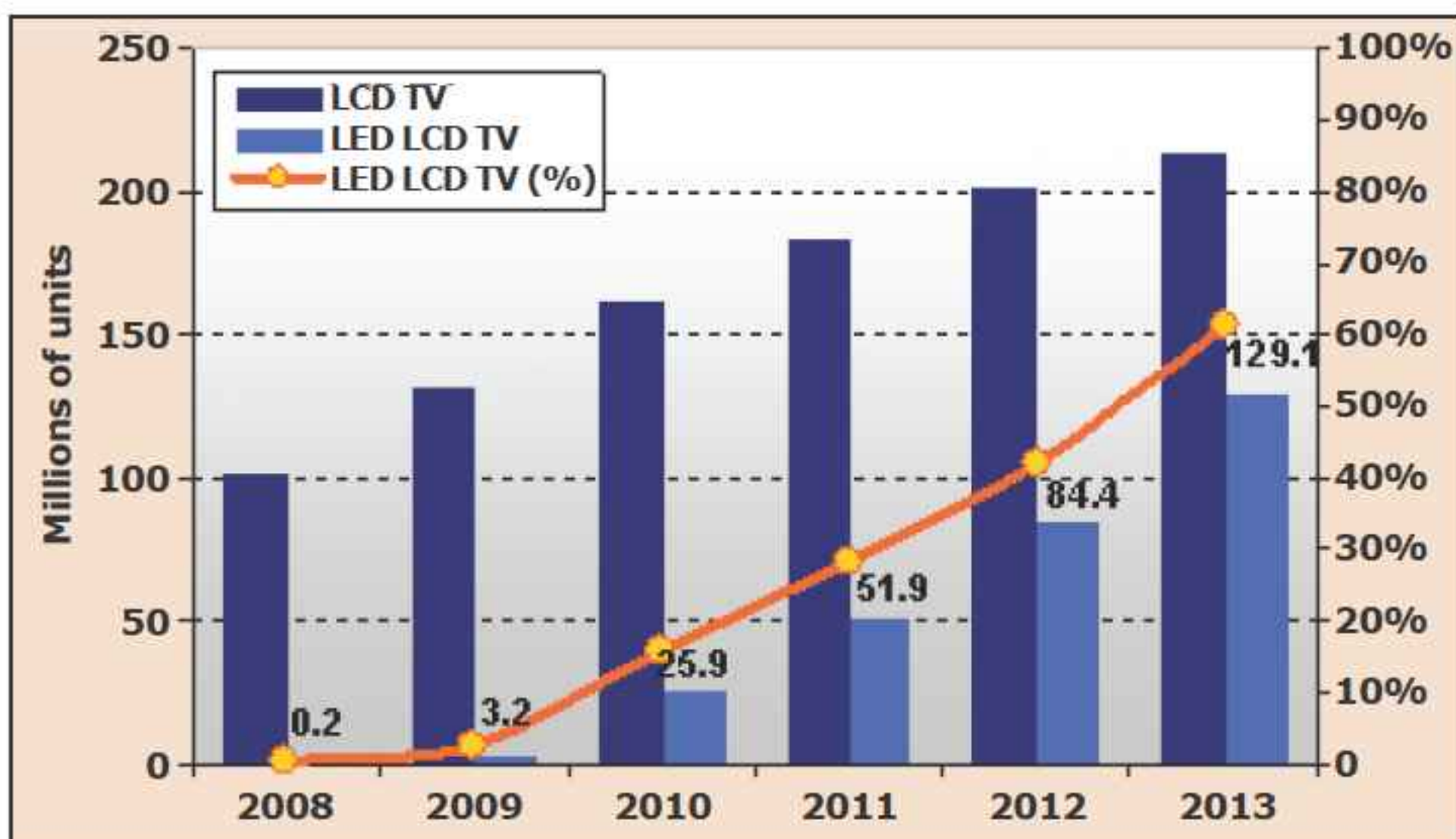
"iSuppli projects that LED light bulbs will address the residential and enterprise general illumination market in earnest in 2010," says Rebello. "Without a doubt, the long-term future of general illumination is LEDs."

www.isuppli.com

LED TV shipments to grow eight-fold to 26 million in 2010

Five years after their launch by Sony in 2004, overall LED-backlit LCD TV shipments rose from just 200,000 in 2008 to an expected 3.2 million units in 2009, marking the first year of general commercialization, according to market research firm DisplayBank's newly updated 'LED LCD TV Roadmap and Market Forecast'. Shipments are expected to then grow more than eight-fold to 25.9 million in 2010 (16% of a total 162 million LCD TVs), and then double to 51.9 million in 2011 before growing to 84.4 million in 2012 and 129 million in 2013 (61.5% of the LCD TV market).

The LCD TV has been expanding its market share continuously along with radical advances in technology in a short period of time, says DisplayBank. Ongoing development of the LED light source appears likely to generate more added-value to the LCD TV industry, adds the firm. With consumers favoring edge-type LED backlighting (which allow slimmer product design) compared with direct-type LED backlighting (which provides better picture quality), in second-half 2009 many TV makers launched edge-type LED-backlit



LED-backlit LCD TV roadmap and market forecast by maker.

LCD TVs. These are expected to account for 82% of all LED-backlit TVs in 2009 and to continue to show strength in 2010, reckons the market research firm.

In addition, large-size (40–50") models launched in 2009 accounted for the biggest segment of the market. However, in 2010, 40" and 30" models are expected to comprise 50% and 29% respectively, as LED-based LCD TVs are projected to also extend to models below 30".

Major TV brands will aggressively target the LED-based LCD TVs market in 2010. Samsung aims to ship more than 10 million units, LG, Sony, and Sharp 5–7 million each and Philips, Toshiba, and Vizio 3–5 million each. Such vendors are generally looking to ship 20–30% of their LCD TVs with LED backlights in 2010, and in some cases as much as 40%, concludes Allan Ji, a senior analyst at DisplayBank.

www.displaybank.com

Market for LEDs in LCD TV backlighting to grow at CAGR of 148% to \$7.5bn in 2013

The market for packaged LEDs used in LCD TV backlights will see rapid growth at a compound average growth rate (CAGR) of 148%, starting in 2010 and reaching \$7.5bn in 2013 as major suppliers deploy the technology in volume, forecasts market research firm Strategy Analytics in its 'Flat-Panel TV LED Backlighting Report 2008–2013'.

In 2008, the market penetration of LED-based backlighting in LCD TVs was less than 1%, but high-profile marketing campaigns in 2009 have raised consumer awareness of the technology. As it penetrates smaller and cheaper TV models in 2010 and

beyond, demand for LEDs will ramp up, says the market research firm. Although conservative compared with public statements from some TV companies, Strategy Analytics concludes that, by 2013, 68% of all LCD TVs will feature LED backlights.

"LEDs have featured in high-end LCD TVs for some time, but

In 2008, the market penetration of LED-based backlighting in LCD TVs was less than 1%... By 2013, 68% of all LCD TVs will feature LED backlights

now they are entering the mainstream," notes Asif Anwar, service director at Strategy Analytics. "With low-cost suppliers now adding to this momentum, LED backlighting of TVs will witness a serious production increase," he predicts.

Other findings of the report include that:

- 2009 has seen a rapid transition toward edge-type backlights that exploit high-performance white packaged LEDs; and
- direct-type backlights and RGB (red–green–blue) designs offer advantages of both localized dimming and higher picture quality.

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IN BRIEF

TriQuint simulates entire MMIC using 3D planar EM solver

High-frequency electronic design automation (EDA) software tool provider AWR of El Segundo, CA, USA says RF front-end product maker TriQuint Semiconductor Inc of Hillsboro, OR, USA has used its AXIEM software to simulate an entire monolithic microwave integrated circuit (MMIC) non-uniform distributed power amplifier (NDPA) on a quad-core PC with 4 Gbytes of RAM and a 32-bit operating system. This is first time the firm has been able to electromagnetically simulate an entire structure of this size on a desktop PC.

Electronic warfare (EW) systems require MMIC amplifiers that deliver high power over broad bandwidths with high efficiency, for which TriQuint's NDPA approach is well suited, says AWR. However, designing such complex devices requires accurate electromagnetic (EM) data up to the fifth to seventh harmonic frequency, which results in a very large mesh/matrix of up to 32 ports and 30,000 unknowns. As a result, solving the entire structure has not been practical using available EM solvers.

However, AWR says that AXIEM's near-linear scaling allowed TriQuint to simulate the entire NDPA MMIC from DC to 120GHz in under 2 minutes per frequency. It adds that the achievement was made possible by AXIEM's shape pre-processor and hybrid adaptive meshing algorithms, which shrank the final mesh size to just over 6000 unknowns. The MMIC demonstrates saturated RF output power of 9–15W over a broad frequency range of 1.5–17GHz with power-added efficiency greater than 20%.

www.awrcorp.com

RFMD raises free cash flow guidance and retires \$197m of debt

GaAs power amplifier maker RF Micro Devices Inc of Greensboro, NC, USA says it has completed all previously announced restructuring activities.

The firm hence expects continued strength in financial results, with an emphasis on non-GAAP operating income, free cash flow (net cash from operating activities minus property and equipment expenditures) and return on invested capital (ROIC). In fiscal second-quarter 2010 (ended 3 October 2009), RFMD delivered year-over-year and sequential improvements in gross margin, operating margin and earnings per share. Free cash flow was \$45.8m in fiscal Q2 and \$80.3m through fiscal first-half 2010.

RFMD now expects that free cash flow in fiscal 2010 will exceed its guidance of \$130m provided on 27 October. The firm also expects to be net cash positive in fiscal 2011 (ending 2 April 2011).

"The new RFMD is positioned today to achieve strong financial results and continued leadership in lucrative and growing core markets," says president & CEO Bob Bruggeworth.

"With our restructuring activities complete, we are focused sharply on building superior shareholder value through profitable growth and ROIC in excess of our cost of capital," he adds. "RFMD is commencing new technology and product cycles, and we are at the forefront of exciting new secular growth trends, such as data mobility, smart grid deployment and alternative energy generation."

● With cash, cash equivalence, short-term investment and trading security investment of \$357.8m at the end of fiscal Q2, RFMD has used cash on hand to repurchase and retire \$197m of its convertible subordinated notes prior to their maturity in July 2010 (paying the principal amount of the notes plus accrued interest). RFMD hence expects to save about \$1.9m in further interest expense.

The aggregate amount of 2010 notes outstanding is now about \$10m (down from \$230m at issue). Since the March 2008 quarter, RFMD has repurchased 30 million shares of common stock and retired about \$262m original principal amount of total convertible debt.

RFMD ships 25 millionth 2G transmit module

RFMD has surpassed 25 million units in shipments of its RF71xx family of 2G dual-band and quad-band transmit modules. Volume shipments of the RF71xx family began in early 2009, and currently exceed 20 million units per quarter.

"The success of the RF71xx product family has been central to RFMD's growth in 2G components and our expanding leadership in Asia," says Eric Creviston, president of RFMD's Cellular Products Group (CPG). "To date, RFMD has shipped RF71xx products to hundreds of customers in China, Taiwan and Korea, and the product family continues to enjoy robust design activity across handset manufacturers and global platform providers

as we continue to develop specific product derivatives."

RFMD says that each product in the RF71xx range is designed to meet the front-end requirements of emerging market handsets, including reduced solution size, improved efficiency and robust ESD protection, while also satisfying requirements for quality, reliability and reduced handset bill-of-material (BOM) costs. The transmit modules are pin-to-pin compatible across the entire product family, enabling the production of dual-band, tri-band or quad-band GPRS or EDGE handsets from a single handset platform (claimed to be an industry first).

www.rfmd.com

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IN BRIEF

Upgraded PDKs for UMS GaAs MMIC foundry processes

At the Asia-Pacific Microwave Conference (APMC 2009) in Singapore (7–10 December), high-frequency electronic design automation (EDA) software tool provider AWR of El Segundo, CA, USA has announced the availability of enhanced process design kits (PDKs) for the PH15 and PH25 gallium arsenide foundry processes of United Monolithic Semiconductors (UMS).

UMS designs and produces RF, microwave and millimeter-wave components and ICs for telecom, space, defense, automotive and industrial, scientific and medical (ISM) sectors at its plants in Orsay, France and Ulm, Germany.

The enhanced PDKs enable designers to take full advantage of UMS' process capabilities within AWR's 2009 Microwave Office design suite, including its latest technologies such as iNets, AC0E, AXIEM and ICED DRC.

"Users of these enhanced PDKs will not only be able to fully exploit the latest features within Version 2009 of AWR's software," says UMS' foundry manager Eric Leclerc. "They can also take advantage of the fact that these PDKs are now release-independent from AWR's own software upgrade cycle," he adds.

UMS has a growing presence in the Asia-Pacific and especially Japan, says AWR's VP of marketing Sherry Hess. "With a significant portion of AWR's customers located in Europe and Asia-Pacific, our partnership with UMS is extremely beneficial as it provides a high-quality, non-ITAR foundry solution to mutual customers."

PDKs from UMS are available to active customers of the UMS foundry and AWR software.

www.ums-gaas.com
www.awrcorp.com

AWR offers RF small-signal design kit for NXP's SiGe:C BiCMOS process

High-frequency electronic design automation (EDA) software tool provider AWR of El Segundo, CA, USA and NXP Semiconductor of Eindhoven, The Netherlands have made available a small-signal RF design kit for NXP's SiGe:C silicon-germanium bipolar junction complementary metal oxide semiconductor (BiCMOS) process. The design kit installs within AWR's Microwave Office software and functions as an integrated part of the simulation environment.

Microwave Office Design Kit Version v1.0 provides models for RF components such as wideband devices, diodes, junction FETs, dual-gate MOSFETs, and MMICs, and includes SPICE parameters, S parameters,

noise parameters, and data sheets.

NXP's BiCMOS process aims to speed the migration from gallium arsenide to silicon components with low-noise performance and IP availability. The process is optimized to allow users to incorporate more functionality into devices at competitive costs and in less space. NXP says that it delivers high levels of integration and performance at high frequencies that can enhance next-generation RF products such as low-noise amplifiers, medium-power amplifiers, and local oscillators used in wireless user equipment and infrastructure.

www.awrcorp.com
www.nxp.com/models/index.html

Belfast spin-off Lamhroe to design GaAs MMICs for OMMIC

Lamhroe, a recent spinout of Queen's University Belfast's Institute of Electronics, Communications and Information Technology (ECIT), has been contracted by III-V foundry OMMIC SAS of Limeil-Brévannes, near Paris, France to design GaAs monolithic microwave integrated circuits (MMICs) for use in a range of wireless communications, space and imaging applications.

The start-up will have direct access to research, design and prototyping resources at ECIT's high-frequency electronics (HFE) division, where managing director Dr Mark Kelly is principal engineer and co-founder professor Vincent Fusco heads research.

The HFE team is said to be one of the largest groups of its kind in the UK and Ireland, with an international reputation for developing generic solutions to problems associated with wireless front-end technology.

The team has a long association with OMMIC (formed in 2000 as Philips Microwave Limeil but divested by Philips in mid-2007). In 2005 the team was made one of the French

firm's European Centres of Excellence for MMIC amplifier design.

Lamhroe is also close to finalizing several other deals, says Kelly. Kelly has also won an Invest Northern Ireland Industrial Enterprise Fellowship, allowing him to concentrate on developing new business opportunities over the coming year.

As well as design services, the firm aims to make ultra-high-frequency, microwave and millimetre-wave modules, to be sold mainly through Amideon of Limerick, Ireland (an electronics/technology transfer firm that holds shares in Lamhroe). Modules will be made in-house to the prototype and demonstrator stage.

Lamhroe's strengths lie in the tight coupling to engineers and equipment at ECIT, says Kelly. "We are working very closely with ECIT to market our combined experience and identify opportunities that will not only generate orders for Lamhroe but also help to attract academic funding for ECIT."

www.ecit.qub.ac.uk
www.ommic.com

Peregrine shipments reflect dip in cell-phone demand in 2009

The Strategy Analytics RF & Wireless Component service predicts slower growth ahead for CMOS silicon-on-sapphire RF switches according to its report 'Peregrine Shipment Milestone Reflects Softer Handset Demand, RF Architecture Shifts'.

In September, RF CMOS and mixed-signal communications IC maker Peregrine Semiconductor Corp of San Diego, CA, USA said that it had shipped its 500 millionth UltraCMOS (CMOS on silicon-on-sapphire) integrated circuit. Its CMOS RF switches, which made up most of the shipped units, have displaced gallium arsenide (GaAs)

switches in antenna switch modules for cellular handsets.

"Peregrine Semiconductor shipped about 250 million RF switches in 2008, but will probably ship significantly fewer in 2009, as a consequence of the economic slowdown," says Chris Taylor, director of the RF & Wireless Components service.

"In spite of the apparent drop in 2009, the future still looks positive for Peregrine, given the expected recovery in cell-phone shipments and the increasing complexity of cellular front-ends driven by more radio bands," he concludes.

www.psemi.com

Peregrine wins TechAmerica San Diego's annual 'High Tech' Award

During TechAmerica San Diego's Annual High Tech Awards banquet at the Hyatt Aventine in La Jolla, CA on 9 November, RF CMOS and mixed-signal communications IC maker Peregrine Semiconductor Corp of San Diego, CA, USA received a 2009 'High Tech' Award from Washington DC-based TechAmerica, which was formed last year through the merger of AeA (formerly the American Electronics Association), the Cyber Security Industry Alliance (CSIA), the Information Technology Association of America (ITAA) and the Government Electronics & Information Technology Association (GEIA).

In its sixteenth year, the annual event recognizes excellence in the region's technology industry, and honors outstanding companies for their technological or business innovation; exceptional products or service; product marketplace validation; perseverance in the face of adversity; and community involvement.

A High Tech Award was given in each of nine categories including Internet/Web Commerce; Com-

puters and Related Products; Communications Products and Services; Clean Technology; Defense/IT Services; Semiconductor, Industrial and Analytical Instrumentation; Medical Device Technology/Instrumentation; and Outstanding Emerging Growth. Many nominations from companies within the San Diego technology community were submitted for consideration; 38 were finalists.

Peregrine's UltraCMOS process technology was chosen for the top award among four finalists in the Semiconductor, Industrial and Analytical Instrumentation category.

"We recently shipped our 500 millionth RF integrated circuit into the global marketplace," comments chief technology officer & co-founder Ron Reedy. Reedy acknowledges support given to Peregrine by the San Diego community since its inception. "Peregrine's commitment to the San Diego community is commendable," adds Kevin Carroll, regional director, TechAmerica San Diego.

www.techamerica.org

IN BRIEF

Ex-Procomp chair begins 14-year jail term

The China Post reports that Sophie Yeh, former chairwoman of Taiwan's Procomp Informatics, has begun serving a 14-year term at the women's jail in Taoyuan County based on a final verdict by the Supreme Court at the end of November. This upholds an original verdict by the Shihlin District Court in December 2005 for her role in a NT\$7bn accounting fraud and embezzlement of Procomp assets. The district court also imposed a fine of NT\$180m on Yeh.

During the police investigation, Yeh was ordered to return slightly more than NT\$10m. The entire amount in Yeh's embezzlement is still to be determined. In what is one of the most severely punished cases of accounting fraud in Taiwan, says the China Post, the prosecutor also convicted 27 other Procomp executives.

Procomp was once Taiwan's largest manufacturer of GaAs chips for wireless communications applications. The scandal was revealed after the firm filed a restructuring plan in summer 2004 amid financial difficulties, as it defaulted on a bond payment of NT\$6.3bn that June. More than 10,000 victims lodged damage claims for a total of NT\$6bn. Because of the accounting fraud, Procomp was delisted from the local bourse in September 2004 (after becoming a listed company in 2000).

According to law, a convict can apply for parole when half of the jail-time has been served. However, prosecutors at the Shihlin office say that Yeh must serve a minimum of seven years, with the condition that she has paid the NT\$180m penalty before being eligible for parole. If she fails to pay the fine, Yeh could serve an additional three-year term.

www.chinapost.com.tw

IN BRIEF

Skyworks extends ISO/TS automotive certification to entire Mexicali test & packaging plant

Skyworks Solutions Inc of Woburn, MA, USA, which manufactures linear products, power amplifiers, front-end modules and radio solutions for handset and infrastructure equipment, has expanded its ISO/TS 16949 certification to include its entire manufacturing facility in Mexicali, Mexico. The firm's 2007 ISO/TS 16949 certification previously covered only certain facets of its Mexicali packaging & test operations.

Jointly developed by the International Automotive Task Force (IATF) and approved and released by the International Organization for Standardization (ISO), ISO/TS 16949 is the automotive industry's international quality management system standard, which aims to answer the need for global consistency, continual improvement, and increased customer satisfaction.

Skyworks says that achieving ISO/TS 16949 certification enables it to become a larger supplier within the automotive market, supporting opportunities ranging from keyless entry, to Bluetooth capability, global positioning system (GPS), satellite radios, climate control, and sensors.

Given that ISO/TS 16949 is a key differentiating standard across a wide range of industries, extending the certification also creates additional opportunities in markets such as broadband, consumer electronics, and meter reading, Skyworks reckons.

www.skyworksin.com

Agilent introduces InP chipset for oscilloscopes with 16GHz bandwidth

Agilent Technologies Inc of Santa Clara, CA, USA has introduced a front-end chipset that uses InP technology that should enable it to deliver oscilloscopes in first-half 2010 that offer true analog bandwidths greater than 16GHz.

Engineers working with high-speed serial data links such as USB, SATA or PCI Express use oscilloscopes to measure jitter and other parameters to ensure compliance to industry standards for interoperability. In the next few years, as data rates extend beyond 8.5Gb/s, engineers will need oscilloscopes with true analog bandwidths greater than 16GHz. In addition, the upcoming IEEE 803.2ba 40/100G standard will drive the need for high-quality, real-time signal analysis capabilities to 16GHz and beyond.

Agilent says that other vendors claim they can achieve higher bandwidths using bandwidth-enhancing techniques such as digital signal processing (DSP) and frequency domain interleaving (or digital bandwidth interleaving, DBI). However, the additional noise and jitter generated with these techniques can interfere significantly with an oscilloscope's measurement accuracy and impact its frequency response, claims the firm.

Silicon process technologies that are commonly used today are unable to achieve true analog bandwidths above 16GHz, says Agilent. Other vendors are using silicon technologies with transistor switching frequencies in the 100GHz range, but this frequency limit presents significant barriers to delivering higher true analog bandwidths. Agilent says that its investment in the InP process extends the capabilities of its InGaP HBT IC technology, enabling high-frequency capability with transistor switching frequencies up to 200GHz. InP technology offers the same capability without sacrificing the reliability and manufacturability of Agilent

instrumentation, says the firm.

Since InP technology also has better material properties compared with Agilent's prior-generation GaAs process, it provides higher saturated and peak electron velocities, higher thermal conductivity, lower surface recombination velocity, and higher breakdown electric field, enabling true analog bandwidths to be pushed to new limits.

In addition, InP provides the following measurement benefits compared with other technologies currently available:

- significantly flatter response at high frequencies;
- higher measurement accuracy due to the low-noise, non-conductive substrate; and
- higher reliability due to lower power consumption.

Agilent implemented in-house fabrication to gain ultimate control of precision in the InP process, with its expertise in microwave semiconductor technology proving key in tuning it to deliver the specifications for real-time oscilloscopes, says Bob Witte, vice president of Agilent's Technology Leadership Organization.

The InP technology is already available in the J-BERT N4903B high-performance serial BERT, which offers complete jitter tolerance testing, and in the N4916B de-emphasis signal converter, delivering pulse fidelity to rise-times faster than 20ps and offering headroom for future needs.

"Our first oscilloscope family offering this new high-speed chipset will start at 16GHz bandwidth," says Jay Alexander, VP & general manager of Agilent's oscilloscope organization. "These new products will complement our existing lineup of oscilloscopes and ensure that we can meet upcoming customer needs in a timely manner." Agilent currently offers high-performance Infiniium 90000 Series oscilloscopes with bandwidths up to 13GHz.

www.agilent.com/find/scopes



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Pit-stop to improved AlGaN-on-Si HEMT breakdown

Deep pits that arise in growth of aluminum gallium nitride (AlGaN) high-frequency power transistors on silicon substrates give rise to increased leakage and lower breakdown voltages, according to the Nagoya Institute of Technology in Japan [Selvaraj, Appl. Phys. Express, vol2, p111005, 2009].

In the past few years AlGaN has been developed beyond its original light-emitting applications into the high-frequency power transistor market (up to ~30GHz). Potential applications include power amplification for the transmission of radio and microwave signals, such as for mobile phone network connections to the main telephone network.

To enable the required high breakdown voltages, material quality is a vital concern. However, there is also the concern of competing with other technologies based in lower-cost production processes using silicon or gallium arsenide. A recent development with cost-cutting potential is the growth of GaN on silicon rather than the much more expensive silicon carbide. The other common GaN substrate — sapphire — is often not suitable for power applications because of its poor thermal conductivity.

Silicon-based GaN also has scale-up potential to larger wafers (up to 300mm diameter), creating economies of scale. The penalty for growing GaN on Si is that the large lattice mismatch (~17%) between the materials negatively impacts material quality.

The Nagoya researchers used Taiyo Nippon Sanso's SR4000 horizontal MOCVD system to grow AlGaN/GaN high-electron-mobility transistors (HEMTs) on 4" silicon substrates (Figure 1). The buffer layers used to transition between the silicon and the GaN lattices included layers of AlN, AlGaN and a super-lattice structure.

A variety of pit structures and densities were found for different wafers, even with the same buffer scheme and total epilayer thickness.

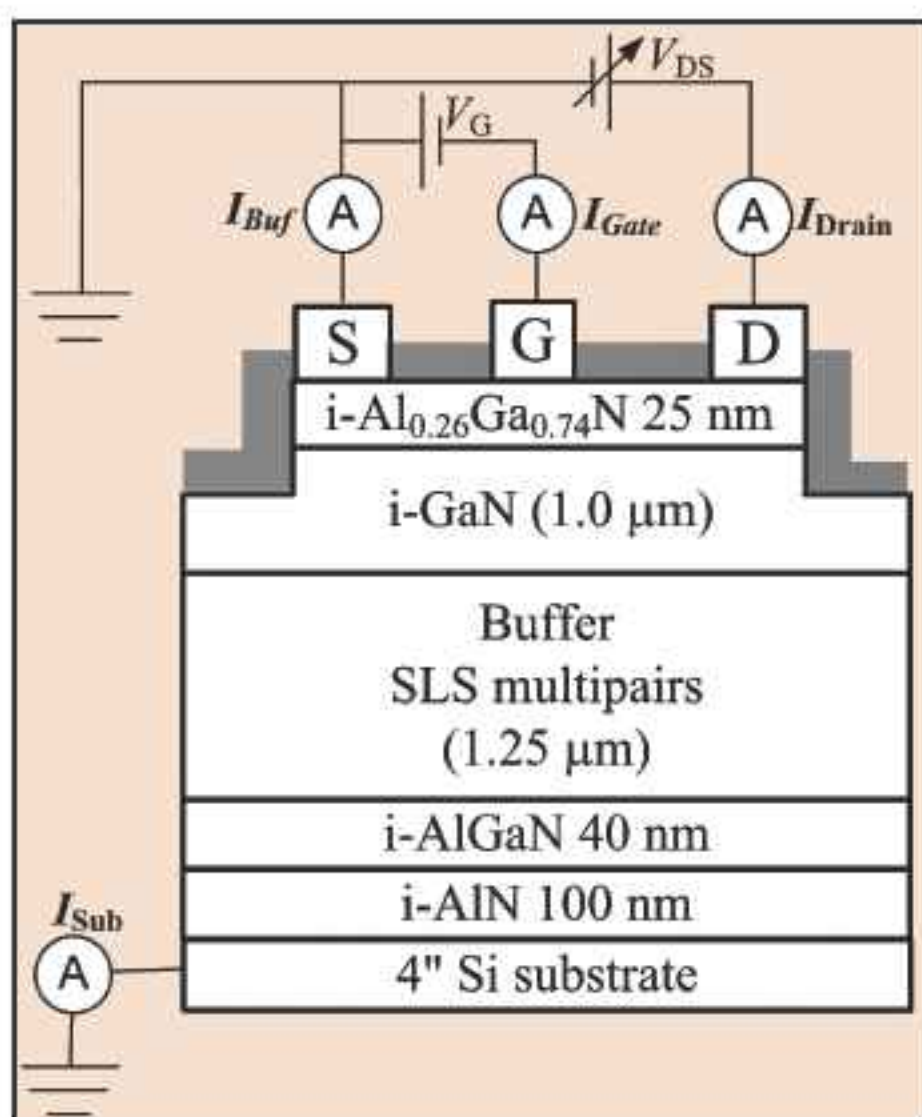


Figure 1. AlGaN HEMT structure used to investigate impact of deep pits on breakdown performance (SLS = super-lattice structure).

In particular, there were two types of pit: shallow (requiring atomic force microscopic detection) and deep (needing only an ordinary microscope). The deep pits have hexagonal pyramid structures.

The aim was to investigate the three-terminal-off breakdown characteristics of the HEMTs. When the transistor is nominally 'off' (i.e. the gate is below threshold), a variety of leakage currents can occur through the gate, buffer and substrate. The combination of these is reflected in the drain leakage current.

The researchers tested their HEMTs with a constant -5V gate bias, which is well below the threshold for the transistor. The breakdown behavior of the devices depended on the deep pit density of the substrate, but not on the shallow pits.

A device with almost no deep pits had a breakdown of about 325V,

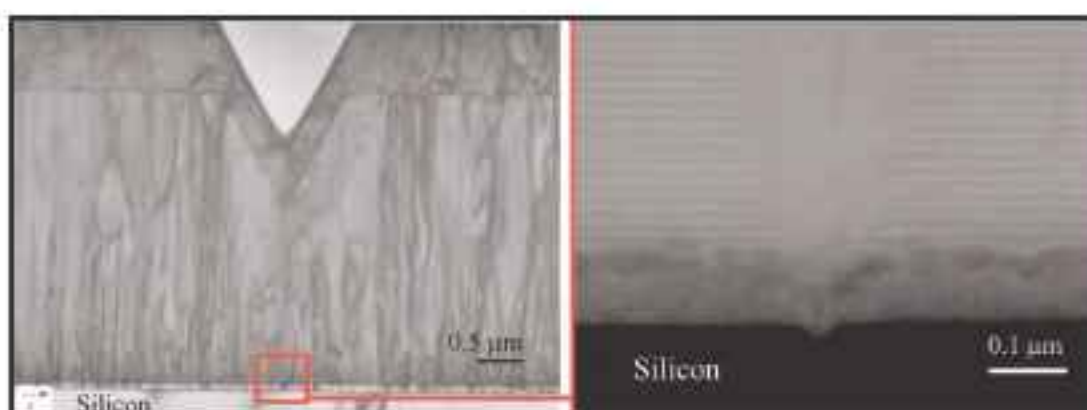


Figure 2. TEM across deep pit on GaN surface originating from Si substrate (left). SEM of etch pit at AlN/Si junction (right).

although the gate leakage is rather high due to the use of a Schottky barrier, rather than an insulator/oxide structure. At an intermediate deep pit density of $2.5 \times 10^3/\text{cm}^2$, buffer and substrate leakage increase to be of similar size to that through the gate, and breakdown occurs at 246V. A further increase in density ($3 \times 10^4/\text{cm}^2$) reduces the breakdown to 130V, due to a leap in substrate leakage. The maximum pit density substrate used ($7.5 \times 10^5/\text{cm}^2$) yielded devices with breakdowns of only 48V.

The researchers used transmission (TEM) and scanning (SEM) electron microscopy to investigate the source of the deep pits on GaN substrates having a thicker 4μm buffer. The resulting images suggest that the deep pits originate from the surface of the silicon substrate (Figure 2, left). Looking more closely at the origin of the pit, one finds a pit in the silicon surface itself (Figure 2, right). The disruption in growth caused by these pits means that deep surface pits arise irrespective of the thickness of the subsequent buffer layers. The pits in the silicon surface can arise from the etching effect of Ga in the MOCVD process. The researchers found etching to occur even when an AlN layer was used to prevent such action by Ga.

The researchers conclude that deep pits found on the surface originate from the silicon substrate and behave like micro-pipes for high substrate current leakage. The deep pits not only affect the buffer and substrate leakage but also boost gate leakage. The researchers believe that this is due to a high

density of tunneling paths from defect levels caused by poor crystal quality and a lowering of the Schottky barrier as a result of higher free-carrier densities.

<http://eng.nitech.ac.jp>

<http://apex.ipap.jp/link?APEX/2/111005>

Author: Mike Cooke.

GaN used to extend fiber deeper into cable networks

To extend the reach of its fiber deep portfolio, Motorola Inc's Home & Networks Mobility business has integrated GaN technology into its SG4000, BTN100, MBN100 and BLN100 optical nodes and its BT, MiniBridger and BLE RF amplifiers.

Motorola claims it now provides the highest-available RF output levels for cable operators driving fiber deeper into their networks, resulting in a reduction of up to 20% in the number of active components in N+1 architectures. This allows operators to lower both capital and operational expenses, while cutting system power needs and increasing network reliability, reckons Motorola.

Cable providers are continuing to leverage cost-effective fiber deep technologies as they drive fiber deeper into hybrid fiber coax (HFC) networks in order to deliver higher-throughput video and broadband services to subscribers. Motorola says that, by introducing extended-reach RF amplification, it is even

more affordable to deploy fiber deeper in the network (by reducing the number of active components and their associated installation and operation costs). Also, the new technology minimizes the need for re-spacing amplifiers as operators upgrade to 1GHz and higher technologies, providing a big cost benefit over existing technologies.

"No other vendor can drive an RF signal as far as Motorola," claims Joe Cozzolino, senior VP & general manager for Access Networks Solutions at Motorola Home and Networks Mobility. This offers cable operators better economics for driving fiber deeper into networks while providing consumers the advanced video and broadband services they demand, he adds.

Introducing extended-reach RF amplification, it is even more affordable to deploy fiber deeper in the network

This means that cable operators can choose to serve more homes from a single node or install fewer amplifiers in the network (extending the reach of fiber more affordably in both cases). For cable operators, this translates into greater throughput for advanced services and more economical network deployment. For consumers, this offers the potential for both higher quality and a broader range of services.

Motorola says that its comprehensive fiber deep portfolio offers four key solution sets to help cable operators migrate fiber deeper into their networks: RF amplifier to node conversion; migration from segmentable node to optical hub node; multi-wavelength solutions; and extended-reach optical nodes and RF amplifiers.

Motorola demonstrated the technology at the 2009 SCTE Cable-Tec Expo in Denver (28-30 October).

www.motorola.com

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IN BRIEF

RFMD ships pre-production hybrid amps for CATV

RF Micro Devices Inc of Greensboro, NC, USA says that it has commenced pre-production shipments of GaN-based CATV hybrid amplifiers to a major US-based cable television (CATV) equipment provider. RFMD is already shipping GaN-based CATV hybrid amplifiers to CATV equipment suppliers in Europe, Japan and North America.

To address the increasing demand for higher-throughput video and broadband services, operators of hybrid fiber coax (HFC) networks are installing fiber capacity deeper into their networks (fiber deep networks), says RFMD. Accordingly, CATV equipment makers looking to cut the cost of fiber deep networks are seeking semiconductor devices capable of higher RF output levels than those available from existing GaAs-based devices.

The firm says that, due to the RF output levels of its GaN CATV hybrid amplifiers, cable operators can reduce the number of amplifiers required in emerging architectures (N+1 architectures) and achieve cost savings of up to 20% in fiber deep networks.

"With our GaN semiconductor expertise and our world-class CATV manufacturing capability, RFMD is uniquely positioned to bring the next generation of high-performance CATV amplifiers to the CATV equipment market," claims Alastair Upton, general manager of RFMD's Broadband Components business unit.

Initial GaN shipments to the CATV customer are intended for use in optical nodes. Subsequent shipments are expected to be used in line extender amplifier applications. Volume production is expected in first-half 2010.

www.rfmd.com

Nitronex and Modelithics collaborate on non-linear models for gallium nitride devices

Nitronex Corp of Durham, NC, USA, which manufactures gallium nitride on silicon (GaN-on-Si) RF power transistors for the commercial wireless infrastructure, broadband and military markets, and Modelithics Inc of Tampa, FL, USA, which provides RF and microwave simulation models for use in electronic design automation (EDA), have announced a collaboration to create non-linear models for Nitronex's high-power GaN devices.

Nitronex reckons that combining its GaN power devices with the Modelithics team's 35+ years of modeling experience will allow power amplifier designers to achieve better performance with faster time to market. Initial models will focus on Nitronex's new thermally improved products targeting broadband and high-efficiency amplifiers for the military communications, electronic warfare, and radar markets.

"We are very pleased to add Nitronex as a strategic Modelithics

Initial models will focus on Nitronex's new thermally improved products targeting broadband and high-efficiency amplifiers

vendor partner and look forward to a productive working relationship benefiting

designers of efficient, higher-power, and broader-band GaN PA designs," says Modelithics' president & CEO Larry Dunleavy.

Models are available free for Agilent's Advanced Design System (ADS) and AWR's Microwave Office (MWO) at www.modelithics.com/mvp/NIT. The models will also be included in Modelithics Select free shareware library, available for ADS and MWO at www.modelithics.com

www.nitronex.com

Cree acquires semi-insulating SiC and power device patents from Daimler

Cree Inc of Durham, NC, USA has acquired a portfolio of patents and patent applications related to semi-insulating silicon carbide (SiC) material and power device technology from Germany's Daimler AG.

The portfolio consists of about 20 patent families, including patents issued in the USA, Germany, Japan, and China. Cree says that US Patent No. 5,856,231 ('Process for Producing High-Resistance Silicon Carbide') is an important piece of the portfolio, relating to the manufacturing of semi-insulating SiC using vanadium doping.

"We had licensed this impressive group of patents for many years, and the full acquisition is a valuable addition to our already extensive

intellectual property position," says Dr Cengiz Balkas, Cree VP & general manager, power and RF.

The '231 patent further bolsters our IP position, especially in semi-insulating SiC achieved through vanadium doping

"Cree is already the leader in high-purity semi-insulating SiC," claims Dr Vijay Balakrishna, Cree product line manager,

materials. "Acquiring the '231 patent further bolsters our IP position, especially in semi-insulating SiC achieved through vanadium doping."

www.cree.com

II-VI supplier 5N buys Firebird to expand into III-Vs and substrates

5N Plus Inc of Montreal, Canada has completed the acquisition of Firebird Technologies Inc, a private company in Trail, British Columbia that manufactures compound semiconductor products and pure metals.

5N Plus was founded in 2000 after developing electronic materials within Canadian natural resource company Noranda Inc (one of the world's largest mining firms). It focuses on specialty high-purity metals such as tellurium, cadmium and selenium, and also produces related II-VI semiconducting compounds such as cadmium telluride (CdTe) and cadmium sulphide (CdS) as precursors for the growth of crystals for electronic applications, including infra-red detectors for night-vision systems, gamma-ray detectors for nuclear imaging in medicine, thermoelectric modules for cooling, and thin-film photovoltaic cells for solar panels. The firm is an integrated producer, with both primary and secondary refining capabilities (enabling it to control the entire manufacturing process), and also provides recycling services to treat production residues.

Founded in 1991, Firebird Technologies' main products — which include indium antimonide (InSb) wafers as well as antimony, indium and tin pure metals — are sold worldwide and used in electronic and optical applications.

The strategic acquisition enables 5N to not only broaden its product line into III-V metals (including indium) but also to address the semiconductor wafer business. 5N's president & CEO Jacques L'Écuyer says that Firebird has expertise in crystal growth and the ability to further strengthen 5N's position as a producer of high-purity metals.

"Becoming part of the 5N Plus group will provide us with greater technical, financial and marketing resources," comments Firebird's CEO Don Freschi.

"We plan on making additional investments in Trail, BC in the near future to expand Firebird's activities and leverage our strategic long-term supply agreements for minor metals with Teck Metals Ltd," says L'Écuyer. This includes indium and germanium feedstock, in accordance with a concurrent memorandum of understanding (MOU) signed with Teck Metals Ltd, a subsidiary of Teck Resources Ltd (a producer of base metals and minor metals), for the long-term supply of strategic metals.

Teck aims to provide 5N with a stable source of minor metal feedstocks including indium, cadmium and germanium. The MOU also outlines the intention of 5N and Teck to cooperate in assessing future business opportunities to support the growth of Firebird. As well as

entering into minor-metals supply agreements, 5N and Teck expect to conclude additional agreements in the near future.

"Strengthening of our relationship with Teck will provide 5N Plus with a stable source of critical minor metals and enable us to address a number of new business opportunities aimed at supporting the growth in Trail," says L'Écuyer. Establishing a closer working relationship with Teck is key to 5N's long-term growth strategy, which calls for both a broadening of its product portfolio and an increasing robustness in its supply chain, he adds.

www.firebird.bc.ca
www.5nplus.com
www.teck.com

IN BRIEF

AkzoNobel HPMO launches Hiperflo bubbler for liquid MO sources

At the 8th International Conference on Nitride Semiconductors (ICNS 2010) on Jeju Island, South Korea in late October, AkzoNobel High Purity Metalorganics (HPMO) — a part of AkzoNobel Polymer Chemicals that produces group III MO sources based on indium, gallium, aluminum, zinc and magnesium — unveiled a novel bubbler type for liquid MO sources.

AkzoNobel says that, through its special design, the Hiperflo bubbler enables a higher gas saturation level, better vapour stability and more complete source utilization. The firm adds that this is especially advantageous for lower-vapour-pressure MO sources such as triethyl gallium (TEGa), as confirmed by the experience of the first users of the new bubbler.

● From 1 January (or as contracts allow), AkzoNobel HPMO plans to increase pricing of its TMGa by 15%. The firm says that the increase is necessary to offset the rising costs of key raw materials and energy, and to support continued investment in increased production capacity. It should also enable it to keep making substantial investments in additional bubbler fleet capacity.

AkzoNobel HPMO is a producer of TMGa and other group III MO-sources. It has recently doubled its output of TMGa in response to the sharply growing demand from the global LED industry. The firm adds that it is committed to keep investing in this product line, to support the future growth of its customers.

www.akzonobel.com/hpmo

IN BRIEF

HRL orders CCS reactor to boost GaN HEMT work

Deposition equipment maker Aixtron AG of Herzogenrath, Germany says that in third-quarter 2009 it received an order for a Close Coupled Showerhead (CCS) 6x2-inch MOCVD reactor for delivery in first-quarter 2010 to HRL Laboratories LLC of Malibu, CA, USA (a corporate R&D lab owned by The Boeing Company and General Motors).

The system will be used to support HRL's work on gallium nitride technologies, including the growth of GaN high-electron-mobility transistors (HEMTs) for millimeter-wave power applications and high-voltage GaN transistors for high-efficiency power switching applications.

"Among the practical aspects which suit our applications are not only the low carrier gas consumption and overall efficient materials utilization but also the ease of maintenance," comments an HRL research staff member working on GaN. "The CCS system has a proven track record thanks to the large number of systems installed worldwide, and we will appreciate the good scale-up potential that enables an easy recipe transfer to a large system," he adds. "The Aixtron system will provide a major augmentation to our GaN material growth capabilities... It will enable fabrication of more sophisticated GaN HEMT structures as well as addressing our need for higher process throughput."

Among HRL's reported successes in millimeter-wave GaN-based monolithic microwave integrated circuits (MMICs) is 500mW of output power at 95GHz for a GaN MMIC, as presented at the 2008 IEEE Compound Semiconductor IC Symposium (CSIC) in Monterey, CA.

www.hrl.com

Bridgelux opts for Praxair high-purity ammonia supply system

To meet its increased high-purity ammonia requirements, lighting firm and LED maker Bridgelux Inc of Sunnyvale, CA, USA has purchased a SureFlow bulk supply system from Praxair Electronics (a division of Praxair Inc).

"Bridgelux is focused on the continuous advancement of our manufacturing processes and LED materials technologies to reduce cost and enable the mass adoption of LED-based solid-state lighting," says Dr Steven Lester, Bridgelux's director of R&D. "Market demand for our LED light sources is driving expansion of our manufacturing capacity."

Praxair says that its SureFlow system, with patented heat-control technology, can deliver sustained ammonia flow rates over 600

standard liters per minute, peaking at over 900 standard liters per minute. "Praxair's SureFlow bulk delivery system is designed to best address the technical challenges associated

Market demand for our LED light sources is driving expansion of our manufacturing capacity

with bulk ammonia supply, and to deliver product safely and reliably at lower cost," says

Praxair's president Mark Murphy. Since the supply system requires fewer cylinder change-outs, it helps reduce labor costs and improves safety and reliability, it is claimed.

www.praxair.com/electronics
www.bridgelux.com

Huga orders six Aixtron MOCVD reactors to boost LED capacity

Aixtron says that, in second-quarter 2009, Huga Co Ltd placed an order for six AIX 2800G4 HT MOCVD systems (in 42x2"-wafer configuration), for delivery to its production facility in Taichung Science Park, Taiwan in Q4/2009.

Huga was founded in 1998, and commercialized its first GaN optoelectronics product in 2000. The firm's manufacturing facility is dedicated to making LED chips using MOCVD through to chip fabrication.

"We already have 13 Aixtron AIX 2800G4 HT mass-production MOCVD systems in operation for the high-volume manufacture of LED epiwafers," says Huga's CEO Sybil Yang. Claiming to be the second biggest LED chip maker in Taiwan, Huga says that it will place more orders for MOCVD systems in 2010 to increase its capacity to surpass its competitors. "The next phase of expansion in our business involves the strongly growing

high-brightness backlighting LED product market, and it is necessary to add further manufacturing capacity," she adds.

In early December it was reported that, in response to optimistic projections about the LED backlighting market, Huga aims to expand its monthly LED chip manufacturing

Huga aims to expand its monthly LED chip manufacturing capacity to 2 billion units by adding 39 new MOCVD systems to its production lines

capacity to 2 billion units by adding 39 new MOCVD systems to its production lines. The firm also plans to enter more diversified

application markets for lighting and automotive in the near future.

www.hugaopto.com.tw
www.aixtron.com

Plasma-Therm opens Engineering Center for Nextral product line

Plasma process equipment maker Plasma-Therm LLC of St Petersburg, FL, USA has opened a sales and service center in Grenoble, France to support its Nextral product line. The new facility will act as a technical support location, training center, and offer upgrade and retrofit demonstrations to Nextral equipment users worldwide.

Product support will be provided by a team of service engineers. As a training center, the facility will provide up-to-date equipment training. Customers can also view demonstrations of equipment upgrades and enhancements that will extend both production capabilities and the lifetime of installed equipment.

Founded in 1983, Nextral has a large global installed base of etch, PECVD and RTP systems. Since being acquired and integrated into the firm, Nextral's prod-

uct line is supported through Plasma-Therm's network of 13 service and support centers throughout Europe and Asia.

"The Nextral Engineering Center will enhance our ability to provide quality support to our valued customers worldwide," comments Steve Brown, managing director of Plasma-Therm Europe. "This sales and service center will give us the opportunity to make sure that Nextral products remain a valuable tool for established users," he adds.

"In response to consistent customer demand, we are happy to expand our service and support organization to direct focus on this product line," says Plasma-Therm's CEO Abdul Lateef. "We continue to expand our organization during this difficult economic environment," he emphasizes.

www.plasmatherm.com

IN BRIEF

SemiLEDs boosts 4" LED chip line

In Q3/2009 Aixtron received an order for a Close Coupled Showerhead CRIUS MOCVD system in 7x4"-wafer configuration for installation at SemiLEDs' 4" LED chip line in Taiwan in Q4/2009.

"We have chosen the Aixtron CRIUS system equipped with the Dynamic Reactor Height Adjustment feature, which facilitates growth at elevated pressures, providing an advantage for our proprietary MVP structure," says president & COO Dr Chuong Tran.

"We are looking forward to this 4" project as it is the first Close Coupled Showerhead Reactor to complement the existing manufacturing line of Planetary Reactor systems at SemiLEDs," adds Dr Christian Geng, Aixtron's VP Greater China.

www.semileds.com

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IN BRIEF

Tegal regains NASDAQ compliance

Plasma etch and deposition system maker Tegal Corp of Petaluma, CA, USA has appointed Ferdinand Seemann to its board of directors (serving on three standing committees: Audit, Compensation and Nominating/Governance).

Seemann is CEO of se2quel Partners LLC, a technology consulting firm with offices in the US, Europe, Middle East and Asia. With roots in the semiconductor industry, se2quel is also a global utility-scale photovoltaic consulting firm. Before founding se2quel in 2003, Seemann held senior posts in technology firms, including VP of Lam Research Corp, executive VP of Mattson Technology, president & CEO of Steag Microtech, and president & owner of Seemann Engineering. Seemann began his career as a process engineer at Germany's Wacker Siltronic. He also has a BSEE from Fachhochschule Regensburg and mastered in 'Novel, cost efficient photovoltaic systems' in 1985.

"Ferdinand's achievements, particularly in the field of photovoltaics, are well known throughout the sun-belt countries, as well as in the USA and Europe," says chairman, president & CEO Thomas Mika. "His insight into potential opportunities for Tegal will be extremely valuable as we continue to look for new, attractive growth opportunities that can help drive profitability as the capital equipment market begins to emerge from the downturn."

On 10 December, Tegal said that, due to Seemann's appointment, it had satisfied all the conditions for regaining compliance with NASDAQ's independent directors requirement and its audit committee composition requirements for continued listing.

www.tegal.com

JEMI France integrates with SEMI to create SEMI Europe – Grenoble Office

At the general assembly of JEMI France (the non-profit association of French semiconductor equipment and materials suppliers), members approved the modification of its statutes to integrate with SEMI, the global industry association serving the manufacturing supply chains for the microelectronic, display and photovoltaic industries. SEMI is headquartered in San Jose, CA, USA but has a SEMI Europe branch in Brussels, Belgium. The new French association, SEMI Europe – Grenoble Office, will fully integrate within the SEMI global structure.

The merger builds on the strengths of the two associations to promote the industry in southern Europe. With access to the European and global semiconductor industry, locating the new combined organization in France allows stronger ties with the region's major microelectronics cluster in Grenoble, it is reckoned.

"What we are doing at the association level mirrors the current industry re-organization and the need to focus on efficiency and core value that we can provide to our members and customers," says SEMI Europe president Heinz Kundert. "The need for European clusters to work closely together is critical in the face of global competition," he adds.

"We welcome this synergy between JEMI France and SEMI Europe," says Geneviève Fioraso, deputy mayor of Grenoble and president of SEM MINATEC Enterprises (which was established in 2004 to offer offices, laboratories and cleanrooms to starts-ups or larger cooperative ventures focused on micro- and nanotechnology). "Europe must strongly advocate for the microelectronic sector because it is highly strategic, and drives innovation in the industry and service markets. This is what the US and Asia are doing," he adds.

"Grenoble, as the main microelectronic cluster in France — from R&D to industry with Minalogic, Minatec, Nano2012 and all organizations that represent this industry (15,000 direct jobs and three times more if we include induced jobs), with the skills and expertise available — has all due legitimacy to host the new organization," Fioraso believes.

"The outstanding support from the city of Grenoble and the public authorities, the proactive cooperation of JEMI France and SEMI, and the choice of Grenoble where the semiconductor industry is highly clustered, have been instrumental for the success of this initiative," comments

Locating the new combined organization in France allows stronger ties with the region's major microelectronics cluster in Grenoble

Alain Astier, group VP at STMicroelectronics and a member of the SEMI European advisory board.

"JEMI France has already collaborated successfully with SEMI Europe for two decades," says André-Jacques Auberton-Hervé, CEO of SOITEC (which manufactures engineered substrates) and a member of the SEMI International board of directors. "With similar interest in our respective memberships, the core competences within JEMI France and SEMI will be extended, bringing even more value to members," he adds.

"Our board's proposal to integrate JEMI France with SEMI was well received by our members," reports JEMI France's president Gaël Schmidt. "They recognised the benefits of the international reach of the global SEMI organization."

www.jemi-france.org

www.semi.org

Cambridge NanoTech sells plasma ALD systems to US national labs

Massachusetts-based Cambridge NanoTech Inc, which was spun off from Harvard University's Gordon Lab in 2003, has sold three Fiji Series plasma atomic layer deposition (ALD) systems to three US national laboratories: the Naval Research Lab (NRL), the Air Force Research Lab (AFRL) and the Army Research Lab (ARL).

"These leading national labs are attracted to the flexibility offered by the Fiji, which in turn allows them to expand their materials and device engineering capabilities," claims Dr Ganesh Sundaram, VP of technology.

The NRL plans to conduct research into the growth of oxides, metals and semiconductors, such as InGaN, which span temperatures ranging up to 1000°C. The materials are of interest to the US Navy because they promise improved performance in future communications, radar and power-management systems.

Research conducted on the Fiji at AFRL Wright-Patterson Air Force Base will be focused on the electrical properties of ultra-thin plasma-generated hafnium dioxide (HfO₂) films, and ARL aims to use the Fiji to support electronic materials and device projects with conformal deposition of high-quality semiconductor, dielectric, and metal films.

"We have found that the Fiji's combined capabilities of growing ultra-thin films with plasma-generated co-reactants and allowing in-situ film analysis, such as OES [optical emission spectroscopy], ellipsometry, Langmuir probes and QCM [quartz crystal microbalance], have been essential to the success of the system," says Cambridge NanoTech senior research scientist Mark Sowa.

Fiji was displayed at the 2009 MRS Fall Meeting in Boston, MA.

www.cambridgenanotech.com

IN BRIEF

OIPT offers flexible support packages

As part of its after-sales support, UK-based etch and deposition equipment maker Oxford Instruments Plasma Technology has launched personalized 'Oi Service' flexible support agreements to suit customers' individual needs.

Benefits include savings on time and spares, reduced lifetime cost of ownership due to regular maintenance, and less downtime. Savings can also be made with a 3 or 5 year contract.

Recognizing users' diverse needs, the agreements have a 'pick and mix' concept — selecting from a number of options to create a support package tailored to precise requirements, rather than the rigidity of set services (some of which are unneeded).

www.oxford-instruments.com

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Obducat joins EU project for LEDs on nanostructured templates

Obducat AB of Malmö, Sweden, which supplies systems based on nano-imprint lithography (NIL) and electron-beam lithography, has been invited to participate in 'SMASH', a project funded by the European Union within its Seventh Framework Program (FP 7). The purpose of the three-year, €11.5m project is to establish new materials and process technologies for use in the production of low-cost, power-efficient, white LED-light sources for the general lighting market.

The project is coordinated by Osram Opto Semiconductors GmbH of Regensburg, Germany and gathers complementary expertise from across Europe. Participants include 14 partners from large firms, small-to-medium enterprises (SMEs), research institutions and universities with an established

track record of productive collaborations.

"Our main focus within the SMASH project will be on stamp manufacturing and replication of nanostructures based on our proprietary IPS-STU nanoimprint lithography technology for high-volume manufacturing," says Obducat's CEO Patrik Lundström.

The concept of SMASH is to establish disruptive approaches that exploit nanostructured compound semiconductors to realize the key market factors of high efficiency and low cost for the broad penetration

The concept of SMASH is to establish disruptive approaches that exploit nanostructured compound semiconductors

of LEDs into the general lighting market. Obducat says that this will be achieved by the epitaxial growth of LED structures on ultra-low-defect nanostructured templates and by the development of LEDs based on nanorod emitters. Such approaches will have great impact on manufacturing costs, because they enable growth on large-area, low-cost substrates such as silicon, says the firm.

"Realizing these technologies will lead to a new generation of highly efficient and affordable LEDs, which enables the entrance to the general lighting market," says Lundström. "That will keep Europe at the forefront of the energy-saving solid-state lighting business and strengthen its position in the manufacturing supply chain and luminaire business," he believes.

www.obducat.com

Obducat appoints new chief executive officer

Obducat says that its CEO Patrik Lundström has announced his intention to leave the company as it reaches the industrialization phase.

Obducat is a public company, partly owned by nanotechnology investment firm European Nanoinvest AB (ENI), where Lundström is the second-largest shareholder. He is returning to ENI.

Lars Tilly has been appointed as the new CEO, and will take up his new position in February. As well as having a PhD in semiconductor physics, Tilly has experience from the semiconductor sector and is currently head of research at Ericsson in Lund, Sweden. His experience of converting research into commercialized products will be of value to Obducat and its future development, the firm reckons.

After an MSc in Engineering Physics at Lund Institute of Tech-

nology followed by graduate research in its department of Solid State Physics, Tilly began his professional career with post-doctoral employment at IBM Research Division in New York, developing technology from an advanced research stage into commercialized technology in the production of ultra-fast semiconductor circuits.

Tilly was employed within the Ericsson Group firstly as a specialist in semiconductor physics, device physics and circuit design at Ericsson Microelectronics in Kista, Sweden. He then moved to Lund where, for the last six years, he has been head of Ericsson's R&D,



Outgoing CEO Patrik Lundström.

focusing on mobile telephone technology (spanning from hardware and radio technology to applications and services). He has also been active in deepening the collaboration between the telecom industry and colleges, including creating industrial research forums, such as Mobile Heights in Lund.

Tilly brings valuable knowledge and industrial background from the semiconductor sector, says Obducat's chairman Henri Bergstrand. "At Ericsson, Lars has been an important driver behind large parts of the technological development as well as the company's strategic collaborations within mobile phone technology," Bergstrand adds. Tilly will lead the industrialization of Obducat's nanoimprint lithography (NIL) sector, he concludes.

www.obducat.com

Nanometrics prices public offering to raise \$20.6m

Nanometrics Inc of Milpitas, CA, USA, a supplier of process control metrology systems primarily for manufacturing semiconductors, photovoltaics and high-brightness LEDs, has announced the pricing of its previously announced underwritten public offering of 2,025,000 shares of its common stock at a price of \$11 per share. Founder Vincent J. Coates is also selling 675,000 shares at \$11 per share as part of the same offering.

In connection with the offering, the underwriters have been granted a 30-day over-allotment option to purchase up to an additional 303,750 and 101,250 shares

of common stock from the firm and Coates, respectively. The closing of the offering is expected to take place on or about 22 December, subject to the satisfaction of customary closing conditions.

After underwriting discounts and commissions and other offering expenses, net proceeds from shares sold by the firm are expected to be \$20.6m. Nanometrics plans to use about \$2m to repay certain obligations related to the acquisition of certain assets of Zygo Corp in June, with the remainder to be used for general corporate purposes, including working capital.

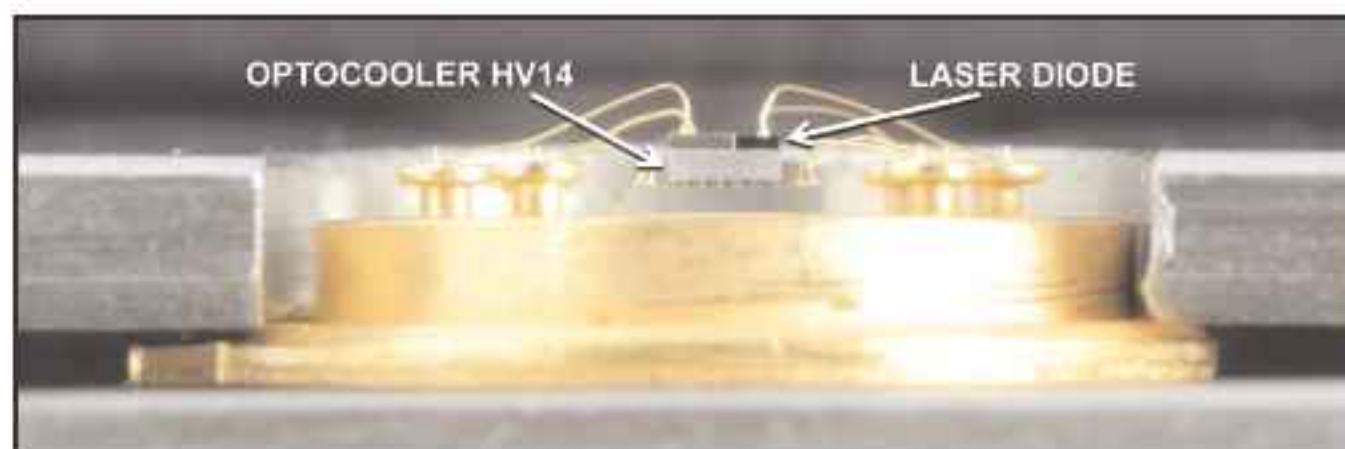
www.nanometrics.com

Nextreme launches high-temp AuSn thermocooler for standard assembly

Nextreme Thermal Solutions of Durham, NC, USA, which designs and makes microscale thermal and power management products, is

offering an updated version of its OptoCooler HV14 thermoelectric module that enables assembly temperatures as high as 320°C, making it compatible with eutectic gold-tin (AuSn) solder (the industry-standard process for packaging optoelectronic devices that require tight tolerances). Specific applications include laser diodes, semiconductor optical amplifiers and sensors.

The HV14 is a high-heat-pumping thermoelectric device designed for standard electrical power needs. At 85°C, it operates at a maximum of 2.7V and can pump 1.7W of heat in a footprint of only 3mm². The module can create a temperature differential of up to 50°C between its hot and cold sides, making it suitable for the cooling and temperature control of optoelectronic devices such as laser diodes.



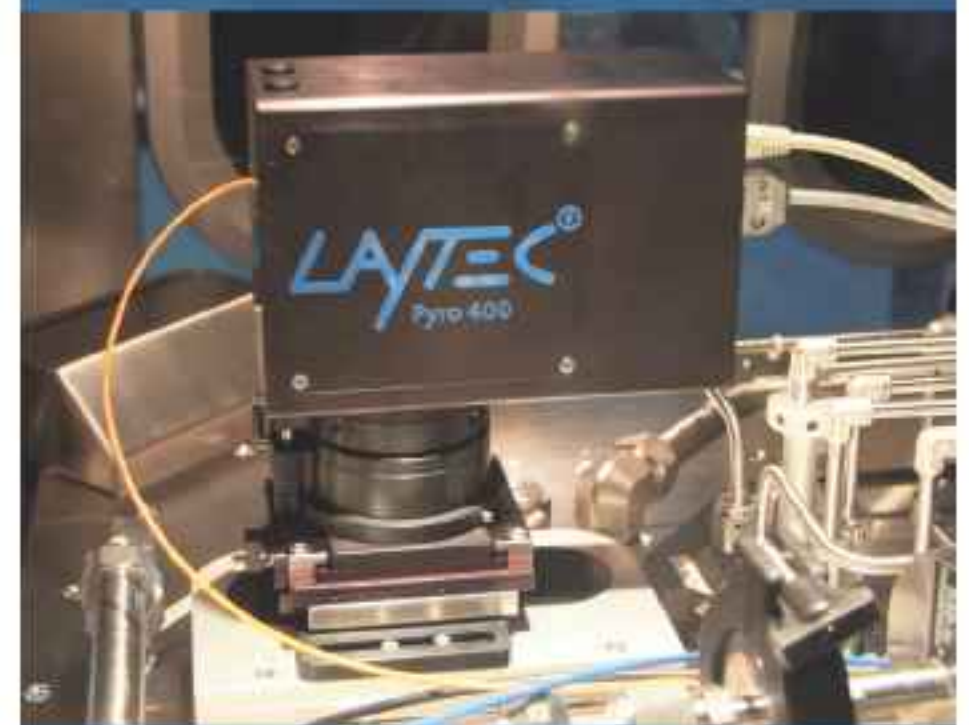
AuSn solder provides excellent joint strength, strain resistance and thermal conductivity. After initial reflow during device assembly, the melting point of the particular AuSn solder is 320°C, enabling attachment of laser diodes and other devices to the thermoelectric module at lower temperature (typically the industry standard of 283°C). Use of this strain-resistant material is very important for lasers, where movement of solder as little as 10µm can cause significant alignment issues.

"Nextreme now offers the standard for solder assembly established by the optoelectronics industry," says Dr Paul A. Magill, VP of marketing & business development. "Introduction of gold-tin in the HV14 product line addresses our customers' most challenging assembly requirements."

www.nextreme.com/optocooler

Real GaN surface temperature

LayTec's groundbreaking new product Pyro 400 finally makes real wafer surface temperature measurements of GaN possible. It offers deep insight into surface temperature changes caused by carrier gas, rotation speed and reactor pressure variations as well as wafer bowing effects. This quantum leap in GaN temperature measurement provides immediate access to emission wavelength variations and thereby provides huge benefit for yield enhancement in future GaN-based LED production.



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IN BRIEF

Seoul Semiconductor raises \$248m from Singapore sovereign wealth fund

Korean LED maker Seoul Semiconductor Co Ltd and its affiliate Seoul Optodevice Co Ltd (which fabricates epiwafers and LED chips) have raised 284.7bn Won (about \$248m) in capital from Singapore's sovereign wealth fund Temasek Holdings Pte Ltd. Seoul Semiconductor issued 6.9 million shares (a stake of 12%) at \$33.565 per share for a total of \$232m and Seoul Optodevice issued 2.7 million shares (a stake of 9%) at \$5.870 per share for a total of \$16m. Under South Korean security rules, Temasek will have to keep the holdings for at least one year.

Seoul Semiconductor and Seoul Optodevice say that the funds will be used for R&D as well as for expanding production capacity in order to address the increased demand that is arising in part due to the improvements in efficiency and market acceptance of its Acriche AC-LED, as well as the firm's patent cross-license agreement with Japanese LED maker Nichia Corp.

Seoul says that the infusion of capital is based on the business potential and growth opportunities in the lighting market. The ability to quickly and easily address expansion requirements with capital equipment and infrastructure will strengthen the firm's LED manufacturing capabilities, it reckons.

According to market analyst firm IMS Research, Seoul Semiconductor is already the world's fourth largest LED maker. The firm has 30 overseas operations, including three subsidiaries and 114 distributor locations worldwide.

www.acriche.com
www.socled.co.kr

Notebook PC firm buys 4.9% stake in LED maker Huga Optotech

In an effort to diversify its business into LEDs, Taiwan-based Inventec Corp (the world's fourth-largest notebook PC maker) has spent NT\$540m (US\$16.61m) to acquire a 4.9% stake in Taiwanese LED maker Huga Optotech Inc, according to the Taiwan Economic News.

To raise its capitalization from the existing NT\$2.478bn (US\$76.2m) to NT\$3.6bn (US\$110.7m), Huga has issued 18 million new shares, valued at NT\$540m for capital increment, all of which have been procured by Inventec.

Everlight Electronics Co Ltd (Taiwan's largest LED packaging company) is also one of Huga's shareholders, who spent NT\$500m on convertible bonds issued by Huga.

Due to optimistic projections about the market in 2010 for LED backlights — especially those used for LED-backlit LCD (liquid crystal display) TVs — Huga has actively

increased capital by issuing new shares and bought new production equipment for making blue and green LEDs. As it prepares to add 39 new MOCVD reactors to its production lines, the firm plans to expand LED chip manufacturing capacity to 2 billion units a month, says the Taiwan Economic News.

Huga has also established a joint venture with South Korea's Seoul Semiconductor (the world's fourth largest LED packaging firm) as part of its efforts to penetrate the Korean market for LED chips, considering that Korea-based Samsung and LG are the world's top two LED-backlit LCD TV brands. The joint-venture strategy allows Huga to avoid patent infringements and secure long-term cooperation with Seoul Semiconductor, it is said.

www.hugaopto.com.tw

http://news.cens.com/cens/html/en/news/news_inner_30327.html

SET claims record performance for large-area single-chip deep UV LEDs

Sensor Electronic Technology Inc (SET) of Columbia, SC, USA, which claims to be the only commercial manufacturer of LEDs operating at wavelengths shorter than 340nm, has achieved what it reckons are industry-best reported R&D results for single-chip UV-C LEDs operating at 273nm.

Constant-current powers of 30mW were achieved at 700mA, representing the highest reported powers for a single-chip device operating at this wavelength at room temperature, the firm says. With a forward voltage of 6.5V and estimated lifetime of more than 3000 hours, Sensor Electronic Technology says that it is continuing its focus on pushing the performance of UV LEDs to address mainstream markets.

"Our LEDs are already being widely deployed in sensing, detection and medical applications, and

Constant-current powers of 30mW were achieved at 700mA, representing the highest reported powers for a single-chip device operating at this wavelength at room temperature

increased performance such as this will not only benefit customers in existing markets, but will also open new market opportunities for deep UV LEDs,"

says CEO Dr Remis Gaska.

www.s-et.com

Taiwanese LED makers set up plants in China

Epistar to build fab in Jiangsu

Due to the increasingly strong demand for LEDs used as backlights in notebook PCs and LCD TVs, Epistar Corp of Hsinchu Science-based Industrial Park has decided to invest US\$600m to build an LED fabrication plant in the Wujin Hi-tech Industrial Zone in Changzhou, Jiangsu Province, central China, according to Taiwan Economic News.

Epistar is already Taiwan's largest LED epiwafer and chip maker, and the world's largest supplier of red LEDs and the fourth-largest of blue LEDs (in terms of production volume). The firm already has a plant operational in both the Fujian and Liaoning Provinces of mainland China.

The firm indicated that, in the first stage of construction (starting in first-quarter of 2010), 30 MOCVD reactors will be procured for the new plant. These should come online in first-quarter 2011 and add 40% to the firm's existing output.

The firm is also planning to strengthen its cooperation with firms downstream in Taiwan's LED supply chain, such as LED backlight module maker Lite-On Technology Corp and LED packaging firm Everlight Electronics Co Ltd, to build an integral supply chain for LED applications in China.

Epistar's expansion is also proceeding in Taiwan, where 30 new MOCVD reactors are due to start production next year, the firm says.

Arima to set up China JV

On 8 December, Taiwan-based LED epitaxial wafer and chip maker Arima Optoelectronics Corp (AOC) announced the formation of a high-brightness LED chip manufacturing joint venture with the local government in Shanxi Province, northern China, according to Digitimes.

AOC will invest US\$17.6m for a 40% stake in the plant but will receive US\$39.6m for providing technical know-how and services in the establishment of production lines and subsequent production.

The joint venture will offer LEDs for backlights, mainly targeting

China's top-five TV makers (including Hisense, Haier and TCL).

A total of 12 MOCVD reactors should be installed by the end of second-quarter 2010, with production starting in third-quarter 2010 at an annual capacity of 1 billion high-brightness LED chips. AOC adds that, over the following three years, the joint venture plans to increase its number of MOCVD reactors by a further 48, to 60.

InGaN-based blue LEDs currently account for about 10% of AOC's revenues, and AlGaInP-based red LED production uses about 70–80% of its total capacity, the firm notes.

AOC plans to restart its suspended general lighting business, and to look for strategic partnerships through private placements, says Digitimes. Eyeing the LED general lighting market in China, it also plans to establish an LED plant at Arima Group's production base in Wujiang, China.

Neo-Neon to site LED epiwafer plant in Yangzhou

In November, Neo-Neon Holdings, which was founded in Taiwan in 1978 and is reportedly the world's No.1 supplier of decorative lighting, said it planned to float Taiwan depository receipts (TDRs) to raise US\$50m to finance construction of its first LED epiwafer plant in mainland China, according to the Taiwan Economic News. Citing excess demand for its LED backlighting used in LCD displays, the firm plans to build an epi-wafer plant in Yangzhou to make LED chips for both its own LED-lighting affiliates and other LED makers.

The issuance will make it the first overseas Taiwanese LED-lighting maker to float TDRs. Neo-Neon's production is based in He-Shan, Guangdong Province, while the firm made an initial public offering on the Hong Kong exchange in 2006.

According to chairman B.C. Fan, Neo-Neon wants to build the plant to ensure sufficient supply of LED chips for its lighting products, as the global supply of chips is expected to be outpaced in 2010 by demand from manufacturers of LCD TV backlights.

According to the Hong Kong Economic Journal and the Hong Kong Economic Times, Neo-Neon has signed an agreement with the Yangzhou industrial zone regarding the citing of the plant, which is designed for 30 MOCVD reactors.

Specifically, according to Neo-Neon's announcement at Hong Kong Exchanges and Clearing Ltd (HKECL), the investment is in three phases, with each phase installing MOCVD reactors for an output of 20,000 two-inch epiwafers per month. First-phase production lines will become operational in June 2010 and second-phase lines in second-half 2010. Installing of third-phase lines will begin in 2011.

The LED chip plant will add a final touch to Neo-Neon's plan to establish integrated manufacturing capability for LED lighting, which is now being supported by its in-house LED packaging and lighting fixture lines.

Neo-Neon's LED manufacturing plan has convinced a venture capital fund owned by Tsinghua University to take a 12% stake in the firm (becoming its main shareholder).

Fan says that the firm has secured contracts to supply a total of 100,000 LED street lights throughout mainland China. It has already opened 21 offices there as distribution footholds.

He also reckons that China's market will see explosive growth once its LED lighting standard is enacted, together with a significant boost in 2010 from Expo 2010 Shanghai China, cityscape beautification projects, and an aggressive government-backed LED street-light project.

www.epistar.com.tw

www.aocepi.com.tw/html

www.neo-neon.com

China's market will see explosive growth once its LED lighting standard is enacted

Osram's second LED chip plant starts production in Malaysia

Two years after breaking ground in July 2007, the last installation work has been completed and the test phase concluded in what Osram Opto Semiconductors GmbH claims is the world's most modern LED chip production plant, in Penang, Malaysia.

Complementing its main facility in Regensburg, Germany (which was expanded in 2008), the plant makes the firm the first LED maker with high-volume chip production in both Europe and Asia. The Malaysian facility in Bayan Lepas already hosts LED chip packaging, employing about 2600 of Osram Opto's total worldwide workforce of 4400.

The 35,000m² facility has involved the investment of tens of millions of euros and created more than 220 new jobs in Penang. Now that the manufacturing processes have been established for the 4"-wafer-based indium gallium nitride (InGaN) chips, routine production is underway.



Osram's new LED chip plant in Penang (top), showing cleanroom (bottom).

The chips form the basis for the blue, green and white LEDs used primarily in architecture and general lighting, for display backlighting and in mobile terminal devices. Osram says that the new production capacity will enable it to respond flexibly to the demand for LEDs at competitive prices, as the market has begun to pick up again steeply.

"There is no question that the rise of the LED, which has only just begun, is set to sky-rocket in the coming years," believes Osram Opto Semiconductors' CEO Dr Rüdiger Müller. "This is why we are pursuing our investment and expansion course consistently and uncompromisingly, even in this difficult economic environment," he adds. "With our production facilities in Germany and Malaysia, we are now in an ideal starting position in terms of quantity and quality."

www.osram-os.com

Golden DRAGON Oval Plus LEDs used for Zhujiang New City

Osram Opto says that the Shanghai RenMin Road Tunnel and Guangzhou Zhujiang New City in China are each using about 30,000 of its Golden DRAGON Oval Plus LEDs. "The former is anticipated to alleviate the Bund traffic in time for the World Expo 2010 while the latter, being the first in the area, will set a benchmark for the future of LED street lighting there," says K C Cheng, marketing director for Hong Kong-based subsidiary Osram Opto Semiconductors Asia.

The firm says that its LEDs have been chosen by Guangdong Zhonglong Communications Technology Co Ltd due partly to their 50,000 hours lifetime, which extends service intervals (reducing maintenance costs and total

cost of ownership). "Installation in the Shanghai RenMin Road Tunnel once again shows that LED is the most suitable light source for tunnel lamps," comments Guangdong Zhonglong Communications Technology's general manager Chen Bin. "The uniformity of illuminance on the tunnel's road surface exceeds 0.9 while over 0.7 on the side walls," he adds. "We also forecast that these LED-based lighting fixtures can bring 35% energy savings yearly."

The Golden DRAGON oval Plus has been developed specifically for street and tunnel lighting, with a focus on ease of use. Due to the integrated lens, no secondary optics are required, easing the design process. The silicone lens

materials also ensure long lifetime and reliable performance, says Osram Opto. Also, the oval radiation pattern directs the light to where it is needed on the road surface, achieving homogeneous illumination.

Osram Opto says that the Chinese government's LED Lighting Program '10,000 lights in 10 Cities' has generated momentum in the LED function lights market, such as street lamps, tunnel lamps, function lights for subways, gas stations and underground park areas. With many construction projects and new city districts being developed, demand for LED lighting is expected to continue to grow.

www.gd-realfait.com/en

LEDs retrofitted in period-style lanterns in Regensburg

Germany's Siemens and LED maker Osram Opto Semiconductors GmbH (a subsidiary of Munich-based lighting manufacturer Osram, which is part of the Siemens' Industry sector) have demonstrated that energy-saving LEDs can provide authentic period-style lighting for the historical centre in Osram Opto's home town Regensburg.

The firms have developed a retrofit solution that, they say, meets the requirements of a modern lighting system while preserving the atmosphere of a world heritage site. Discreetly installed in luminaires prescribed by the Office for the Preservation of Historical Monuments, the Golden DRAGON Plus LED light sources target the precise spot they are intended to illuminate, avoiding light pollution, says Osram Opto.

Regensburg has narrow alleys and many winding streets in a multitude of different lengths and widths, so the intricately structured town needs luminaires that enhance its historical ambience, says the firm. To ensure consistently attractive lighting, the different colors of the buildings had to be taken into account and the kind of use, correlated color temperature (CCT) and color rendering index (CRI) adjusted accordingly (e.g. the street lights must not dazzle in residential areas).

With its retrofit prototype based on the Golden DRAGON Plus LED, Osram says that light from the luminaire is fully directed to the exact target area for illumination (e.g. to the street, or also to the façade when it is used to highlight architectural features). Also, the desired level of illuminance and the light distribution can be precisely adjusted by adapting the number, the optical devices and the dimming of the LEDs. The LEDs have a CCT of 3500K and a CRI of 80. A common optical device combines light from the individual LEDs into a single beam and accurately directs it towards the desired target. As part



Alleyways retrofitted with LEDs.

of the project, two alleyways were fitted with new luminaires and some of the LEDs were selectively directed towards the façade (ensuring that the lighting can be precisely tailored to the architecture).

"This modern lighting solution can be perfectly integrated in the historical centre and offers other advantages, too, such as energy savings, the avoidance of light pollution and optimum façade illumination," says Alfons Swaczyna, head construction manager & director of the Civil Engineering Office of the municipality of Regensburg. He adds that there are plans to convert most of the luminaires in the town centre.

The prototype luminaire allows the replacement of ordinary 90W mercury vapor lamps with LEDs. Manufactured by the Regensburg branch of Siemens, its design is based on a cylinder and can be fitted with different numbers of LEDs on either side, as required (and to produce the desired lighting effect), allowing for completely different light distributions. Up to now, there was an uneven distribution of light, but now a homogenous illumination of about 3 lux has been achieved, says Osram Opto. "We have achieved the same illuminance while cutting energy consumption from 90W to just 42W and additionally integrating façade illumination for historical buildings," says Dr Martin Moeck, Osram Opto's project manager for Application Concepts. "There has also been a marked reduction in the direct glare."

www.osram-os.com

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Boston joins LED City program as it trials LED streetlights

As part of the continuing effort of its mayor Thomas M. Menino to 'green' the city's operations, Boston in Massachusetts has recently explored the use of LED lighting for public spaces, sidewalks and roadways through the installation of a demonstration project that has upgraded streetlights with LED technology. This includes installing LED lights on Boston Common (beginning near the Brewer Fountain near Park Street and continuing along the Mayor's Walk to the Public Garden) as part of an effort to showcase the technology and to solicit community input (submitting via www.CityofBoston.Gov/LED or Twittering 'BostonLED').

The temporary installation (which will be in place through the end of the year) features 'acorn'-style street lamps (three each from six different manufacturers: Lumec Lighting Company, Hadco Lighting, Sternberg Lighting, Osram Sylvania Company, King Luminaire Company and Spring City Electrical Company).

Already, in a program begun

nearly ten years ago by the Boston Transportation Department, more than 11,000 traffic signals and 1800 pedestrian crossing lights were gradually replaced with LEDs, saving the city nearly \$400,000 annually in energy costs.

"We're really pleased that LED technology has been coming down in price and going up in terms of quality and the range of applications," says Bryan Glascock, commissioner of the Boston Environment Department. "In the coming months we'll be working with the city's Street Lighting Division to find more opportunities to try out LED technology in our neighborhoods." The city is in the process of identifying sites for temporary installation of 'cobra head'-style street lights.

Boston operates and maintains more than 67,000 streetlights throughout the city. These generate 24,000 tons of carbon (eCO₂) emissions annually (about 8% of all municipal emissions). Conversion to LED technology would cut that by about half, it is reckoned.

"Once again, Boston is demonstrating how advanced technology can improve service quality, reduce operating costs, and protect our environment," says Jim Hunt, chief of Environment and Energy for the City of Boston. "Deploying this type of innovative technology further enhances Boston's reputation as one of the greenest cities in America," he claims.

Menino also announced that Boston has joined the LED City program, an international community of government and industry parties initiated by LED maker Cree Inc of Durham, NC, USA in December 2006 to evaluate, deploy and promote LED lighting for municipal infrastructure. Boston joins existing program members Raleigh, NC, Ann Arbor, MI, Austin, TX, Anchorage, AK, Indian Wells, CA, Fairview, TX and Danville, VI in the USA; Toronto and Welland in Canada; Tianjin and Huizhou in China; Gwangju in South Korea; and Torraca and Apecchio in Italy.

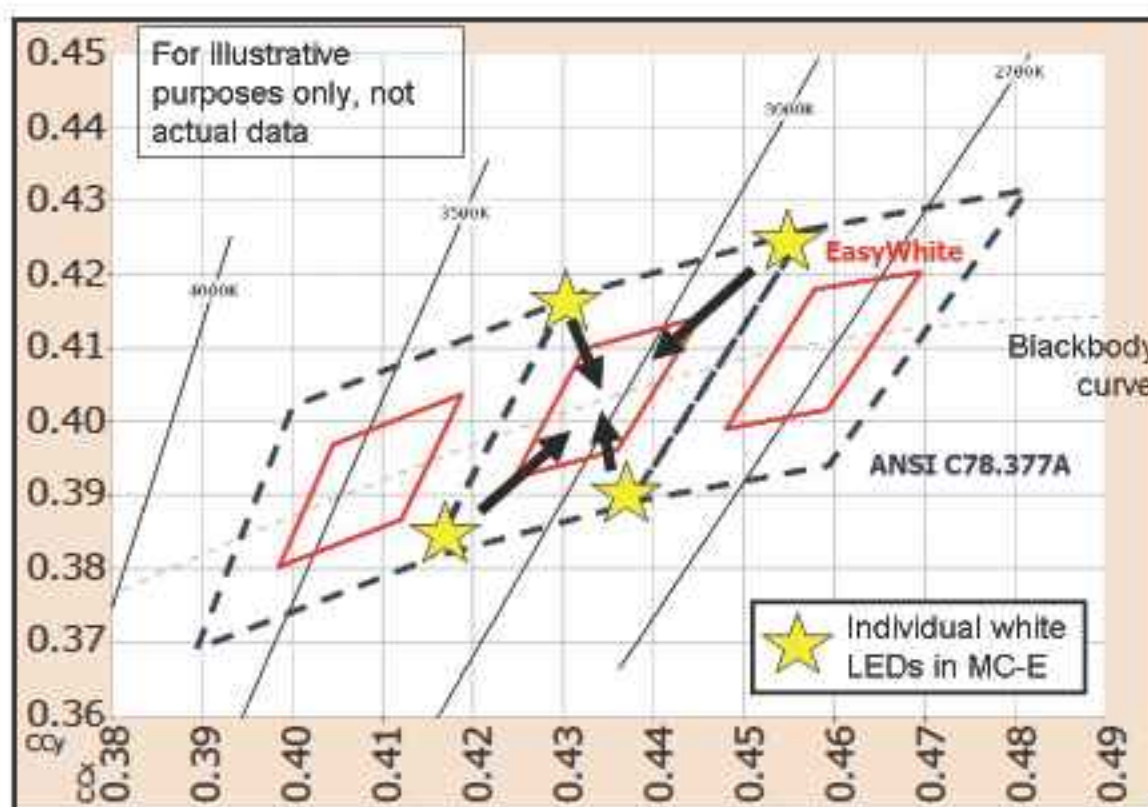
www.cityofboston.gov/environment

EasyWhite bins to aid design & improve color consistency

Aiming to both simplify LED system design and improve LED-to-LED color consistency, Cree has made available EasyWhite bins, which give emission at a correlated color temperature (CCT) of either 3500K, 3000K or 2700K as well as being as much as 75% smaller than the ANSI C78.377 standard color bins.

The bins are initially offered for multi-chip XLamp MC-E LEDs. Rather than four chips with a common phosphor coating, the MC-E's package contains four individual white LED emitters (chips with different phosphor coating, and hence different properties). The chips are chosen to allow color-mixing internally within the package so that the resulting white-light output is within the desired EasyWhite color bins.

Prior to this, users have had to manually mix different LEDs from



Narrower color bins of EasyWhite MC-E LEDs.

multiple bins to achieve consistent color points. However, for many LED lighting applications, such as MR-16 light bulbs, color-mixing multiple LEDs (where possible) made manufacturing undesirably complex, with more inventory, more parts to place, and complicated mixing recipes.

"We've listened to our customers' requests for tighter color points, especially for warm- and neutral-white lighting applications," says Paul Thieken, Cree's director of marketing for LED components. "Our goal is to increase end-product color consistency for all lighting applications... Customers can now buy LEDs just like traditional light bulbs, by specifying CCT and light output."

The MC-E EasyWhite LED, at 3000K CCT, can produce up to 560 lumens when operated at a drive current of 700mA. Cree says that this single LED is a suitable replacement for 20-35W halogen light bulbs in indoor lighting applications such as accent, track and pendant lighting.

www.cree.com

Cree and Liaoyuan demonstrates 98.3 lumens/Watt LED street light

At the 2009 LED Lighting Fixture Promotion Conference in Guangzhou, China (featuring government officials and leaders from city street lamp management offices), co-hosts Cree Inc of Durham, NC, USA and Ningbo Liaoyuan Lighting Co Ltd of Zhejiang Province, China jointly exhibited several lighting products based on Cree's LED technology, including street lamps featuring Cree's brightest and most efficient XLamp XP-G LED components. This is the first time that Liaoyuan Lighting has used Cree XLamp XP-G LEDs in a light fixture.

The XP-G LED delivers up to 132lm/W component efficiency, and has enabled Liaoyuan Lighting to create a street-lamp system efficacy of 98.3lm/W in a 150W product. Liaoyuan Lighting is planning volume production of the 150W street lamps to address the lighting needs of more Chinese cities.

Liaoyuan Lighting also demonstrated a 300W street lamp that uses Cree XLamp XP-E LEDs. These lights are installed on Southern Guangzhou Avenue (a key 10-lane thoroughfare in downtown Guangzhou). The Liaoyuan street lights are said to demonstrate

increased luminance and uniformity compared with the previous high-pressure sodium lights. Guangzhou is also reporting energy savings of more than 40% over the old high-pressure sodium lights, as well as better light quality.

"Energy-saving products are becoming increasingly popular in the current economy. The LED street lamps we installed help us better meet our energy-efficiency and environmental protection goals," says Lin Zhengang, engineer of the Guangzhou Streetlamp Management Office. "With the government's ever-growing demands for energy-efficiency and clean technology, we expect that such products will be widely used in our urban facilities," he adds.

"Working with Cree, we plan to continue our efforts to produce more environmentally friendly and more efficient LED lighting products," says Liaoyuan Lighting's general manager Shao Yunwei. "We anticipate more and more energy-saving and environmental lighting products will be installed on streets throughout China," comments Tang Guoqing, general manager for Cree China sales.

www.nbliaoyuan.com

Cree claims record 186lm/W efficiency from high-power white LED

Cree has achieved what it claims are industry-best reported R&D results of 186 lumens per watt for a white power LED.

Cree's tests confirmed that the LED produced 197 lumens of light output and achieved 186 lumens per watt efficacy at a correlated color temperature of 4577K.

The tests were conducted under standard LED test conditions at a drive current of 350mA, at room temperature.

"This result is a testament to the tremendous progress Cree has

made this year," says co-founder & director of advanced optoelectronics John Edmond. "As energy efficiency becomes increasingly important in addressing our nation's energy challenges, Cree is doing its best to deliver the most energy-efficient LED technology possible."

While this level of performance is not yet available in its production LEDs, Cree offers volume quantities of what it claims is the industry's broadest family of 100+lm LEDs.

www.CreeLEDlighting.com

IN BRIEF

Neutral-white LEDs tailored for outdoors

Cree has made commercially available a new, high-efficiency 'outdoor white' XLamp XP-E LED, which provides the same flux and efficacy levels as XLamp cool-white LEDs but with a neutral color more closely matching high-intensity discharge (HID) installations (with a correlated color temperature, CCT, of 4000–5300K).

Available in sample quantities now and in production quantities with standard lead times, the outdoor white XP-E LEDs output up to 122 lumens at a drive current of 350mA (at a CCT of 4500K).

"Outdoor lighting manufacturers can now offer either a cool-white or a neutral-white color point without trade-offs in lumen output or LED efficacy," says Paul Thieken, director of marketing, LED components. "Since it's part of the XLamp XP-E family, changing existing XP-E system designs to high-efficiency outdoor white can be simple."

Cree's IES LM-80 lumen maintenance test data for the XP-E LED has been accepted by ENERGY STAR. The firm's lighting-class XLamp XP LEDs are also UL-recognized, conforming to ANSI/UL 8750, Safety Standard for LED Equipment for Use in Lighting Products.

● Cree has signed an agreement with LED do Brasil Comercio de Produtos Eletronicos Ltda to promote the sale of its LED components — from high-brightness to lighting-class XLamp LEDs — in Brazil (which is the world's 10th largest energy consumer and third largest in the western hemisphere after the USA and Canada).

"In December, we are holding a seminar about designing with Cree LEDs," says LED do Brasil's commercial manager Paulo Taminato.

www.cree.com

IN BRIEF

GigOptix appoints new CFO

GigOptix Inc of Palo Alto, CA, USA, which designs modulator and laser drivers and transimpedance amplifier (TIA) ICs based on III-V materials as well as polymer electro-optic modulators, says that its chief accounting officer & acting chief financial officer Dawn Casterson has resigned (effective from 11 December). Casterson helped GigOptix through the merger of Lumera Corp of Bothell, WA (a manufacturer of polymer electro-optic modulators) in December 2008, the subsequent S-4 filing, and the new regulations that GigOptix was required to follow as a public company.

Ron Shelton has become CFO, and will be the firm's principal financial officer and principal accounting officer. "Ron is a long-term veteran of the semiconductor industry who not only brings an exceptional background and success in building public companies to major scale but is also, most importantly, well respected and recognized as a business partner and true leader in the teams he has participated in," says CEO & chairman Dr Avi Katz. "We continue to rapidly grow the company through global acquisitions such as the recent ChipX transaction [in early November]."

Shelton has more than 15 years experience in senior financial roles for technology companies based in Silicon Valley. Since 2007, he has provided consulting services to various technology companies, including the role of acting chief financial officer. During 2005 and 2006, he served as senior VP & chief financial officer of Alien Technology Corp (which specializes in emerging RF identification). Previously, Shelton was CFO for Alliance Semiconductor, Cirrus Logic and Lara Technology.
www.GigOptix.com

Presstek agrees to sell Lasertel to SELEX for \$10m

SELEX Sensors and Airborne Systems (US) Inc (SELEX S&AS) has agreed to acquire high-power laser diode maker Lasertel Inc of Tucson, AZ, USA from digital offset printing product maker Presstek Inc of Greenwich, CT for \$10m. This comprises \$8m in cash and about \$2m worth of laser diode inventory for Presstek's future product requirements (in its digital offset presses and computer-to-plate systems).

A supply agreement will be entered into that will provide the currently utilized laser diode product to Presstek at existing prices for a two-year period. Subject to regulatory approval in the USA and Europe, the transaction is expected to close in first-quarter 2010.

The disposal allows Presstek to focus on its core business and further reduce its debt, says the firm's chairman, president & CEO Jeff Jacobson. "While selling Lasertel has been a key objective during the past year, we needed to ensure that we received an appropriate value for Lasertel," he adds.

"This sale to SELEX S&AS will place Lasertel into a large organization whose core business is closely aligned with Lasertel's mission," says Presstek chairman, president & CEO Jeff Jacobson.

Headquartered in Arlington, VA (and with locations in Huntsville, AL; Stennis, MS; Fort Walton Beach, FL; and Norcross, GA), SELEX S&AS is a business development, marketing and US product support arm of Italy-based SELEX Galileo, which is part of Italian aerospace, defense, and security conglomerate Finmeccanica's defense electronics business unit.

SELEX Galileo is focusing on strengthening its footprint in the USA and securing strategic technologies for its US business. The firm says that laser diodes sit well within this strategy and reinforce its position in the high-power

airborne military laser market. "Acquisition of Lasertel will strengthen SELEX Galileo's position in the US laser market and offer growth opportunities both with SELEX Galileo and through DRS Technologies [of Parsippany, NJ]," reckons SELEX Galileo's operations director Norman Bone.

Lasertel will be managed as a subsidiary of SELEX S&AS operating under a special security agreement, fully owned

by the UK part of SELEX Galileo. Lasertel will still act as a merchant supplier of laser in the defense sector, and continue to serve the graphics, medical and industrial markets.

SELEX S&AS will assume the current lease on Lasertel's 35,000ft² MBE-based production facility in Tucson, from which in-house epitaxy, wafer processing and packaging enables delivery of a wide range of standard and customer-specific products. Lasertel's chips, bars, array packages and fiber-coupled devices are available with peak wavelengths from 770nm to 1050nm, and peak powers from 200mW to several kW.

"This acquisition will support our continued growth in the market for laser diode components and assemblies," says Lasertel's president Mark McElhinney. "It will enable us to better serve our current customer base by supporting the development of new technologies and products," he adds. "The transfer of ownership from Lasertel's current parent, Presstek Inc is expected to be seamless for both customers and vendors, and no change or interruption in normal business processes is anticipated."

www.selexgalileo.com

www.lasertel.com

www.presstek.com

Accessing higher THz gain with switched QCLs

France's École Normale Supérieure, Université Denis Diderot and the UK's University of Leeds have been seeking to improve amplification at terahertz frequencies (THz = 10^{12} Hz) using a quantum cascade laser (QCL) [Nathan Jukam et al, Nature Photonics, online 22 November 2009].

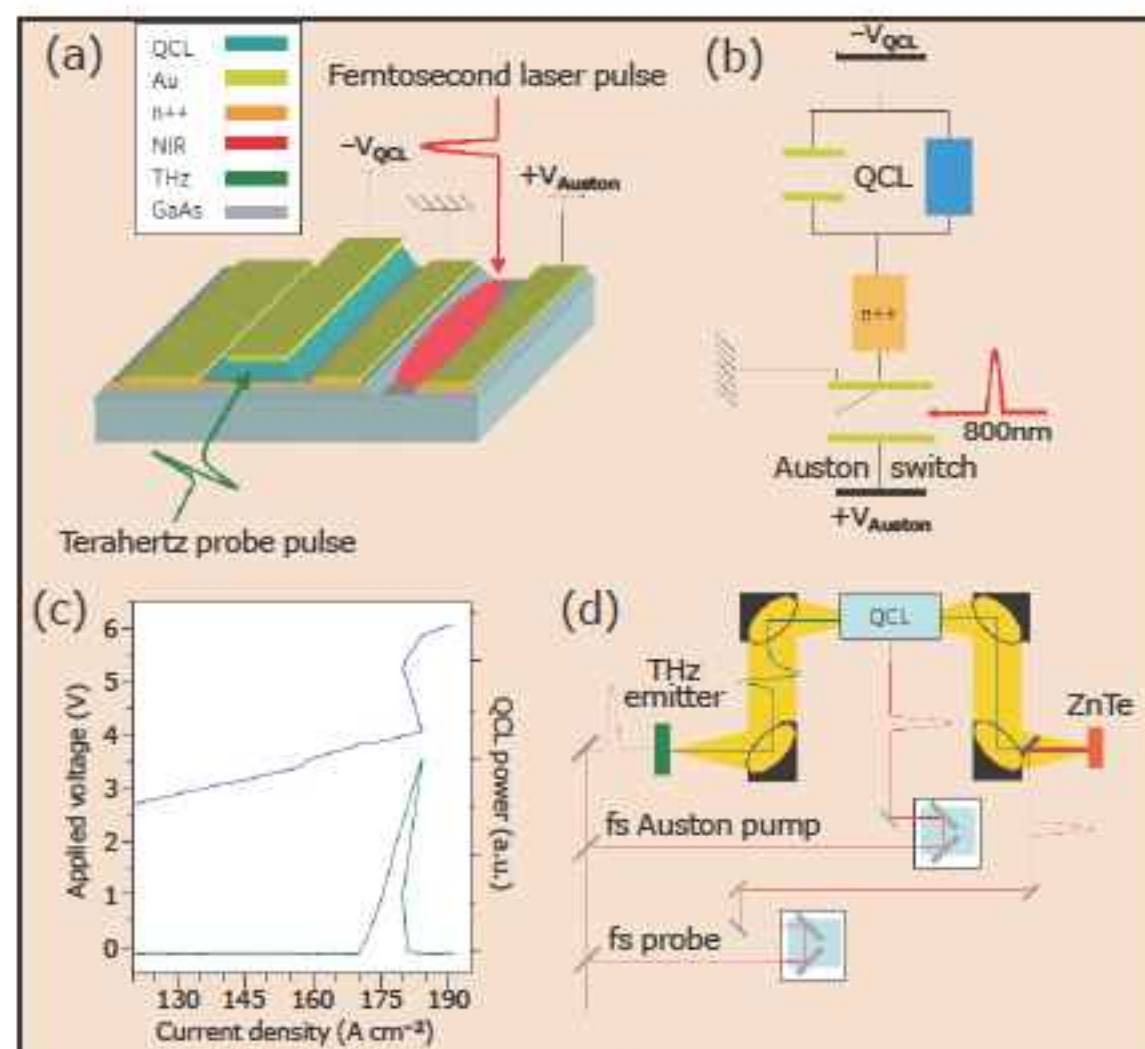
The main interest is in improving time-domain spectroscopy (TDS) in the THz region, where amplification of amplitude and phase information in signals would increase the usefulness of the technique. However, such amplification is lacking in the THz 'gap' between electromagnetic waves in the radio/microwave region (roughly, less than 300GHz) and light (i.e. mid/near-infrared, visible, ultraviolet, x-ray, etc more than 3THz = 3000GHz).

TDS works by exciting a sample with a narrow pulse of radiation and then looking for the response. The technique has been used to create images, for non-destructive testing, and for detection of complex compounds (e.g. explosives).

Another recent application has been to study QCL gain spectra. QCLs consist of thousands of layers of semiconductor material to create 'sub-bands' with very low-frequency transitions in the far- and mid-infrared, even shading into the THz range.

Gain probing suggests QCLs could be a useful medium for amplifying THz signals, but a difficulty arises. When laser action begins, gain is limited by waveguide and mirror losses in QCL structures (gain clamping). Reducing such losses by applying anti-reflective coatings is hard, since in the THz region such coatings have to be very thick. Another technique, where one tapers the laser structure, leads to astigmatism of the amplified signal. TDS needs high beam quality and a tight focus on the detector to maximize the measured signal, precluding the use of tapered QCLs at present.

The French-UK team has used gain switching to boost QCL-based THz amplification by up to 26dB ($\sim 400\times$), excluding coupling losses.



(a) QCL with Auston switch integrated into side contact. (b) Circuit schematic with QCL as a capacitor and resistor in parallel. (c) Pulsed light-current (bottom) and voltage-current (top) of 2.4THz QCL at 7K. (d) Apparatus.

This is achieved by limiting the time that the QCL is on. In the build-up period of the laser field, the gain is not clamped by the value during laser action, and the gain can be greater than the clamped value.

The team uses an 'Auston switch' to turn on a QCL, which is kept at a voltage level just below threshold. An external femtosecond laser pulse (80fs duration with 820nm center wavelength) creates carriers in the Auston switch region, increasing its conductivity and pushing the voltage of the QCL above threshold.

The QCL was based on transitions from an isolated bound state in a mini-bandgap to continuum states in the mini-band below. The active region of the QCL consisted of 90 periods of 18 alternating layers of GaAs wells and $Al_{0.15}Ga_{0.85}As$ barriers of various thicknesses. The lasing frequency was 2.4THz.

The adjacent Auston switch was created by etching through a gold-germanium-nickel (AuGeNi) contact layer to the semi-insulating GaAs substrate. Laser bars were created through cleavage to give 1.5mm-long devices. Measurements were made with the QCL assembly in a helium flow cryostat that maintained a temperature of 7K.

The detector was based on a zinc telluride crystal using electro-optic techniques where the polarization of a light pulse is shifted by the presence of THz radiation, allowing amplitude and phase information to be collected.

The femtosecond laser pulse used in the experiments to activate the Auston switch was also used to generate the THz radiation from a photo-conductive antenna. Such an antenna is deposited on GaAs. It responds to the laser radiation by creating a burst of photo-current between different parts of a biased antenna array. The burst creates the THz radiation.

The femtosecond laser pulse repeated at a 76MHz frequency and had an average power of 360mW.

Measurements of transmitted THz pulses show that, with the Auston switch off, the signal decays as it passes back and forth in the QCL. By contrast, when the switch is on, the signal increases, showing gain. The gain increases up to about 60ps, after which it begins to fall.

The researchers speculate that using the same switch-on technique with different sorts of QCL (e.g. longitudinal phonon-based devices) with better bare cavity gain could give even more amplification. Also, better ways of coupling THz radiation into the QCL would lead to improved performance. Current coupling efficiencies are about a few percent. Increasing the length of the cavity could also reduce losses from the QCL facets.

Increasing the duration of the photo-induced current in the Auston switch may lead to amplification up to the saturation field value ($\sim 1\text{kV/cm}$). This would be an injection-locking effect that could also create a high field source of narrow-band THz radiation pulses.

<http://dx.doi.org/10.1038/NPHOTON.2009.213>

Author: Mike Cooke.

IN BRIEF

Sanyo to exit red and infrared lasers

Due to the recent merger of Panasonic and Sanyo, authorized distributor Photonic Products Ltd says Sanyo will end production of its industrial red (635–670nm) and infrared (782–830nm) laser diodes at the end of September 2010. The latest date for buying all affected product lines will be the end of March.

Photonic Products has negotiated an agreement with Sanyo whereby it can guarantee order coverage for up to two years, providing that final orders are placed by the end of March. It will also source and recommend suitable alternatives from manufacturers that can provide equivalent performance and reliability at a comparable price. During the transition, engineers will help to evaluate and approve alternative laser diodes to prevent disruption to production schedules and minimize inconvenience.

Sanyo will continue to make 405nm blue-violet lasers (available in industrial strength up to 85mW optical output and with the stability required for critically demanding industrial and medical applications). Photonic Products will continue to distribute them.

www.photonic-products.com

Advanced Photonix awarded high-speed photodiode patents

Picometrix LLC of Ann Arbor, MI, USA, a subsidiary of Advanced Photonix Inc (which designs and makes silicon, InP- and GaAs-based photodetectors, subsystems, and terahertz instrumentation), has been awarded US patents 7,078,741 for enhanced-responsivity photodiodes and 7,468,503 for planar photodiodes.

The firm says that these technologies can be used either individually or in combination and are deployed in its high-speed optical receiver (HSOR) products for the 40Gb/s and emerging 100Gb/s telecom markets. They enable increased responsivity, higher optical power handling capacity, and can be used across both the C and L wavelength bands. Picometrix says that its receivers are incorporated into high-speed optical communications equipment deployed to support high-definition video, data and voice users worldwide.

The patented photodiodes are high-reliability structures that accept light in a surface-normal geometry, achieve responsivity up to 0.85 amps per watt at 40Gb/s, and can handle high optical input power. The firm says that this patented surface normal design does not require complicated semiconductor optics to illuminate the photodiode, such as the spot-size converters that are necessary for

waveguide photodiodes. As a result, a product based on these photodiodes covers both the C and L wavelength bands, is indifferent to optical polarization states, and has better reliability than mesa waveguide photodiodes, it is claimed. Indifference to polarization changes in leading-edge optical communication systems is important in maintaining transmission integrity due to the constantly changing polarization state of the incoming light.

"Proprietary, patented technology like this helps us differentiate our products in the market," says Robin (Rob) Risser, president & general manager of Picometrix and chief financial officer of Advanced Photonix. Since the photodiodes can be used for both C and L wavelength bands, customer material management can be simplified and their inventory requirements reduced, he claims. "In addition, indifference to polarization changes improves our product uniformity across operating conditions, which can contribute to improved customer manufacturing yield," Risser adds. "Our high-reliability planar photodiode structure also offers our customers the comfort of long-term reliability they have become accustomed to with lower-speed legacy systems."

www.advancedphotonix.com

Advanced Photonix announces 40G telecom design win

In early November, Picometrix was selected to supply high-speed optical receivers to what it describes as a leading OEM telecom systems provider. The annual commitment is estimated to be more than \$800,000, with volume shipments beginning in the firm's fiscal fourth-quarter 2010 (to end March). The new design win is for 40Gb/s ultra-long-haul communications in dense wavelength division multi-

plexing (DWDM) systems that use NRZ-DPSK (nonreturn-to-zero differential phase-shift keying) modulation.

The patented photodiodes and proprietary amplifiers used in the receivers are designed with dual inputs for balanced detection to support data rates up to 43Gb/s. The balanced receiver operates over the entire C and L wavelength bands with low polarization-

dependent responsivity.

"This agreement with a major tier 1 telecom OEM is only one of several design wins with tier 1 and tier 2 OEMs that we have been working on this past year," says Risser.

"We anticipate additional design wins will move to volume production status during 2010, and look forward to a long and rewarding relationship with this key customer," Risser concludes.

3S to acquire optical telecom component firm Avensys

3S Photonics of Nozay, France has entered into a €6.5m (\$9.3m) share purchase agreement with Avensys Corp of Montreal, Quebec, Canada to acquire its sole operational subsidiary Avensys Inc (including its two divisions Avensys Technologies and Avensys Environmental Solutions) and ITF Laboratories Inc (in which Avensys Corp owns a 42% stake, with most of the rest belonging to the Canadian State). The deal is expected to close in January.

The acquisition corresponds to the implementation of 3S' external growth strategy, which was planned in July after it raised €13m from three investment funds: €2.5m (\$3.49m) from Alto Invest, €450,000 (\$628,000) from Midi Capital, and €10m (\$14.1m) from the French government's Strategic Investment Fund (Fonds Stratégique d'Investissement, or FSI, formed in November 2008 to help key companies amid the financial crisis).

3S was founded in 1994 as Alcatel Optronics S.A. (a subsidiary of the Alcatel group) and acquired in 2003 by Avanex Corp of Fremont, CA, USA, becoming Avanex France S.A. In April 2007, it was bought by entrepreneur Alexandre Krivine (becoming chairman & CEO) and Didier Sauvage (former director of Avanex France) and renamed 3S Photonics. The firm designs and manufactures both active optical components (incorporating GaAs and InP optoelectronic laser chips fabricated in-house at Nozay, France) and passive optical components based on fiber Bragg gratings, for use in discrete modules for high-speed telecom networks, as well as providing epitaxial and wafer processing foundry services. Staffing is 160 and revenues were €23.04m for fiscal 2009 (to end-June).

With staffing of 200, Avensys realized turnover of \$23m in the fiscal year to end June. Avensys Technologies designs and makes optical components, modules and fiber Bragg gratings for the telecom market as well as high-power devices, sub-assemblies and packaged fiber-based sensors for the industrial market. Avensys Environmental Solutions provides the Canadian market with environmental monitoring solutions and services for air, water, soil and geo-structures. ITF Labs develops integrated photonics solutions as well as components and fiber-based systems for fiber lasers and optical sensing applications.

"This is an important and necessary step for Avensys Inc," says Avensys Corp's CEO John Fraser. The deal follows Avensys Corp's announcement earlier this

year of the hiring of a financial advisory firm to assist it in reviewing and evaluating its financial and strategic alternatives.

"Given Avensys' continuing default under its financing agreements, Avensys' board of directors concluded that the transaction was the best possible solution for the business," Fraser adds.

"Combining the operations of two businesses with leading-edge and complementary technologies maximizes technological synergies, operational consolidation and opens up bigger market prospects for Avensys Inc and 3S."

Integration of Avensys should help 3S Photonics to build a more balanced and comprehensive portfolio of activities, consolidating its offerings in optical components, filters and packaging for both the industrial laser and telecoms markets, as well as providing expertise in environmental management solutions.

3S Photonics should also benefit from significant expansion of its R&D capacities. Currently, the firm invests 15% of its revenue in R&D (compared with the average in France of 3%). With Avensys, R&D staffing should exceed 70 (more than 20% of the overall combined workforce). The Canadian State should also contribute to financing R&D, in the form of a tax credit granted to ITF Labs (of almost CDN\$1m per year), enabled by the legal and financial structure of ITF Labs.

3S Photonics says that, with 95% of its turnover realized abroad (mainly in the Asia-Pacific), the acquisition is extending its perimeter of activity, complementing and strengthening its know-how and bolstering its client portfolio in international markets, as well as allowing the firm to invest in North American production and distribution of optical components (particularly in the submarine telecoms market).

With the integration of Avensys, 3S expects a cumulative turnover of US\$70m in the next fiscal year. It also expects significant synergies, with additional EBITDA (earnings before interest, taxes, depreciation, and amortization) of more than US\$3m for 2012. The ultimate aim is to achieve sufficient critical mass for annual turnover of €100–150m.

www.avensyscorporation.com
www.3Sphotonics.com

Avensys should help 3S to build a more balanced and comprehensive portfolio of activities, consolidating its offerings in optical components, filters and packaging

First single-chip transceiver for motherboard deployment

At Supercomputing 2009 (SC09) in Portland, OR in November, fabless silicon photonics firm Luxtera Inc of Carlsbad, CA demonstrated its new OptoPHY family of PCB-mountable optical transceivers, which deliver low-cost optical connectivity and pave the way to breaking the \$1 per Gbps cost barrier, the firm claims.

Combining electronics and optics on a CMOS silicon chip, OptoPHY's small form-factor enables optics-on-a-motherboard deployment for point-to-point connectivity, says Luxtera. The firm claims the new product line signifies the next step in evolution from pluggable modules to chip-on-board solutions with optoelectronic system-on-chip integration.

"10Gbps is the new system interconnect 'currency,'" says Brad Smith, senior VP analyst at market research firm LightCounting. "But the current generation of high-speed systems for switch/routers, supercomputers, telecom equipment, datacom and servers are built internally with 2.5G/5G SNAP12 technology developed in 1998... This requires four transmitter/receivers, at 2.5W, costing \$400+ each. Full duplex connections cost \$1600, burn 10W power, and large board space. The market begs for a new solution. Optical technology, once relegated to the long haul and inter-system interconnects, now moves inside the box and is clearly heading for optics-on-a-chip."

Luxtera aims to replace legacy optical modules with a high-density, integrated chip-on-board transceiver. Available in one- and four-channel configurations (and next year in 12-channel), OptoPHY offers data rates of 10Gbps per channel for high-bandwidth parallel connectivity. It also claims the highest footprint density per Gigabit. This enables flexible system design and allows transceivers to be placed inside a system to maximize front-panel connector density, simplifying thermal and EMI management. Using only 20mW per Gigabit, OptoPHY is claimed to be the lowest-power optical transceiver on the market.

"To address the need for increasing data rates, data centers have had to choose between lower-cost, lower-performance electrical interconnects or higher-performance, higher-cost optical interconnects," says Steve Conway, research VP for High Performance Computing at analyst firm IDC. "Luxtera's new OptoPHY product line is designed to address this problem by delivering high-performance optical interconnects at costs below \$1 per Gb/s," he adds.

OptoPHY also builds on Luxtera's Blazar active optical cable (AOC) product line (launched in August 2007) by providing data centers with extended reach of up to 4000m, enabling flexible layouts in a multi-building campus environment. Overcoming the 100m range barriers of legacy multi-mode fiber VCSEL optics, OptoPHY offers the longest reach for on-board optics, suiting enterprise networking, InfiniBand, storage, Ethernet and backplane applications, Luxtera claims.

"By utilizing Luxtera's silicon CMOS photonics technology platform, the OptoPHY product line breaks cost and power consumption barriers of traditional optics and positions us to ultimately deliver optical interconnects at the price points of copper," reckons the firm's CEO Greg Young. "Using the same chip design platform as our award-winning AOC, OptoPHY successfully enables optical deployment on a motherboard to offer a new direction for the architecture of system interconnects."

At SC09, Luxtera sampled both one-channel (LUX6001) and four-channel (LUX6004) OptoPHY chips, with production scheduled for mid-2010. 12-channel OptoPHY will sample next year. The devices are available with multiple optical connector options for serial and parallel 10Gb/s applications. Pricing varies depending on the number of channels, connector options and volume, reaching sub-\$1 per Gb/s price points in 12-channel configurations.

● Luxtera demonstrated the new LUX5010A low-power version of its Blazar 40G active optical cable at SC09, where it served as the cabling solution backbone for SCinet, the world's fastest network, showing its extended reach and low power by connecting exhibitors through the InfiniBand network to enable multiple high-performance computing (HPC) demonstrations.

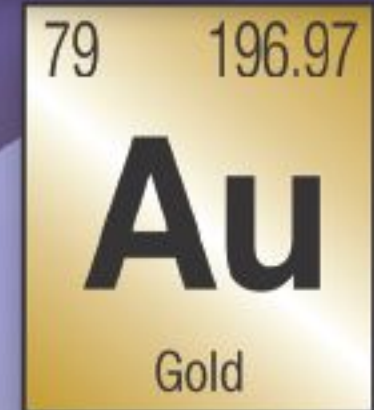
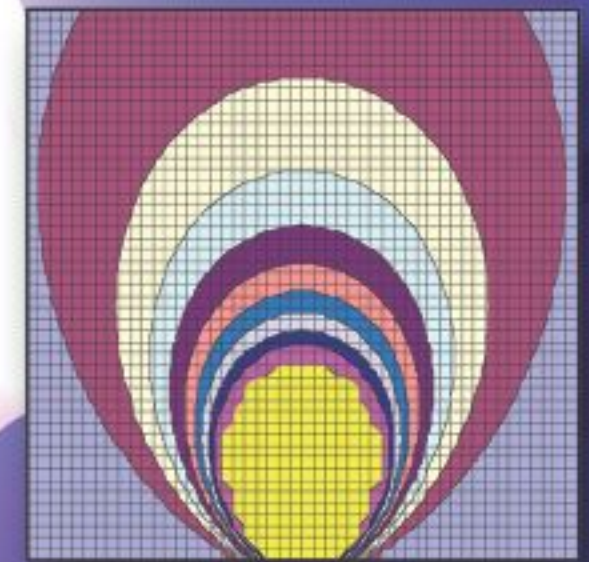
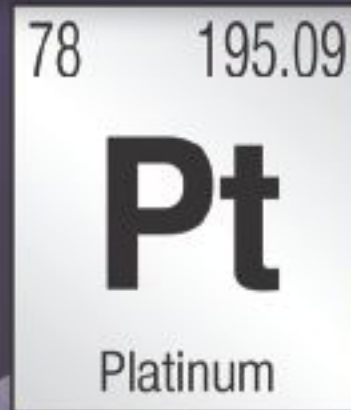
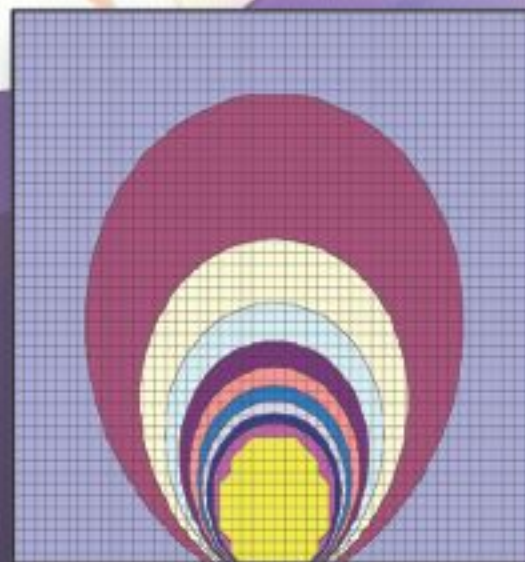
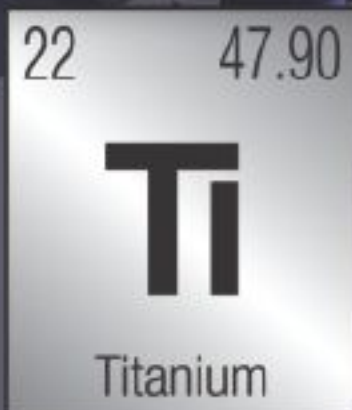
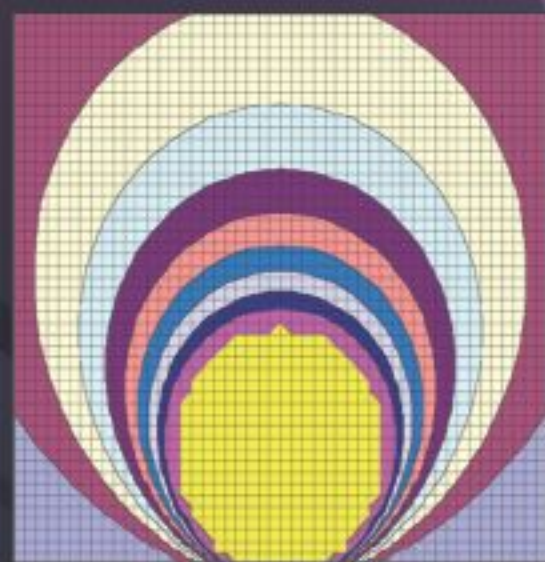
The new Blazar uses over 30% less energy, improving overall data-center power consumption and thermal efficiency. Its transceivers operate at less than 20mW/Gbps, well below that of traditional multi-mode VCSEL optics, reducing heat dissipation, operating expenses and the carbon footprint. By combining CMOS photonics technology and single-mode fiber, it maintains a low price point while supporting long-reach connectivity from 1m to up to more than 4000m. High reliability and design flexibility also suit the interconnection of HPC clusters as well as high-density applications such as blade servers.

"Our highly integrated 40Gbps switch systems and switch blades are providing data centers with the computing power and density required for HPC and scaled data-center applications, but with density come distance, power consumption and thermal design challenges," says Shai Rephaeli, VP of product engineering at Mellanox Technologies of Sunnyvale, CA USA and Yokneam, Israel, which supplies end-to-end connectivity solutions for servers and storage. "Low-power optical solutions, such as Luxtera's low-power Blazar, solve these challenges by minimizing power consumption while providing benefits in distance, weight and flexibility."

Low-power Blazar is also the first secure optical cable available for HPC deployments, claims Luxtera. Optoelectronic integration enables use of embedded germanium photodetectors with receiver logic to detect cable intrusion attempts.

www.luxtera.com

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Finisar demos 120Gb/s CXP-to-QSFP active breakout cable

At the SuperComputing 2009 (SC09) exhibition in Portland, OR (16–19 November), Finisar Corp of Sunnyvale, CA, USA, which makes fiber-optic communications components and subsystems as well as network test & measurement systems, gave the first public demonstration of a 120Gb/s CXP-to-QSFP active breakout cable.

The active optical cable contained a single CXP transceiver at one end and three 40Gb/s QSFP transceivers at the other end to provide maximum flexibility in high-performance computing and network infrastructure environments.

Finisar says the multi-connector

cable can provide high-density switches with connectivity to multiple top-of-rack switches and/or server nodes. Compliant with both CXP and QSFP specifications, the breakout cable provides a hot-pluggable, low-power, low-weight, and flexible solution for high-port-count network topologies.

In addition, Finisar demonstrated an active 10Gb/s Ethernet copper cable, the latest member of the Laserwire cable family targeted at server connectivity applications. The cable is optimized for very short, low-cost, intra-rack links. It is designed to comply with the SFF-8461 specification through the

use of SFP+ to Laserwire adapters.

Also on display was Finisar's extended family of high-performance active optical cables, which includes Quadwire (a 40Gb/s parallel cable for 40GbE and InfiniBand QDR) as well as C.wire (a 150Gb/s parallel cable for 100GbE and InfiniBand 12xQDR applications).

During SC09, Finisar also demonstrated a new QSFP-to-Laserwire adapter, which promises to drive convergence of multiple connector form factors in data-center applications, says the firm. The adapter can enable system manufacturers to design a single PCB layout for both 10G and 40G solutions.

Finisar's Laserwire demoed in QSFP ConnectX-2 VPI adapter card

SuperComputing 2009 also saw the first public demonstration combining Finisar's 10GbE Laserwire QSFP adapter with the ConnectX-2 Virtual Protocol Interconnect (VPI) adapter card of Sunnyvale-based Mellanox Technologies, delivering multi-protocol options on a single board.

The new QSFP adapter is part of Finisar's Laserwire family, which it claims is the industry's first serial active optical cable designed to accelerate and support 10Gb/s Ethernet server connectivity. Since Laserwire uses fiber-optic technology, it reduces the weight, density and power consumption of passive copper cable connections. The Laserwire family includes adapter modules for SFP+ and XFP, allowing plug-and-play with legacy equipment in existing data centers.

Mellanox's ConnectX-2 VPI adapter card is said to provide fabric flexibility with InfiniBand and Ethernet connectivity, while expanding the performance potential of applications within



data center, high-performance computing, and embedded environments. ConnectX-2 VPI's unified I/O technology provides a one-wire solution for any networking, clustering, storage, and management application with what is claimed to be an enhanced quality of service to deliver high application productivity.

ConnectX-2 VPI adapter devices will also drive dual-port LAN-on-motherboard designs based on the QSFP host connector utilizing lightweight Laserwire cables (via the QSFP adapter) for 10GbE and Quadwire cables for 40Gb/s InfiniBand QDR.

"By providing a Finisar QSFP-to-Laserwire adapter option into Mellanox's ConnectX-2 VPI cards, we are able to jointly deliver a solution important to the evolution of next-generation high-speed server interconnects," claims Jan Meise, Finisar's director of strategic marketing.

The ConnectX-2 VPI adapter card's combination of interconnect bandwidth and latency performance with I/O infrastructure agility provide a robust connectivity solution for data centers and high-performance, high-transactional computing environments, claims Bill Lee, Mellanox's senior product marketing manager. "Coupled with Finisar's active optical cable solutions for InfiniBand and Ethernet, ConnectX-2 VPI provides a single-adapter solution and enhances the ease of use for converged server interconnects."

www.laserwire.org

www.mellanox.com

www.finisar.com/cables

<http://sc09.supercomputing.org>

Foxconn to make Finisar's Laserwire serial interconnect

Finisar Corp of Sunnyvale, CA, USA, which makes fiber-optic communications components and subsystems as well as network test & measurement systems, has agreed a strategic partnership in which its Laserwire connectors, adapters and cable assemblies will be manufactured and sold by Taiwanese contract manufacturing services provider Foxconn Technology Group.

Laserwire is a family of 10Gb/s active optical and active copper cables designed to accelerate and support 10 Gigabit Ethernet (10GbE) server connectivity. Launched by Finisar in November 2007, the extended Laserwire family consists of active cables, a high-density electrical connector and 10 Gigabit Ethernet adapter modules to facilitate adoption into legacy transceiver ports.

"We have been following Finisar's progress with Laserwire since its



Left to right: Brian Sill (Foxconn's senior director Strategic Alliance), Jerry Rawls (Finisar's executive chairman), Sidney Lu (Foxconn's executive VP NWinG) and Jan Meise (Finisar's director Strategic Marketing).

debut and are looking forward to driving 10G Ethernet into LAN on motherboard designs," says Caesar Chen, Foxconn senior VP of cable R&D.

"Laserwire enables us to provide low-power and low-cost 10GbE connectivity in the data center,"

comments Barry Cioe, VP of product management at network equipment maker Enterasys Networks Inc of Andover, MA. "Its flexibility to connect to our XFP and SFP+ ports allows us to offer true plug and play across our entire product portfolio. Adding a second source to Laserwire will help drive the 10GbE ecosystem to adopt active cables into next-generation network architectures," he adds.

"Foxconn has been a trusted leader in interconnect solutions for a long time and shares our vision of driving low-power, low-cost serial cables into next-generation server connectivity," says Jan Meise, Finisar's director of strategic marketing. "I have great confidence in their ability to support customers with the same level of service as Finisar."

www.laserwire.org

www.finisar.com

www.foxconn.com

Avago Technologies ramps up production of its QSFP+ active optical cable and transceiver solutions

At the Supercomputing 2009 event (SC09) in Portland, OR (16-19 November), Avago Technologies of San Jose, CA, USA showcased its QSFP+ active optical cable (AOC) and transceiver solutions for short-range Infiniband and Ethernet applications.

The AFBR-79Q4xACyyZ is a high-performance integrated AOC for short-range multi-lane data communication and interconnect applications. It integrates four data lanes in each direction with 40Gbps aggregate bandwidth into a single module. Each lane can operate at 10Gbps with lengths of 1-100m.

The AFBR-79Q4xACyyZ QSFP+ active optical cable assembly and AFBR-79Q4Z transceiver use multi-mode fiber utilizing a wavelength of 850nm. The electrical interface uses a 38-contact edge type connector. Additionally, the four-channel pluggable AOC and

transceiver incorporate Avago's integrated circuit and VCSEL technology to provide what is claimed to be reliable long life, high performance, and consistent service.

"As the bandwidth needs have increased, copper interconnects are becoming less and less attractive due to the bulk of the connectors, cables, electromagnetic interference (EMI) issues, weight management, and reduced distance capability," says Sami Nassar, senior director of marketing for Avago's Fiber Optic product division. Copper cabling typically has a limited reach of 3-15m at 10Gbps/lane data rate. A fiber-optic QSFP+ solution provides a longer reach and a tighter bend radius. "As a result, parallel optics is now a natural replacement for parallel copper interconnects," he adds. The QSFP+ active optical cable

assembly and transceiver provide a hot-pluggable solution with data rates of 5-10Gbps per channel. "Compared to other 10Gbps serial solutions, these QSFP+ solutions help to improve port density by more than two times and reduce power consumption by more than 50% to allow systems companies to lower their overall cost per port," says Nassar.

At Supercomputing 2009, Avago conducted live demonstrations of its QSFP+ AOC and transceiver products, including a 120Gbps 12x QDR Infiniband link streaming traffic from the SCInet network and an example of a real-time advanced remote desktop that allows exhibitors to share simulations, live video and presentations.

Pricing for the AFBR-79Q4xACyyZ AOC is about \$500 for a 10m cable in small quantities.

www.avagotech.com

Finisar's capacity constraints suppress profit margin despite upturn

For its fiscal second-quarter 2010 (ended 1 November 2009), Finisar Corp has reported revenues from continuing operations of \$145.7m. Excluding the Network Tools business (sold on 15 July), this is down 1.4% from \$147.7m a year ago (the first quarter in which the results of Optium were included following the merger on 29 August 2008), but up 13.2% on \$128.7m last quarter (and above the guidance of \$132–142m).

Of the \$17m rise in revenue from last quarter, LAN/SAN products grew 20% or \$9.9m (including \$6.9m for sub-10Gbps applications), reconfigurable optical add-drop multiplexer (ROADM) products grew 41% or \$4.5m (despite being capacity constrained during their ramp up), and long-distance metro telecom and cable TV products grew by \$2.6m.

On a non-GAAP basis, gross margin was 29.6%, up on 28.8% last quarter (due to higher product shipment levels, partially offset by lower production yields from ramping production volume for several high-speed products). However, this was still lower than expected, due to: (i) an unfavorable product mix, as revenue from sub-10Gbps transceivers rose \$7.7m (12%) on last quarter; and (ii) much higher scrap levels, due to rapid volume growth in 8 and 10Gbps transceivers and ROADMs.

In particular, problems in ramping up volumes were exacerbated by simultaneous transfer activities for these products from the plants in Horsham, PA, USA and Sydney, Australia to offshore manufacturing locations, including subassemblies used in WSM ROADMs being transferred from Sydney to Shanghai as well as the first quarter of volume production for optical subassemblies formerly made at the plant in Allen TX.

"As demand ramps, we're sometimes faced with the choice of either getting products out of the door or focusing on process improvements," says CEO Eitan Gertel, adding that not as much production had been transferred offshore as the firm would have liked. This is leading to organizational changes in order to put more emphasis on yield improvement, but this may take a few quarters to see results, he notes.

Non-GAAP operating income was \$8.9m (an operating margin of 6.1% of revenues). This is up from \$3.3m (2.5% of revenues) last quarter due mainly to higher gross profit on higher revenues partially offset by slightly higher operating expenses (\$34.2m, up \$0.4m from last quarter).

Though down on \$8.6m a year ago, non-GAAP net income has risen from \$1.8m last quarter to \$7.5m.

During the quarter, cash and short-term investments, plus other long-term investments that can be readily converted into cash, rose from \$60.4m to \$80.7m. This reflects net proceeds of \$98.8m from the sale of a new series of 5% convertible notes partially offset by using \$82.6m in cash to retire \$106.9m aggregate principal amount of existing 2.5% convertible notes. Excluding these transactions, Finisar generated \$4.1m in cash.

Not as much production had been transferred offshore as the firm would have liked. This is leading to organizational changes in order to put more emphasis on yield improvement, but this may take a few quarters to see results

"Incoming orders continued to be strong during the quarter, particularly for transceivers used in less than 10Gbps LAN/SAN applications," says executive chairman Jerry Rawls. "The other area of strength was in ROADMs for telecom WDM networks," he adds. "Our backlog position suggests that we can look forward to another sequential increase in revenues next quarter, led by a surge in demand for 10Gbps products."

For its fiscal third-quarter (to end-January 2010), Finisar expects record revenue of \$148–158m (up about 5% sequentially, and ahead of the estimated \$148m), led by strong orders for 10–40Gb/s products as well as record ROADM revenue. Due to the slightly improved product mix, non-GAAP gross margin should rise to 30–32%. Also, despite reversing the 10% salary cut imposed in February — contributing \$1.4m to operating expenses rising to \$37–38m — operating margin will still be 6–8%.

However, although Finisar is still targeting non-GAAP operating margin of 10% in fiscal first-half 2011, it acknowledges that quarterly revenue may have to be at the top of the \$150–160m guidance range. It is also dependent on further cost reductions (through engineering efforts that are currently underway) and the completion of as much as possible of its transfer of production to offshore locations.

"We continue to work on the transfer of additional production activities to our off-shore locations," says Gertel. "This work will largely be completed by the end of the fiscal year as we also work in the interim at those facilities to ramp several new products," he adds. "We expect continued improvements in our profitability in the meantime in conjunction with a rising top line."

www.finisar.com



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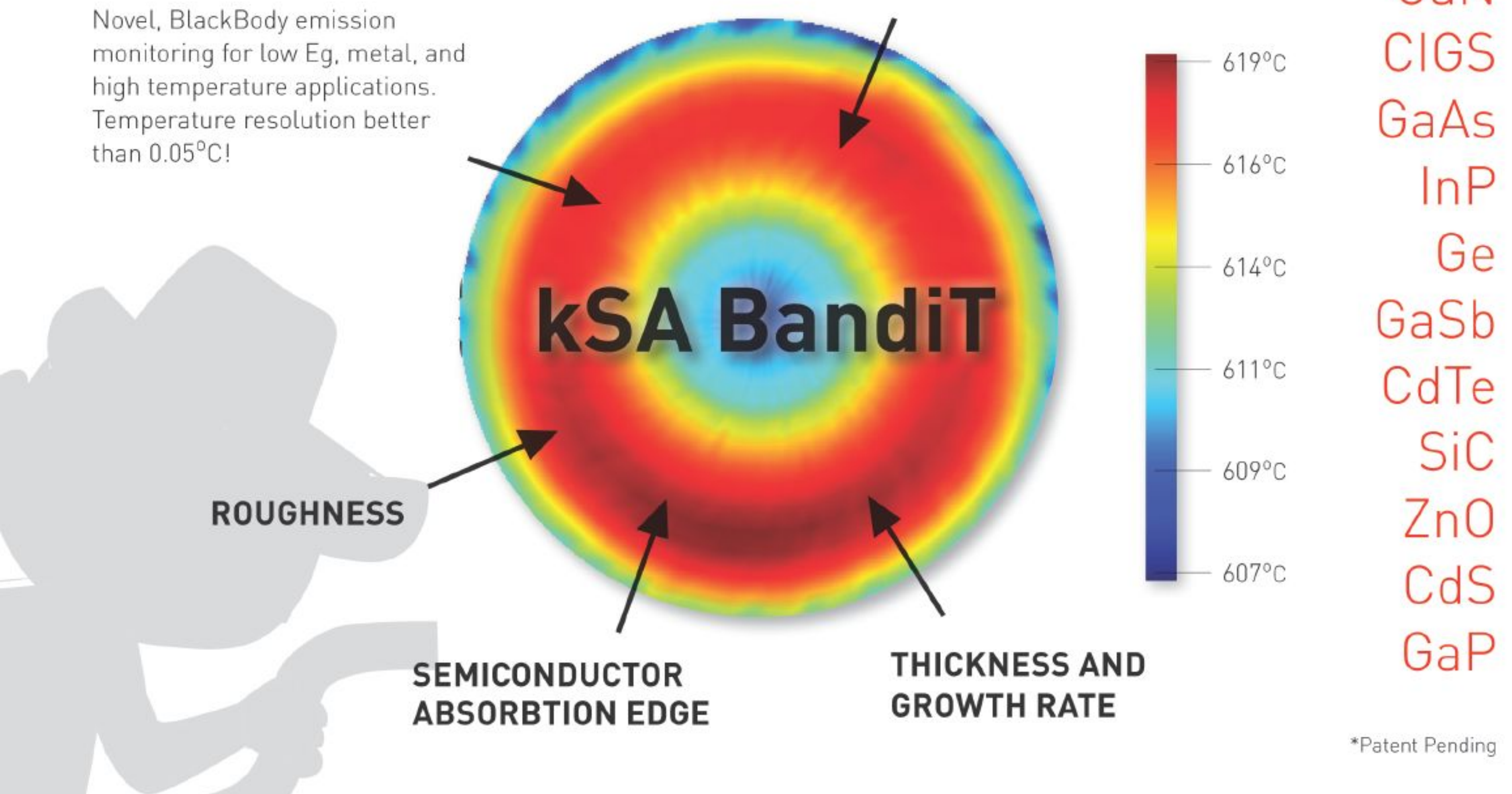
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Soitec acquires Concentrix

Soitec Group of Bernin, France, which manufactures engineered substrates including silicon-on-insulator wafers (as well as III-V epiwafers through its Picogiga International division), has agreed to acquire about 80% of the shares of privately held concentrated photovoltaic (CPV) system maker Concentrix Solar GmbH of Freiburg, Germany, valuing the whole firm at €55m (\$80.9m). The remaining 20% of the shares continue to be owned by Fraunhofer Institute for Solar Energy Systems ISE (from which Concentrix was spun off in 2005) as well as the firm's founders and senior management. Upon closing the transaction, Concentrix will retain its staff and operate within a new PV business unit of Soitec Group.

The transaction also includes access to CPV cell technologies from Fraunhofer ISE (Europe's largest solar energy research institute, with more than 20 years of experience in III-V solar cell development).

Soitec says that entering the fast-growing solar industry is in line with its strategy: capturing value at the system level as well as expanding its revenue base as demand for CPV systems is expected to increase strongly in the coming years.

CPV technology offers a competitive solution for large power plants in high irradiation countries, says Soitec. Concentrix's patented solution, which is proven in various power plants and demonstration installations in Spain, Italy, Korea and the USA, uses Fresnel lenses to focus sunlight almost 500-fold onto a small area of high-efficiency solar cells, reducing the need for costly materials and increasing system efficiency. In August, Concentrix said that it had raised its record for CPV alternating-current (AC) system efficiency from 23% (achieved in May 2008) to 25% by using its new CX-75 generation of modules.

Soitec reckons that its engineered substrate technologies are key to improving solar cell performance, and hence complement Concentrix's expertise in high-efficiency CPV systems for solar power plants.

"The Concentrix solution, which we believe is the best for solar farms and therefore industrial production of solar-sourced electricity, has exceptional synergy with Soitec technologies," says Soitec's president & CEO André-Jacques Auberton-Hervé. The acquisition represents a natural expansion into the fast-growing solar market, allowing Soitec to leverage its technology and process knowledge in developing cost-competitive PV solutions up to the system level, he adds. "We plan to become an active player in the city of Freiburg both through Concentrix industrial activities and through the long-term partnership between Soitec and the Fraunhofer ISE. Like other Soitec core businesses, the CPV business aligns with our mission to innovate and create new, energy-efficient materials for high-volume markets serving sustainable development."

As part of the deal, Fraunhofer ISE has entered into a long-term license agreement with Soitec related to CPV cell manufacturing technology. The partners aim to co-develop next-generation very-high-efficiency CPV cells based on Soitec's proprietary technologies, boosting CPV system performance. The collaboration includes French government microelectronics research laboratory CEA-Leti, Soitec's long-term partner within the Grenoble R&D cluster.

"We look forward to maintaining and strengthening our long-standing partnership with Concentrix through Soitec," says Fraunhofer ISE's director Eicke Weber. "Soitec will provide remarkable resources for advanced technical development of our III-V solar cell technology and will increase efficiency of existing Concentrix products and technologies," he reckons.

"We are very pleased to further expand our long-standing collaboration with Soitec, and to reinforce our relationship with the Fraunhofer Institute," comments CEA-Leti's CEO Laurent Malier. "Combining our R&D efforts in Europe is key to supporting European industrial leadership in the critical field of renewable energy," he adds.

"We are looking forward to the strategic and technical opportunities arising from the combination of our skills and technologies and the acceleration of our cost reduction and system efficiency roadmaps," says Concentrix's CEO Hansjörg Lerchenmüller. "With Soitec's experience and financial strengths, we are going to be able to boost our growth further and move faster in the industrial phase."

From September 2006 to August 2008, Concentrix operated a CPV module pilot-production line with a capacity of 1MW. Since September 2008, Concentrix has produced CPV modules using a fully automated production line with an annual capacity of 25MW. The building and infrastructure are designed in such a way that production capacity can quickly be increased to 100MW, says the firm.

The transaction includes an earn-out option based on sales growth performance in 2010. The agreement also contains put-and-call option rights granting:

- Soitec a call option (from January 2012) to buy the remaining 20% of Concentrix shares; and
- Fraunhofer Institute, Concentrix founders and senior management a put option (from January 2013) to sell their shares to Soitec. Pre-agreed multiples determine the exercise price of the put-and-call option rights, and the exercise of the put option is also subject to Concentrix achieving certain financial targets.

www.soitec.com

www.concentrix-solar.de

CPV system maker Circadian and Radboud University form tf2 devices

Circadian Solar of Coventry, UK, which is developing concentrated photovoltaic (CPV) systems incorporating gallium arsenide multi-junction photovoltaic cells, and Radboud University Nijmegen in The Netherlands have formed the joint venture tf2 devices to develop thin-film III-V technology for use in solar cells. The aim is to match the record conversion efficiency of III-V solar cells (which is greater than 41%), while reducing the cost of manufacture.

Radboud University has developed a unique technology to lower costs by using epitaxial lift-off to remove a complete, fully functional thin-film solar cell from the expensive III-V substrate, which can then be reused.

"We have been collaborating with the team there for almost two years, and have already developed an excellent relationship," says Circadian's CEO Dr Robin Godfrey about Radboud University Nijmegen. "The group of Dr John Schermer has been pioneering the field of III-V thin-film technology and holds the world record for single-junction GaAs photovoltaic thin-film cell efficiency [raised from its previous record of 24.5% to 25.9% in July 2008]." The joint venture represents an opportunity to bring the technology to market and work more closely with the team at Radboud University Nijmegen, he adds. Schermer holds key patents, which will be available to tf2 devices.

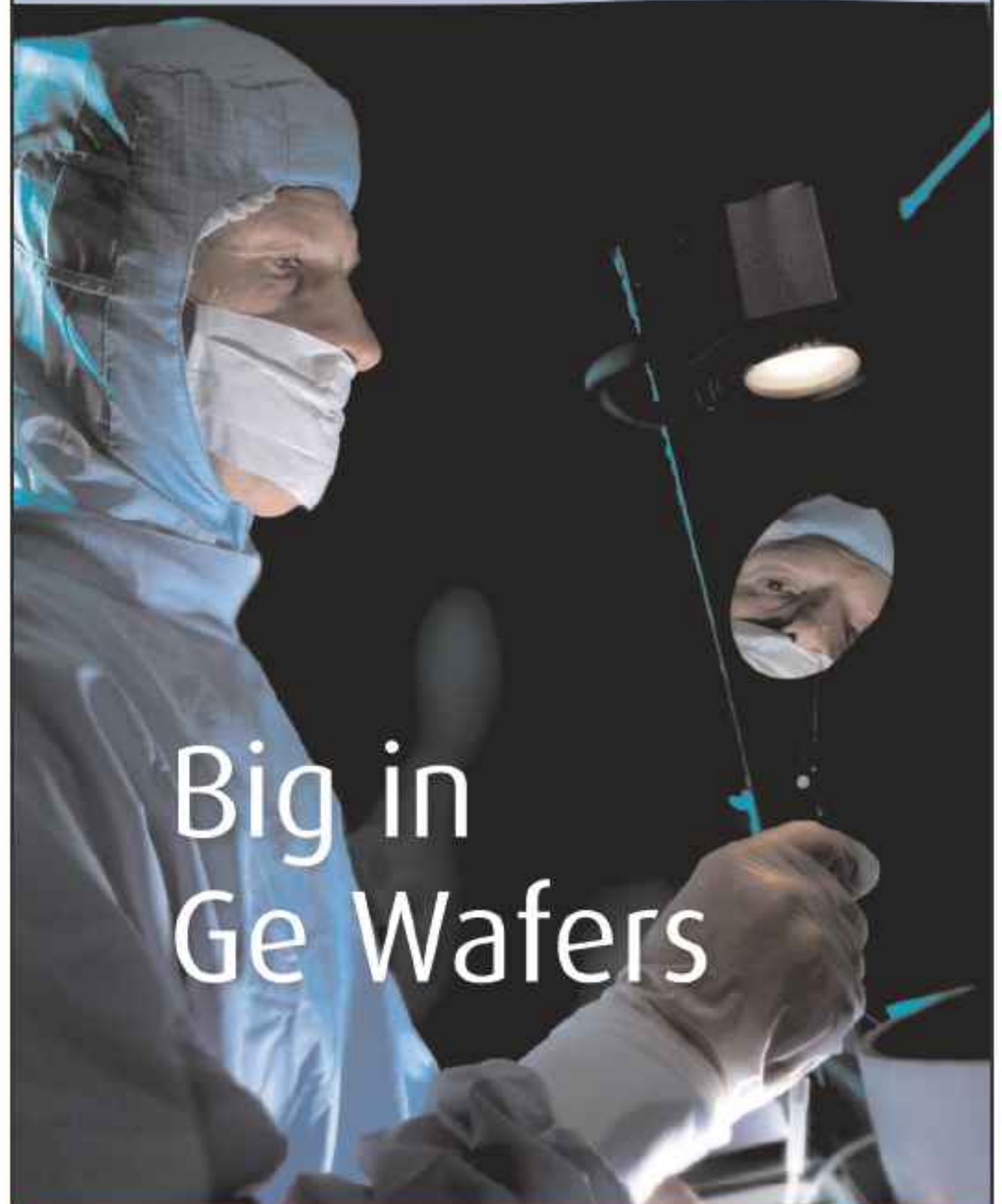
"As the proportion of energy generated from solar power increases worldwide, the drive towards higher efficiency at lower cost will become even more important," says professor Elias Vlieg of Radboud University Nijmegen. "tf2 devices' technology is well-positioned to play a significant role in helping the world to meet its growing energy needs," he reckons.

"STW's focus is towards basic scientific research that has a strong potential for real-world application," says Huub Eggen at Technology Foundation STW, a major funder of the research. "Our mission is to realize knowledge transfer between applied sciences and potential knowledge users," he adds. "tf2 devices has the potential to make a big impact on energy generation and on reduction of carbon emissions internationally."

www.circadiansolar.com

www.ru.nl/ams/research/classical_iii-v

The aim is to match the record efficiency of III-V solar cells (which is greater than 41%), while reducing the cost of manufacture



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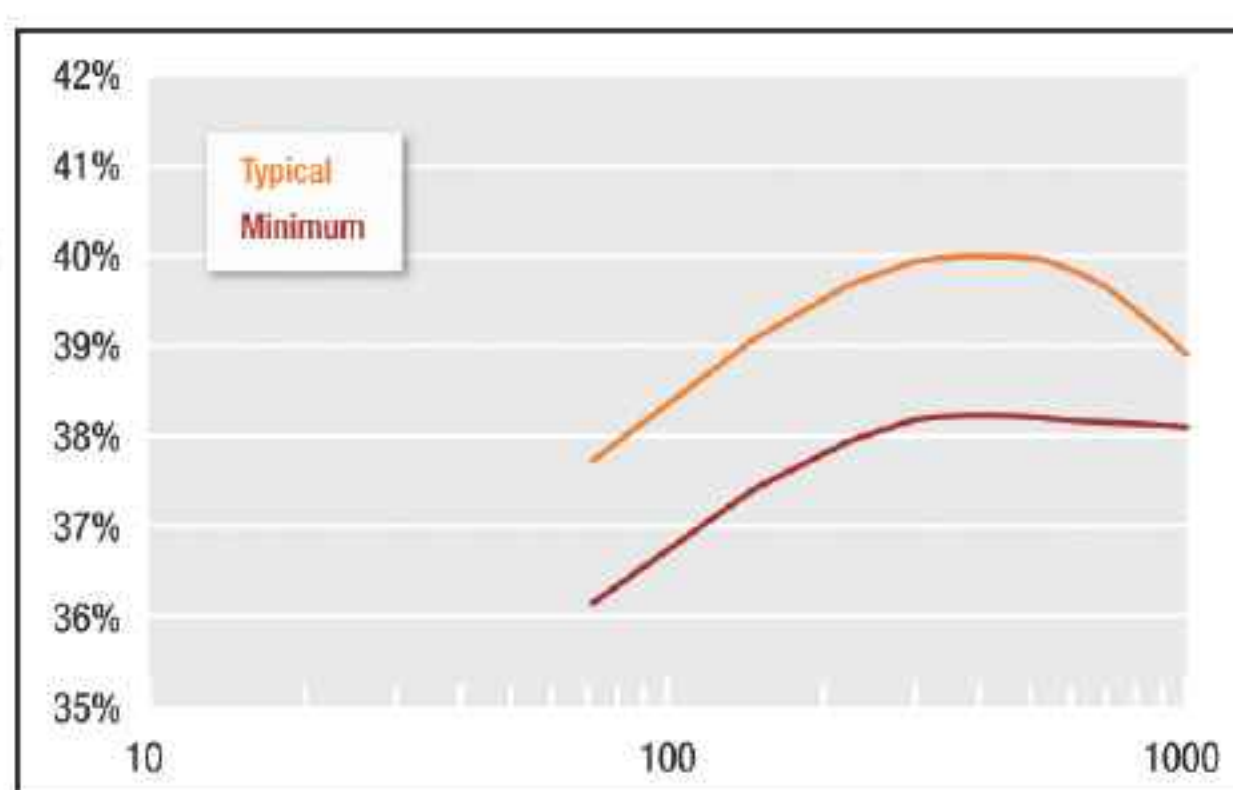
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Cyrium launches 40%-efficient QD-enhanced cell for CPV

Cyrium Technologies Inc of Ottawa, Canada, which makes multi-junction solar cells for concentrator photovoltaic (CPV) systems, has launched its first commercial product line: the QDEC (quantum dot enhanced cell) for terrestrial applications.

Cyrium was spun off from the National Research Council of Canada (NRC) in 2002. "Our primary objective in developing the QDEC line is to provide our clients with high-efficiency cost-effective cells with consistent reproducible performance," says president & CEO Harry Rozakis.

Due to Cyrium's proprietary quantum dot technology (with a triple-junction AlGaInP-Ga(In)As-Ge structure on germanium substrate), efficiency is 40% on average at a concentration above 500 suns (announced in May) and a minimum of 38% on a standard 10mm x 10mm cell. The QDEC products are hence expected to outperform all existing commercially available CPV cells on the market. "Cyrium's product



QDEC efficiency versus concentration at 25°C.

introduction sets new performance standards for solar cell suppliers to the CPV industry," Rozakis adds. The QDEC product line should also exceed the existing performance targets of Cyrium's clients, it is reckoned, offering further performance choices to CPV system makers.

"Delivering sustained performance at >500-1000 concentrations with very little performance degradation at the highest illuminations is a major distinguishing feature of our QDEC products," explains chief technical officer Simon Fafard.

"Another advantage of the QDEC line, which we designed specifically for CPV applications, is that it delivers improved performance in the case of non-uniform illumination," he adds. "Cyrium's proprietary quantum dot technology enables those benefits without added thicknesses or complexities."

In addition, Cyrium's fabless CPV cell manufacturing model allows the flexibility to offer

QDEC devices in a range of cell sizes at a competitive cost, Rozakis comments. Such high-efficiency cells with the lowest overall cost of ownership are required by CPV system makers in order to achieve the lowest levelized cost of energy. "The exceptional performance of our cells will enhance the CPV's business case, while the technology becomes a significant factor in moving the cost of renewable solar energy toward grid parity," he concludes.

www.cyriumtechnologies.com

CPV panel maker OPEL rebounds in third-quarter 2009

OPEL International Inc of Shelton, CT, USA and Toronto, Ontario, Canada, which makes high-concentration photovoltaic (HCPV) panels (as well as both roof- and ground-based dual- and single-axis solar trackers for mounting them), says that for the first nine months of 2009 its revenues were \$547,000, down \$31,000 year-on-year. However, for third-quarter 2009, revenue was up \$20,000 on Q2. "The solar market has started to break out of the slump," believes chief financial officer Michael McCoy.

In October, OPEL said that, together with its Spanish partner BETASOL (which builds utility-grade solar farm installations for subsequent sale to investor groups), its subsidiary OPEL Solar Inc had grid-connected the third 110kW phase of its utility-grade photovoltaic

power plant in the Tarragona region of northern Spain. This brings the plant's installed electricity-generating capacity to 330kW of the targeted 440kW, allowing for sale to a third party. The solar farm is one of the first operable solar grid fields in the world using OPEL's HCPV panel technology, and will supply electricity to over 350 households when fully completed.

"With our Spanish installation now successfully generating utility-scale solar power, we can focus our attentions to closing and delivering on our new quoting activities in addition to continuing to deliver on our overall goals," says McCoy.

The quarter saw increases in quoting activity for HCPV panels and tracker systems, as well as in the size of the projects being quoted. In early November, just after the

close of the quarter, OPEL filed for a cash payment of \$179,000, awarded as part of the US Department of Energy and Treasury Department program under the American Recovery & Reinvestment Act (ARRA). The award is in recognition of the development and installation of one of Connecticut's first rooftop tracking solar power systems, completed by OPEL Solar in March. The installation generates 131kW of power, supplying up to 20% of the electricity needs of the Linden Elementary School in Plainville, CT. The firm was also awarded a grant by the Connecticut Clean Energy Fund (CCEF) for the installation.

OPEL adds that its balance sheet remains in a strong liquidity position, with no debt.

www.opelinc.com

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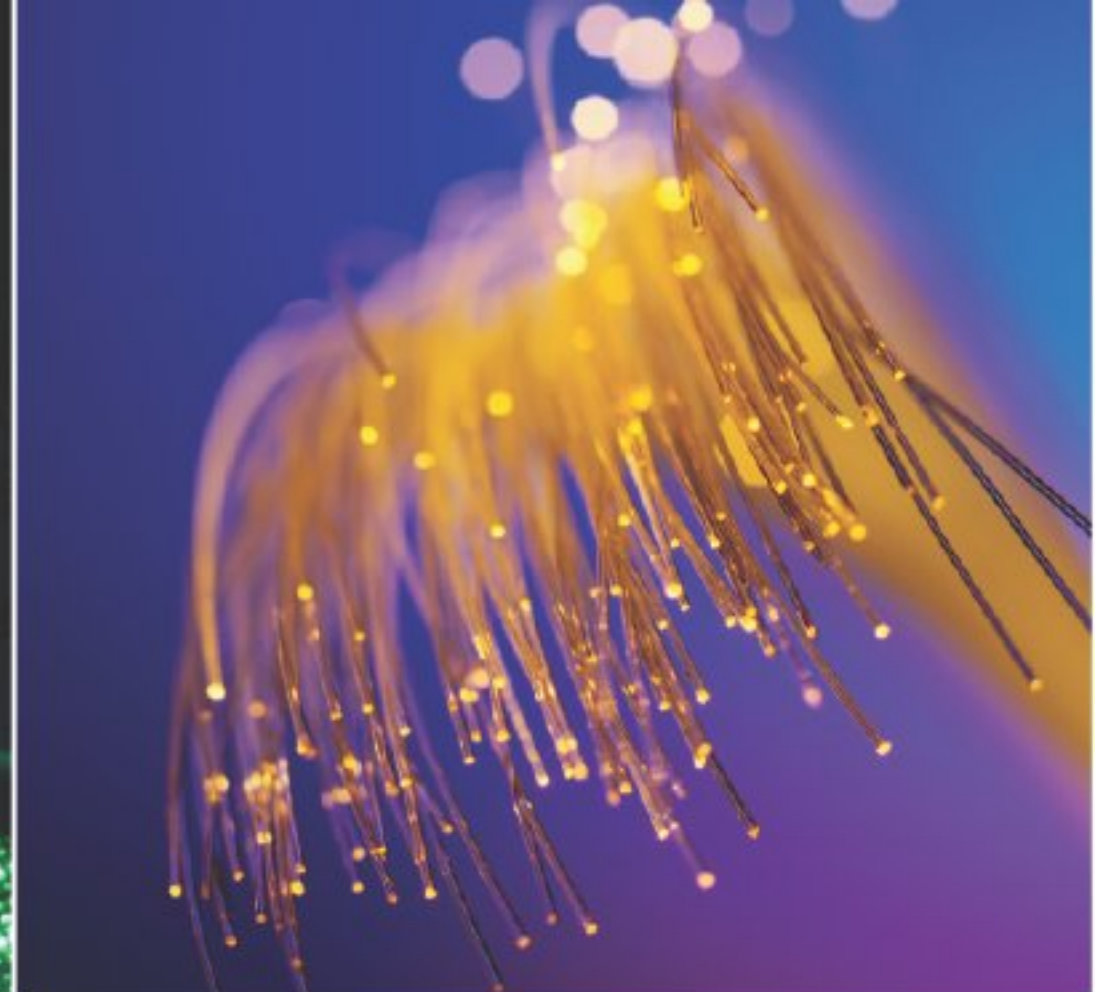
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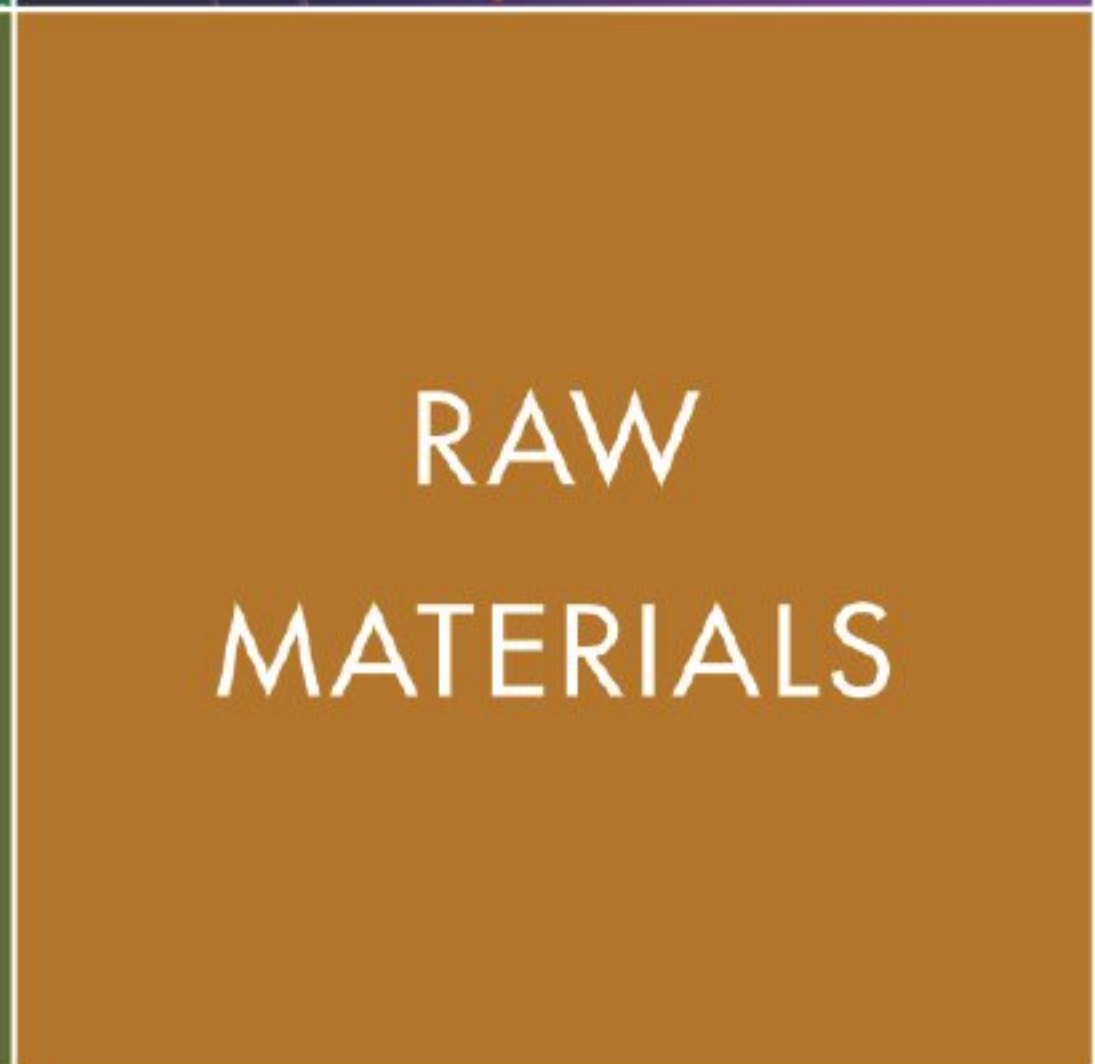
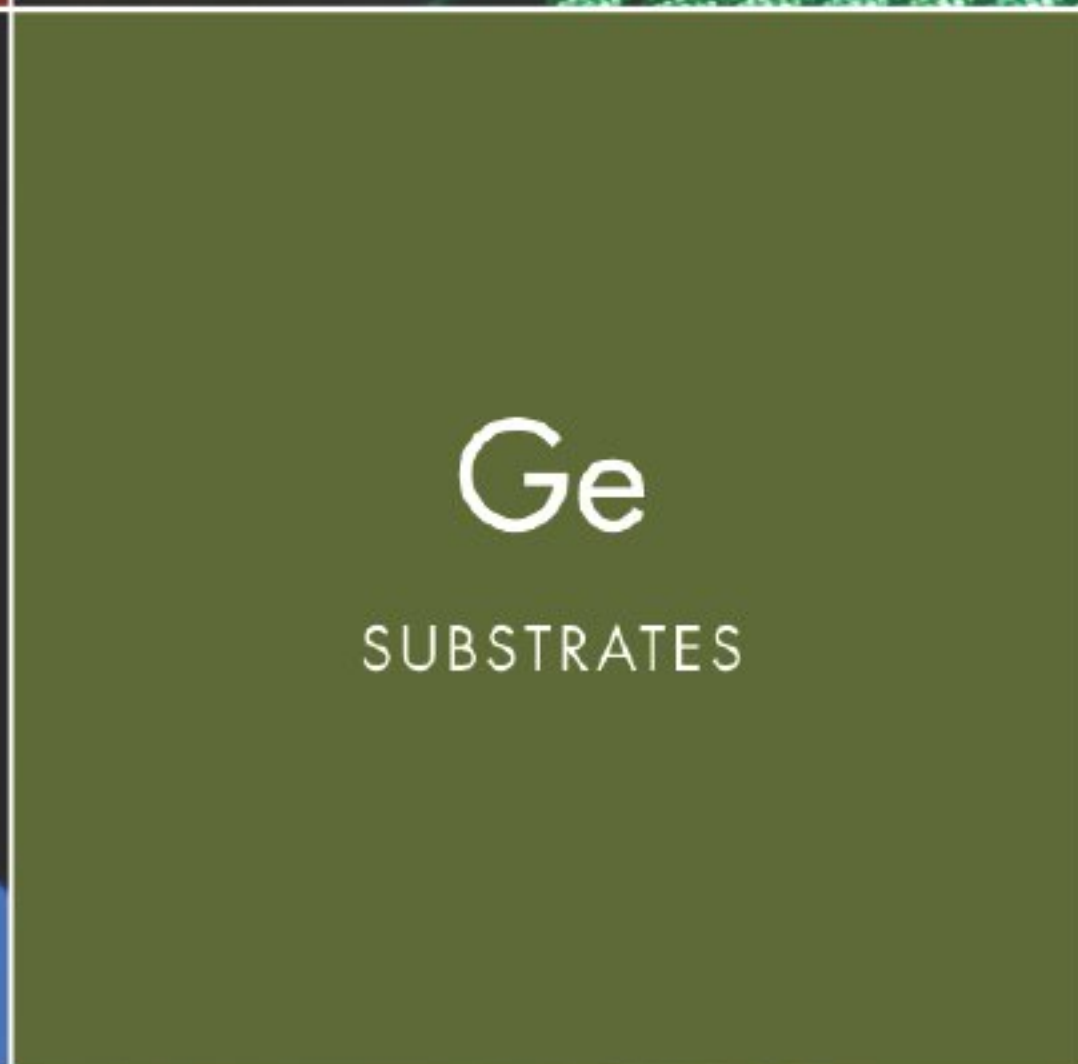
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First Solar forecasts 2010 sales of \$2.7–2.9bn as it plans to boost capacity to 1.8GW with eight new Malaysia lines

First Solar Inc of Tempe, AZ, USA, which manufactures thin-film photovoltaic modules based on cadmium telluride (CdTe), says that, for 2010, it projects net sales of \$2.7–2.9bn. Gross margin is expected to be 38% and operating margin 23–24%, influenced by a shift in revenue mix to the systems business (which includes \$0.6–0.8bn of EPC/project development in addition to \$2.1bn in modules).

The firm consequently expects to generate \$730–790m of operating cash flow and \$180–290m of free cash flow, after total capital spending of \$500–550m (almost double the expected \$260–275m in 2009) plus start-up expenses of about \$25m to expand the firm's manufacturing center in Kulim, Malaysia.

Of the \$500–550m in CapEx, First Solar plans to invest \$365m in Malaysia to add eight production

lines (in two production plants consisting of four manufacturing lines each), starting operation in first-half 2011. On the basis of First Solar's third-quarter 2009 annual line run-rate of 53MW, the expansion is expected to increase manufacturing capacity by 424MW.

Together with the two-line factory in France being built with Paris-based EDF Energies Nouvelles (announced in July, and projected for full production in second-half 2011), First Solar expects to add 10 production lines during 2010–2011, raising capacity by over 48% from current levels. With the total number of lines to rise from 23 to 34, this should bring annual or announced production capacity to about 1.8GW by 2012 (based on current production levels).

First Solar began full commercial operation of its initial manufacturing

line only in late 2004, and annual production capacity was not much more than 500MW as recently as 2008, before doubling to more than 1GW in 2009. Revenue more than doubled from \$504m in 2007 to \$1,246.3m in 2008, so 2010's projection of \$2.7–2.9bn is more than double that (after an expected \$1.975–2.025bn for 2009).

"First Solar is expanding capacity to satisfy a global contracted and advanced pipeline of over 6GW from 2010–2012," says CEO Rob Gillette. "In 2009 we increased our contracted North American pipeline by approximately 1.5GW, expanding our penetration in transition markets," he adds. "This drives further capacity needs around a demand pool that is less volatile and more predictable than the traditional feed-in tariff-based markets."

www.firstsolar.com

Abound appoints new CEO; interim CEO to be chairman

Abound Solar of Loveland, CO, USA (formerly AVA Solar until last March) has appointed Thomas Tiller as CEO, effective 18 January, when interim CEO & board member Doug Schatz will become chairman of the board of directors.

For the past nine years Tiller has been CEO at Polaris Industries (a \$1.9bn manufacturer of outdoor recreational vehicles), overseeing the launch of more than 170 new products (leading to a doubling in the firm's size and a tripling of its stock price) and expanding into international markets.

Previously, he worked at General Electric for 15 years, beginning in the aerospace sector, later becoming VP of manufacturing at GE Appliances, and ending as general manager of GE Silicones (a \$1bn, 3,000-employee unit doing business in more than 40 countries).

Tiller also has a Bachelor of Science degree from the Massachusetts

Institute of Technology, a Master of Science from the University of Vermont, and a Master of Business Administration from the Harvard Business School.

"Abound is uniquely positioned to leverage its proprietary manufacturing technology in reducing the cost of solar power," reckons Tiller. Based on 15 years of research at Colorado State Uni-



CEO Thomas Tiller.

versity (with the support of the National Renewable Energy Laboratory in Golden, CO), AVA was founded in January 2007 to commercialize a proprietary process for manufacturing CdTe thin-film PV modules. A seed round of funding in February 2007 led to construction of the initial 3MW pilot-production line in Fort Collins,

CO, followed that June by a second round of funding plus \$3m over 18 months from the Photovoltaic Technology Incubator Program of the US Department of Energy's Solar America Initiative. This April, Abound unveiled its fully automated commercial-scale manufacturing facility in Longmont, CO (with annual capacity of 65MW from the first production line, and 200MW ultimately).

"In the last year, Abound Solar has reached several key milestones, including commercial production of modules and achieving product certification [from Underwriters Laboratories, in late October]," says Schatz. "With Tom's strong track record of delivering outstanding results — both at Polaris and General Electric — the Abound Solar board of directors is confident he is the best person to capitalize on that progress."

www.abound.com

CD PV maker First Solar to expand Enbridge's Sarnia project by 60MW

After the initial 20MW solar energy project achieved full commercial operation on 7 December, energy distributor Enbridge Inc of Calgary, Alberta, Canada and First Solar Inc of Tempe, AZ, USA have agreed to expand the capacity of the Sarnia Solar Project in Ontario to 80MW, involving a total extra system cost of about CDN\$300m. "It demonstrates confidence in First Solar's engineering, procurement and construction team," comments the PV maker's president Bruce Sohn. First Solar's CdTe PV technology has already been deployed in 1.5GW of installations in the USA and Europe in total.

With about 6000 staff, Enbridge owns and operates Canada's largest natural gas distribution firm, providing distribution services in Ontario, Quebec, New Brunswick and New York State, and operates the world's longest crude oil and liquids transportation system, but is expanding its interests into renewable energy technologies.

In October, Enbridge agreed to acquire the initial 20MW project that First Solar developed at the site. "We're delighted to further strengthen our relationship with First Solar," says the firm's president & CEO Patrick D. Daniel. "First Solar has delivered the initial 20MW as committed — demonstrating their strong technical competence combined with attention to meaningful community engagement and corporate social responsibility practices that align with our own values."

First Solar is constructing the solar project under a fixed-price engineering, procurement and construction contract, and will also provide operations and maintenance services to Enbridge under a long-term contract. The 60MW phase is expected to begin construction this month and be completed by December 2010. Sarnia is now expected to be the largest solar energy facility in North America,

with 1.3 million modules covering a total surface area of 973,000m². At 80MW, Enbridge expects the Sarnia Solar Project to generate 120 million kWh annually (enough to meet the needs of over 12,800 homes) and to help to save the equivalent of 39,000 tonnes of CO₂ per year.

"Enbridge has made significant strides in growing its green energy business in 2009," Daniel continues. "With this investment, we will have interests in more than 470MW of green power capacity from our five wind energy projects, expanded solar facilities, four waste heat recovery facilities and the world's first commercial application of hybrid fuel cell technology." Daniel says solar energy is a key component of Enbridge's environmental performance strategy to invest in renewable and alternative energy sources, complementing its core operations.

"Our increased investment in the Sarnia Solar Project maintains risk-and-return characteristics which are fully consistent with Enbridge's low-risk business model, and similar to our crude oil pipeline business," says Daniel. The expansion takes advantage of the Sarnia site's ability to accommodate additional capacity, he adds. "Following on our recently announced wind energy project, the Sarnia solar expansion provides a good balance in our renewable energy portfolio between solar and wind."

The 80MW plant's output will be sold to the Ontario Power Authority pursuant to 20-year power purchase agreements under the terms of the Ontario Government's Renewable Energy Standard Offer Program.

"Our recent investments in green energy projects in Ontario are evidence of Enbridge's commitment to advancing environmentally preferred energy solutions, and of the value of the Ontario government's proactive support and encouragement of investment within the province," concludes Daniel.

www.enbridge.com

IN BRIEF

First Solar first firm to ship 1GW annually

First Solar has become the first PV firm to produce more than 1GW of solar modules in a single year (enough to serve the needs of about 145,000 average American homes and save 1 million metric tons of carbon dioxide emissions annually).

As the world's largest PV module manufacturer, First Solar has raised its production capacity from 75MW per year at the beginning of 2007 to more than 1GW currently.

"This proof that the solar industry can achieve the manufacturing scale necessary to fight climate change is especially timely in light of the Copenhagen conference [in mid-December]," says president Bruce Sohn. "Our efforts in scaling our technology are critical to creating a more sustainable energy infrastructure and reducing greenhouse gas emissions," he claims.

First Solar has also continued to lower the cost of manufacturing solar modules, breaking the \$1 per watt barrier earlier this year.

● First Solar has appointed TK Kallenbach as executive VP of marketing & product management.

Kallenbach joins First Solar from Honeywell Aerospace, where he led numerous areas including its strategic planning, product management and marketing communications. He joined Honeywell (formerly AlliedSignal) in 1979, serving in various senior leadership positions before taking on his most recent role as VP of marketing & product management.

"TK's extensive experience makes him ideally suited to lead First Solar's product management and marketing initiatives," says CEO Rob Gillette.

www.firstsolar.com

CIGS PV panel maker Solyndra signs \$105m supply deal with Italian solar integrator Sun System

Solyndra Inc of Fremont, CA, USA, which was founded in 2005 to manufacture copper indium gallium diselenide (CIGS) photovoltaic (PV) systems for commercial rooftops, has signed a new multi-year framework agreement worth up to \$105m with Sun System S.p.A. of Milan, Italy, an integrator of medium- and large-scale commercial PV systems.

"Sun System's strong presence in Italy and beyond, coupled with Solyndra's advanced PV systems, will accelerate the deployment of world-class photovoltaic installations on commercial rooftops in southern Europe," comments Solyndra's CEO & founder Dr Chris Gronet.

Sun System has already installed (in September) an array of solar power systems using Solyndra panels in northern Italy at the firm Tessitura Uboldi.

Solyndra has developed a proprietary cylindrical thin-film solar panel built from tubes that capture sunlight across a 360° photovoltaic surface capable of absorbing direct, diffuse and reflected sunlight (from below). The firm says that this 'self-tracking' design allows the capture of more sunlight from low-slope commercial rooftops than conventional flat-surfaced solar panels, which need costly tilted mounting devices to improve the capture of direct light from the sun, offer poor collection of diffuse light, and fail to collect reflected light. Also, gaps between the tubes and their frame let wind pass through, reducing the need for heavy, roof-penetrating fastenings or anchoring; their lighter weight also allows installation on scantier roofs. Simple horizontal mounting hardware also allows fast and economical installation, claims the firm.

"Solyndra's technology sets a new standard of performance on commercial rooftops compared to conventional PV technologies in terms of installation cost, rooftop loading, non-penetrating wind performance, and energy production per roof," remarks Sun System's CEO Dr Davide Scarantino.

The deal with Sun System raises Solyndra's total announced amount of framework and sales deals since May to almost \$650m. After securing a \$535m loan guarantee from the US Department of Energy (DOE), in early September Solyndra started construction on its second solar panel manufacturing plant in nearby Milpitas (with an annual capacity of 500MW), joining its existing 110MW plant in Fremont (in volume production in mid-2008).

www.sunsystem.it

www.solyndra.com

Solyndra to supply CIGS panels to roofing firm alwitra

Solyndra has signed a long-term framework agreement to supply panels to roofing system maker alwitra GmbH & Co of Trier, Germany.

"With alwitra's global presence and their award-winning line of highly reflective Evalon roofing membranes, this agreement builds on the benefits of Solyndra PV installations on reflective commercial rooftops and will expand our footprint in the important roofing channel," says Solyndra's CEO & founder Chris Gronet.

alwitra has sealed a roof area of more than 140 million square meters worldwide with its roofing systems. Almost four decades ago, alwitra pioneered the production of light-reflecting EVA roofing membranes in the sense of the current 'cool roof' concept. "The optimal solution is the combination of Solyndra's innovative PV system with our tried-and-tested, highly



Solyndra CIGS photovoltaic arrays on alwitra roofing.

reflective white EVALON roofing membrane," says managing director Stefan Rehlinger. "The Solyndra system is the best we've found in terms of non-penetrating wind performance, energy production per roof, rooftop loading, and installation cost, and builds on our 10 years of success in solar with

our building-integrated EVALON Solar system," he adds.

"We look forward to working with Solyndra to capitalize on the vast opportunity presented by this synergistic relationship," adds alwitra's president Joachim Gussner.

www.alwitra.de

Thin-film photovoltaic share of solar panel market forecast to double to 31% by 2013

Compared to incumbent crystalline silicon technology, thin-film photovoltaics accounted for just a 14% share of the global solar panel market in terms of watts in 2008, but this will more than double to 31% by 2013, reckons market research firm iSuppli Corp.

"The market viability of thin film has been solidly established by First Solar Inc [which makes cadmium telluride (CdTe) solar cells glass panels in Tempe, AZ, USA] as it rockets to become the world's top solar panel maker this year, with more than a gigawatt of production," says chief research officer Greg Sheppard. "The company has driven its cost of production to less than 90 cents per watt, keeping its costs at approximately half the level of crystalline module producers."

Compared to most existing solar panels being made of crystalline wafers with 180–230 microns of polysilicon, thin-film panels are made by depositing multiple layers of other materials just a few microns thickness onto a substrate that can be a thin sheet of metal or plastic, and hence can cost significantly less to make in terms of cost per watt of electricity generation.

iSuppli expects the average selling price of thin-film panels to fall 17.6% from \$1.70 per watt in 2009 to \$1.40 per watt in 2010, but that of crystalline silicon panels to fall 20% from \$2.50 to \$2.00. iSuppli also expects that, through 2012, crystalline prices will continue to close the pricing gap to thin film, to some degree because its purveyors collectively have deeper pockets and keep pouring on capital spending, technology R&D developments and manufacturing refinements.



Thin-film percentage of total PV module production (percentage of Watts).

Also, when installation space is limited (such as on a residential rooftop), a thin-film installation can take 15–40% more space to achieve the same total system wattage output as crystalline, limiting its appeal in certain applications.

In addition, the main tradeoff is that thin-film panels are less efficient at converting sunlight to electricity. The conversion efficiencies of the various types of thin-film PV technologies are mostly less than 10%, although some have lab results pushing into the mid-teens.

Market viability of thin film has been solidly established by First Solar Inc as it rockets to become the world's top solar panel maker this year, with more than a gigawatt of production

Some of these technologies are single-junction. However, recent developments use multiple junctions stacked on top of each other (e.g. tandem and triple-junction cells) so that more parts of the spectrum can be absorbed by using different combinations of material, increasing efficiency.

To deposit the layers of materials on various substrates, for example glass or plastics, most of these technologies use variants of chemical vapor deposition (CVD) or screen printing. In addition, some recent technologies employ variants of ink-jet printing to deposit the materials more quickly.

Another accelerator of thin-film technology, concludes iSuppli, is the rising availability of turn-key production lines from equipment suppliers such as Applied Materials, Oerlikon Solar, and Centrotherm Photovoltaics AG.

www.isuppli.com

Two-step anneal smoothes way to SiC power transistors

Japan's Fuji Electric Device Technology has been researching the digging of U-shape trenches in silicon carbide (SiC) with a view to next-generation power transistor technology [Yasuyuki Kawada, *Jpn. J. Appl. Phys.*, vol48, p116508, 2009].

Although technological development has produced improved pure-silicon power devices such as superjunction metal-oxide-semiconductor field-effect transistors (SJ-MOSFET) and field-stop insulated-gate bipolar transistors (FS-IGBT), SiC is expected to eventually produce superior results for blocking voltages, on-resistance and operating frequencies.

Accessing these new levels of performance would enable more efficient power consumption, more compact equipment and less active cooling requirements. SiC Schottky diodes are already commercially available, and demonstrations of SiC transistor devices and circuits have been made by various companies and research groups.

Power devices often use vertical trench-shaped structures to reduce on-resistance compared with traditional planar designs (see Figure 1). U-shaped trenches are particularly favored, since rounded structures reduce the peak electric field and hence the breakdown of the device. However, producing trenches in SiC is a particularly difficult process since the material has a hardness approaching that of diamond. It also has a very stable chemical structure.

Plasma etching (dry etch) of SiC is a very slow process. Even at high plasma density, etch rates are of the order of a couple of microns per minute. An additional difficulty for the U-shape trenches that are needed for power devices is that one needs a very smooth surface with no sharp angles. This is hard to achieve with dry etch — in fact,

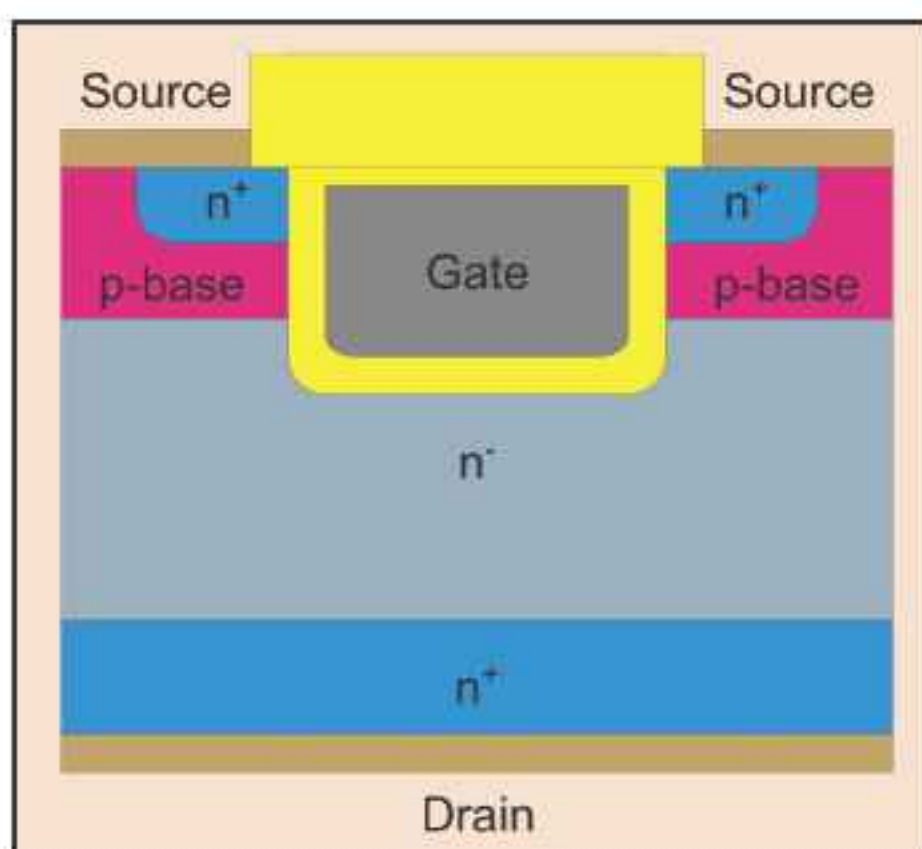


Figure 1. MOSFET with U-shaped gate (UMOSFET).

some groups follow up a dry process with a slower wet chemical etch to create a smooth surface finish.

The Fuji group has studied an alternative to this — annealing at high temperatures up to 1800°C. The SiC was etched using SF₆/O₂/Ar gas chemistry in an inductively coupled plasma process. The trench patterns were made with a silicon dioxide (SiO₂) mask that was patterned

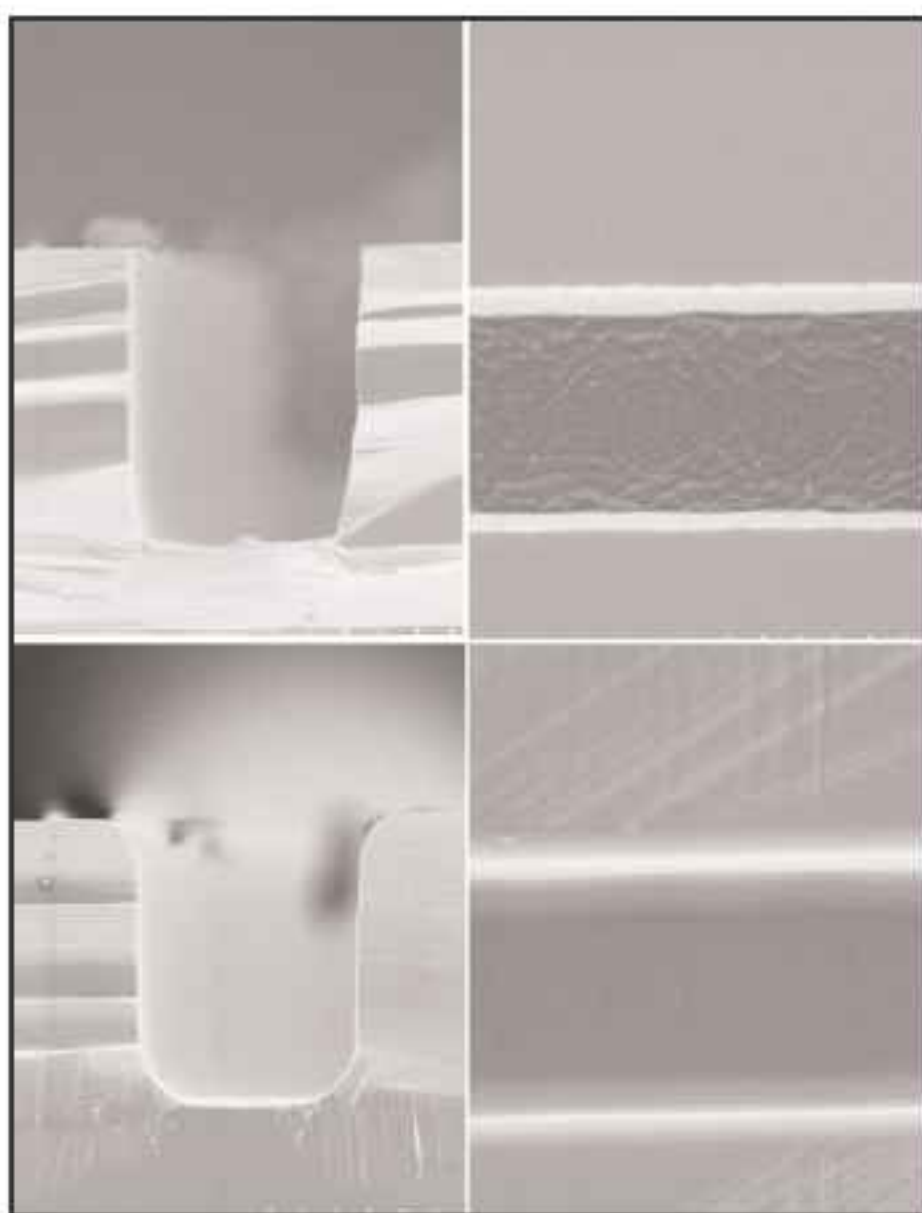


Figure 2. Cross-sectional (left) and plane-view (right) SEMs of trenches without (above) and with (below) two-step annealing, at 1700°C in SiH₄/Ar (10min) then 1500°C in H₂ (10min).

with photoresist and then subjected to a reactive ion etch to reach the SiC substrate. Once the trenches had been produced, the SiO₂ was removed with a wet chemical etch.

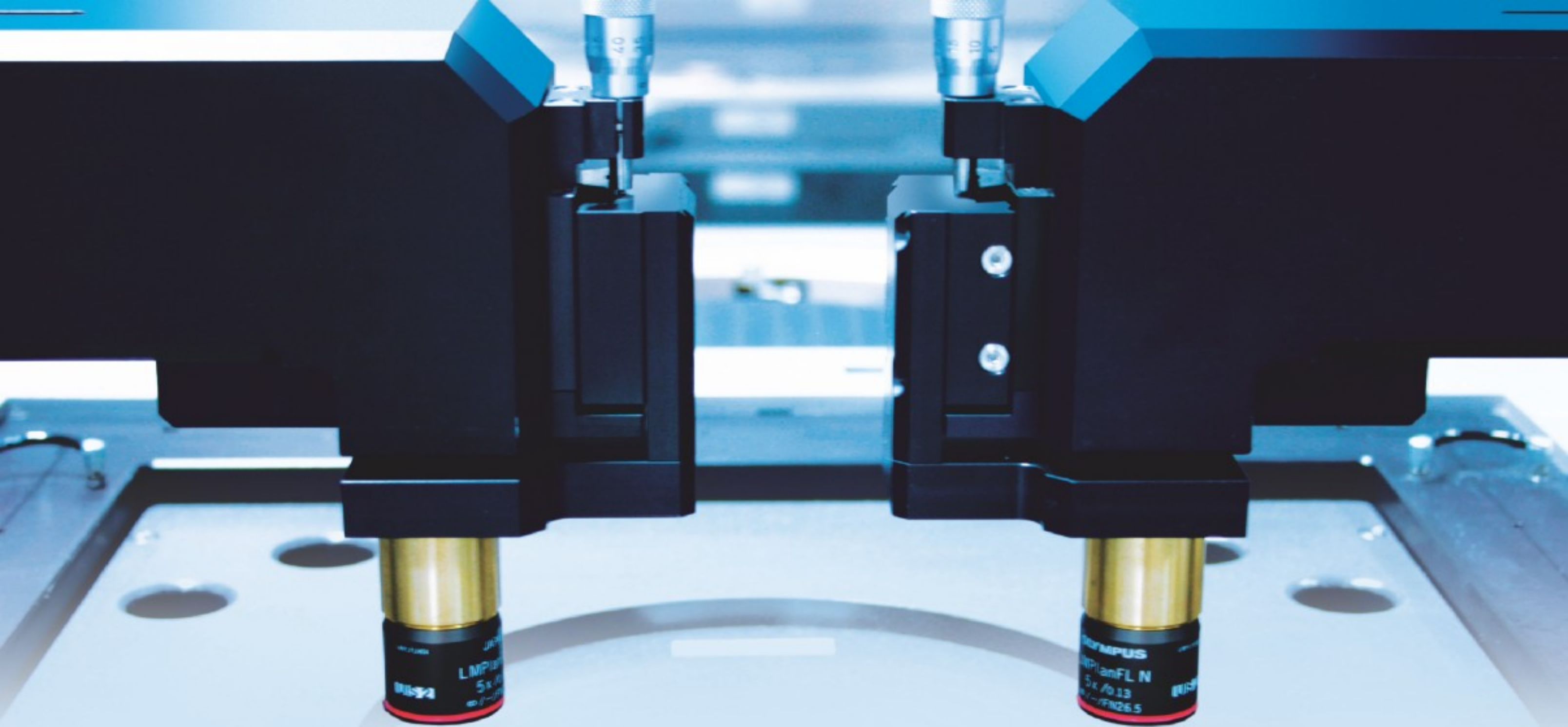
Trench depths of 3–8µm were produced. The substrate was a 4H polytype with a c-face (8° off-axis). The trench directions were chosen to give sidewalls consisting of [1110x] and [1110x] faces. The annealing duration was varied between 1 minute and 2 hours in a horizontal hot-wall reactor originally designed for SiC epitaxy. Various atmospheres were applied during the process: pure argon (Ar), silane-argon (SiH₄-0.09%Ar), or hydrogen (H₂). Pressures varied from 1.5 to 720 Torr.

After a wide-ranging investigation, the Fuji group concluded that a SiH₄/Ar anneal at high temperature is useful for obtaining rounded trench corners without significant etching, while H₂ at the low end of the temperature range that was studied is an effective way to obtain a smooth substrate surface without changing the trench shape. The best pressure was found to be about 80 Torr.

The Fuji team therefore proposes a two-step anneal process: first at 1700°C in SiH₄/Ar to round the trench corners, and then at 1500°C in H₂ to smooth the SiC surfaces (Figure 2). The group believes that its results are comparable with what is achievable with silicon trench technology. The mechanism behind the transformations achieved by these annealing processes is believed to be surface diffusion and evaporation-condensation.

<http://jjap.ipap.jp/link?JJAP/48/116508>
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The author Mike Cooke is a freelance technology journalist who has worked in the semiconductor and advanced technology sectors since 1997.



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Digging into SiC etch

Silicon carbide is an extremely challenging material to etch, with dry processes apparently limited to etch rates of about a couple of microns per minute. While laser drilling is an option, production rates are slow, given the small numbers of features that can be formed at a time (one or at most a few per cycle). Two groups of researchers, at Fujitsu and TriQuint, have been looking at some problems of etching back-side via holes in SiC substrates. **Mike Cooke** reports.

High-thermal-conductivity silicon carbide is an attractive substrate material for power applications such as lasers and power amplification of high-frequency radio/microwave signals. High thermal conductivity allows better dissipation of the heat created in power devices. However, not only is the material difficult to grow (and hence expensive), it is also difficult to work, since the material has hardness properties close to that of diamond.

For plasma etch, a nickel mask is often used. This can achieve selectivity rates for SiC etch of 45:1. Etch rates have been improved from initial attempts giving less than 0.6 $\mu\text{m}/\text{min}$ to the 2.7 $\mu\text{m}/\text{min}$ achieved more recently (2005) by Surface Technology Systems (STS, now SPP Process Technology Systems, or SPTS).

For power transistors, improved electrical performance can result from creating back-side through-substrate via connections to transistors produced using the wide-bandgap properties of SiC itself, or by adding III-nitride layers. To produce such via holes, the wafer is generally ground down mechanically and then polished. This reduces the distance needed to etch the hole and also makes the substrate more thermally conductive between the device layer and heat sink arrangements.

Fujitsu researchers have reported on their work to overcome some of the problems of reactive ion etching

(RIE) of SiC material with a view to creating back-side via holes for gallium nitride (GaN) high-electron-mobility transistors (HEMTs) [1].

One strange effect the Fujitsu team dealt with was the formation of pillars in the via hole (Figure 1). The researchers believe that these structures form on the end of micro-pipes that are created in the original growth of the SiC material (Figure 2). Micro-pipes are empty tubes in the SiC material. Their ends have a slower etch rate than the surrounding SiC material, and further problems for etching arise from byproducts of the etch being deposited on the micro-pipe cap. These byproducts create the pillars that consist of a chemical combination of nickel from the mask and SiF_x from the etch process.

Some firms (e.g. Cree) supply 'micro-pipe-free' material, at a price, where this effect should not be a problem. However, for those not using such material, these pillars form a barrier to proper metallization of the via-holes and should be eliminated. The researchers found that reducing the pressure to about 5Pa eliminated the pillars by enhancing Ni desorption and an oxygen flow of 20sccm reduced micro-trenching effects that can occur at lower pressures.

The Fujitsu team also comment that it is best to keep the via holes uniform in size to avoid 'lag' effects where

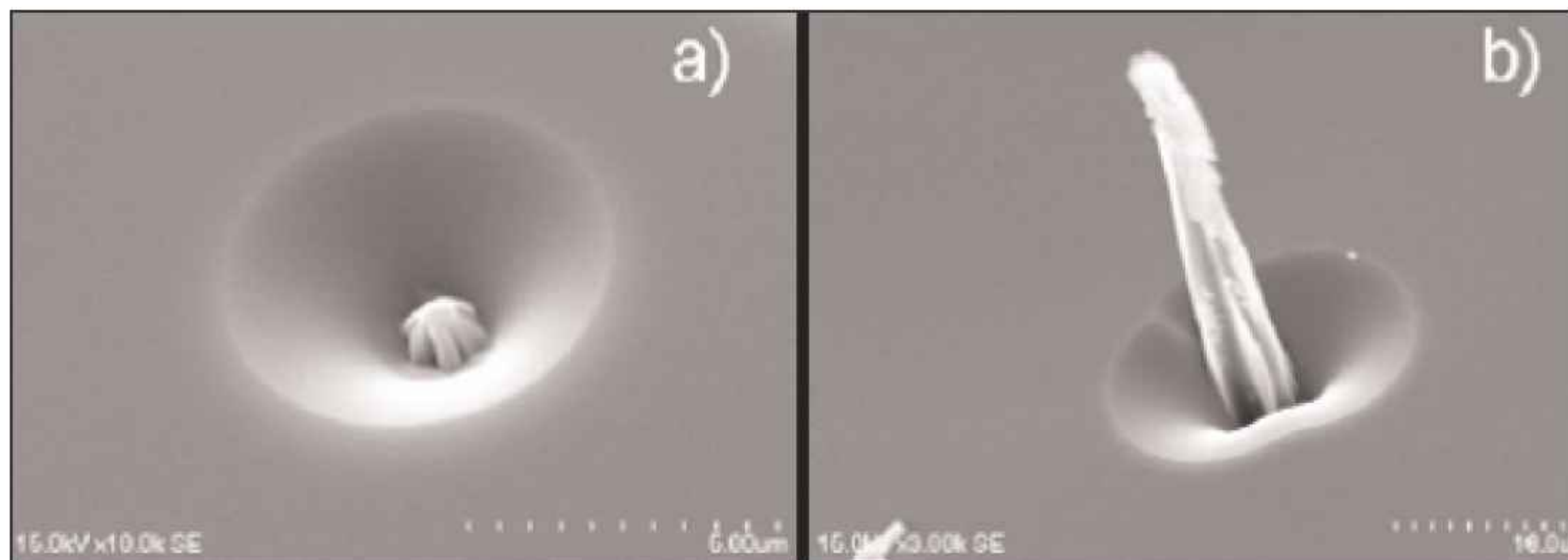


Figure 1. Example of pillar formation during etch of via hole in SiC.

small-diameter structures etch more slowly than large ones. It is also important to remember that doped and semi-insulating wafers etch at different rates. On the basis of their work, Fujitsu developed a process to etch SiC via holes at a rate of $2\mu\text{m}/\text{min}$ (Figure 3).

TriQuint has also been looking into SiC etch for via holes [2]. It is more interested in etch process sustainability, and so dialed the rate back to about $1\mu\text{m}/\text{min}$. Opening up the etch chamber for wet cleaning with chemicals such as chlorine (Cl_2) and boron trichloride (BCl_3) can substantially deteriorate subsequent etch performance.

Like Fujitsu, TriQuint has problems with pillar formation that it attributes to micro-masking inside the via being formed. Returning the etch chamber to its initial performance required replacement of some parts, costing time and money. These problems must be overcome for the etch process to become part of a mass production environment.

The researchers carried out a series of experiments on 1cm^2 pieces in an STS inductively couple plasma (ICP) etch system. The SiC was an n-type 6H polytype. There were further samples of GaN/SiC and Ni/Si used for selectivity and etch rate studies. Pillar formation was studied on SiC samples that had previously been ground down by $10\mu\text{m}$ and then polished a further $1\mu\text{m}$.

The researchers found that SiC etch rates were relatively constant with respect to the RF coil power (1500–2500W), but that the rate increased with increased platen power (150–300W). However, low coil powers did result in severe pillar formation. But, even at high powers, pillars persisted in some isolated vias. Hence, pillar formation at low power is attributed to the process parameters, while at high power it is attributed to the surface condition of the particular sample.

In terms of SiC-to-GaN selectivity, the results were relatively insensitive to platen power, but improved with coil power. However, the TriQuint researchers point out that a modest selectivity of ~ 25 is sufficient to stop the etch when it reaches the GaN layers, and that there is not much benefit to increasing the RF coil power to achieve more than this. Further, high coil powers can lead to thermal and mechanical stress, causing failure of the ceramic parts used to isolate the coil from the rest of the chamber. The SiC-to-Ni selectivity was greater than 50 for the whole range of powers tested.

Another factor affecting pillar formation was the carrier. For example, gross pillar formation was not observed with a Ni-plate Si carrier. With a Ni/sapphire carrier, intermittent pillars were observed. A Ni/glass carrier had the worst performance after Cl_2/BCl_3 cleans, with repeated pillar formation. The sample temperature is believed to affect pillar formation, and it is to be noted that Si has the highest thermal conductivity and glass the lowest. Temperature measurements suggest the sample temperature was $\sim 80^\circ\text{C}$ for silicon and sapphire carriers, but increased to $\sim 110^\circ\text{C}$ for the glass carrier.

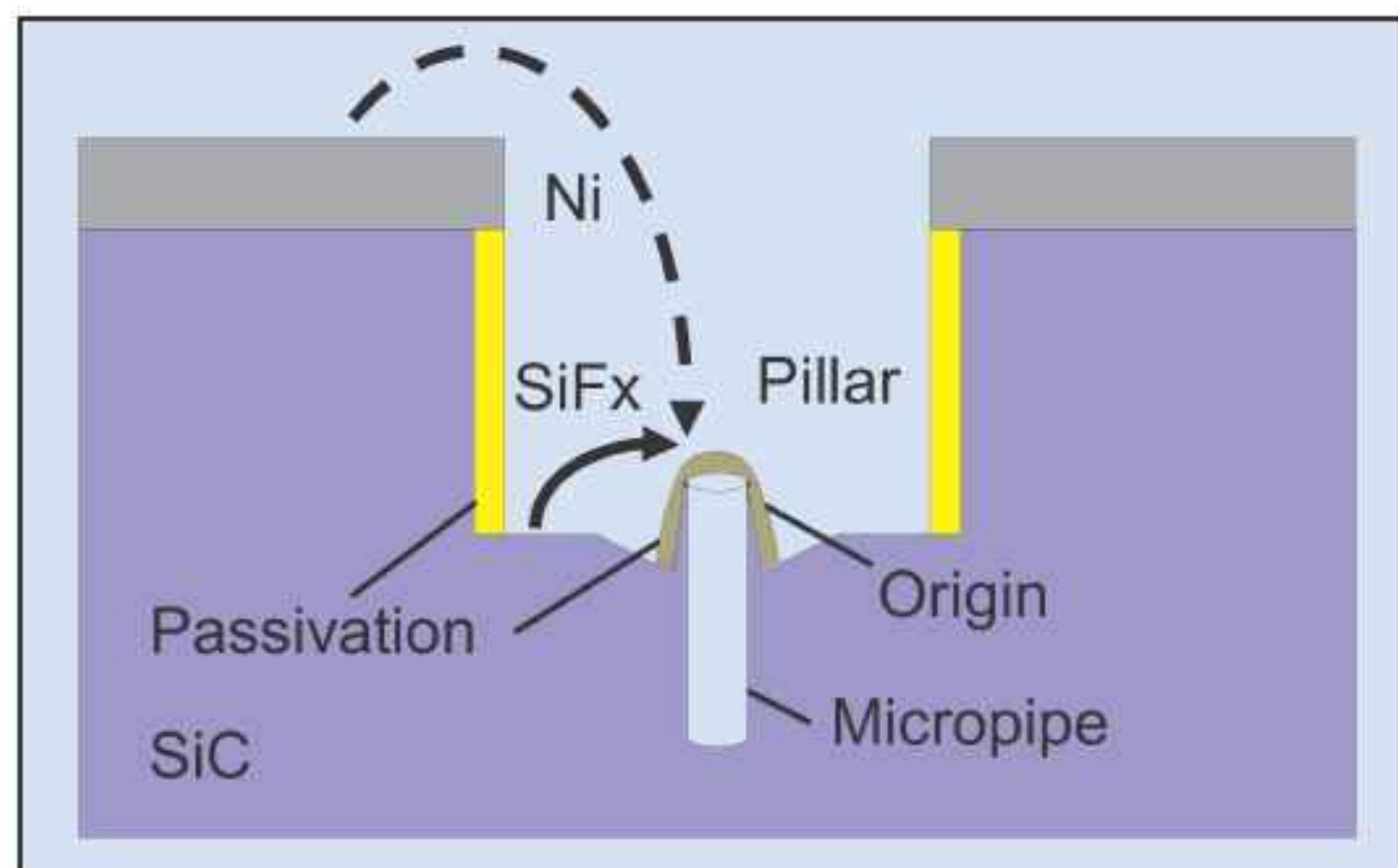


Figure 2. Fujitsu view of pillars forming on micro-pipes.

'Seasoning' a chamber before use with oxygen and sulfur hexafluoride (SF_6) can reduce gross pillar formation. The pre-etch sputter clean used to break through the surface and begin the etch is also important, since a significant amount of Ni can be generated that is then deposited on the chamber wall and back onto the sample surface, including in the via areas. This sputtering is increased at higher temperature, offering a partial explanation of why pillar formation is more severe on glass carriers. ■

References

1. Naoya Okamoto et al, CS Mantech 2009, 'SiC backside via-hole process for GaN HEMT MMICs using high etch rate ICP etching'
2. Ju-Ai Ruan et al, CS Mantech 2009, 'SiC substrate via etch process optimization'



Figure 3. Fujitsu process for SiC via-hole etch.

Thickening AlN layers on sapphire substrates

Growth of aluminum nitride on a-plane rather than c-plane sapphire yields lower defect densities, reports **Mike Cooke**.

Japan's Mie University has been investigating various ways of depositing thick layers of aluminum nitride (AlN) on sapphire substrates using hydride vapor phase epitaxy (HVPE) [Jiejun Wu et al, Appl. Phys. Express, vol.2, p111004, 2009].

The research group believes AlN is promising as the basis for ultraviolet LEDs and high-electron-mobility transistors (HEMTs). UV radiation has important medical applications and, in combination with suitable phosphors, could be used as the driver of white-light modules.

However, thick AlN layers are difficult to grow with the high quality that is needed for such applications. In the x-ray diffraction characterization of such layers, some peaks can have full-width at half maximum (FWHM) values of ~ 1000 arcsec, indicating poor quality.

In fact, the large FWHMs in AlN layers seem to arise from edge-type threading dislocations (TDs), as indicated by the asymmetric (10.2) and (10.0) planes giving rise to broad reflection peaks, while symmetric ones such as (00.2) can be as small as 100 arcsec. Edge threading dislocations have a far bigger impact on device performance compared to screw threading dislocations.

Epitaxial lateral over-growth and related techniques have been used to decrease densities of threading dislocations in both GaN and AlN layers. However, these techniques are complex and expensive. The Mie group therefore wants to develop simple methods for growing thick AlN layers.

As a preliminary to this work, the researcher group sought to understand the reasons for the dislocations. First, growing c-plane AlN on c-plane sapphire allows the initial islands of AlN crystal material to be twisted relative to each other. When these islands coalesce, edge threading dislocations can arise (see Figure 1, top).

Growing c-plane AlN on a-plane sapphire (making the two c-axes perpendicular) reduces this twisting effect (see Figure 1, bottom). While the tendency for neighboring AlN islands to have different out-of-plane tilts is increased, this can be controlled with suitable

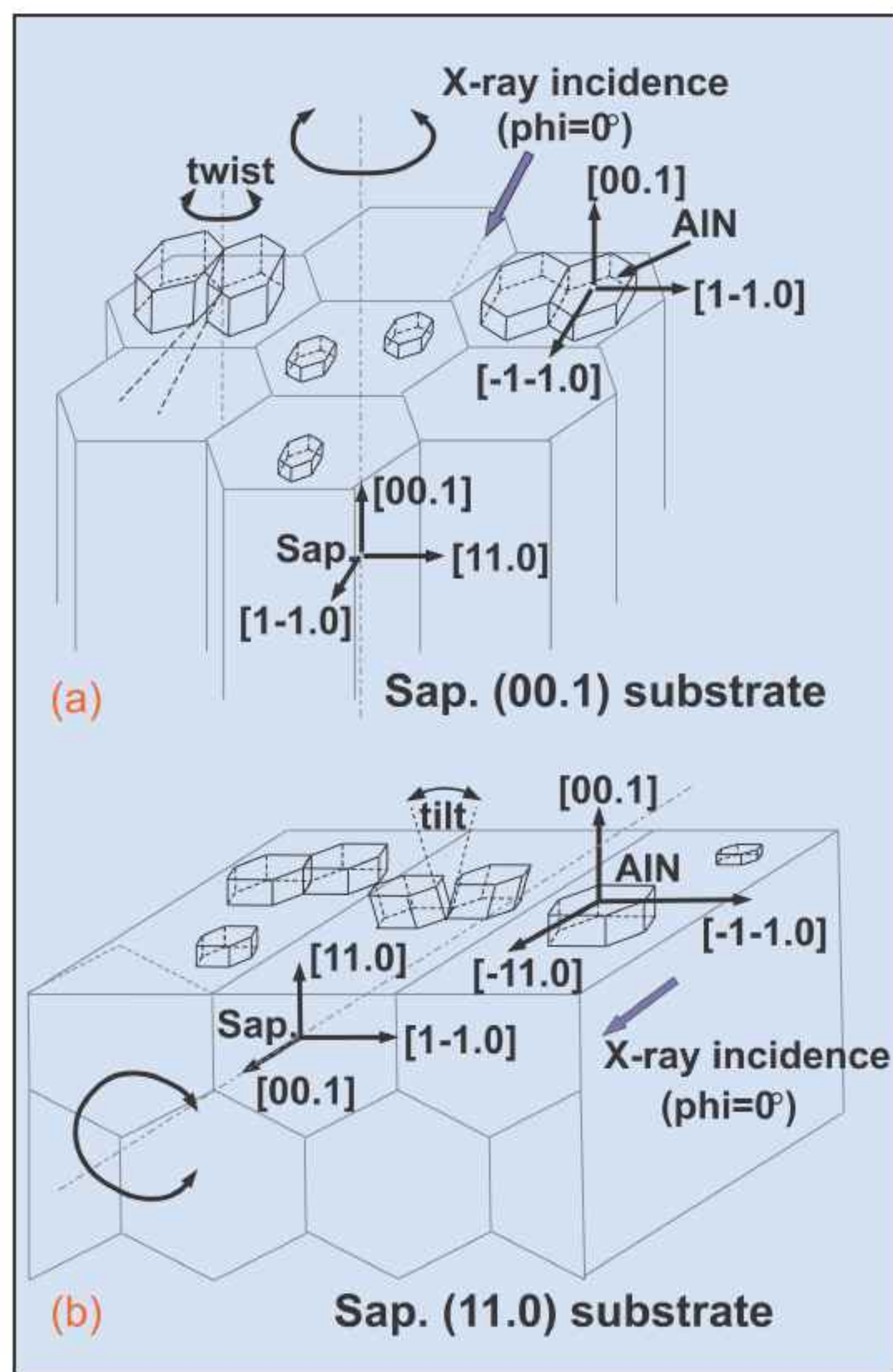


Figure 1. Twist and tilt variations between AlN islands grown on c-plane (a) and a-plane (b) sapphire.

optimization of growth temperature and III/V element ratios.

The researchers also comment that a-plane sapphire has a smaller lattice mismatch with AlN and that easy cleavage along the r-plane would be convenient for the construction of laser diode facets.

The researchers used HVPE at low pressure (5kPa) to

grow c-plane AlN on c-plane (00.1) and on a-plane (11.0) sapphire. The material sources were ammonia (NH_3), Al and hydrogen chloride (HCl). The sapphire surface was prepared with a thermal clean in hydrogen for 10 minutes at 1150°C . The AlN was grown at $1350\text{--}1550^\circ\text{C}$. No buffers or interlayers were used. Optimized conditions for AlN growth varied for the different sapphire orientations: for (00.1)/c-plane sapphire, 1400°C with a V/III ratio of 200; for (11.0)/a-plane, 1500°C with the V/III ratio set at 600.

The resulting XRD measurements suggest a lower edge-type threading dislocation density for the a-plane sapphire growth, although the screw threading dislocation density increased somewhat. In particular, the asymmetric (10.2) and (10.0) peaks had FWHMs of 487arcsec and 636arcsec , respectively, for the a-plane sapphire grown sample, while the c-plane sample recorded 752arcsec and 927arcsec , respectively. The symmetric (00.2) reflection was 312arcsec for the a-plane sample, but only 176arcsec for the c-plane sample.

From these figures, the Mie group derives a rough estimate for edge and screw threading dislocation densities of 2.7×10^8 and $2.6 \times 10^7/\text{cm}^2$, respectively, for the a-plane sample, and 5.8×10^8 and

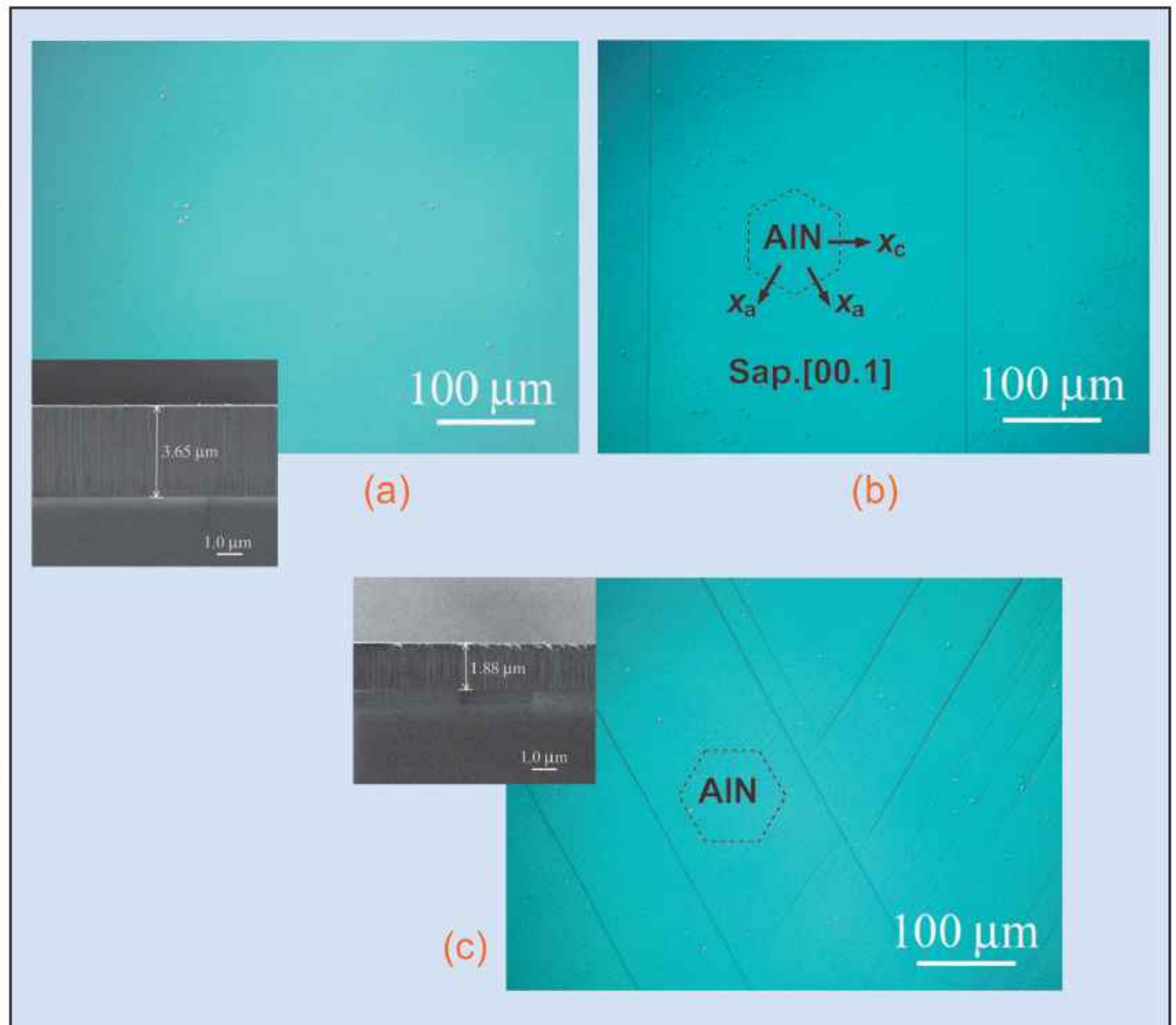


Figure 2. Optical microscope images of AlN grown on a-plane sapphire: crack-free $3.6\mu\text{m}$ layer (a); cracking in a slightly thicker $4\mu\text{m}$ layer (b). On c-plane sapphire, a relatively thin $1.8\mu\text{m}$ layer exhibits cracks (c).

XRD measurements suggest a lower edge-type threading dislocations density for the a-plane sapphire growth, although the screw threading dislocations density increased somewhat... The window for off-optimum growth while maintaining reasonable crystal structure was wider for the a-plane compared with c-plane growth

$8.1 \times 10^6/\text{cm}^2$, respectively, for the c-plane sample. It was also found that the window for off-optimum growth while maintaining reasonable crystal structure was wider for the a-plane compared with c-plane growth.

The researchers also studied cracking effects in the AlN layer. They were able to maintain crack-free AlN growth on a-plane sapphire beyond $3.6\mu\text{m}$ thickness (Figure 2), while cracks appeared in material grown on c-plane sapphire at $1.8\mu\text{m}$. Cracking did occur on a-plane sapphire with a $4\mu\text{m}$ -thick AlN layer, but the density of cracks ($25.5/\text{cm}$) was a factor of five lower than that for the $1.8\mu\text{m}$ layer on c-plane sapphire ($145.9/\text{cm}$).

The a-plane sapphire sample showed cracks in only one direction, which the Mie researchers explain in terms of the larger thermal expansion coefficient of sapphire parallel to the c-axis, compared with the perpendicular direction. ■

<http://apex.ipap.jp/link?APEX/2/111004>

The author Mike Cooke is a freelance technology journalist who has worked in the semiconductor and advanced technology sectors since 1997.

Triangular wells aim to beat polarization

Researchers at China's Xiamen University show how bandstructure engineering promises improved nitride-based LEDs, reports [Mike Cooke](#).

China-based researchers have been investigating the use of triangular shaped quantum well structures to counteract the deleterious effects of polarization fields in nitride semiconductor light emission [Li-Hong Zhu, *Semicond. Sci. Technol.*, vol.24, p.125003, 2009].

Polarization fields arise spontaneously from the ionic charges on the component elements in the nitride semiconductor, such as gallium and nitrogen, and from strain-induced piezoelectric effects. Such fields can cause the injected electrons and holes to separate and recombine through indirect mechanisms rather than emitting light (the quantum-confined Stark effect, or QCSE).

Xiamen University researchers are seeking to overcome polarization-induced effects by using a triangular quantum well structure to shift the band structure and also to compensate to some extent for the polarization fields, encouraging the electron and hole wave-functions to overlap more. The triangular wells are achieved by using the growth properties of indium gallium nitride (InGaN) to construct the wells. In particular, indium is the most volatile element in the combination and tends to evaporate at higher growth temperatures.

The growth method was MOCVD on c-plane sapphire substrates. Tri-methyl-gallium (TMG), tri-methyl-indium (TMI), ammonia (NH₃) and silane (SiH₄) were used as the precursor/sources for Ga, In, N, and silicon (Si-dopant) with nitrogen/hydrogen as carrier gases. Conventional MQW structures were grown using constant temperatures for the various layers. Triangular structures were grown using temperatures that varied either from 680°C or 730°C

Xiamen University researchers are seeking to overcome polarization-induced effects by using a triangular quantum well structure to shift the band structure and also to compensate to some extent for the polarization fields

up to 840°C. At the latter temperature, the resulting material contains near-zero indium composition. By using different initial temperatures, one can achieve devices with varying emission wavelengths.

Photoluminescence (PL) and electroluminescence (EL) experiments were carried out on the samples. While the conventional MQW structure's integrated PL intensity fell by about two orders of magnitude (a factor of 10², or 100) between 17K and room temperature (300K), the triangular structures had emissions that fell by only a single order of magnitude (a factor of ten). This indicates that the triangular structures have higher internal quantum efficiency (IQE) even at higher temperatures.

Under an electric current, the triangular MQW samples exhibit stronger peak intensities and narrower line-widths over the conventional samples, say the researchers. The blue shift of the triangular samples with increasing current is also smaller: 23meV compared with 74meV for the conventional sample between 5mA and 120mA. The researchers believe that the smaller blue-shift indicates the almost complete absence of the QCSE that is a feature of the performance of normal nitride-based LEDs due to polarization fields. High-current operation revealed that the triangular wells continued to increase in integrated emission up to about 300mA, rather than about 200mA for the conventional structure. This indicates a smaller efficiency droop at high currents.

Although quantitative comparisons between the con-

While the conventional MQW structure's integrated PL intensity fell by about two orders of magnitude (a factor of 100) between 17K and room temperature (300K), the triangular structures had emissions that fell by only a single order of magnitude (a factor of ten) the triangular structures have higher internal quantum efficiency

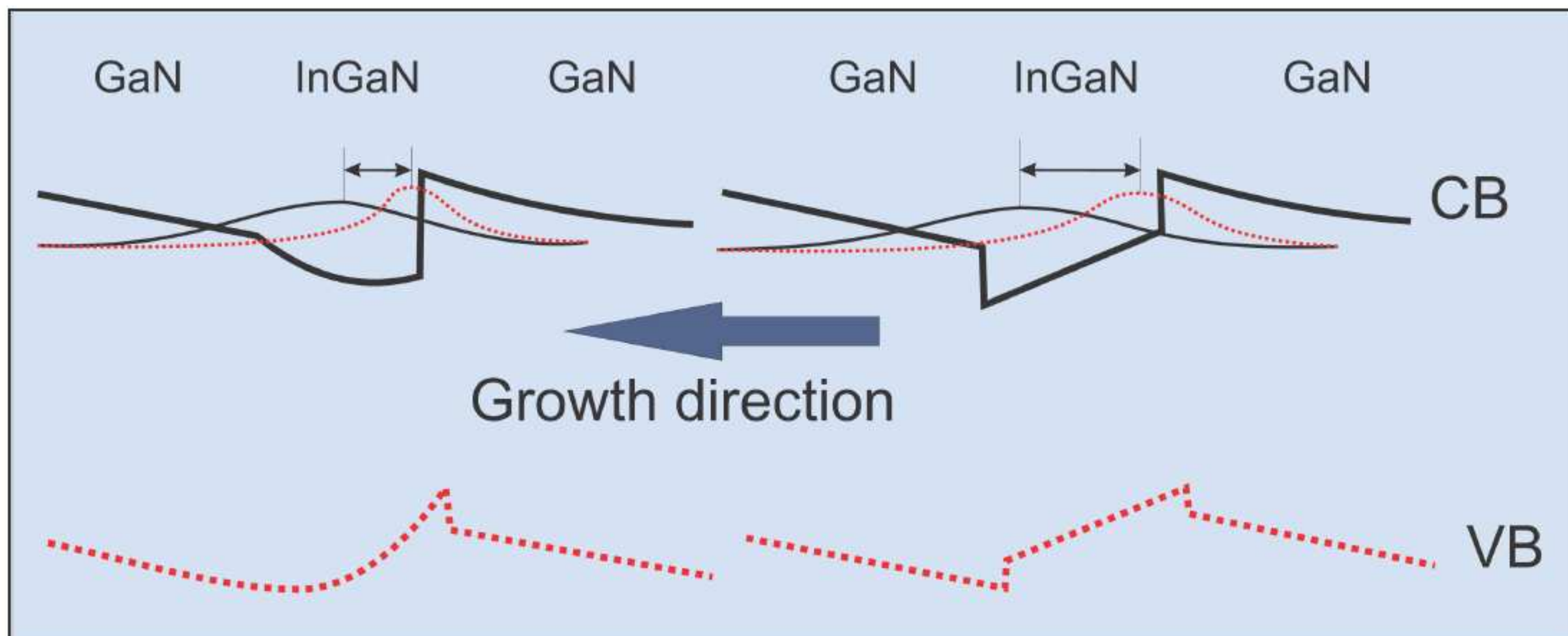


Figure 1. Simulated band structure of triangular quantum well (a) compared with rectangular structure (b). Solid lines indicate conduction bands and electron wave-functions; dashed lines refer to valence bands and hole wave-functions. (The wave-functions are the 'bell-shaped' structures.)

ventional and triangular LEDs have yet to be carried out, the thermal, current and spectral behavior imply that the utilization efficiency of the injected carriers for radiative recombination is much higher in the triangular MQW.

Other groups have attempted to reduce polarization fields by changing the crystal orientation of the nitride

semiconductor from c-plane to another orientation where there is less polarization in that direction, such as the m-plane. This is particularly the case with recent work towards green laser diodes [see Cooke, Semiconductor Today, p.62, October 2009]. ■

www.semiconductor-today.com/features.htm

<http://dx.doi.org/10.1088/0268-1242/24/12/125003>

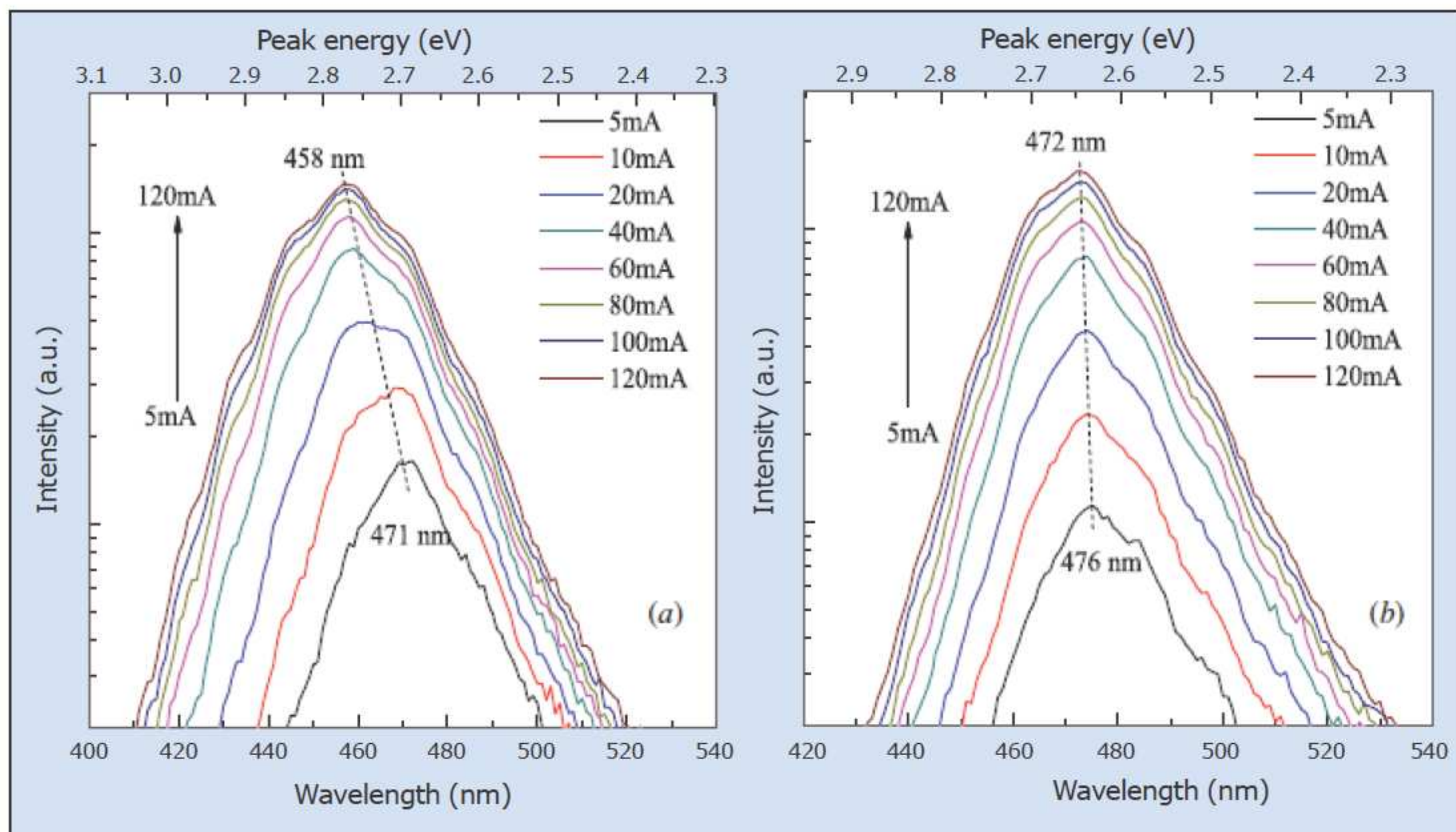


Figure 2. Electro-luminescent spectra as a function of injection current from 5mA to 120mA at room temperature for rectangular MQW LEDs (a) and triangular MQW LEDs (b). The emissions are in the green (520–570nm) and yellow ranges (570–580nm).

Advances in nitride precursors pave way to HB-LED mass production

SAFC Hitech discusses the demands on nitride MOCVD precursor manufacturing from the rapid development in application areas such as solid-state lighting, including the delivery of triethylindium for high-quality indium nitride growth.

One of the fastest-growing sectors in the III-V materials market is currently nitride-based high-brightness LEDs (HB-LEDs). With significant growth in demand for HB-LEDs for use in applications such as LED televisions, automotive and architectural lighting, market forecasts for this area predict steady growth over the coming years to about \$12bn in 2012, as illustrated in Figure 1. In particular, instrumental in this rise has been the research into nitride-based devices that has expanded potential solutions to enable access to the whole visible spectrum (i.e. to the output wavelength of devices spanning the visible range of the electromagnetic spectrum using a single material system). Exciting new applications in solid-state lighting are moving towards commercialization, adding further to the demand for increasing numbers of products across more application areas, as highlighted in Figure 2.

To keep pace with the growth of this industry, the precursors employed to deposit the thin films required must be made available in significantly larger volumes to meet demand. Such increases in material quantity must be achieved without compromising product quality, and technical excellence must be maintained

to ensure that performance meets exceptionally high standards. For example, proprietary equipment and handling protocols must be developed, installed and commissioned to ensure that parts per million (ppm) levels of contamination are not introduced to 100kg lots. In particular, oxygen and silicon impurities at these levels have an extremely detrimental effect. Significant effort over many years has seen contamination levels in group III organometallic compounds decrease from 0.5ppm to 5ppb (parts per billion). These advances are what have made possible the ultra-high-brightness devices that are driving the LED market forward.

The importance of delivery systems

Achieving the best quality compound semiconductor layers and structures for device fabrication requires the correct combination of ultra-high-purity chemicals. However, in order to achieve the most cost-effective process, the most reliable delivery systems are needed. The introduction of chemicals to the deposition system must be performed in a fully controlled manner with no contamination in order for users to develop the most efficient methods to manufacture competitive products. SAFC Hitech has undertaken extensive research into all

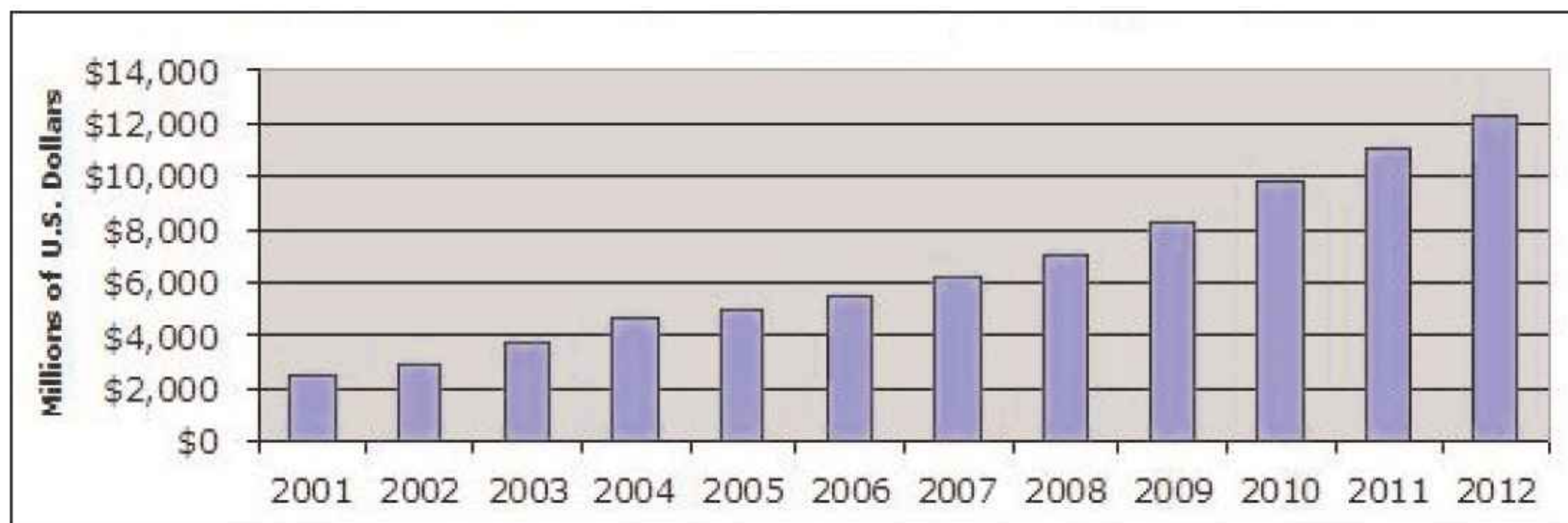


Figure 1. Total LED market 2001–2012 (millions of dollars). Source: iSuppli Corp (November 2007).

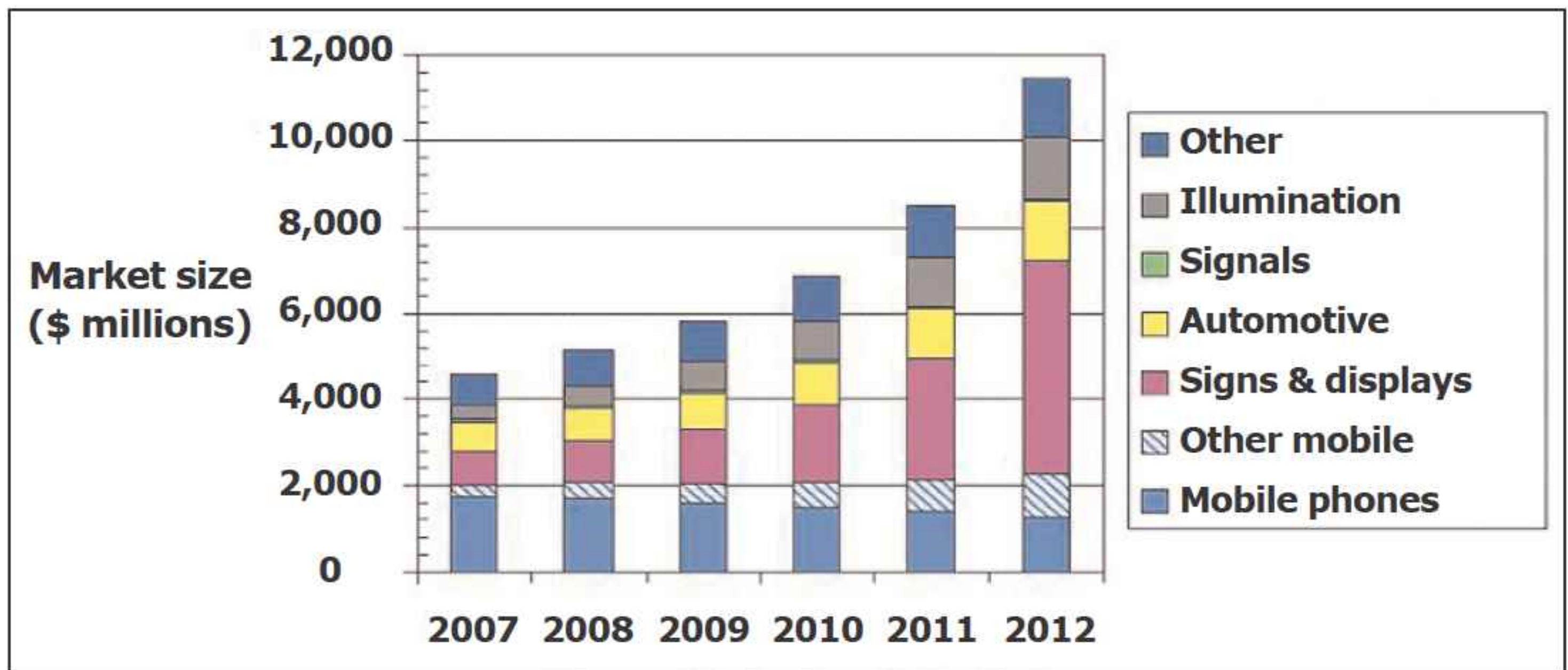


Figure 2. Predicted LED applications 2007–2012. Source: Strategies Unlimited.

aspects of the precursor delivery technology needed to offer complete solutions for customer applications.

The deposition of gallium nitride (GaN) and aluminum nitride (AlN) by MOCVD has been well established using the conventional liquid precursors trimethylgallium (TMG or Me_3Ga) and trimethylaluminum (TMA or Me_3Al) in combination with ammonia (NH_3) and the production of these group III molecules in high volume. Their delivery in bulk has been addressed using a variety of proprietary techniques. Production and subsequent treatments, including SAFC Hitech's unique adduct purification, has ensured that high-purity routes are available that can be scaled effectively to increase capacities. Robust chemistry has been combined with in-house plant engineering, resulting in plant capacities in the tonnes per year range. SAFC Hitech's EpiFill delivery tool allows users to handle large volumes of chemical in a safe, controlled fashion. In the EpiFill system, liquid

precursor is pumped from a bulk reservoir to a tool unit on demand to minimise the kit modifications required to upgrade the precursor delivery system and to take advantage of reduced bubbler change-out time and qualification run requirements, resulting in reduced system downtime. The savings from such a system can make the difference between profit and loss in this highly competitive market, where strong price pressure is evident.

In the case of gallium and aluminum, the starting compounds, along with the target nitride layers, are reasonably well matched, easing the choice of deposition parameter that will ensure a compatible process that affords a wide range of mixed metal alloy compositions. The situation is not the same with regards to indium, due to the solid nature of the preferred precursor, trimethylindium (TMI or Me_3In), and the instability of the target indium nitride (InN) layers with respect to GaN and AlN. In particular, the

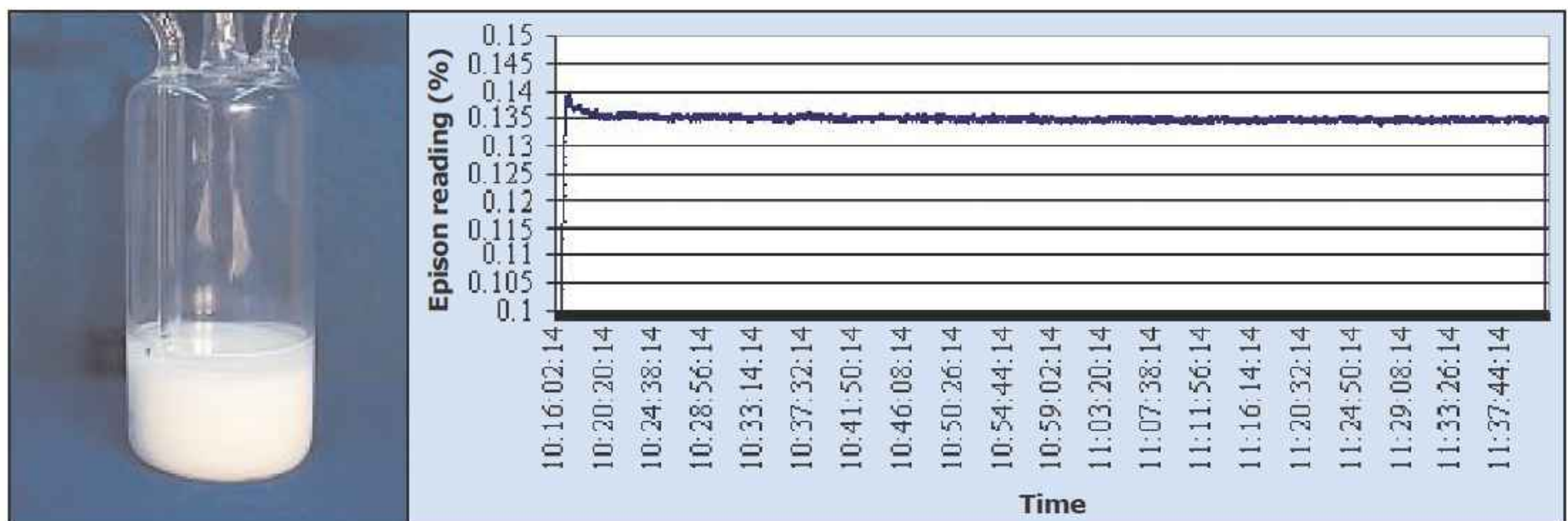


Figure 3. Solution TMI (left) physical appearance and (right) performance (standard, 10°C, 300scm, 500mbar in crossed dip leg bubbler).

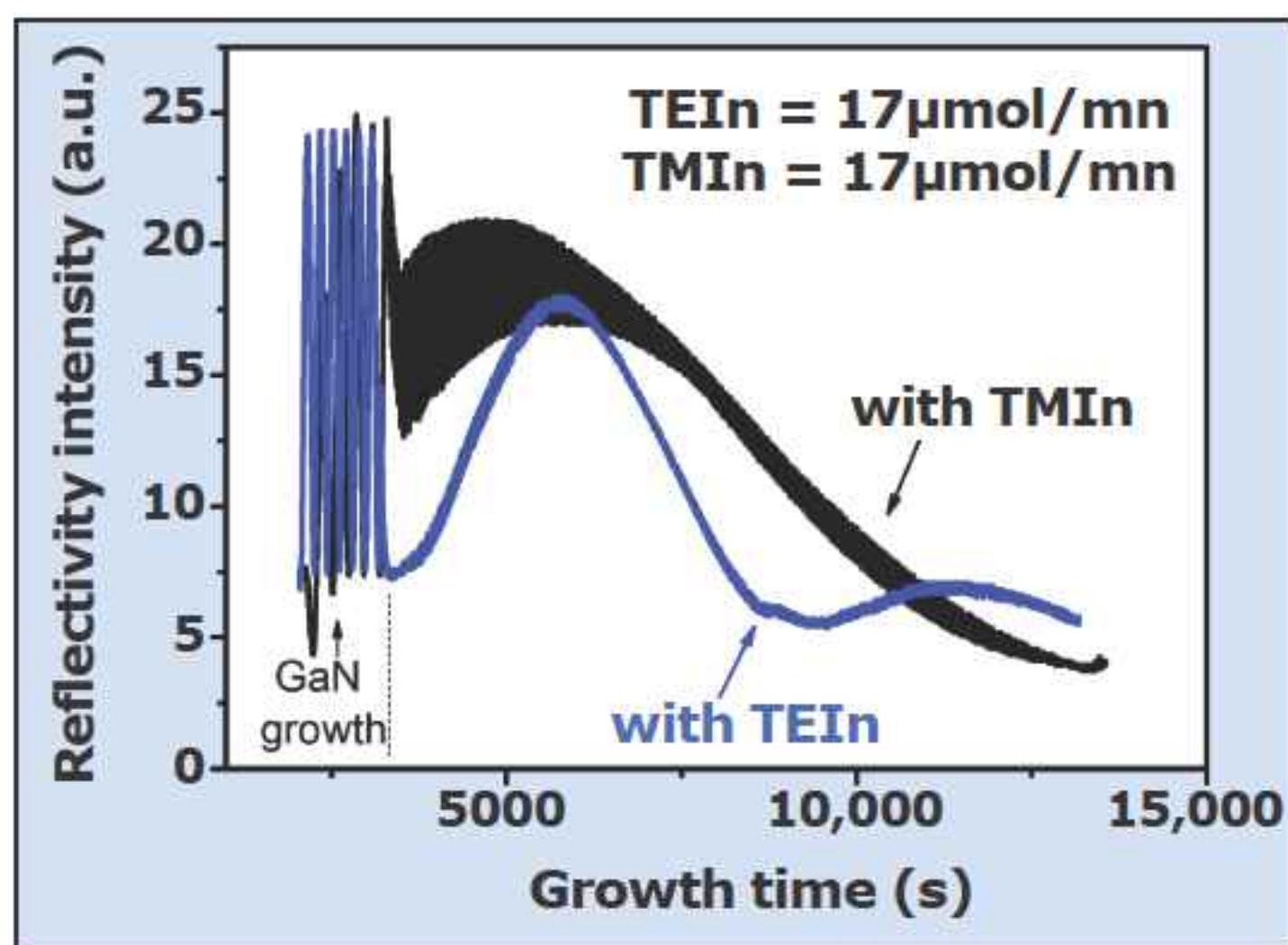


Figure 4. In-situ reflectivity measurement during MOCVD growth of the InN layers grown with TEIn and TMIn, with ammonia as the nitrogen precursor.

requirement to reduce deposition temperatures from 1050°C to 600°C or below (in order to avoid layer decomposition) leads to problems in finding conditions where mixed In/Ga/Al nitrides can be formed controllably. It is well known that the very interesting inclusion of InN into devices — in order to allow the full spectrum of visible LED output wavelengths to be accessed using a single material family (nitrides) — has been hampered by the above issues, and this is an area where SAFC Hitech has focused significant effort in working to develop new technologies.

Bubbler design

When we look at precursor handling and delivery, the solid nature of TMI makes it impossible to simply pump liquid samples from one place to another, as we can for TMG or TMA. Transport, therefore, must be targeted in the form of vapor. In small volumes, vapor pick-up from the ampoule can be achieved with excellent consistency and supply results from all of the bubbler options available are comparatively similar. However, for bulk delivery, numerous obstacles must be overcome to provide stable, reliable output fluxes. To address this issue, bubbler design has received significant attention in recent years, with a number of innovative approaches being studied. Currently though, for high volumes no single bubbler method can meet customer demands. However, SAFC is developing an innovative, scalable approach to this issue and will launch new products in 2010.

Historically, to obtain reproducible 'bubbling' transport of TMI, the formation of a TMI solution has been highly successful. The patented Solution TMI product provides liquid-like saturation efficiencies for the solid precursor and slurry transfer of larger batches offers the potential to increase lot size accordingly. Excellent growth results are routinely achieved with this

approach, although for a very high-volume delivery system a true liquid is more desirable to be fully compatible with the existing TMG/TMA bulk delivery technologies mentioned previously.

In order to further develop this methodology SAFC Hitech recently returned to TEI (Et_3In) studies that were halted a number of years ago due to the relatively low thermal stability of the source. In the previous studies, the adduct purification approaches that were investigated required such excessive temperatures to isolate the final product that partial decomposition was observed during collection, causing safety concerns in the laboratory-scale experiments and hence limiting production scale up potential. Since returning to the study of TEI to access the technologically important InN films, fabrication at SAFC Hitech has employed alternative methodologies and, in studies conducted recently, high-purity product has been isolated successfully using low-temperature protocols that are much better suited to this compound, thus solving a number of safety, delivery and quality issues in a major step forward.

The TEI produced at laboratory-scale using these new methodologies was also studied as part of the recently completed European project INDOT. This three-year project was a collaboration between SAFC Hitech, Aixtron, France's Montpellier University and SAES Getters which focussed on InN and InGaIn film deposition and their quality improvements. The TEI that was isolated was found to significantly aid the ability of a team at Montpellier University to grow advanced InN films. High-quality, homogeneous layers were deposited reproducibly to high standards of precision, making the fabrication of full operational devices integrating this material a possibility for the first time. In detail, highly crystalline films with a full width at half maximum (FWHM) of 600 arc sec in the (0002) x-ray diffraction (XRD) peak rocking curve and 1600 arc sec in the (1000) peak rocking curve were achieved at more than double the growth rates possible with TMI. This is shown in Figure 4, where the in-situ reflectance oscillations correlate to the film thickness. Coupled with the breakthrough use of bromotrichloromethane (CBrCl_3) as a co-reagent to smooth the deposited layers, ultra-high-quality InN is now a reality.

A different solution to precursor vapor delivery is to provide a saturated gas reservoir for supply to a number of kits. Provision of a constant composition requires excellent vaporization control and a feedback system to ensure any fluctuations due to the solid nature of the TMI are compensated for. Of course, this delivery technology can also be applied to liquid sources so that, rather than pumping liquids to the tool and then using bubbling to vaporize the group III sources (as in the EpiFill system), controlled-

concentration gases can be generated and transported. To achieve this goal, the TMG and TMA is fed to liquid vaporizers in the bulk delivery system itself and then to a manifold for direct dispensation to one or more kits. The controlled introduction of the liquid to the vaporizer via a feedback loop and demand control system is such that a highly uniform output of vapors is produced for feeding directly into a number of deposition kit manifolds simultaneously, as demonstrated by the EpiVapor system schematic in Figure 5.

This approach eliminates the requirements for kit bubblers and the requisite heating/cooling baths and gas handling systems, and offers the potential for several much simpler solely vapor-fed tools to be linked to a single remote precursor supply point in the same way that process gases are currently connected. Safety is a large and very important factor when developing production lines, and the ability to contain the bulk hazardous chemicals in remote bunkers is attractive, provided that no loss of process control is introduced. Indeed, the flexibility of precursor supply in the vapor phase to several kits enhances usage monitoring and streamlines all supply mechanisms.

The choice of delivery system largely depends on the existing customer equipment and the relative costs to install upgrades. The EpiFill system is easy to retrofit to existing equipment and does not affect current process parameters, as the bubbling of carrier gas through the tool bubbler is still the control source for the precursor transport rate, while the EpiVapor system is more suited to new facilities where substantial simplification of tool precursor introduction systems can be made (saving capital investment). A simple gas manifold on each local deposition system can be employed to meter all chemicals controllably from an all-vapor bulk supply.

Finally, from SAFC Hitech's perspective as a precursor supplier, significant investment in new laboratory and plant capacity around the globe enables the manufacture of high-purity chemicals in localized facilities, ensuring the highest levels of service for customers in each market. This local manufacturing is required due to the pyrophoric nature of the chemicals and the resulting transportation limitations that prohibit air freight and cause unacceptable time delays when shipping products over long distance. In particular, production in Taiwan has been expanded in

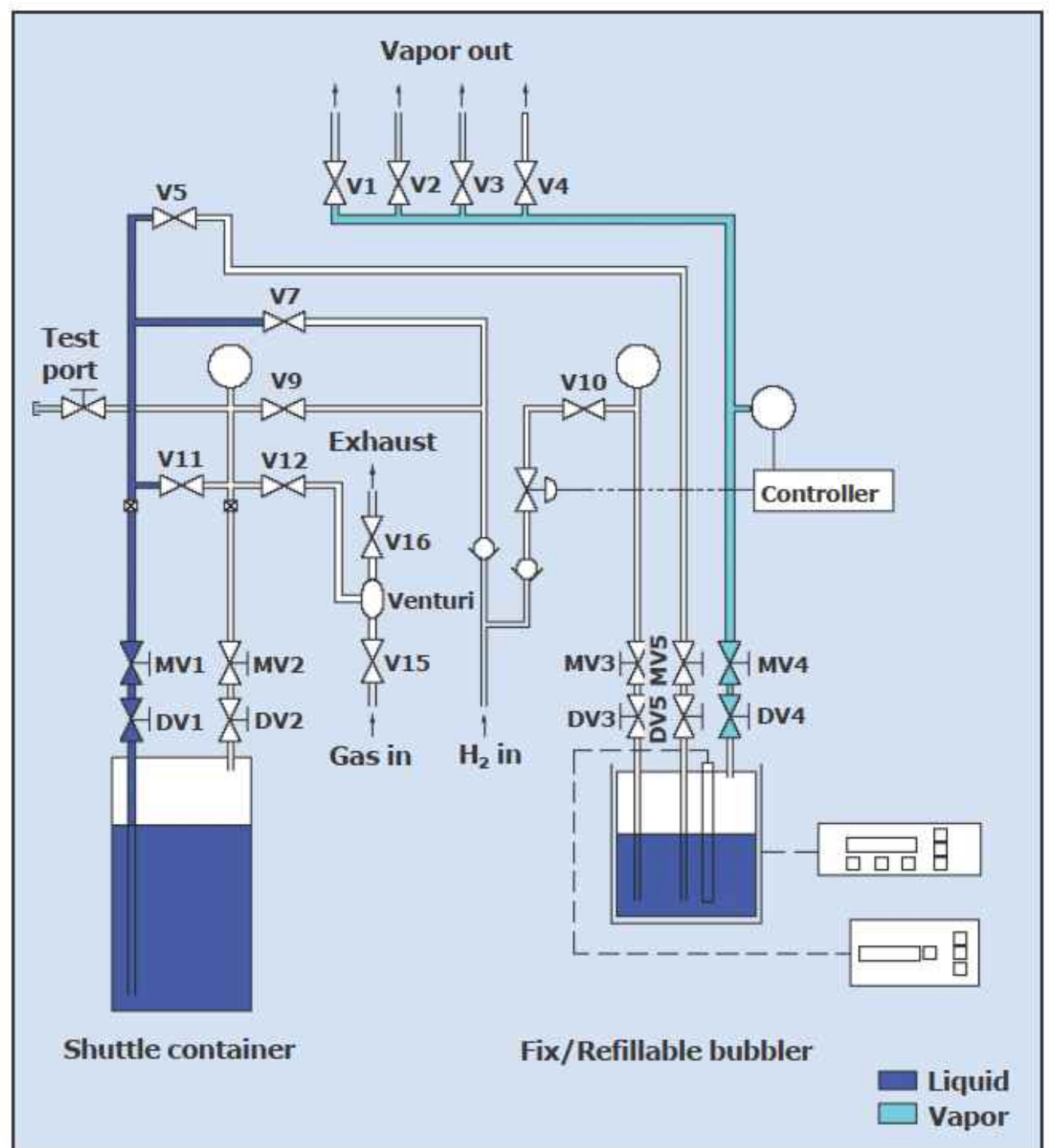


Figure 5. Schematic of EpiVapor system.

recent years to meet the growing customer requirements in the Far East as high-efficiency LED manufacturing increases year on year. This policy is also being pursued in other countries to complement the existing sites and to maintain unparalleled access to high-purity precursors worldwide. ■

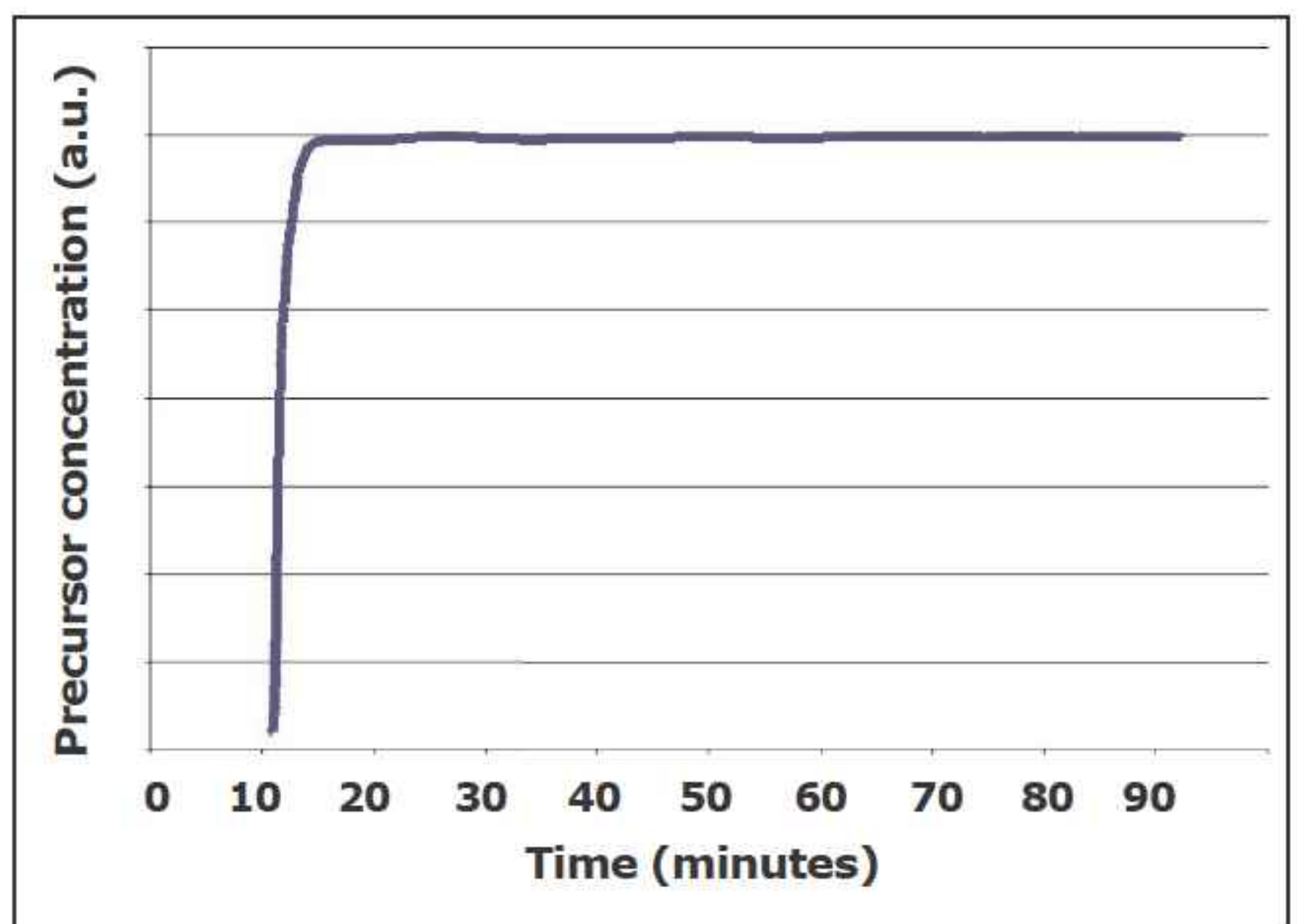


Figure 6. EpiVapor system output performance.

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Fax: +1 480 899 0779
www.nikkomaterials.com

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Germany
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www.sicrystal.de

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Fax: +1 503 693 8275
www.sesmi.com

TECDIA Inc

(see section 16 for full contact details)

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(see section 3 for full contact details)

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5 Deposition materials

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(see section 1 for full contact details)

Power + Energy Inc
(see section 8 for full contact details)

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6 Deposition equipment


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MA 02464, USA

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Fax: +1 617 965 5818

E-mail: sales@microchem.com

www.microchem.com

Power + Energy Inc

(see section 8 for full contact details)

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9 Materials & metals

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www.saesgetters.com

11 Process monitoring and control

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www.jawoollam.com

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14 Chip test equipment

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15 Assembly/packaging materials

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www.epak.com

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Fax: +41 329257115

www.ismeca.com

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www.jp-salaser.com

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www.kns.com

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Fax: +33 169 33 02 92
www.ums-gaas.com

19 Facility equipment

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Fax: +1 541 917 3623
www.marlerenterprises.net

20 Facility consumables

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21 Computer hardware & software

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Fax: +1 604 320 1734
www.crosslight.com

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Fax: +1 804 740 3814
www.semitech.us

22 Used equipment

Class One Equipment Inc

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www.mw-zander.com

TECDIA Inc

(see section 16 for full contact details)

24 Consulting

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www.wsr-ods.com

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<http://rawcon.org>

20–22 January 2010

10th Fiber Optics Expo (FOE 2010)

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E-mail: foe@reedexpo.co.jp

www.foe.jp/en

23–28 January 2010

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E-mail: heidi@newsolartoday.com

www.cpvtoday.com/usa

2–4 February 2010

PHOTON's 5th Photovoltaic Technology Show 2010 USA

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E-mail: solidstate@courtesyassoc.com

www1.eere.energy.gov/buildings/ssl/raleigh2010.html

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SOLARCON Korea

COEX, Seoul, Korea

E-mail: julee@semi.org

www.solarconkorea.org/SOLARKOREA-EN

7–9 February 2010

Industry Strategy Symposium Europe 2010

Dublin, Ireland

E-mail: clee@semi.org

www.semi.org/isseurope

10–12 February 2010

Strategies in Light 2010

Santa Clara Convention Center, CA, USA

E-mail: tcarli@strategies-u.com

<http://sil09.events.pennnet.com>

2–5 March 2010

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Gungzhou, China

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Tokyo Big Sight, Japan
E-mail: pv@reedexpo.co.jp
www.pvexpo.jp

7–9 March 2010

Photovoltaic Fab Manager's Forum

Berlin, Germany
E-mail: semieurope@semi.org
www.semi.org/pvfmf

16–18 March 2010

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<http://semiconchina.semi.org/scchina-en>

16–18 March 2010

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www.world-of-photonics.net/en/laser-china/start

17–18 March 2010

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Berlin, Germany
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www.thinfilmtoday.com/eu

18–19 March 2010

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www.invest-in-photonics.com

21–25 March 2010

Optical Fiber Communication Conference and Exposition and National Fiber Optic Engineers Conference (OFC/NFOEC 2010)

San Diego Convention Center, CA, USA
E-mail: info@ofcconference.org
www.ofcnfoec.org

22–24 March 2010

SEMATECH Surface Preparation and Cleaning Conference (SPCC 2010)

Austin, TX, USA
E-mail: erica.mcgill@sematech.org
www.sematech.org/meetings/spcc

24–26 March 2010

6th Photovoltaic Science Application and Technology (PVSAT-6) Conference

and Exhibition

University of Southampton, UK
E-mail: info@uk-ises.org
www.pvsat.org.uk

29–31 March 2010

Semiconductor and Integrated Opto-Electronics Conference (SIOE'10)

Cardiff University, Wales, UK
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www.astro.cardiff.ac.uk/research/pm/events

5–9 April 2010

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<http://spie.org>

5–9 April 2010

2010 MRS Spring Meeting

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E-mail: info@mrs.org
www.mrs.org

7–9 April 2010

CPV-6: the Sixth International Conference on Concentrating Photovoltaic Systems

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8–10 April 2010

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12–16 April 2010

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<http://spie.org/photonics-europe.xml>

13–14 April 2010

Photovoltaics Europe 2010

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www.idtechex.com/printedelectronicseurope10/en/index_pv.asp

19–22 April 2010

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