

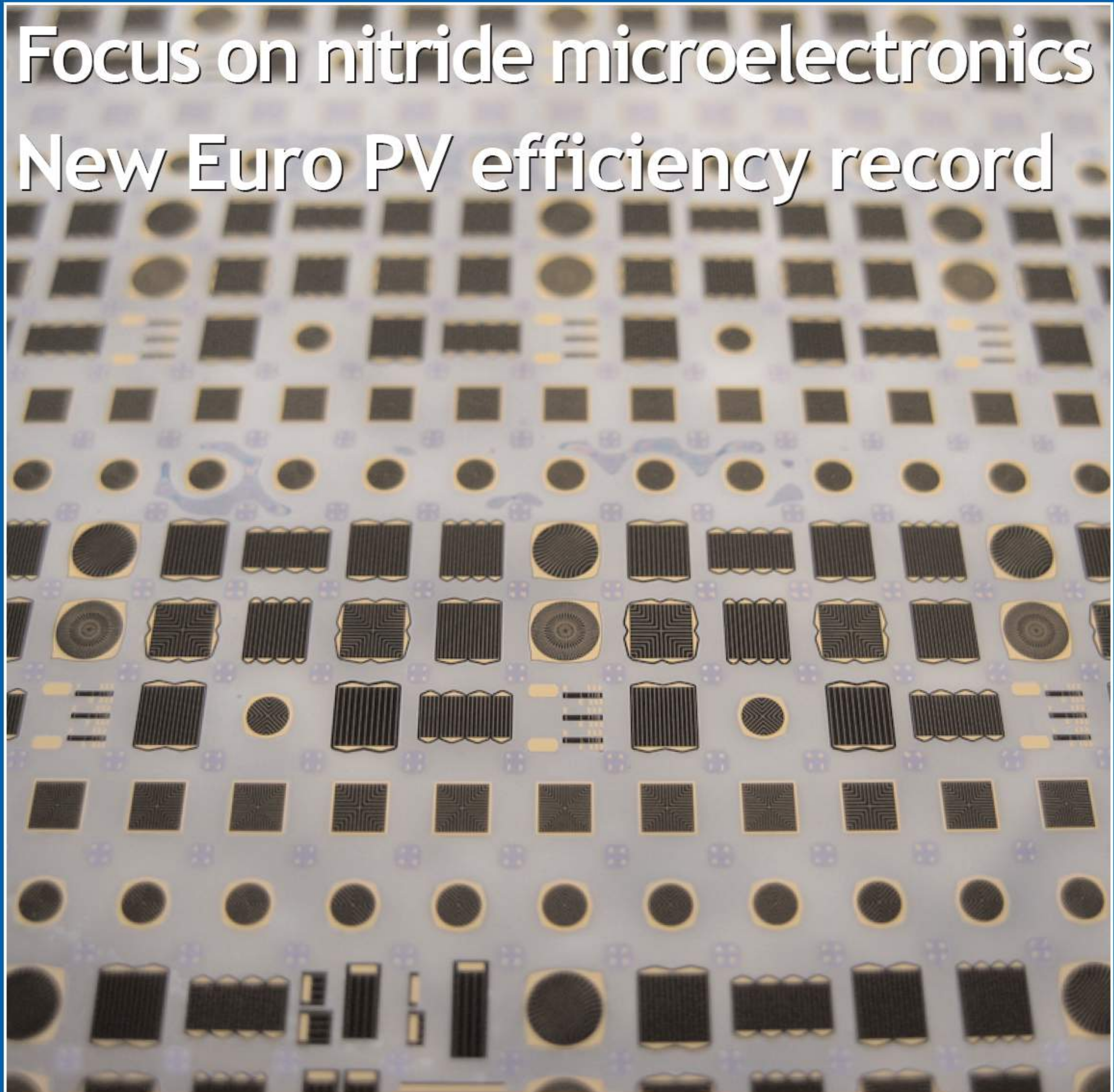
semiconductor TODAY

COMPOUNDS & ADVANCED SILICON

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Focus on nitride microelectronics New Euro PV efficiency record



Avanex cuts plant and staff • Peregrine cuts off Rubicon
Caracal re-starts • Sanyo's record 450mW 12x BluRay laser

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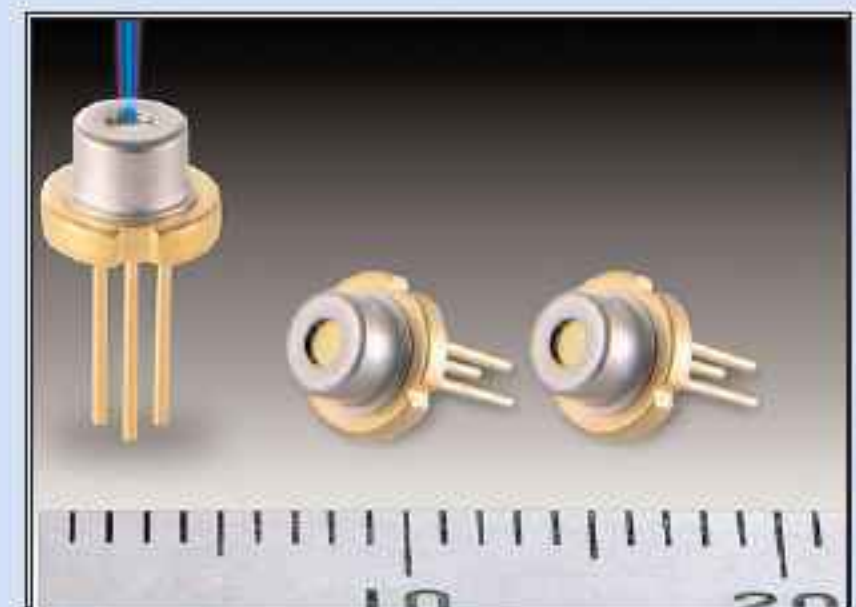
We want to hear from researchers, engineers and managers interested in contributing articles. Ideas for Feature articles or one-page Opinion articles can be e-mailed to the Editor at mark@semiconductor-today.com



p26 Evatec launches cluster tool at Semicon Europa.



p39 Osram's red, green and blue Advanced Power TopLED Plus LEDs, which boost light by 15% for large LCD displays.



p45 Sanyo's 5.6mm-diameter 450mW 405nm Blu-ray laser diode, which allows recording at 12x speed.



Cover: Photo of a solar cell wafer with different concentrator solar cell structures. Germany's Fraunhofer ISE has used theoretical calculations to optimize the front-side contacts and raise its European efficiency record for triple-junction III-V solar cells from 37.6% to 39.7%. **p63**

Long-term development vs short-term slowdown

This issue we cover the topic of gallium nitride based microelectronics, including developing insulated gate structures for GaN MOSFET devices (see page 67). Meanwhile, at the International Symposium on Compound Semiconductors (ISCS) in late September, Fujitsu reported what it claims to be the first high-output 'normally off' GaN-based HEMT transistor, achieving power of more than 100W yet also enabling the power to be cut while in standby mode without requiring a negative voltage (see page 65).

Furthermore, at the 2008 IEEE Compound Semiconductor IC Symposium (CSICS) in mid-October, Fujitsu announced the development of two GaN HEMT-based high-efficiency RF amplifier with record power output in the C-band (320W at 57% and 250W at 60% efficiency) — see next issue for details, along with other news from CSICS).

Regarding wide-bandgap electronics using silicon carbide (rather than GaN), Microsemi of Irvine, CA, USA (which makes mainly silicon as well as GaAs ICs) has launched its first commercial SiC products (see page 23) after supplying devices under contract to Northrop Grumman for some time. Meanwhile, SiC substrate and epiwafer maker Caracal Inc of Ford City, PA, USA has resumed operations after filing for chapter 7 bankruptcy protection in April but recently being bought by a multinational consortium (page 22).

Similarly, after UK defense firm Cobham plc completed its acquisition of M/A-COM's RF Components and Subsystems business in Lowell, MA, USA from Tyco Electronics at the end of September, the commercial part of the business has been re-formed as M/A-COM Technology Solutions (page 16).

Shortly before closing for press, GaAs RFIC maker Anadigics said that, after being unable to expand fast enough to satisfy customers' demand, it would be cutting costs, and possibly jobs (see next issue for details).

One firm that has already announced it is cutting jobs (8% of staff) is optical communications component maker Avanex of Fremont, CA, USA, which is closing its plant in Florida (page 56). But despite this, other fiber-optic component makers are continuing to grow and move into profitability, with Finisar for example expanding manufacturing capacity in China (see page 57, as well as coverage of new product launches and technology demonstrations at September's European Conference on Optical Communications on pages 48–55). Growth is evidenced by the market for indium phosphide substrates being forecast to rise at a compound annual average growth rate of 38% through 2012 (see page 4).

The sapphire substrate market is likewise growing, at 21% (page 5). However, supplier Rubicon has been hit by economy-driven slowdowns in demand from RFIC maker Peregrine and makers of LEDs for handheld consumer devices, despite growth for large-area displays (see page 34). Third-quarter results for other companies (to be reported next issue) may indicate further whether any slowdown-driven drop in demand (e.g. from Taiwanese LED makers) is short-term or long-term.

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

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- event calendar and event previews;
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PVs to be 20% of SC GaAs market in 2012

End demand for semiconducting (SC) gallium arsenide bulk substrates from photovoltaic markets has the potential to grow at a compound annual average growth rate (CAAGR) of 79% through 2012 to more than 20% of total demand, forecasts Strategy Analytics in its report 'Semi-conducting GaAs Bulk Substrate Market 2007-2012'.

LEDs will continue to represent the largest end market for SC GaAs bulk substrates, accounting for 39% of demand, adds the market research firm. Overall, the merchant market for SC GaAs bulk substrates will grow at a compound annual average growth rate of 7% through 2012 in terms of wafer area, with Asia-Pacific continuing to drive regional demand as the market moves towards larger-diameter substrates.

"Mitsubishi Chemical, Sumitomo Electric Industries and Hitachi Cable are the market leaders," notes

Asif Anwar, who is director of Strategy Analytics' GaAs service. "Collectively, the Japanese leaders accounted for over 64% of the total market," he adds.

"Other significant suppliers in 2007, in rank order, included AXT, Dow, Freiberger Compound Materials, and Neosemitech."

Other key findings of the report include:

- The merchant market represented 88% of total output in 2007, with the Japanese suppliers accounting for the captive demand.
- 3- and 4-inch material accounted for 70% of wafer output in 2007, and the market for larger-diameter material will continue through 2012.
- Substrates grown using the vertical gradient freeze (VGF) and vertical Bridgman (VB) methods accounted for 64% of wafer output in 2007, and this will increase to 75% through 2012.

www.strategyanalytics.com

IN BRIEF

InP substrate market to grow at 38% to \$75m in 2012

With demand for bandwidth spurring on development of 40Gb/s and 100Gb/s optical communications networks, the market for indium phosphide bulk substrates will grow at a compound annual average growth rate (CAAGR) of 38% through 2012 to more than \$75m, forecasts market research firm Strategy Analytics in its report 'InP Bulk Substrate Markets 2007-2012'.

Japanese producers continued to dominate the overall supply of InP material in 2007, led by Sumitomo Electric Industries and followed by Nikko Materials, adds Strategy Analytics.

The USA's AXT and France's InPACT were the leading suppliers of indium phosphide material outside Japan, with the UK's Wafer Technology currently following behind these two firms by several market share percentage points.

www.strategyanalytics.com

Base-station RF component market flat at \$1.1bn to 2013

Cellular base-station shipments will increase at a compound annual average growth rate (CAAGR) of over 69% from just 803,000 units in 2007 to 13.4 million units in 2013 as the market for femtocell products starts to take off from 2009-2010 onwards (accounting for 84% of shipments in 2013), forecasts Strategy Analytics in its report 'Cellular Base Station RF Component Market 2008-2013'. However, the corresponding market for RF components for cellular base-stations will remain effectively flat at \$1.1bn over 2008-2013.

The migration to 3G+ (third generation plus) networks and 4G

(fourth generation) networks will also drive a move toward smaller form factors as operators look to reuse existing sites and infill capacity with smaller base-stations, says the market research firm. The penetration of micro base-stations will increase to 29% through 2013, but the largest growth in shipments will come from picocell and femtocell shipments.

Demand for standalone power amplifier (PA) modules for upgrading existing networks will be flat to negative as the market focuses on infrastructure rollout for emerging platforms. The PA will account for the largest proportion of RF compo-

nent revenues through 2013, but only exhibit overall growth of 2%.

"Despite the volumes, we do not expect to see a major increase in component revenues, but there will be a few bright spots based around emerging technologies," observes Asif Anwar, director of the Strategy Analytics GaAs service. Silicon LDMOS will remain the incumbent technology for cellular base-station PAs. However, gallium nitride (GaN) technology will start to fulfill earlier promises, with demand for GaN power amplifiers growing at a CAAGR of 76% through 2013, reckons Strategy Analytics.

www.strategyanalytics.com

Sapphire substrate market to grow at 21% to \$400m by 2012

The sapphire material market for electronic applications should grow at an average of 21% annually to \$402m by 2012, according to the report 'Sapphire Market 2008' from Yole Développement.

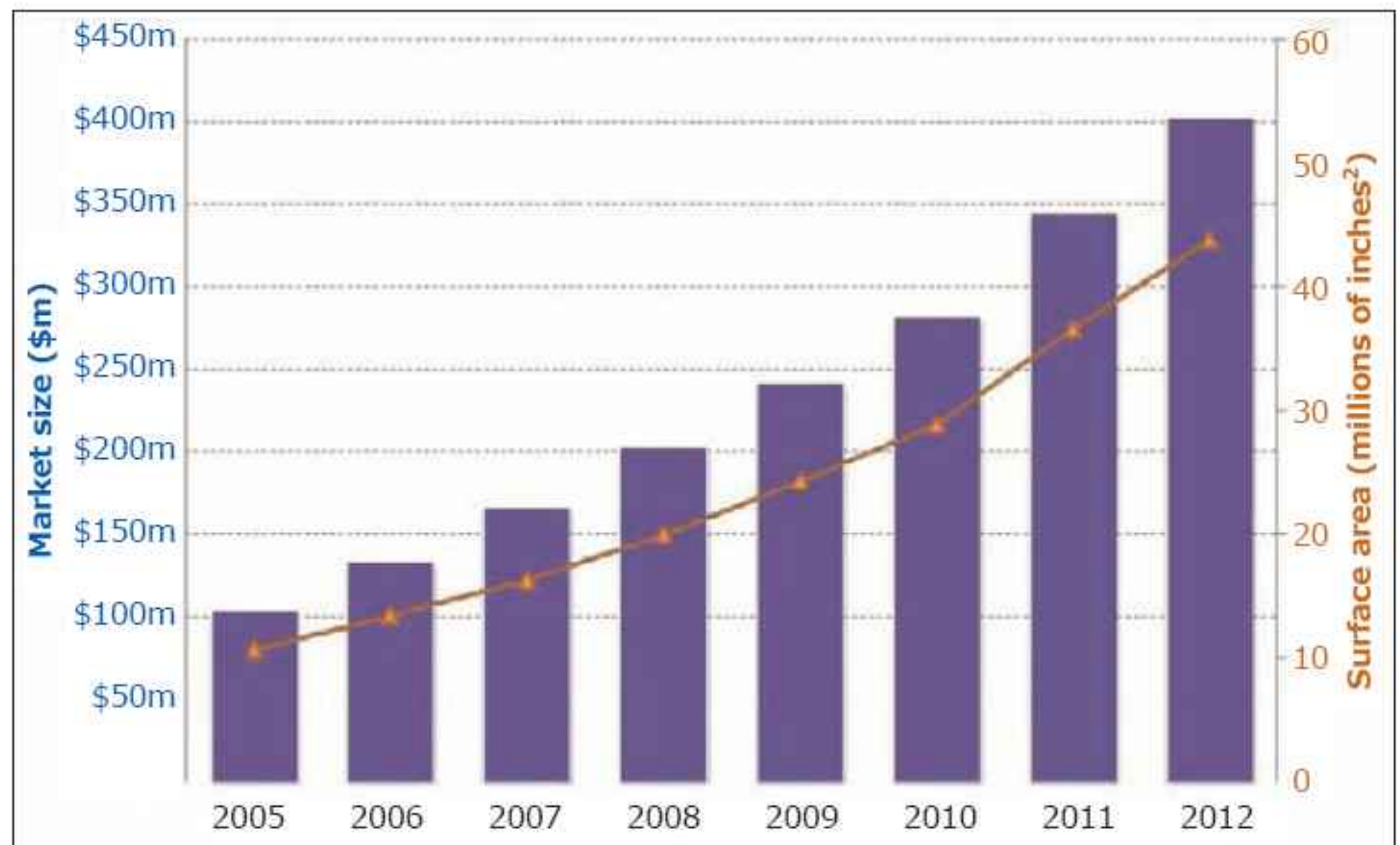
In 2007, the market reached a unit volume of 4.61 million wafers (2"-equivalent) for gallium nitride based LEDs, boosted by several tens of thousands of 6" wafers for silicon-on-sapphire (SoS) RF switch devices in mobile phones.

For several years, nitride LEDs have been driving the market, representing more than \$100m in revenues in 2007, and are expected to rise at a compound annual growth rate (CAGR) of 15% to 2012.

But in addition, since 2006, SoS applications have ramped up, with Peregrine Semiconductor Corp of San Diego, CA, USA becoming the main driver of the SoS RF market. Its SoS Ultra-CMOS technology is gaining momentum in cell-phone applications, displacing established switch technologies such as PiN diodes and GaAs pHEMTs. Although SoS' revenue at the substrate level was less than \$35m in 2007, this is expected to surpass \$100m by 2011.

Despite expected growth overall, sapphire sales for the LED market are suffering from huge pricing pressure in the main regions of Asia. With an LED die-on-wafer now selling at just 2-3 cents, LED makers are requesting sapphire substrates at as little as \$17 for a 2" wafer. This has forced some suppliers to focus instead on countries in the West, where market prices are more attractive, says the report's author Philippe Roussel.

Nevertheless, demand for 4" wafers is booming, with recent announcements that some major LED makers such as Osram and Showa Denko are migrating some of their production to the larger-diameter substrate.



Market (\$m) and surface area (million inch²) of c- and r-plane sapphire wafers.

In addition, in September Samsung announced plans for 6" nitride LED production, and Russia's Monocrystal has demonstrated 8" c-plane epi-ready sapphire wafers for LEDs.

Asian suppliers (including Japan's Kyocera, Interoptec/Fujimi, Namiki, Shinkosha and Sumitomo Metal Fine Technology, plus Taiwan's Crystal Wise, Tera Xtal Technology and Sino American Silicon, and China's Saifei) have captured 67% of the sapphire market by revenue, with five of the top ten suppliers. Europe accounts for 20% of revenue (due mainly to France's Saint-Gobain

and Monocrystal) and North America 13% (driven mainly by Rubicon).

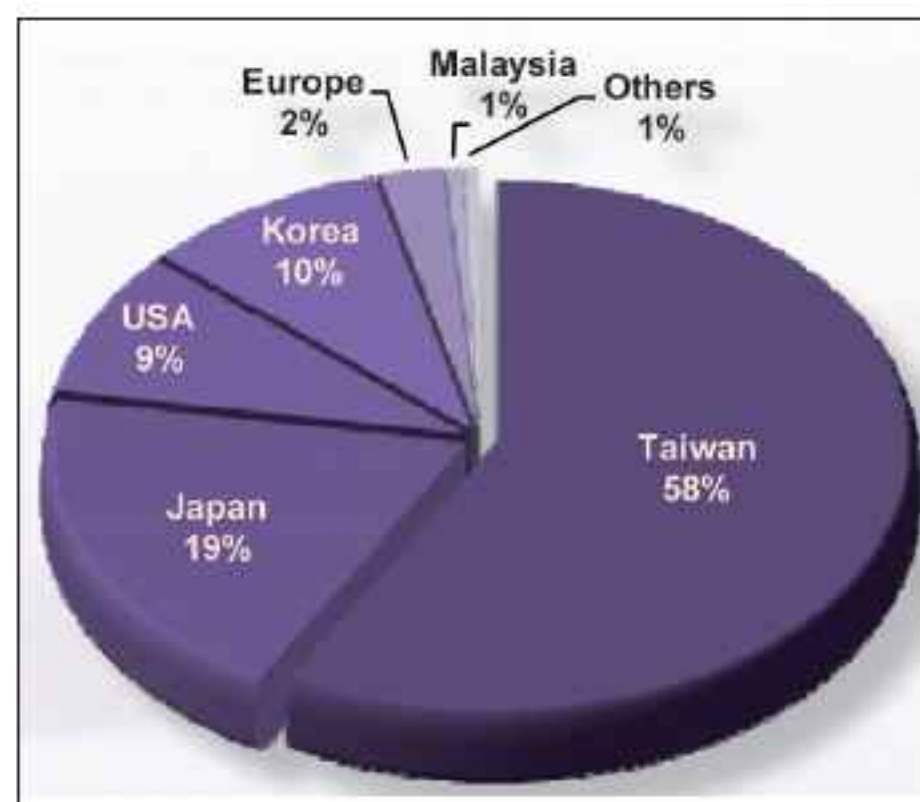
Sapphire for LED usage is concentrated in Asia, comprising more than 88% of sales. Taiwan alone represents 58% of demand, and Japan 19%.

Sapphire for SoS-based devices was originally located in Australia, but is now moving to Asia as Peregrine is becoming fabless and has agreed several deals with Korean fabs to outsource production.

Kyocera is still the biggest sapphire vendor worldwide, with 2007 sales of \$100m for both electronics and optical materials. However, Namiki and Rubicon are challenging Kyocera in the top three.

Roussel notes that the sapphire market is very active, with mergers and acquisitions creating new entrants and some firms exiting the sector. Most recently, Monocrystal's parent company Energomera Group acquired Russian compatriot Atlas, placing the firm firmly in the top three, and in April Honeywell sold its Canadian sapphire manufacturing plant to China's SilianTech.

www.yole.fr



Projected 2008 sapphire usage in GaN-based LED production by region.

Skyworks doubles shipments for smart phones to 40m

Skyworks Solutions Inc of Woburn, MA, USA, which manufactures linear products, power amplifiers, front-end modules and radio solutions for handset and infrastructure equipment, says that it has roughly doubled its shipments of smart-phone front-end modules (FEMs) year-on-year since 2004.

Over 40 million units were sold in fiscal 2008 alone, as its Intera portfolio of FEMs continues to support the steep growth trajectory of the rapidly emerging smart-phone segment (given the premium placed on space and power efficiency).

Equity research group Oppenheimer & Co forecasts continued robust demand for smart phones. In a recent survey, Skyworks was highlighted as a key beneficiary of growth within the smart-phone segment, which is being driven primarily by new subscribers and an upgrade cycle.

Meanwhile, Gartner and Credit Suisse anticipate 37% year-on-year growth in 2008 to 170m smart-phone shipments. Furthermore, they are forecasting a compound annual growth rate (CAGR) of 51% from 2007–2010, and unit growth from 122m to 422m units —

reflecting healthy fundamentals for the market.

“Based on customer demand, we see continued strong growth in the smart-phone segment, particularly as penetration rates move upward from the sub-teens of the global handset market,” says Gregory L. Waters, executive VP & general manager of front-end solutions. “As these devices become increasingly mainstream, Skyworks is leading the way with our family of Intera front-end modules, which uniquely enable power efficient, multi-mode, multi-band applications in ever smaller footprints,” he claims.

Skyworks surpasses 2 billion PA module shipments

Skyworks says that it has shipped more than 2bn power amplifier (PA) modules since the inception of the product near the turn of the decade.

The firm claims to be an architectural pioneer of power amplifier modules and complete front-end modules (FEMs), and uniquely supplies to each of the world’s top five handset original equipment manufacturers (OEMs) as well as two leading smartphone manufacturers.

Skyworks says that it has also developed design partnerships with

all of the industry’s leading base-band suppliers and, most recently, has captured key sockets on Qualcomm and MediaTek reference designs.

“We are even more excited about the design-win traction of our next-generation of multi-mode Intera front-end modules,” says Liam K. Griffin,

Skyworks is benefitting from the trend towards highly integrated, multi-band FEMs for 3G, EDGE, LTE and WLAN applications

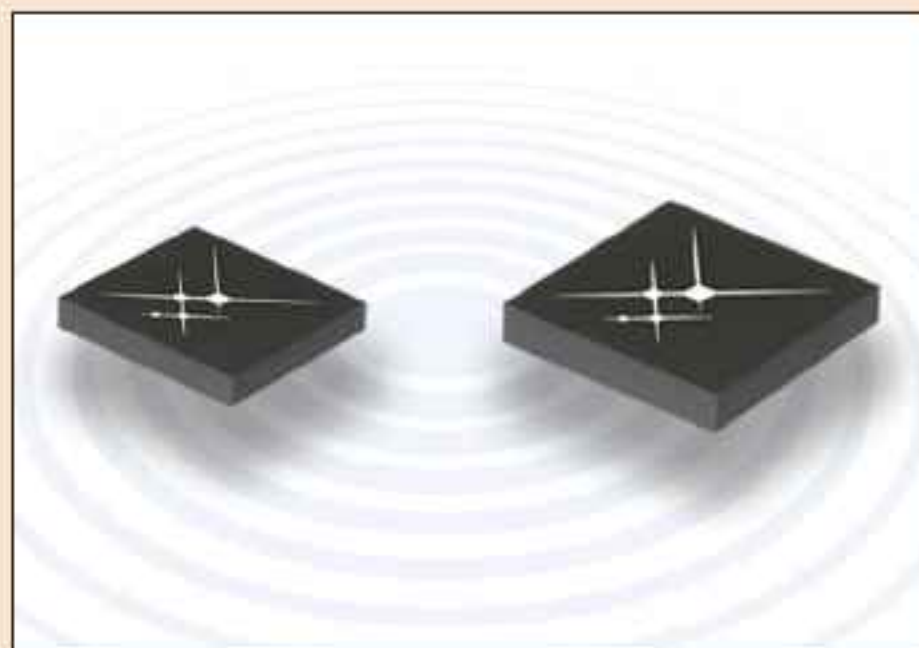
Skyworks’ senior VP of sales & marketing. “Given the strength of our product pipeline, Skyworks is benefitting from the trend towards highly integrated, multi-band FEMs for 3G, EDGE, LTE (long-term evolution) and WLAN (wireless local-area network) applications,” Griffin adds.

“New product ramps of our content-rich Intera portfolio, coupled with our diversification initiatives, are positioning Skyworks to outpace our addressable markets this quarter and moving forward,” he reckons.

RF subsystem for femtocell base-stations and cellular repeaters

Skyworks has launched what it claims is the industry’s first highly integrated RF subsystem for GSM, GPRS and EDGE femtocell base-stations and cellular repeaters. The new RF subsystem supports femtocell base-station and cellular repeaters in the GSM850, EGSM900, DCS1800 and PCS1900 bands.

“Skyworks’ new and innovative RF subsystem solves a variety of real-world issues that manufacturers face daily,” said Stan Swearingen, VP and general manager of Linear Products. “Ultimately, we’re



enabling them to reap considerable benefits by reducing space, expense, and time-to-market.”

According to the firm, the dual-chip RF subsystem provides excellent

linearity, blocker performance, dynamic range, and output power required by cellular operators, carriers and equipment manufacturers deploying femtocell base stations and cellular repeaters.

Skyworks adds that the market research firm In-Stat reckons that worldwide femtocell subscriptions (installed devices) will grow to 40 million by 2011 and represent a market opportunity of over \$4bn.

The RF subsystem is priced at \$15 each in quantities of 10,000.

www.skyworksin.com

Ember partner with Skyworks on first ZigBee FEMs

Skyworks Solutions Inc of Woburn, MA, USA has partnered with Ember Corp of Boston, MA to develop the industry's first portfolio of ZigBee front-end modules (FEM). Target applications include smart meters in energy management, home area networks (HAN), and industrial automation.

Ember and Skyworks showcased their ZigBee solution at the Autovation 2008 event at the Georgia World Congress Center in Atlanta (7-10 September).

"Skyworks' partnership with Ember accelerates our efforts in the energy management industry by more than doubling our addressable market for front-end modules," said Stan Swearingen, Skyworks' VP and general manager of Linear Products. "By integrating our front-end modules with Ember's ZigBee silicon, we are offering our customers a high-performance plug-and-play solution."

"Ember and Skyworks are teaming together to create the industry's first ZigBee FEM that dramatically reduces component size, cost and power consumption," says Bob Gohn, Ember's VP of marketing.

According to Skyworks, analyst firm West Technology Research Solutions (WTRS) forecasts that the ZigBee/IEEE 802.15.4 market will grow at an annual rate of over 117%, from about 8.4m units shipped in 2007 to about 516m in 2012.

Ember develops ZigBee wireless networking technology. Its low-power wireless technology can be embedded into a variety of devices to be part of a self-organizing mesh network. The firm is a board member of the ZigBee Alliance and its platform is the Golden Suite for 802.15.4/ZigBee interoperability testing.

Ember says that its EM250 system-on-chip (SoC) along with the EmberZNet PRO networking stack is the industry's only true SoC platform supporting the ZigBee PRO Feature Set. The EM250 integrates an IEEE 802.15.4 radio, a 16-bit microprocessor, flash, random access memory and peripherals.

The EM260 is the industry's first ZigBee network co-processor that combines a 2.4GHz IEEE 802.15.4 compliant radio transceiver with a flash-based microprocessor running the EmberZNet PRO ZigBee stack.

Skyworks' SKY65336 is an 8mm x 8mm multi-chip module FEM for ZigBee and other 2.4GHz industrial, scientific and medical (ISM) band applications. It consists of a selectable transmit and receive path. The Tx path includes a harmonic filter and high-efficiency PA that delivers 20dBm at the module's

output port. The Rx path includes a low-noise amplifier, which boasts a total Rx path noise figure of 1.9dB, including switch loss. Both Tx and Rx paths integrate baluns to provide differential ports to Ember's EM250 and EM260 transceivers.

The SKY65337 is a FEM that is footprint compatible with the SKY65336, with the LNA removed for applications that require lower cost. The Tx path delivers 20dBm of high-efficiency output power, while balanced input and output ports have been provided to connect to the EM250 and EM260.

www.ember.com

IN BRIEF

Microsemi's WLAN RF power amplifier shipments surpass 75 million units

Microsemi Corp of Irvine, CA, USA, which designs and manufactures analog and mixed-signal ICs and high-reliability semiconductors, says that cumulative shipments of its wireless local-area network (WLAN) RF power amplifiers (RFPAs) have now exceeded 75 million units.

The company claims that its portfolio of WLAN RFPAs enables the design of high-performance solutions that provide extended range and superior reception for various WLAN standards such as 802.11a/b/g and 802.11n. The range of products also addresses the rapidly growing WiMAX market.

"Microsemi's continued investment in its RF power amplifier business has yielded excellent dividends," says Steven Litchfield, executive VP & president of the firm's Analog Mixed Signal group.

"Customers recognize that Microsemi's products provide superior performance and best-in-class power efficiency," he claims.

"With these attributes, our customers are able to design systems that have extended range and reduced power consumption. Microsemi's wireless LAN (WLAN) RF power amplifiers have found widespread acceptance in a wide variety of end applications, ranging from mobile phone handsets to wireless LAN access points and WiMAX systems."

Microsemi says that its WLAN RFPAs are available in packages and formats ranging from surface-mount devices to sub-systems in a package (SSIP) and front-end modules (FEMs).

www.microsemi.com

IN BRIEF

Mimix launches DC-2.8GHz 5V 0.5W medium-power amp in SOT-89 package

Mimix Broadband Inc of Houston, TX, USA has launched a 5V InGaP HBT amplifier that combines medium power and high gain with low power consumption.

The versatile CGB8001-SC multi-purpose amplifier consumes 100mA of current and covers DC to 2.8GHz frequency bands with 27dBm P1dB and 15.5dB gain at 2.1GHz.

Designed for 5V applications, the medium-power amplifier is suitable for high linearity transmit, receive and IF applications, including CATV, 3G, WiBro and WiMAX. The low current consumption and high linear performance under complex modulation makes it a suitable output stage for multi-carrier applications.

The device is offered in an industry-standard, RoHS-compliant, SOT-89 package and includes an integrated active bias circuit and ESD protection, significantly enhancing quality, reliability and ruggedness.

"The integrated ESD protection, low thermal resistance and low power consumption increase the MTTF of the CGB8001-SC, making it a robust gain block solution" says product manager Amer Droubi. "Furthermore, the integrated active bias circuit minimizes performance variation over temperature and enables direct operation from a +5V supply, eliminating the need for an external dropping resistor," Droubi adds.

www.mimixbroadband.com



RFMD opens customer support center in Bangalore to capitalize on growing market in India

Underscoring its commitment to what it describes as one of the world's fastest-growing markets for RF semiconductor components, RF Micro Devices Inc of Greensboro, NC, USA has opened a customer support center in Bangalore, India, housing applications engineering, customer service, sales management and technical sales.

RFMD says that the center expands its ability to support regional manufacturers in Greater India, who are increasingly developing leading-edge products for wireless and other applications. The available client base in India spans multiple growth markets, including aerospace and defense, broadband, cellular, WiFi, WiMAX, and wireless infrastructure.

The center demonstrates RFMD's commitment to providing local support to regional customers in high-value growth markets, says Greg Thompson, VP of sales for the firm's Multi-Market Products Group. The center will provide product designers

in India with real-time access to technical support, and assistance to a wide range of customers as they drive greater levels of functional integration in RF applications across multiple growth segments, he adds.

The Indian Semiconductor Association (ISA) reckons that the semiconductor market in India will grow

ISA reckons the semiconductor market in India will grow from \$2.7bn in 2007 to \$5.5bn in 2009

from \$2.7bn in 2007 to \$5.5bn in 2009, and increase by 29.9% annually to \$36bn by 2015, due mainly to growth in the

design, development and consumption of electronic devices.

Since opening its first office in Taiwan in 2000, RFMD now employs nearly 100 sales, applications engineering and customer service staff working in seven customer support centers throughout Asia.

RFMD power amplifiers to support more than 10 new Samsung 3G handsets

RFMD says its power amplifier (PA) products will support more than 10 upcoming Samsung 3G handsets (including the SGH-L700, the SGH-L770 and the SGH-G400), with volume shipments starting in the December quarter. RFMD will supply wideband CDMA/high-speed packet access (WCDMA/HSPA) PAs and EDGE PAs.

According to market research firm Gartner Inc's report 'Dataquest Insight: Market Share for Mobile Devices, 2Q08', Samsung's mobile phone sales reached 45.7 million units (15.2% market share) in Q2/2008.

RFMD says that the new phones represent a significant expansion

of its 3G shipments to Samsung. The firm began volume shipments into earlier Samsung 3G handset models in the June quarter with the launch of the SGH-U900 Ultra Edition III SOUL handset.

"We enjoy very strong business with Samsung in EDGE handsets, and we look forward to expanding our relationship with Samsung as we supply our innovative 3G front ends into their feature-rich, next-generation handsets," says Eric Creviston, president of RFMD's Cellular Products Group. "We are particularly enthusiastic about ongoing design activity in support of Samsung's future handset platform development

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Anadigics' DOCSIS 3.0 amp featured in Sigma Designs' reference design for IP-Cable set-top box

Anadigics Inc of Warren, NJ, USA says that its ARA2017 programmable gain amplifier, which it claims is the first of its kind to be optimized for DOCSIS 3.0. cable modem applications integral to the performance of DOCSIS 3.0 terminal products, is featured in the new multi-channel, multi-standard, IP-Cable set-top box (STB) reference design of the fabless semiconductor provider Sigma Designs of Milpitas, CA, USA.

Developed for deployment in existing cable TV systems, Sigma's new Tru2way SMP8634-based reference design is a turnkey solution for a DOCSIS 3.0 STB with an integrated cable modem and voice-over-internet protocol (VoIP) capability. The firm says that it enables a virtually unlimited channel line-up for cable systems to display (or record) up to three channels simultaneously. Fast upstream and downstream DOCSIS data channels are also supported.

Providing the reverse path amplification, the ARA2017 supports high linearity and power levels, which facilitate channel bonding, enabling the STB to deliver a higher data rate of 120Mb/s in the cable system upstream (return) path. The downstream data rate is as high as 160Mb/s. The ARA2017 operates in



Anadigics' ARA2017 programmable gain amplifier.

the 5–85MHz frequency range and supports DOCSIS 3.0-specified signal levels of +64dBmV while minimizing harmonic distortion and output noise levels. At minimum attenuation, it has 33dB of RF gain, and an integrated, digitally controlled, multi-stage precision step attenuator provides up to 58dB of attenuation in 2dB increments. The device requires a single 5V supply and is offered in a 28-pin 5mm x 5mm x 1mm QFN package.

"Our new design leverages Anadigics' DOCSIS 3.0-based technology to provide manufacturers with an industry-leading, next-generation home entertainment product," says Sigma's VP of

strategic marketing Ken Lowe. "Anadigics' DOCSIS 3.0 programmable gain amplifier is an industry first and, as such, it adds a critical element to the overall performance and functionality of our STB design," he adds.

"The ARA2017 is integral to the performance of DOCSIS 3.0 hybrid set-top boxes and cable modem products," notes Ron Michels, senior VP & general manager of Anadigics' broadband business. "Infrastructure upgrades in the

Infrastructure upgrades in the cable industry are facilitating faster up- and downstream communications ... Fast up-stream and downstream DOCSIS data channels are also supported.

www.sigmadesigns.com
www.anadigics.com/products/cable_broadcast/reverse_amplifiers/ARA2017

cable industry are facilitating faster up- and downstream communications, and Sigma has leveraged the performance of our new amplifier to offer a first-class triple-play experience in one package."

Anadigics delivers 3G power amplifier for LG's touch-screen handset

GaAs-based wireless and broadband communications component maker Anadigics Inc of Warren, NJ, USA says that it is delivering HELP2 PAs to Korea's LG Electronics for its new 3G Vu mobile device, which is currently available through AT&T.

The LG Vu is one of the first touch-screen devices to support AT&T Mobile TV, allowing users to view live streaming TV shows on a 3" display. The ultra-slim design offers a 2.0 megapixel camera with zoom, music player, messag-

ing, mobile e-mail and web browsing abilities. Anadigics claims that the 3G handset delivers significantly longer talk time by using the power-saving features of its HELP2 technology.

"Our HELP2 power amplifiers consume significantly less battery power, allowing users longer talk time on a feature-rich mobile device like the Vu," Dr Ali Khatibzadeh, Anadigics' senior VP and general manager of wireless business.

Anadigics says that the HELP2

family of power amplifiers delivers low quiescent current and significantly greater efficiencies at power levels where the phone operates most of the time and consumes up to 50% less battery power than conventional two-state power amplifiers over the full range of powers in modern wireless networks. HELP2 products include a built-in voltage regulator that eliminates the need for an external reference voltage and associated switches in the phone design.

www.anadigics.com

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TriQuint claims smallest, most integrated GPS RF front-end module

RF product maker and foundry services provider TriQuint Semiconductor of Hillsboro, OR, USA is sampling the TQM640002, its latest highly integrated RF module for global positioning satellite (GPS) navigation systems.

The new front-end module combines filter and low-noise amplifier (LNA) functions in what is claimed to be the smallest package available, enabling new wireless handset applications as well as mobile and automotive designs.

The device expands TriQuint's existing GPS portfolio, which includes surface acoustic wave (SAW) filters in use by most of the world's leading personal navigation device (PND) makers. TriQuint has shipped more than 130 million filters to global GPS manufacturers, including three of the top four PND vendors (as determined in estimates by Canalys in late 2007). According to GPS SAW filter shipment records, TriQuint supplied the world's leading PND makers with 66% of all SAW filters used worldwide last year, and has maintained its leadership position in 2008.

"The market for GPS is clearly moving toward integrated modules," says TriQuint's GPS product marketing manager Joshua Raha. "It's a similar pattern we've seen and continue to see in the mobile phone handset market," he adds. "TriQuint is already the world's largest GPS SAW filter manufacturer and a leading designer and manufacturer of highly integrated handset modules. It was a natural move for us to bring our integration expertise from handsets to the GPS space."

Raha claims that the new GPS module is unique in several ways, including a 3mm x 3mm form factor that suits adding location-based functions to size-conscious wireless handsets. He adds that the compact size also suits new generations of mobile GPS consumer devices,



TriQuint's TQM640002 module, which combines filter and LNA functions in small-form-factor package for handset, PND & automotive applications.

industrial and automotive applications.

The TQM640002 includes TriQuint's smallest two-in-one SAW filter and can operate with a supply voltage of either 1.8V or 2.8V. The firm claims that the filters provide better rejection than other market solutions (a key factor for manufacturers needing to filter out signal interference). Filtering is especially important for GPS products, because satellite-based location data signals are relatively weak compared to terrestrial RF sources. "Better rejection preserves the signal you want while filtering out the rest," says Raha. "This is particularly important in the hostile RF environment seen in handset applications, where noise or spurious signals interfere with functions like simultaneous voice and GPS usage," he adds. "The out-of-band cellular signals can compress the GPS LNA, rendering the entire GPS chain unusable." The rejection that the new module provides effectively protects that chain, enabling simultaneous GPS and voice communication on a cell phone.

"This new module also offers the advantage of zero matching," Raha continues. "This 'plug-and-play' approach simplifies both design and manufacturing of our customers' GPS-enabled devices," he reckons. "The fact that there are no

matching components results in additional space on the board," (a key advantage in handset applications, where every square millimeter saved enables another function or a smaller form factor).

TriQuint says that it engineered the new module in consultation with several major GPS and personal navigation pioneers, including SiRF Technology Inc of San Jose, CA, USA, which creates solutions that use the GPS system to bring location awareness to consumer products.

"The location-based services market has great potential, with GPS now appearing in a wide range of exciting new consumer and industrial products," says Tim McCarthy, director of SiRF's Wireless Marketing Group. "The new TriQuint module will make it easier to add GPS to these new products."

Consumer demand for products based on global navigation satellite system (GNSS) technology is accelerating. According to Chris Taylor, director of RF and Wireless Components for market research firm Strategy Analytics, shipments of GPS products will continue to grow worldwide, with the newest devices on the market benefitting from integrated modules.

Strategy Analytics estimates that more than 200 million GPS-capable electronic devices will ship this year, and that shipments will continue to increase at a compound average annual growth rate (CAAGR) of 27% through 2012 as the use of GPS expands in cell phones, PDAs, mobile computing devices and vehicles. The GPS radios in most of these systems benefit from higher sensitivity and faster time to 'first fix' (the time that a GPS receiver needs to acquire navigation data and calculate a solution) when used with an external LNA such as the TQM640002, says Taylor.

www.triquint.com

www.sirf.com

Infineon claims smallest GPS receive front-end module

Germany's Infineon Technologies has launched the BGM681L11, which it claims is the world's smallest GPS receive front-end module.

"GPS functionality will be a standard feature for the next generations of mobile phones," says Michael Mauer, senior marketing director Silicon Discretes. According to IMS Research, the GPS market is growing at a compound average growth rate (CAGR) of 33.7% until 2011, when GPS will feature in at least one third of all mobile phones produced.

The main challenges for mobile GPS are to achieve higher sensitivity and higher immunity against interference of cellular signals, so low-noise amplifiers (LNAs) and filters are becoming indispensable components for the GPS receive front-end line-up. As more features are added to new generations of high-end mobile phones, PCB space is becoming the main limiting factor, so small front-end modules are highly desirable.



Leadless 2.5mm x 2.5mm x 0.6mm package of the BGM681L11 module.

The BGM681L11 incorporates all key components to amplify a GPS signal and filter out interference, including Infineon's GPS LNA chip and two integrated filters with high ESD ruggedness (input and output) in a leadless TSLP11-1 package measuring 2.5mm x 2.5mm x 0.6mm (3.75mm³, over 60% smaller than the closest competitor with a similar level of integration, the firm says). The operating voltage is 2.4–3.6V.

The GPS LNA chip is also available as the stand-alone BGA615L7,

which is based on Infineon's B7HF silicon germanium (SiGe) process technology and operates at 2.4–3.2V. More than 70m units of the BGA615L7 LNA have already been shipped to the GPS market.

With the BGM681L11, Infineon complements its broad range of high-performance GPS LNAs by providing fully integrated GPS receive front-end components, helping handset makers to fulfil the toughest space requirement, says Mauer. Infineon is providing evaluation kits for the BGM681L11. Pricing starts at a 10,000-piece price of \$1.20.

Infineon also says that, by making use of its carbon-doped SiGe:C LNAs capable of 1.8V operation (launched in July) as well as its CMOS RF switches, it is expanding its product portfolio of GPS modules further. "Infineon is committed to continue developing a strong portfolio of completely integrated GPS receive front-end modules," says Mauer.

www.infineon.com/BGM681L11

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TriQuint wins \$4.5m US Navy contract to extend GaAs pHEMT capabilities to frequencies above 20GHz

The US Office of Naval Research (ONR) in Arlington, VA has awarded TriQuint Semiconductor Inc of Hillsboro, OR a 21-month, \$4.5m contract (no. N00014-08-C-0636) to advance manufacturing methods used to produce high-power, high-frequency gallium arsenide amplifiers. TriQuint is the sole contractor and is performing the work at its facility in Richardson, TX.

TriQuint was chosen on the basis of its experience developing high-performance, high-reliability amplifiers for a wide range of defense and aerospace applications, according to Dr David Fanning, TriQuint Contract program manager. "Winning this contract demonstrates the government's confidence in TriQuint's ability to develop the critical technologies needed for Department of Defense applications," he says. "High-voltage GaAs is a tested and proven technology that exhibits high reliability using existing processes and materials, ideally suited for military and commercial production programs."

TriQuint's high-voltage pseudomorphic high-electron-mobility transistor (pHEMT) GaAs technology will be the focus of the new ONR research and production development program, since it provides higher power density (more power per square millimeter of surface area) and efficiency compared to other processes, claims Fanning. Such performance characteristics are required for critical Navy applications, including phased array radar, electronic warfare and communications systems. TriQuint has been developing high-voltage GaAs pHEMT technology since 2000; advanced X-band and S-band versions of the process were developed under previous ONR contracts.

The new GaAs technology will provide a new capability intermediate between today's GaAs and the emerging GaN technology

Fanning says the new program's objectives are to extend the use of the high-voltage GaAs pHEMT technology to higher frequencies. In a first phase, TriQuint will develop new high-frequency, high-power device technology and extract circuit design models. In the second phase, the firm will design and fabricate high-power monolithic microwave integrated circuits (MMICs).

"TriQuint currently supplies high-volume, cost-effective foundry services and standard products based on both low- and high-voltage GaAs," says Dr Gailon Brehm, director of Defense & Aerospace Product Marketing. "This enhanced high-frequency technology will extend the capability of our GaAs process family to the higher voltage needed for both military and commercial applications at frequencies above 20GHz," he adds. "As such, it will provide a new capability intermediate between today's GaAs and the emerging GaN technology."

www.onr.navy.mil

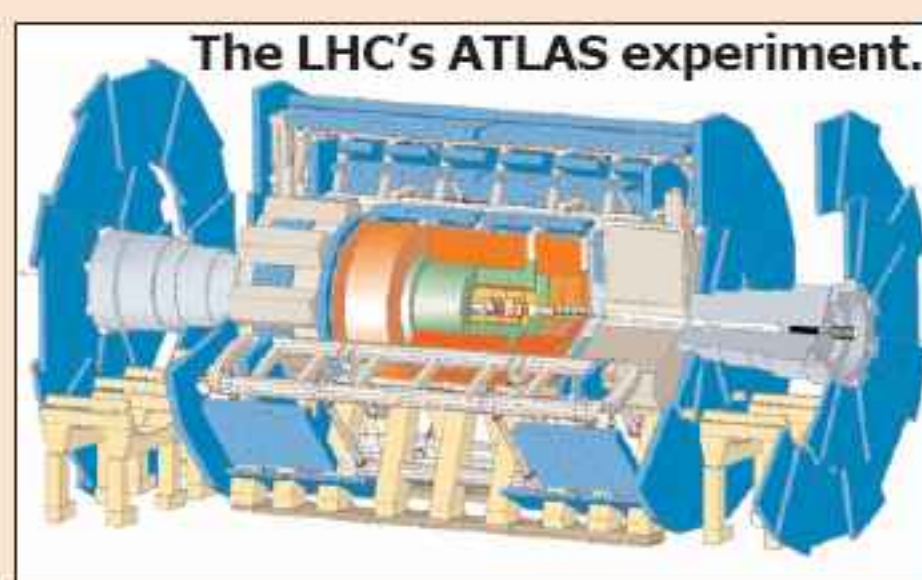
www.triquint.com/rf

GaAs foundry process used for ICs in Large Hadron Collider

RF front-end product maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA says that its technology has been implemented in the design of ICs being used in the Large Hadron Collider (LHC) at the European Center for Nuclear Research (CERN).

The LHC is a 27km-long particle accelerator that has been in development for 20 years and includes input from 7000 scientists from 60 countries. Besides pursuing basic physics goals, experiments may help scientists to treat diseases and improve the Internet.

TriQuint's gallium arsenide foundry process was used by the fabless semiconductor firm IPtronics A/S of Roskilde, Denmark,



which was established at the end of 2003 by former managers and technical staff from GIGA A/S (sold in 2000 to Intel Corp for \$1.25bn). The firm offers ICs for parallel optical interconnects, including transimpedance amplifiers (TIAs) and drivers for vertical-cavity surface-emitting lasers (VCSELs) that enable low-power, high-density, high-bandwidth and low-cost modules for the computer, storage

and communications industries.

In the LHC, thousands of IPtronics' PA8-E GaAs ICs are used as front-end electronics for resistive plate chambers (RPC), a gaseous detector capable of sub-nanosecond time resolution on very large areas. The GaAs-based ICs were shipped to the Italian National Institute for Nuclear Physics and are being used as muon trigger detectors in ATLAS, one of the four experiments being carried out at the LHC.

"It is fascinating to see what can be achieved when great processes and design houses come together," comments Jesper Bek, IPtronics' VP of sales & marketing.

www.iptronics.com

<http://public.web.cern.ch/public/en/LHC/ATLAS-en.html>

Tower completes Jazz acquisition

After approval by Jazz's shareholders at a meeting on 17 September, pure-play specialty silicon wafer foundry Tower Semiconductor Ltd of Migdal Haemek, Israel completed its acquisition of Jazz Technologies of Newport Beach, CA, USA, the parent company of Jazz Semiconductor Inc (a wafer foundry focused on analog-intensive mixed-signal process technologies).

Each outstanding share of Jazz common stock was converted into 1.8 of Tower's ordinary shares, each outstanding warrant and outstanding option to acquire Jazz common stock became exercisable for 1.8 Tower ordinary shares, and Jazz's convertible notes became convertible into Tower ordinary shares based on the same exchange ratio. When the deal was announced in May it was valued at \$40m. Including net debt, the total value is about \$169m.

Both Jazz Technologies and its subsidiary Jazz Semiconductor Inc have become subsidiaries of Tower, with Jazz Semiconductor being known as Jazz Semiconductor Inc, a Tower Group Company.

Jazz's chairman & CEO Dr Gilbert F. Amelio has retired as an officer and director, although he continues as a special advisor to Tower's board. Amelio co-founded Jazz (formerly Acquicor Technology) in 2005, and led the firm through an IPO in 2006 and its merger with Jazz Semiconductor Inc in 2007. "He was a driving force in helping Jazz evolve into a public company and played a critical role in the merger with Tower," says Tower's CEO Russell Ellwanger, who is now Jazz's chairman, responsible for developing final details of the merged organizational structure and the integration plan over the next several months. "I am pleased to have helped Acquicor evolve from a blank-check company to a leader in AIMS foundry solutions, and with the merger with Tower, into a truly international company," says Amelio. "The future for Tower and Jazz is bright."

Tower was founded in 1993 and has two fabrication plants: Fab 1 has 1.0–0.35 μ m process technology (with a capacity of 15,000 6-inch wafer starts per month) and Fab 2 has 0.18–0.13 μ m process technology (with a capacity of 30,000 8-inch wafer starts per month). In addition to digital CMOS process technology, Tower offers mixed-signal and RF CMOS, power management, CMOS image-sensor and non-volatile memory (NVM) technologies. The firm also provides complementary technical services and design support.

Spun off from Conexant Systems Inc in 2002, Jazz is an independent 8-inch wafer foundry focused on analog-intensive mixed-signal (AIMS) process technologies. Its process portfolio includes specialty technologies such as power management (CMOS and BCD) and RF (RF CMOS, SiGe BiCMOS, SiGe C-BiCMOS), and high-voltage CMOS. Jazz also offers design enablement tools to allow complex designs to be achieved quickly and more accurately. It also has agreements for its process technologies to be used by China's Advanced Semiconductor Manufacturing Corp and Shanghai Hua Hong NEC Electronics Co Ltd.

Tower and Jazz together provide one of the broadest portfolios of specialty process technologies. Also, with about 1400 Tower staff and 700 Jazz staff, the combined firm has one fab in the USA, two in Israel, and a stake in a fab in China, giving a capacity of 750,000 8"-equivalent wafer starts annually (the largest specialty foundry and seventh largest pure-play foundry). The merger enhances both firms' geographic reach and distribution capabilities, creating a significant opportunity for revenue enhancement and increased efficiencies in manufacturing, it is reckoned.

The combined firm becomes the world's seventh largest pure-play foundry

"Technology leadership and scale are critical in meeting the unique requirements of our customers," says Ellwanger. "With the merger now complete, we will continue to focus on customer needs for increased capacity, expanded process offerings, and industry-leading design enablement services."

"We expect the merger of the two companies to provide expanded opportunities for growth based on the significant cross-selling opportunities and the broader, more complete product, technology, and service portfolio we are now able to offer," adds Ellwanger. Jazz's process technologies and customer base are complementary to Tower with minimal overlap, which should address a diverse customer base in high-growth markets. Jazz's major customers include Conexant, Entropic, Marvell Technology, Mindspeed Technologies, RF Micro Devices, Skyworks Solutions, and Texas Instruments. Tower's include Atheros Communications, International Rectifier, Macronix International, On Semiconductors, SanDisk, Siliconix-Vishay and Zoran.

These opportunities enhance the expected cost-structure benefits which, combined with Tower's anticipated restructuring of debt, is expected to significantly improve financial results, EBITDA and cash flow margins, as well as the balance sheet of the combined firm.

Trailing twelve month (TTM) revenues should be about \$440m and pro forma TTM EBITDA \$120m (including the effects of an expected \$40m in annual cost-saving synergies). Following the closing of a restructuring transaction with lenders agreed in August, Tower's balance sheet will reflect a \$250m reduction in debt and a corresponding \$250m rise in shareholders' equity. The restructuring should also result in improved financial performance and cash flow margins due to lower interest expense.

www.towersemi.com

IN BRIEF

Mimix appoints vice president of Special Projects

Mimix Broadband Inc of Houston, TX, USA, which supplies GaAs semiconductors from DC to 50GHz for microwave and millimeter-wave applications, has appointed Guy Krevet as its vice president of Special Projects, focusing on establishing strategic practices to maintain operational excellence across manufacturing, engineering and quality functions as the company continues to grow.

Krevet has more than 35 years experience at leading RF manufacturing firms, most recently with RF Micro Devices Inc of Greensboro, NC, USA and Sirenza Microdevices Inc of Broomfield, CO, USA. By providing expertise in new product line development, off-shore manufacturing, operational integration, acquisition outsourcing and product line optimization, Krevet has enabled growth-oriented organizations to achieve operational excellence, Mimix says. Prior to joining Mimix, Krevet also worked at Xicom, Avnet and Avantek.

"Guy has extensive experience in working with cross-functional teams to optimize operational practices by devising and implementing strategic activities," says CEO Rick Montgomery. "We believe his past successes within growing organizations in the RF industry will directly apply to our initiatives," he adds.

"Mimix has established a solid manufacturing and quality organization, and I look forward to working with the Mimix team to build on their achievements to date and deliver best practices created specifically for a growth environment," Krevet says.

www.mimixbroadband.com

Cobham forms M/A-COM Technology Solutions

Following its \$425m purchase of M/A-COM Inc's RF Components and Subsystems business in Lowell, MA, USA from Tyco Electronics (announced in May and concluded on 26 September), UK defense firm Cobham plc has formed M/A-COM Technology Solutions Inc from the Commercial part of the business. The Aerospace & Defense part has been absorbed into the Cobham Defense Systems (CDS) division.

M/A-COM Tech will continue to focus on commercial, industrial and government markets, specializing in RF, microwave and millimeter-wave component technology for applications including wireless infrastructure, handsets, WLAN, WiMAX, CATV, VSAT, automotive, test & measurement, radar and government solutions.

Cobham says that M/A-COM Tech will build on its 60 years of experience as a supplier of RF, microwave and millimeter-wave components to develop and manufacture both active and passive products, including silicon- and GaAs-based devices from facilities in Lowell, MA and Torrance, CA. Infrastructure products will continue to be provided by the plant in Cork, Ireland and laser diode products by the plant in Edison, NJ.

M/A-COM Tech says that it provides designs and products including:

- silicon, GaAs, AlGaAs, InGaAs, InP and SiGe devices;
- unique monolithic microwave integrated circuit (MMIC) processes, including HMIC (heterolithic microwave integrated circuit), GMIC (glass microwave integrated circuit), MSAG (multi-function self-aligned gate GaAs MESFET), and iHBT (InGaP/GaAs heterojunction bipolar transistor);
- in-house design, fabrication, assembly and screening capabilities;
- multiple facilities (for improved flexibility and local content manufacturing); and
- design expertise from RF through millimeter-wave frequencies.

"This is an exciting new chapter for M/A-COM Technology Solutions and we are committed to upholding the high standards of quality and innovation that our clients have come to expect from us," says M/A-COM Technology Solutions' president Joe Thomas. "We plan to introduce new automotive and RFID products in the coming months," he adds.

www.macom.com

www.cobham.com



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IQE joins DARPA-sponsored CERA program to develop graphene-channel FETs for RF microelectronics

Epiwafer and substrate foundry IQE plc of Cardiff, Wales, UK says that its Pennsylvania-based operation is taking part in the program Carbon Electronics for RF Applications (CERA), which began in July, led by HRL Laboratories LLC of Malibu, CA, USA and involving commercial, university and military research establishments.

Sponsored by the US Defense Advanced Research Projects Agency (DARPA), the work will investigate the unique qualities of graphene carbon-based RF technology to create components that could enable unprecedented capabilities in high-bandwidth communications, imaging, and radar systems.

Often referred to as a 'semi-metal' or 'zero-gap semiconductor',

graphene comprises a one-atom-thick layer of carbon atoms that are densely packed in a honeycomb crystal lattice. The program team proposes to use advanced epitaxial processes to grow an organized layer of bandgap-engineered graphene carbon crystals on silicon-based wafers.

The CERA team is tasked with developing wafer-scale graphene synthesis approaches focused on enabling ultra-high-speed, low-power graphene-channel field-effect transistors (FETs). The aim is to demonstrate high-performance W-band (>90GHz) low-noise amplifiers ($\leq 1\text{dB}$), making use of graphene transistors on wafers with diameters greater than or equal to

8-inches and cross-wafer yields in excess of 90% (creating more efficient, scalable, and cheaper-to-manufacture transistors).

"Graphene is an exciting new material for future generation, ultra-high speed, ultra-low power consumption RF components for specialist applications," says Steve Gergar, VP & general manager of IQE Bethlehem, PA. "The use of highly advanced materials such as graphene is essential in developing components for the next generation of sophisticated military imaging systems and high-bandwidth communications systems," he adds.

The CERA program is expected to be completed by September 2012. www.darpa.mil/MTO/programs/cera

Device-quality GST precursors for phase-change memory

SAFC Hitech of St Louis, MO, USA (a unit of SAFC within Sigma-Aldrich Group) has made progress with both the precursors and MOCVD techniques in developing device-quality germanium antimony telluride (GeSbTe, or GST) for high-volume manufacturing of phase-change memory (PCM).

PCM (a non-volatile computer memory) takes advantage of the unique properties of chalcogenide compounds to enable scaling of ultimate feature sizes further than possible with conventional Flash memories, boosting storage capacity and performance. Chalcogenide compounds such as GST are attractive for PCM, and have already been used as the basis for optical storage media and prototype PCM devices.

"Until now, PCM materials have generally been deposited by sputtering or other PVD techniques, which are line-of-sight methods and have inherent weaknesses relating to uniformity of deposition," says SAFC Hitech's chief technology officer Ravi Kanjolia. Vapor phase deposition techniques such as

MOCVD offer several advantages for GST precursors, e.g. better step coverage in deposition on patterned substrates, industrial scaling, and high compositional control. "We have achieved advances in precursor chemistries that allow similar layers to be deposited using conventional MOCVD, without the need for an activation process," adds Kanjolia.

Since 2005, SAFC Hitech has participated in the European Commission-supported CHEMAPH project, a consortium set up to look at GST film deposition methods. The firm's Bromborough plant in the UK has investigated a variety of GST sources for MOCVD, and matched the physical properties of each metal precursor to enhance efficiencies at the desired growth parameters.

"Variations in cracking efficiencies were one major hurdle that we had to overcome," says Kanjolia. "A combination of sources was found with a much improved match of thermal stability to allow decomposition to the same degree when simultaneously introduced to the deposition reactor chamber."

The preferred chemicals are $\text{Ge}(\text{NMe}_2)_4$, $\text{Sb}(\text{NMe}_2)_3$ and iPr_2Te . Synthesis protocols were then developed to allow the isolation of high-purity product in both small and large lab-scale equipment. The materials are now commercially available. Samples have been shipped, and collaboration partners have tested different combinations. Growth trials have yielded device-quality GST using nitrogen carrier gas.

"While a full process to make MOCVD devices remains to be demonstrated on anything other than very small research structures, the quality of the films on flat substrates is improving," says Kanjolia.

The next challenge is to find the correct parameters to control the growth and lay down the correct layers in the correct structure, he adds. "The temperature window with this process remains critical, and highlights both the difficulties associated with this system and the need for advanced precursors to move forward with integration into future phase-change memory."

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IN BRIEF

Raytheon wins DoD 'Trusted Foundry' accreditation

The US Department of Defense (DoD) has accredited Raytheon Company's semiconductor foundry — Raytheon Radio Frequency Components (RRFC) at the firm's Integrated Air Defense Center in Andover, MA, USA — as a DoD Category 1A Trusted Foundry.

The Category 1A designation, the highest awarded by the DoD, recognizes Raytheon's support of Mission Assurance Category I (MAC I) systems, determined to be vital to the operational readiness or mission effectiveness of deployed and contingency forces. MAC I systems require the most stringent protection measures.

"This accreditation reflects our capability to provide the most rigorous protection measures required by the Department of Defense for gallium arsenide and gallium nitride foundries," says Mike Delcheccolo, vice president of engineering for Raytheon Integrated Defense Systems.

The RRFC foundry provides compound semiconductor technology development, products and services for military and homeland security applications. Capabilities include design, development and manufacturing of GaAs and GaN monolithic microwave integrated circuits (MMICs) and modules for advanced radar, electronic warfare, communications and weapon systems.

Integrated Defense Systems is Raytheon's leader in global capabilities integration, providing affordable, integrated solutions to an international and domestic customer base that includes the US Missile Defense Agency, the US Armed Forces, and the Department of Homeland Security.

www.raytheon.com

Nitronex extends 5W GaN-on-Si RF power transistor to 5.1–5.8GHz

To coincide with the WiMAX World event in Chicago in late September, Nitronex of Durham, NC, USA, which manufactures GaN-on-silicon RF power transistors for the commercial wireless infrastructure, broadband and military markets, says that it has expanded the performance data of its 28V, 5W-class NPTB00004 high-electron-mobility transistor (HEMT), which was launched in November 2007, to include higher frequencies of 5.1–5.2GHz and 5.7–5.8GHz (beyond the 3.5GHz originally detailed).

The NPTB00004 achieves 27dBm (400mW) average output power at 2% error vector magnitude (EVM) in 5.2GHz WiMAX systems, and 28dBm (630mW) average output power at 2% EVM in 5.8GHz WiMAX systems (single-carrier orthogonal frequency-division multiplexing (OFDM), 64-QAM 3/4, 8-burst, 20ms frame, 15ms frame data, 3.5MHz channel bandwidth, peak/average = 10.3dB).

"This data on the NPTB00004 provides our customers with an ideal solution for WiMAX applications in



The NPTB00004 GaN-on-Si HEMT.

the 5GHz band of operation," claims Ray Crampton, director of marketing. The NPTB00004 is a versatile product that, combined with other broadband devices from Nitronex, allows designers to develop power amplifiers for multiple frequency bands using a common power device lineup, he adds.

The transistors are packaged in a cost-effective plastic over-molded PO150S (similar to a SOIC-8) package with an exposed thermal pad. Samples and application boards are available. Typical pricing is \$9 each in quantities of 1000.

www.nitronex.com

Improved performance of Schottky diodes on pendeo-epitaxial GaN

Researchers from the US Army Research Laboratory in Adelphi, MD and the Materials Reliability Division of the National Institute of Standards and Technology (NIST) in Boulder, CO have investigated the role of dislocation density on the performance of Schottky diode devices of varying geometries that were fabricated both on low-defect-density gallium nitride regions grown selectively by pendeo-epitaxy and on conventional GaN material with high dislocation density (Zheleva et al, 'Improved performance of Schottky diodes on pendeo-epitaxial gallium nitride', Appl. Phys. Lett. (2008) 93, 091909).

The experiments conducted by the researchers found that Schottky diodes fabricated on pendeo-epitaxial material showed nearly two orders of magnitude lower leakage current than the Schottky diode devices fabricated on conventional material.

In addition, the pendeo-epitaxial Schottky diodes displayed an improved ideality factor, while in contrast the diodes built on conventional GaN material displayed nonideal characteristics.

www.arl.army.mil

www.nist.gov

<http://link.aip.org/link/?APPLAB/93/091909/1>



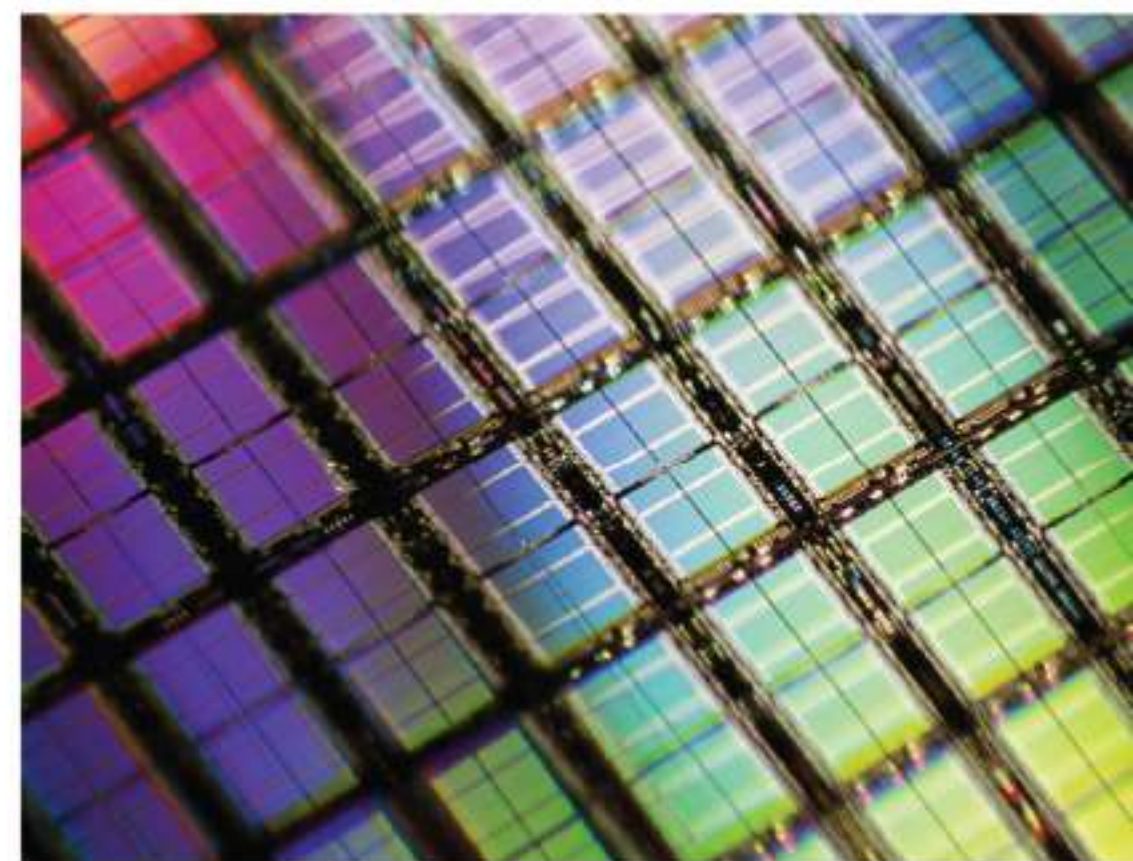
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SiC wafer maker Caracal re-starts after bankruptcy

In August, the assets of Caracal Inc, which manufactures silicon carbide substrates and epiwafers, were bought by a multinational consortium 'Caracal of North Carolina' with the intention of resuming the firm's operations at its base in the Heritage and Technology Industrial Park of Ford City, PA, USA.

Caracal filed for voluntary operational chapter 7 bankruptcy protection from creditors in April after its \$1.2m-a-year US Navy research contract was not renewed. However, the firm says that its entire estate has remained fully intact.

The purchasing consortium is described as having a strong and stable financial background, as well as a traditionally long-term perspective on its investments. "We have kept an eye on the wide-bandgap semiconductor market and see potential for strong growth year over year, particularly in the power device market," says a member of the consortium. "We are developing

a long-term plan for the new enterprise, with particular emphasis on cutting-edge R&D, cost-efficient manufacturing methods, and establishing efficient business functions."

Caracal was co-founded in 2003 by Olle Kordina from the SiC Materials Science center of Sweden's Linköping University and entrepreneur Rajiv Enand. The firm says that it will continue developing its proprietary and patented gas-based crystal growth process and chlorinated epitaxial process, which can grow high-quality epitaxial layers 10–20 times faster than using conventional chemistry (more than 100µm/hr, versus 5–10µm/hr), the firm claims. "We can today also grow very high-quality films on on-axis wafers which eliminate the problem of basal plane dislocations that harm bipolar devices," says Stefano Leone from Linköping University, who is the lead scientist responsible for developing the firm's epitaxial process.

At the European Conference on Silicon Carbide and Related Materials (ECSCRM 2008) in Barcelona, Spain in early September, Leone presented results on epitaxial growth on on-axis substrates (winning the prize for the best student poster on material growth).

Caracal will also continue to develop its grinding and slicing processes. The firm claims that its unique setup allows it to process very large-diameter crystals with high speed and precision. "We have provided slicing and grinding services for a number of customers," says a spokesperson for Caracal. "There is a need for these services, as so much focus must be spent on growing the crystals, leaving little resources for grinding and slicing," they add. "We have processed a number of different wide-bandgap materials other than SiC, including sapphire, gallium nitride, and aluminum nitride," it is pointed out.

www.caracalsemi.com

SemiSouth appoints VPs of sales and marketing

SemiSouth Laboratories Inc of Austin, TX, USA, which designs and makes silicon carbide (SiC) based discrete electronic power devices and epiwafers, has appointed Chris Thompson and Dan Schwob as VP of marketing and VP of sales, respectively. Both bring decades of global experience in the solar, wind, and power electronics markets that will help SemiSouth capitalize on its new products, the firm reckons.

Schwob joins SemiSouth with over 30 years experience in sales and marketing of power electronics and semiconductor devices. Prior to joining SemiSouth, Schwob was VP of marketing for power management IC firm iWatt Corp of Los Gatos, CA and VP of sales at power semicon-

ductor and module maker IXYS Corp of Milpitas, CA. "Dan is a veteran power semiconductor sales & marketing executive, having built sales organizations and market share at our target customers in solar, IT and telecom power markets while at IXYS," says CEO Kenney Roberts. "His global experience and industry relationships with customers and sales channels will be a big asset," he adds.

Thompson has over 15 years of experience in sales & marketing and product development in renewable energy, data centers, UPS (uninterruptible power supplies), and other high-growth markets. Prior to joining SemiSouth, Thompson was VP & general manager of

Solar Inverters for power system maker Advanced Energy Industries Inc of Fort Collins, CO. Previously, he was VP of engineering & product development at power supply maker Xantrex Technology Inc of Burnaby, BC, Canada and director of Datacenter Power Solutions at American Power Conversion of West Kingston, RI, USA.

"Not only does he bring a wealth of global experience developing and launching products for the solar, wind, and datacenter industries but, as a past customer of SiC devices, he understands the high value they can offer in many of our target markets," says SemiSouth's founder & chief technology officer Jeff Casady.

www.semisouth.com

Record-power SiC RF transistors for VHF and UHF radar

Microsemi Corp of Irvine, CA, USA, which makes analog/mixed-signal ICs and high-reliability semiconductors has launched its first two commercial silicon carbide products.

Targeted at high-power VHF- and UHF-band pulsed radar applications, the devices are the first in a series of SiC RF power transistors designed by Microsemi's Military & Aerospace Division in Santa Clara, CA using SiC chips produced in its wafer fab in Bend, OR. Both the Bend and Santa Clara operations are formerly Advanced Power Technology Inc (APT), a supplier of power semiconductors focusing on high-power, high-speed segments of the market for RF, microwave, linear, and switch-mode applications. Microsemi acquired APT in early 2006 for \$169m, along with SiC technology (including patents) licensed from US defense contractor Northrop Grumman's Electronics Systems division, allowing it to make proprietary SiC devices.

Mike Mallinger, Microsemi's director of business development for wide-bandgap products, says that the new SiC products use new chip design and processing enhancements to offer high power as well as small transistor and circuit size with a pulse width of 300 μ s and long-term duty factor of 10%. The 0150SC-1250M and 0405SC-1000M common-gate, n-channel, class AB static-induction transistors (SITs) offer what are claimed to be the industry's highest power outputs at VHF (150–160MHz) and UHF (406–450MHz) frequencies, respectively, of a minimum 1250W (typically 1400W) and 1000W (typically 1100W), with power gains of 9dB and 8dB and drain efficiencies of 60% at 155MHz and 50% at 450MHz at a bias of 125V. The firm says that the high operating voltage (versus 50V for silicon) drastically cuts power supply size and dc current demand. In addition, low conducting current minimizes system noise effect.



The 0150SC-1250M SiC transistor.

Also, Microsemi says that typical silicon-based RF power solutions, e.g. BJT (bipolar junction transistor) or LDMOS (laterally diffused metal oxide semiconductor) devices, must use complex push-pull circuit designs to achieve similar power. In contrast, the SiC RF power transistors have a single-ended design with simplified impedance matching.

In addition, the SiC devices are fabricated with all-gold metallization and gold wires in hermetically sealed packages (measuring a compact 0.9-inches x 0.4-inches, which is 50% smaller than the highest-power BJT or LDMOS) devices. This gives what is claimed to be the highest reliability for weather radar and long-range tracking radar (providing military-grade long-term reliability). The product capability at 10:1 load mismatch tolerance performance improves system yield, the firm adds.

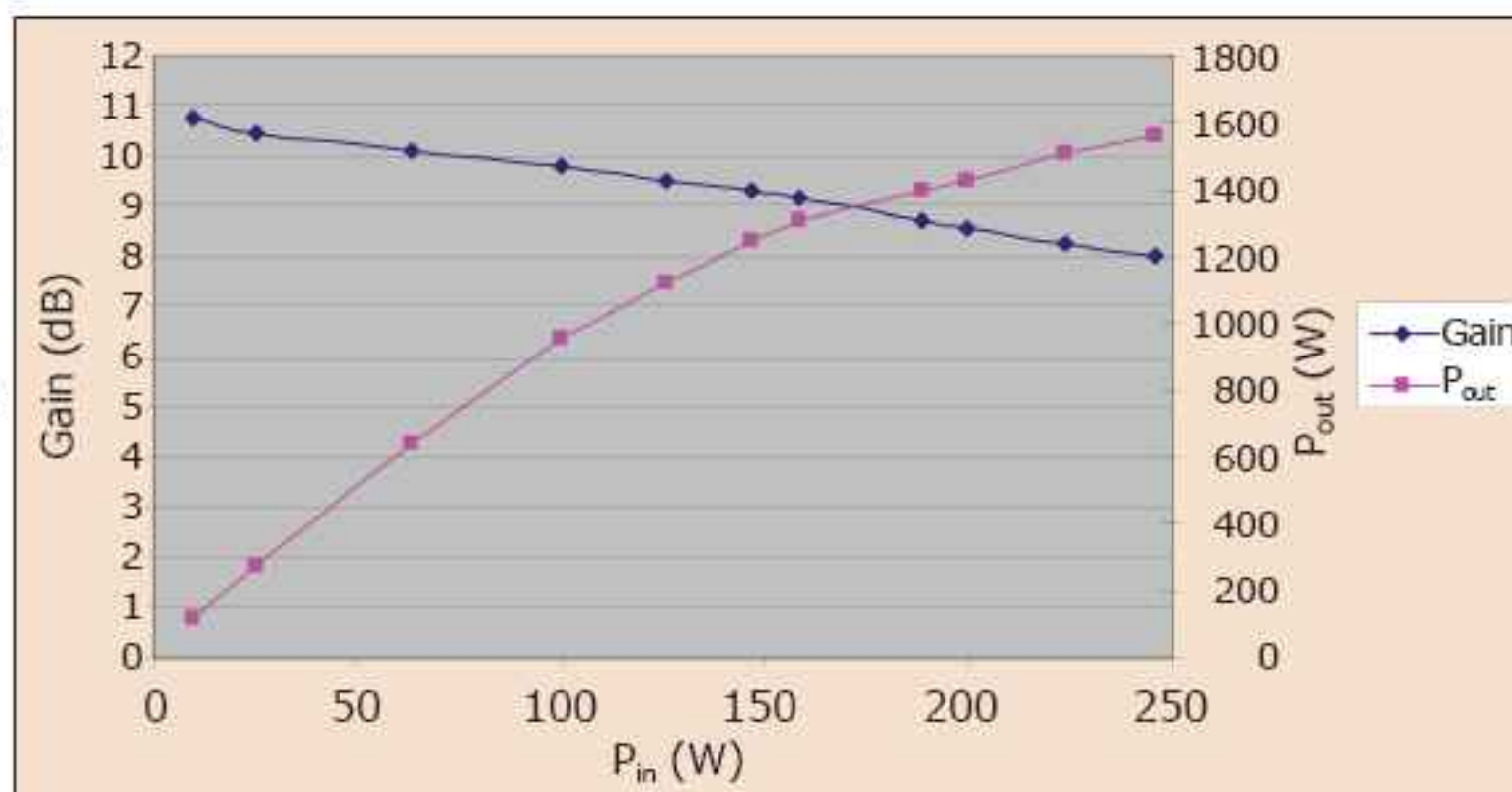
The new devices' performance demonstrates the advantages that SiC technology brings to avionics, radar, and electronic warfare applications, says Charlie Leader, VP of Military and Aerospace business

(in Santa Clara) of Microsemi PPG. Demonstration kits of the new SiC RF power transistors are available by e-mailing sic@microsemi.com. "They also underscore the leadership position Microsemi's Power Product Group has established in providing innovative and cost-effective solutions for the most demanding RF pulsed power applications."

Mallinger told Semiconductor Today that, by upgrading the package technology, Microsemi aims to extend the power output capabilities of its SiC technology (e.g. increasing the power output of its UHF products from 1kW to 2kW over the next 9–12 months).

As new system designs demand substantial performance increases beyond the capabilities of silicon, Microsemi will continue to develop and bring to market high-power SiC transistors for radar applications, from HF (where SiC can offer performance improvements to replace existing silicon technology, with 500W L-band products scheduled next year and 750W products for Q4/2009) through to S-band (with 150W MESFETs in development, for launch in early 2009, followed by 200W products later next year, and 300–400W devices after further packaging development).

Mallinger added that Microsemi is using 3-inch diameter SiC epiwafers made by Cree Inc of Durham, NC. However, it is working with a 'matrix' of four vendors, so other epiwafer suppliers will be coming on-stream as second sources. Also, Microsemi hopes to transition to 4-inch substrates in the next couple of quarters, but only when the cost drops sufficiently and the defect density is low enough. Mallinger comments that the firm has been working with the US Department of Defense on material evaluation, and that 4-inch substrate quality is "getting close".



Output and gain versus input power for 0150SC-1250M.

www.microsemi.com

Blunt receives SEMI Europe Standards Honor Award

At the SEMI Executive Summit during the SEMICON Europa show in Stuttgart, Germany, SEMI Europe of Brussels, Belgium presented Roy Blunt, Special Projects manager at epiwafer foundry and substrate maker IQE of Cardiff, Wales, UK, with the 2008 Standards Honor Award for establishing the SEMI European Standards Compound Technical Committee and for his contribution to the development of compound-related standards and guidelines.

In conjunction with Wolfgang Jantz, Blunt established the SEMI European Standards Compound Committee in 1998. Prior to that, he has been actively involved with the association since the early 1980s, when he



From left to right: Heinz Kundert, Roy Blunt, and SEMI's CEO Stan Myers.

worked on magnetic bubble memories and attended a SEMI GGG (gadolinium gallium garnet) committee meeting at one of the big magnetics conferences in the USA.

As co-chair of the SEMI European Standards Compound Committee, he led several task forces and contributed to the development of several other standards on both a European and international level.

Blunt was presented with the Honor Award for his long-standing dedication to the advancement of SEMI standards, says SEMI Europe's president Heinz Kundert. "SEMI would like to express its gratitude for his unselfish contributions, perseverance, commitment and enthusiasm toward the SEMI International Standards Program, and the overall success of our industry," he adds.

www.semi.org/europe

IMEC's CEO Declerck receives European SEMI Award

At SEMICON Europa's SEMI Executive Summit, professor Gilbert Declerck was presented with the European SEMI Award 2008 for leading IMEC, as its CEO, to become one of the world's most prestigious independent micro-electronics research institutes.

Declerck led process technology research at IMEC from its foundation in 1984, growing it into IMEC's most successful domain. SEMI says that, by building teams with the skills to match research with industry's needs, over the years he has kept IMEC at the forefront of required semiconductor process development.

Declerck was a driving force in the creation of a strong IMEC position in European cooperative projects during the early 1990s, enabling it to become a leading research center in Europe by the decade's end. This coincided with a transition from basic process research to full CMOS process integration R&D. European partnerships, at university and industrial level, also rose.

In the new millennium, Declerck realized that continuity of R&D could only be guaranteed by an ambitious innovation program in terms of



Gilbert Declerck.

plant capabilities (300mm), resources, and targets, requiring a commitment to collaborate with worldwide industrial partners in many semiconductor segments.

Declerck has been an advocate of cooperative R&D as the optimum way to stimulate IC manufacturers, equipment makers, material suppliers, and leading groups to join IMEC. Together with Dr Luc Van den hove, he set up a cooperation model for IMEC's nanoelectronics platform, attracting leading semiconductor companies to commit to leading-edge sub-32nm CMOS research.

Over the past five years, they took up the challenge of building IMEC's research platform, which now employs 1500 people on site with an annual budget of €240m (more than 80% from industrial partnership contributions). Most leading world semiconductor manufacturers participate in this effort, along with all major equipment

and material suppliers, making it the world's largest R&D consortium for semiconductor research in partnership. IMEC has built on this by expanding its activity toward memory-related research.

Convinced that a stronger European industry would emerge from worldwide alliances, over the course of his career Declerck has adopted an open-minded strategy towards industry, building from its European base by cooperating with the US and Asia. He has invested in scientific and industrial relationships, while continuing to fight for Europe on various boards and committees such as ENIAC, Catrene, and others.

Today, many of the world's major semiconductor makers have contracted research programs at IMEC. IMEC hence plays an important role in the creation of new semiconductor technologies, manufactured and commercialized by industrial partners. The R&D program at IMEC has boosted Europe's capabilities in semiconductor technologies, concludes SEMI, and has been instrumental in the development of a cooperative academic/industrial ecosystem in Europe.

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Materials**

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LPE

VPE

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InSb

VCSEL

MOCVD

PIN

GaAs

APD

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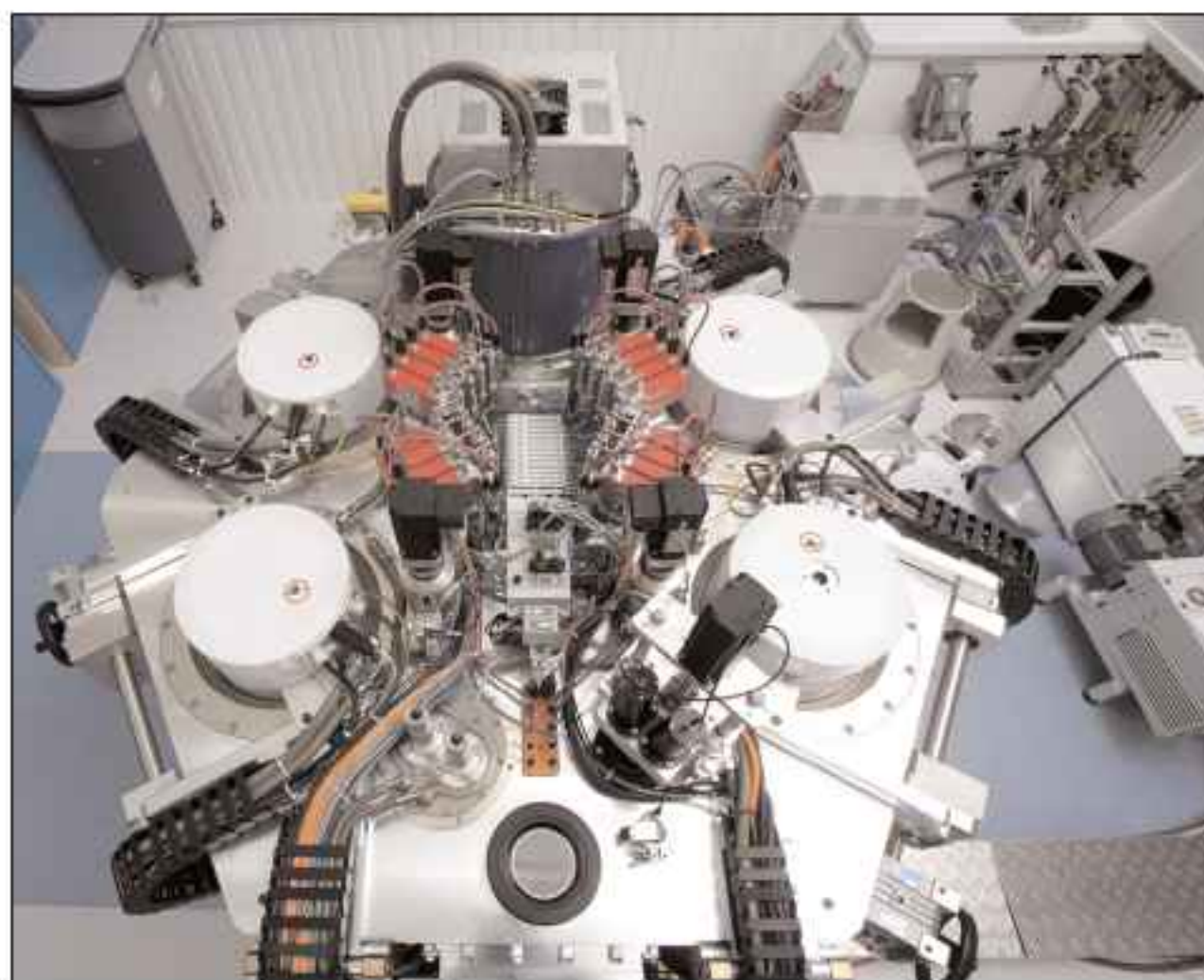
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Evatec launches cluster tool; installed at Philips' MiPlaza

At SEMICON Europa 2008 in Stuttgart, Germany in early October, Evatec Ltd of Flums, Switzerland launched its new Radiance multi-process sputter platform with cluster architecture for semiconductor and optoelectronic applications (available in variants for substrate sizes up to 12 inch; in addition, machined substrate holders offer the flexibility to process differing substrate sizes simultaneously).

Radiance is based around a central transport module with a vacuum cassette elevator, robot and load lock, and can be equipped with Evatec's single- or multi-process batch modules according to customer throughput and process requirements. Single modules can be configured for standalone PVD and CVD deposition or etch processes, while a six-process position batch module can be equipped for sputter, etch, heating and metrology. Substrate rotation combined with a capability for heating or cooling plus fingertip control of the source/substrate distance



Evatec's new Radiance multi-process cluster tool.

makes the tool suitable for critical process control environments.

The first tool is being installed at Philips Research's MiPlaza (Microsystems Plaza) facilities at its High Tech Campus Eindhoven, The Netherlands, which offers expertise, services and infrastructure to high-tech organizations both inside and outside Philips. The MiPlaza tool is configured with custom pre-

clean and in-situ broadband optical monitoring capability, enabling deposition of the most complex dielectric stacks. Applications include laser optics, photonics and high-efficiency solar devices.

"Because MiPlaza is a shared facility, our processing equipment has to be versatile enough to support a wide range of applications," says Frank Dirne, head of MiPlaza's Thin Film Facilities. "At the same

time, it has to satisfy highly demanding specifications. In this case we need flexibility in substrate materials and target materials, in conjunction with excellent quality of thin optical films," he adds. "The Evatec Radiance can fulfill both roles, as well as provide the predictive capabilities needed to accelerate technology innovation."

www.evatecnet.com

CVD/ALD system integrates vaporizer technology

At SEMICON Europa 2008, process equipment maker Altatech Semiconductor of Grenoble-Monbonnot, France debuted its AltaCVD system for the chemical vapor deposition (CVD) and atomic layer deposition (ALD) of advanced materials.

The system uniquely integrates the chamber design, gas/liquid panel, and vaporizer technology (which enables deposition from new, viscous and non-volatile precursors). The combination of a proprietary reactor design and precursor introduction path with pulsed liquid injection and vaporization enables unique new capabilities for R&D facilities and pilot-productions lines, including nanoscale control of thickness, uniformity, composition and stoichiometry in complex materials, claims Altatech.

AltaCVD is suited to plasma-enhanced MOCVD and ALD of a wide range of materials used in logic and memory devices as well as in micro-systems and 3D



The AltaCVD system.

integration, such as high-k gate dielectrics, metal electrodes, high-k coupling dielectrics and electrodes in metal-insulator-metal (MIM) and dynamic random access memory (DRAM) capacitors, ferroelectric materials,

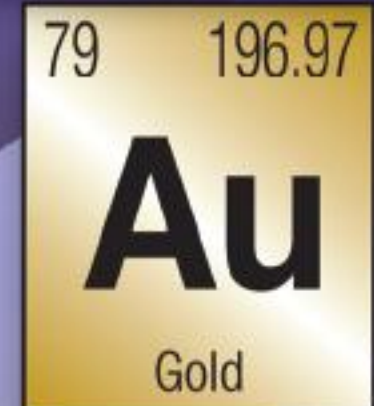
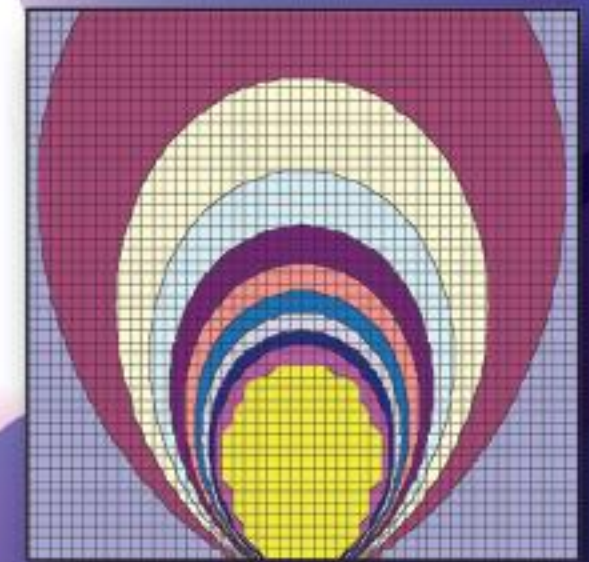
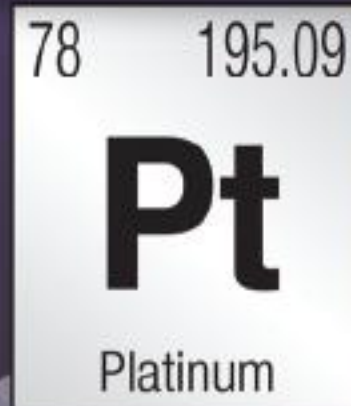
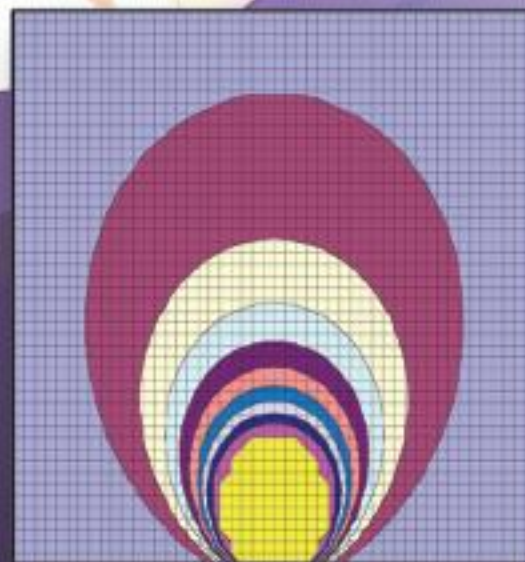
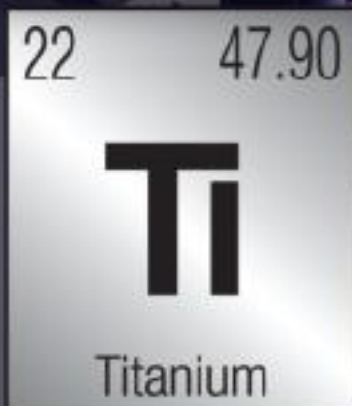
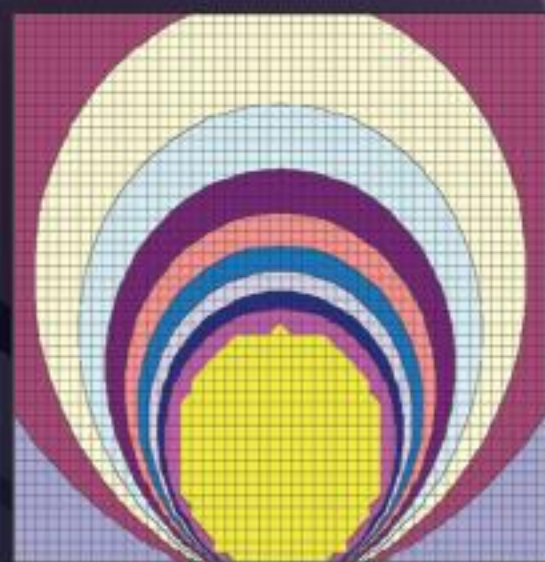
chalcogenide alloys for phase-change RAM (PCRAM), seedless and self-forming copper diffusion barriers, copper seed layers, transparent conductive oxides, and thin-film battery electrodes and electrolytes.

AltaCVD's unique design and technology is in line with Altatech's product strategy, which aims to accelerate the introduction of the next-generation materials into the semiconductor supply chain, says technology director Hervé Monchoix.

Altatech says that multiple beta versions of AltaCVD systems have already been installed for advanced high-k gate dielectric integration at front-end-of-line R&D facilities and for through-silicon-via (TSV) metallization at a back-end-of-line R&D facility.

www.altatech-sc.com

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IN BRIEF

Linköping orders MOCVD system for ZnO nanostructures

Aixtron AG of Aachen, Germany says that, in second-quarter 2008, Linköping University ordered a Close Coupled Showerhead (CCS) MOCVD system in 3x2-inch wafer configuration, for delivery in first-quarter 2009.

The system features a triple showerhead developed specifically for research on zinc oxide (ZnO) heterostructure materials.

"One of the key reasons why we chose Aixtron equipment is the wide process window of the CCS reactor," says professor Magnus Wallander of the Department of Science and Technology at Linköping's Norrköping Campus. "It will also provide us with the inherent growth uniformity and minimized pre-reactions necessary for the preparation of this interesting new family of ZnO-based devices," he adds.

ZnO nanostructures have unique characteristics that make them especially suitable for short-wavelength optoelectronic devices including white LEDs, UV biosensors and resonators. Nanostructures also have potential use as the middle electrode in tandem solar cells employing polymer and small molecule materials. Moreover, the ferromagnetic properties of ZnO doped with rare-earth metals are also of interest for the design of novel data storage devices.

Before these properties can be realized in commercial devices, suitable growth techniques are essential. Initial results from devices fabricated using research techniques have been encouraging, so Linköping is now moving on to using standard industrial equipment such as the CCS, optimized for nanostructures and other challenging materials.

www.itn.liu.se/english
www.aixtron.com

Aviza ships multiple PVD systems to top-3 GaAs RF device maker

Aviza Technology Inc of Scotts Valley, CA, USA says that it has shipped multiple Sigma fxP PVD systems to one of the top three manufacturers of GaAs devices, for fabricating ICs used in RF wireless and broadband applications.

Aviza supplies equipment and technology expertise for physical vapor deposition (PVD), etch and chemical vapor deposition (CVD) processing to support compound semiconductor applications (as well as advanced silicon for memory devices, 3D packaging and power ICs for communications). The firm says that its systems are installed in eight of the top 10 GaAs-based IC manufacturers, and claims that it continues to strengthen its process of record (PoR) status at these customers' manufacturing sites by continuing to secure follow-on orders. A series of recent order announcements for a combination of PVD, etch or CVD systems is further validation of this trend.

"Aviza is one of the largest suppliers of sputtering systems to this customer," says Kevin Crofton, senior VP, Product Business Units. Follow-on shipments are further evidence of Sigma fxP's capability to meet the

specialized PVD processing requirements for GaAs devices, he adds.

The compound annual growth rate (CAGR) for the GaAs device market through 2012 is estimated to be about 10%. Demand for GaAs-based ICs is fuelled by wireless applications in cell phones and Wi-Fi, with wireless applications expected to account for about 85% of all GaAs devices consumed in 2012, according to market research firm Strategy Analytics.

● Aviza has also received multiple orders for its Delta i2L plasma-enhanced CVD (PECVD) and Omega i2L etch systems from "one of the world's leading optoelectronics manufacturers". The tools will be used to produce GaAs- and InGaN-based high-brightness LEDs (HB-LEDs) for solid-state lighting, mobile communications and automotive applications.

"Securing these system orders validates Aviza's ability to produce results that meet or exceed our customers' process specifications," claims Crofton.

The Omega i2L system is now the process tool of record (PTOR) for etch at the customer's facility.

www.aviza.com

Aviza appeals delisting notice from NASDAQ

Aviza Technology says that, on 22 September, its application to transfer the listing of its securities to The NASDAQ Capital Market was denied and that it received a Staff Determination Letter from NASDAQ on 24 September notifying it that its securities are subject to delisting from The NASDAQ Global Market.

On 3 April, NASDAQ notified Aviza that the bid price of its common stock had closed below the minimum \$1 per share requirement for continued inclusion under Marketplace Rule 4450(a)(5), and that it had 180

days to regain compliance. The Staff Determination Letter stated that Aviza had since not regained compliance and that trading of its stock would be suspended on 3 October and a Form 25-NSE filed with the Securities and Exchange Commission to remove its securities from listing and registration on NASDAQ.

Aviza has since appealed the Staff Determination to a NASDAQ Listing Qualification Panel. A hearing request stays suspension of the securities and the filing of the Form 25-NSE pending the panel's decision.

LayTec to develop in-situ sensor for ISE's triple-junction PV cells

LayTec GmbH of Berlin, Germany says the German Federal Ministry of Economics and Technology (Bundesministerium für Wirtschaft und Technologie) has approved funding under the PRO Inno Program for the development of a new in-situ sensor for the photovoltaic market.

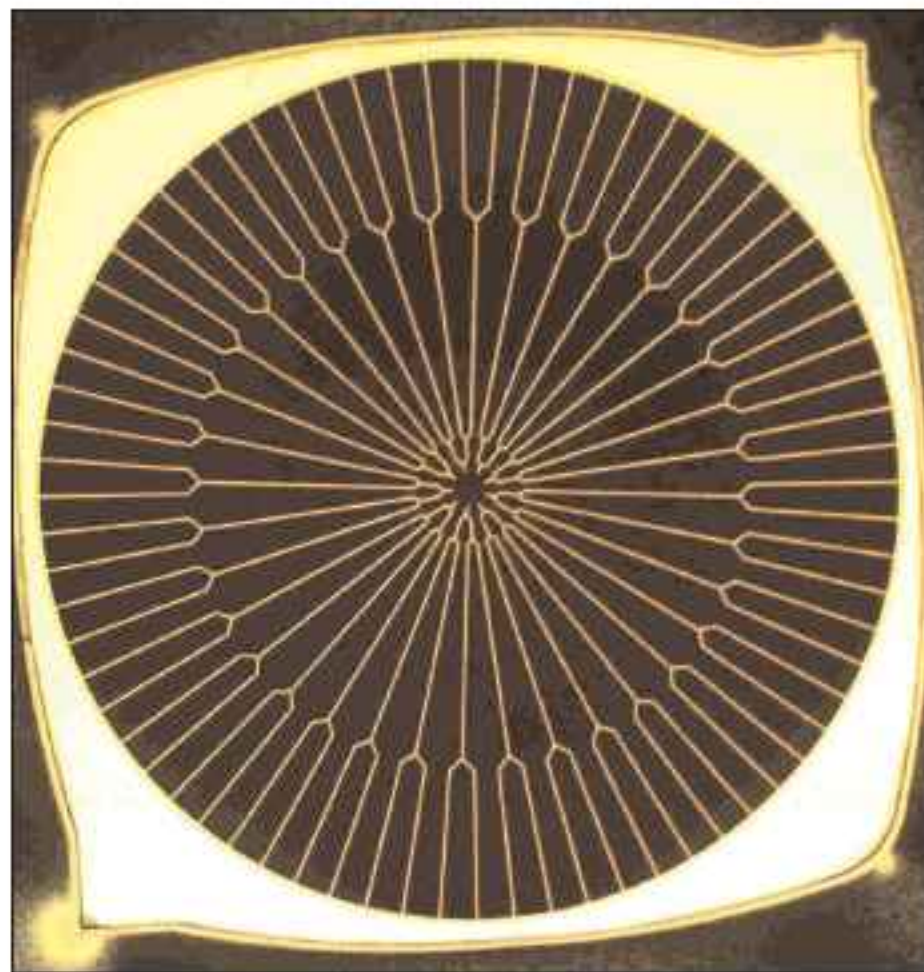
In collaboration with the Fraunhofer Institute for Solar Energy Systems (ISE) in Freiburg, Germany, a research project has been launched to improve the in-situ monitoring of MOCVD processes for triple-junction photovoltaic cells being developed at Fraunhofer ISE (which recently set the European record for solar cell efficiency, at 39.7%).

Cooperation between LayTec and ISE's III-V Epitaxy and Solar Cells group is aimed at developing monitoring sensors for industrial-scale manufacturing of triple-junction solar cells with improved process control in multi-wafer MOCVD reactors. "Real-time analysis and control of our processes is becoming a key for the development of complex semiconductor structures such as multi-junction solar cells," says Dr Frank Dimroth, head of ISE's III-V Epitaxy and Solar Cells group.

ISE's cells are the most efficient produced in Europe. ISE transfers its process technology to the cooperation partner Azur Space Solar Power GmbH of Heilbronn, Germany (Azur SSP), which prepares them for commercial production. ISE and Azur SSP use Aixtron Planetary systems for both development and manufacturing.

LayTec's EpiCurveTT sensor, which the firm claims is already the best-seller for the MOCVD LED market, will be further improved to achieve the resolution necessary for multi-junction solar cell growth under the conditions of planetary rotation.

In addition to temperature, layer thickness and strain measurements, the new sensor aims to



Multi-junction concentrator solar cell with an efficiency of 39.7% at a concentration factor of 300, developed at Fraunhofer ISE.

determine the composition and help to better understand the reasons for dislocations and strain within the layers. This will help to compensate for strain-induced temperature inhomogeneities, to determine the thickness of individual thin layers and to monitor the composition of critical heterojunctions, says LayTec.

● LayTec has recruited Dr Qi Cao as a sales engineer. After graduating in physics from China's Nanjing University of Science and Technology, Cao undertook research on optical features of nano-structure materials and obtained a PhD in Optical Engineering in 2004, before continuing research on laser transmission characteristics of nano-holes at Germany's Konstanz University and finally focusing on opto-electric features of single molecules at Münster University.

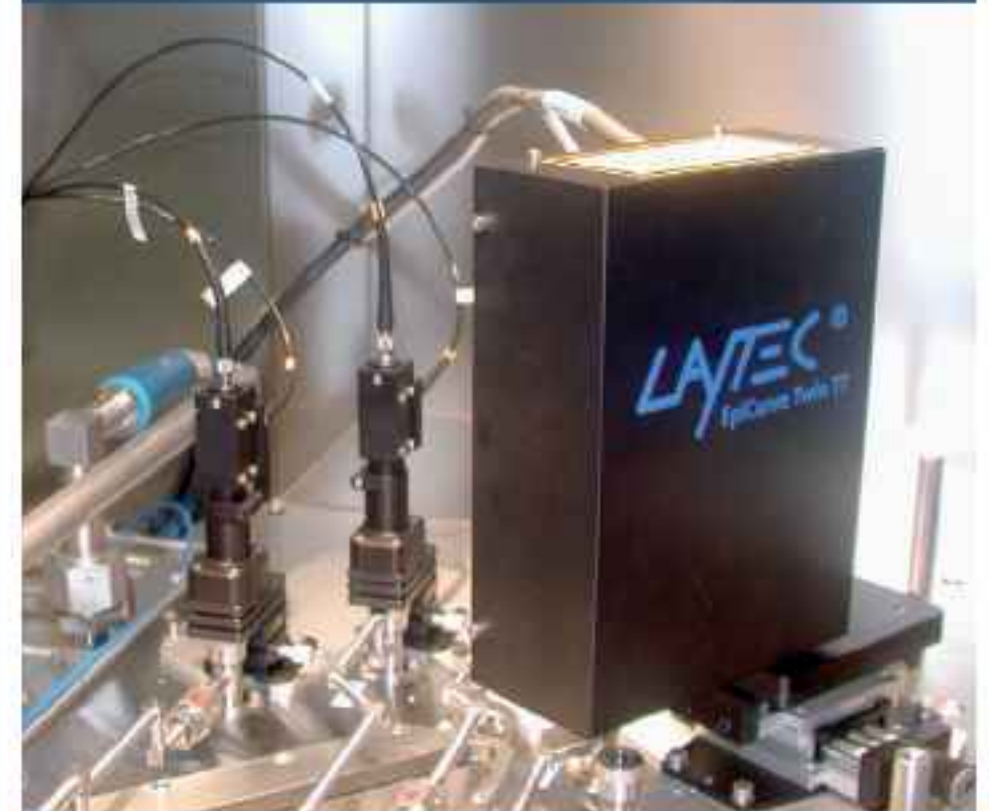
Since 2006, Cao has gained experience in sales and customer support working for Olympus Microscope in the USA.

At LayTec, Cao will be in charge of sales activities mainly in Taiwan and Greater China, and will support customers and distributors worldwide.

www.laytec.de

Every move you make

LayTec's uniquely flexible EpiTT in-situ sensor system is adaptable to every MOCVD growth environment. Additional twin head and bowing measurement options enhance standard growth rate and true temperature parameters, allowing you to create the ideal sensing system for your specific production or R&D application.



The EpiCurveTwin TT uses two EpiTT heads and a bowing sensor for maximum control of multi-ring reactors.

I'll be watching you

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Lores launches dopant mixing system with piezo-control

Lores Industries Inc of Poughkeepsie, NY, USA has launched a Dopant Mixing System (DMS) that, it claims, better fulfills the needs of silicon and compound semiconductor manufacturers for improved doping process control. Pre-mix gases that can be used include arsine, di-borane, di-silane, germane, methylsilane, phosphine, and silane.

Starting with a dopant pre-mix concentration of 1–10% at the inlet, the Piezocon DMS uses the concentration measurement and control capability of Lorex's Piezocon sensor to control the dilution of the pre-mix down to a lower adjustable concentration of 50–200ppm, with what is claimed to be both excellent



Piezocon Dopant Mixing System integrated in a valve manifold box.

concentration control (± 0.5 ppm at 50ppm and ± 1 ppm at 200ppm) and reproducibility. The firm says that this makes it immune to cylinder-to-cylinder shifts in inlet pre-mix concentration or to drifts in concentration over the life of the cylinder.

As well as providing improved doping control, by starting from a higher pre-mix concentration level the DMS allows the frequency of pre-mix tank exchange to be reduced, virtually eliminating follow-on time-consuming tool re-qualification and significantly cutting the associated production cost, claims the firm.

www.Lorex.com

SemiLEDs upgrades to Ultratech projection stepper lithography system for LED mass production

Lithography and laser-processing system maker Ultratech Inc of San Jose, CA, USA has received a multi-system order from high-brightness LED (HB-LED) maker SemiLEDs Corp of Boise, ID, USA for its manufacturing facility in Hsinchu Science Park, Taiwan.

SemiLEDs will use Ultratech's Star 100 lithography tools for its white HB-LEDs and high-power UVC-LEDs as well as other lighting applications. Ultratech says that advanced lithography is enabling SemiLEDs to grow its position in a burgeoning market as the industry shifts from conventional lithography to projection stepper lithography for advanced LED production.

"With improved alignment and resolution of the Star 100 Ultratech stepper system, we will start volume production of our advanced UVA high-power LED product family (365/395/405nm), with output optical power as high as 350mW/mm²," says SemiLEDs' chairman & CEO Trung Tri Doan. "This new family of UVC high-power LED products will enable new LED applications that could only be

dreamed of — polymer curing such as inkjet printers, sanitation, semiconductor processes, and medical applications such as dental, cancer treatment, tanning, etc," he adds.

SemiLEDs claims to be the only mass producer of metal-base LED chips. "The MvPLED [metal vertical photon LED] blue product family has seen a 15% improvement in performance; the new class of 120 lumens/watt SemiLEDs solid-state lighting devices (SL-SSL) will help accelerate the adoption of solid-state lighting," Trung Tri Doan reckons.

"We selected Ultratech's lithography steppers based on the tools' high reliability and low cost of ownership," he continues. "Ultratech will continue to play an integral role as advanced LED device volumes grow."

HB-LED leaders such as SemiLEDs are increasingly turning to stepper-based projection lithography due to its cost and yield

"While this multi-system order demonstrates our ability to provide lithography systems that enable greater economic value to emerging markets, it also reinforces Ultratech's focus on energy conservation," comments Ultratech's chairman & CEO Arthur W. Zafiropoulos. "With energy conservation driving up demand, HB-LED leaders such as SemiLEDs are increasingly turning to stepper-based projection lithography due to its cost and yield advantages."

The Star 100 lithography system is used by HB-LED and laser diode manufacturers, and is designed to be easily integrated into a broad range of fabs with varying equipment types and wafer sizes. Ultratech says that its resolution, depth of focus, proprietary alignment system, and substrate handling capability combine to provide high productivity, reliability, flexibility, and cost-of-ownership advantages critical for advanced and emerging markets as they move toward high-volume production.

www.semileds.com

www.ultratech.com

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IN BRIEF

EVG ships 100th NIL system

EV Group of St Florian, Austria, which supplies wafer bonding and lithography equipment for MEMS, nanotechnology and semiconductor markets, has shipped its 100th nanoimprint lithography (NIL) tool. EVG says that the shipment is significant not only for the firm (which has the biggest share of the market, at about 30%) but also for the industry overall, as it highlights growth of the NIL installed base, which has doubled in the past four years.

"Nanoimprint lithography is an enabling technology for optical and microfluidic applications," says executive technology director Paul Lindner. "With EVG's firm commitment to NIL development and commercialization, together with our industry-leading NIL products, including our EVG770 fully automated NIL Stepper and EVG750 fully automated Hot Embossing systems, we remain well positioned to benefit as these and other markets such as chemical and biosensor move into high-volume production," he adds.

EVG says its 100th NIL system shipment underscores the ongoing drive to broaden adoption of NIL processes. In 2004, EVG founded the NILCOM Consortium, whose dozen members span equipment, materials, processes and research. It aims to establish a high-volume NIL manufacturing platform that can be commercially deployed in areas including nanoelectronics, optoelectronics and data storage.

Recent successes have included NIL processes being used commercially in the optics market for CMOS image sensors, optical gratings and LEDs, as well as a commitment from the hard disk drive market to employ NIL in discrete track recording (DTR) and bit pattern media (BPM).

www.EVGroup.com

Kulicke & Soffa completes sale of wire business unit

Chip assembly equipment and packaging materials supplier Kulicke & Soffa Industries Inc (K&S) of Fort Washington, PA, USA has completed the sale of its wire business unit (announced at the end of July) to German precious metals and technology group W.C. Heraeus GmbH for \$165m (including estimated working capital adjustments). The final consideration will be subject to additional, post-closing working capital adjustments.

K&S and Heraeus have also entered into a development and engineering services agreement to provide reciprocal base engineering support, and will consider joint R&D initiatives aimed at customers' future packaging needs.

"This transaction will provide us with the financial resources and technical focus necessary to pursue attractive growth opportunities on the equipment side of our business," says K&S' chairman & CEO Scott Kulicke. "The working capital requirements of the wire business have become significant in recent years and we believe can no longer be justified," he adds. "The wire business fits Heraeus' core competences well, especially in global precious metals trading and related services

like refining. Heraeus has the necessary resources to support the continued growth of this business, and to exploit the advanced wire products like MaxSoft and Relmax we have recently developed." The development and engineering arrangement formed with Heraeus will allow K&S to cooperatively pursue technical opportunities between the two businesses, Kulicke concludes.

"This transaction strengthens our balance sheet and, together with

The wire business fits Heraeus' core competences well

our pending acquisition of Orthodyne [a supplier of ultrasonic wedge bonders and wedges for

the power management and hybrid module markets], will deliver value to our shareholders," says K&S' senior VP & chief financial officer Maurice Carson. "Coupled with last year's acquisition of Alphasem [a Swiss-based supplier of die bonder equipment], we believe we have enhanced our already strong position in the semiconductor assembly business, along with our ability to respond to customer needs as industry conditions improve."

www.kns.com

K&S appoints Inseto as its distributor in the UK and Ireland

Semiconductor assembly equipment & materials distributor Inseto of Andover, UK has been appointed by Kulicke & Soffa (K&S) as its exclusive distributor in the UK and Ireland.

Inseto will supply and support the complete Kulicke & Soffa product range, which features the Micro-Swiss brand of bonding capillaries and wedge tools, manual wire bonding equipment for ball and wedge bonding,

automatic ball bonding and bump bonding machines, die bonding systems, and hub dicing blades.

"With this new arrangement we expect to increase the level of sales and service offered to existing and potential customers, plus benefit from Inseto's proficient customer support infrastructure," says Siegfried Hagenmiller, K&S' European sales director.

www.inseto.co.uk
www.kns.com

Nextreme appoints head of new telecom- and photonics-focused thermal management products unit

Nextreme Thermal Solutions of Durham, NC, USA, which designs and makes microscale thermal and power management products for the electronics, telecom, semiconductor, consumer, and defense/aerospace markets, has appointed Jim Mundell as senior VP & general manager of its newly created thermal management products business unit.

Nextreme's thin-film thermoelectric products are manufactured in volume with the copper pillar bump process, an electronic packaging approach that scales well into large arrays. The process integrates thin-film thermoelectric material into the solder-bumped interconnects that provide mechanical and electrical connections for high-performance/high-density ICs.

Mundell's appointment signals Nextreme's intention to focus on its thermal management products and

to aggressively engage with the telecoms and photonics markets to enable integration of its thin-film thermoelectric OptoCooler product line into optoelectronic devices.

Smaller packaging and higher heat densities can directly affect the performance and longevity of existing optoelectronic devices, says Nextreme. Its products act as solid-state heat pumps and add thermal management functionality directly into the package to maintain the device's temperature at optimal conditions.

After graduating from Purdue University with a BS in Electrical Engineering Technology and an MBA, Mundell accrued more than 30 years of experience in managing and growing high-tech businesses in small and large companies. Most recently, he was Nextreme's chief operating officer, responsible for

transitioning technology from research to product.

Previously, Mundell served in executive management positions at General Electric, Harris Corp, SCI Systems, and CTS Corp covering the semiconductor, microelectronic, and electronic manufacturing services businesses. He also has over 15 years of experience in managing and growing start-up companies.

"As an initial target, the telecommunications and photonics markets represent a large opportunity," says Mundell. "The size, efficiency and power-pumping capability of our thermoelectric product line make them ideally suited for optoelectronics," he adds. "We are also seeing a lot of interest for microscale thermal management in other markets, including computing, mobile and consumer product applications."

www.nextreme.com

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Peregrine cuts off deliveries, hitting Rubicon's sapphire sales

Sapphire-on-silicon (SoS) RFIC maker Peregrine Semiconductor Corp of San Diego, CA, USA has told Rubicon Technology Inc of Franklin Park, IL, USA, which makes sapphire substrates and products for RFICs, LEDs, blue lasers and other optical applications, that it will not take any further shipments of sapphire products until further notice due to declining demand for its products.

Peregrine, which is Rubicon's main silicon on sapphire (SoS) customer, has incurred a buildup of sapphire inventory. Hence previously, in September, to accommodate Peregrine's inventory build up, Rubicon executed a contract modification that shifted the delivery of \$4.3m of contracted volumes from 2008 into first-half 2009.

In addition, the current economic slowdown is hitting handheld device and small-display markets that use Rubicon's small-diameter (2") LED wafers. This has affected customer orders throughout Asia, says Rubicon's CEO Raja Parvez.

"As an accommodation to our customers, we have agreed to move some of the contracted volumes for the remainder of 2008 into the first half of 2009, which is when our customers believe the market will begin to strengthen."

Combining deferred revenues from both Peregrine and LED-making customers, the total value of shipments deferred to first-half 2009 amounts to \$7m.

Hence, despite LED revenue from larger-diameter material continuing to be strong, Rubicon lowered its revenue guidance for Q3/2008 from \$12.5m to \$11.5-12m. Together with guidance for fourth-quarter 2008 revenue of \$8-8.5m, guidance for full-year 2008 was also lowered, from \$47-49m to \$41.5-42.5m.

Gross margin was forecast to be 35-37% in Q3, but will likely drop to the mid-20% range in Q4, given the larger deferral of orders for that period, says Rubicon's chief financial officer Bill Weissman. "During this period, we will retool some of our manufacturing operations by retiring old equipment and installing newer, more efficient equipment this year and early next year in order to reduce costs and increase throughput," he added. The revised guidance includes an anticipated write-off of remaining book value of those assets to be retired of \$1-1.2m in Q3. "In addition, we recently met the major deliverables on our agreement to develop a new 8-inch SoS product and will benefit from milestone payments this year."

This should allow Rubicon to better manage production schedules over the next several quarters to avoid down time. "The outlook for the SoS market remains strong, with a growth rate that is expected to be about 50% per year for the next several years," he adds.

However, since Rubicon's revision of revenue guidance in September, more recent demand reductions by Peregrine's customers related to the global economic slowdown have resulted in the further action by Peregrine to curtail deliveries. The remaining value of its current contract is about \$7m; \$2m was to be delivered in Q4/2008 and the remaining \$5m in first-half 2009.

"This unexpected news from Peregrine will affect our production planning for the rest of this fiscal year and into next year," says Parvez. "We are in the process of evaluating all options related to the customer's contract obligations and we are examining the potential impact to our operations. This contract issue, along with the uncertainty of the global markets, makes it premature for us to provide a meaningful update to earnings guidance at this time," he adds.

"Right now, macroeconomic

LED chip manufacturers working on large-diameter processing seem to be moving faster than we had anticipated

conditions are having a significant impact on demand for consumer electronics, where much of our sapphire is used for LED and RFIC applications," Parvez continues.

"For the near term, we will control expenses as we weather this challenging economic environment." He stresses that Rubicon has a strong balance sheet in its cash position, with no debt.

Rubicon's products serve the LED, SoS RFIC and optical markets — all of which offer strong long-term growth potential, the firm reckons. "There is no viable substitute for sapphire in these applications," claims Parvez. "LED chip manufacturers working on large-diameter processing seem to be moving faster than we had anticipated," he adds. "We continue to expect to benefit from future opportunities... Longer term, we will maximize shareholder value by continuing to invest in our facilities and technologies."

www.rubicon-es2.com

We are in the process of evaluating all options related to the customer's contract obligations and we are examining the potential impact to our operations

Emerging Standardization for Sapphire Substrate Inspection

By Frank Burkeen

Senior Product Marketing Director at KLA-Tencor
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The HBLED industry continues to thrive driven by market demand from mobile devices, automobiles, computer screens, and niche exterior and interior lighting applications. As HBLED device technology evolves and fabrication techniques become more advanced, defect detection and process control are critical to improving device yields. Sapphire substrate contaminants such as particles, scratches, pits, bumps, stains and residues from CMP processing are known to impact subsequent epi deposition processes and substantially degrade device performance and yield. As such, the need for higher quality sapphire substrates is of critical concern for HBLED device manufacturers.

The adoption of optical surface analyzer (OSA) technology is gaining momentum for use in HBLED manufacturing, specifically sapphire substrate inspection.

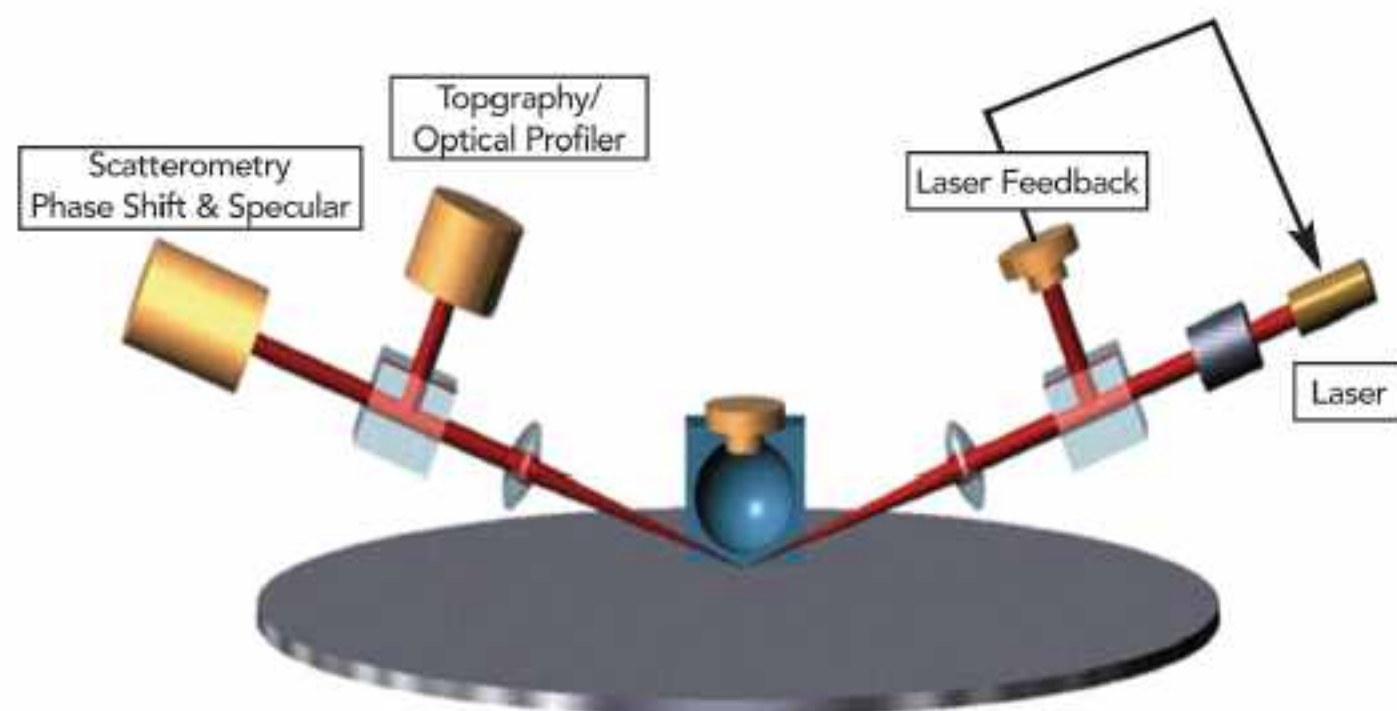


Figure 1: OSA technology combines four signal detection channels, enabling a wide range of inspection applications.

The design of OSA technology combines reflectometry, optical profilometry, scatterometry, and phase shift to measure topographic variations and detect a wide variety of surface defects. The inspection method achieves full surface coverage in minutes to produce high-resolution imaging, wafers maps, and automated defect classification.

At a throughput exceeding 40wph, an OSA system is the only wafer inspection method amenable to volume production and capable of advanced inspection of transparent sapphire substrates. Other inspection tools based solely on scatterometry cannot effectively measure transparent materials due to scattered light interference from the backside of the substrate. An OSA system is designed specifically for defect detection and classification of transparent materials including sapphire, GaN, SiC, and glass.

Figure 2 illustrates a sapphire substrate defect map after OSA inspection. Particles, scratches, pits, and stains are detected and classified in user-defined bins. The defect traceback images show a scratch as detected in the topography channel and two different types of stains as detected in the phase channel.



Scratches are known to transfer to the subsequent epi layer thereby degrading or killing device performance. Substrate stains have been reported to cause poor epi layer adhesion or result in rough epi morphology.

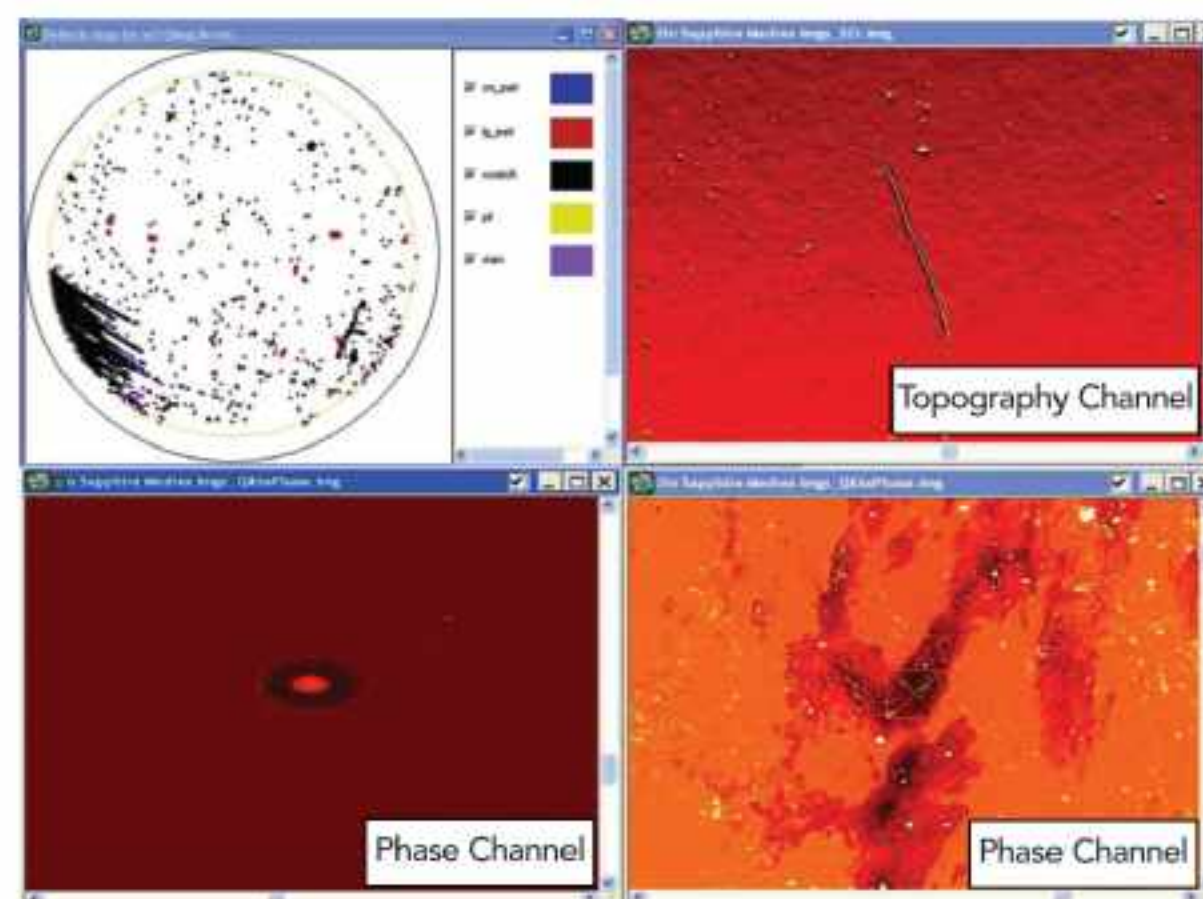


Figure 2: KLA-Tencor's Candela™ OSA defect map and traceback images of scratches and stains as detected in topography and phase channels, respectively.

As HBLED competition tightens and margins are squeezed, manufacturers are relying more on automated OSA inspection technology for process control and yield improvement. The emergence of sapphire substrate reclaim is also driving the need for advanced automated inspection. As supply is strained and material costs rise, the sapphire reclaim business is becoming more prevalent — whether for captive consumption or merchant supply. The reclaim business is even more dependant on OSA inspection as reworked material is highly susceptible to yield impacting defects.

Optical surface analyzer technology is setting the benchmark for automated inspection of sapphire substrates, and is emerging as the industry standard for overall sapphire quality control. HBLED device manufacturers and sapphire substrate suppliers are together converging on OSA inspection specs for quality assurance. Moreover, manufacturer's utilizing OSA technology are the beneficiaries of higher quality sapphire substrates passing distinct inspection specs.

Optical surface analysis technology enables manufacturers and suppliers to automate defect inspection and define objective-controlled process control limits. OSA technology can be employed at incoming substrate inspection, post-clean inspection, and after epi and film deposition processes.

To learn more, go to:
www.kla-tencor.com/candela

BluGlass Technology Council to drive commercialization

To support its transition to the commercial phase of development of its GaN-on-glass LED technology, BluGlass Ltd, which was spun off from Macquarie University in Sydney Australia in 2005, has supplanted its former Technical Advisory Committee and chief technology officer (CTO) functions by establishing a Technology Council of four experts.

CTO & founding scientist Dr Scott Butcher has taken a part-time role for health reasons, but will still assist the technology team by remaining active in the technical aspects of GaN film growth. Over time, he will also focus on researching alternative group III nitride applications to create strategically important IP and commercial opportunities.

CEO Giles Bourne says that establishing a Technology Council enables BluGlass to draw on world-leading expertise to keep its technical team focused on industry needs (both current and future). The firm is in the process of re-positioning from a research-based proof-of-technology enterprise to being a market-focused product development company.

The Technology Council aims to provide direction and support for the commercial delivery of the firm's remote plasma chemical vapor deposition (RPCVD) GaN-on-glass LED manufacturing technology, which targets cutting the cost of GaN wafers. BluGlass's technology team, led by Butcher, has developed techniques for commercializing its nitride manufacturing platforms.

Applications for the GaN manufacturing technology include LEDs for mobile appliances, signs/displays, automotive, signals and illumination. The high-brightness LED market is forecast to grow from \$4bn to \$12bn by 2012, but BluGlass's low-cost GaN manufacturing technology could allow LEDs into mass markets such as the \$100bn general lighting sector.

BluGlass opened its pilot plant in Silverwater, Sydney in July, and is in discussions with lighting firms about their commercial use of its LED production process, Bourne says.



Professor Jagadish. The Technology Council is chaired by professor Chennupati Jagadish (chair of BluGlass's former Technical Advisory Committee), joined by Dr Petar Atanackovic

(an expert in CMOS ICs, compound semiconductors and optoelectronics) and (from BluGlass) senior research scientist Dr Marie Wintrebert-Fouquet and equipment design and development manager Conor Martin.

Jagadish worked in India and Canada before moving to Australia in 1990. He is an Australian Research Council (ARC) Federation fellow, professor and head of the Semiconductor Optoelectronics and Nanotechnology Group in the Australian National University's Research School of Physical Sciences and Engineering, and convenor of the ARC Nanotechnology Network. Jagadish has published more than 500 research papers, has five US patents, and won the 2000 IEEE Millennium Medal.

"It is important to develop new technologies to improve the efficient use of energy, such as solid-state lighting, in which the company is aiming to be a major player," says Jagadish.

"BluGlass is a unique enterprise offering significant technology innovations in one of the highest commercial growth areas of nitride-based compound semiconductors," adds Atanackovic. "The BluGlass technology and commercialization roadmap is well positioned to develop cost-effective industry solutions and improve energy efficiency in the area of solid-state lighting."

Atanackovic gained a PhD in Physics from the University of Adelaide in 1996 and was a senior research scientist at Australia's Defence Science & Technology Organisation before becoming a visiting scholar at Stanford University in 1998-2001 (working on optical interconnects, photonic devices and atomically

engineered semiconductors). In 2001, he founded Translucent Inc in Palo Alto, CA (acquired this May by Australia's Silex Systems Ltd) where, as CTO, he developed new silicon-based photonic technology and was principal investigator in an Electronics & Photonics Integrated Circuits program funded by the US Defence Advanced Research Projects Agency (DARPA). Atanackovic is now CTO for nanotech research firm Zcells Pty Ltd. He has more than 20 US patents in fundamental semiconductor materials, high-performance electronics and optoelectronics, and alternative energy concepts.

After graduating from France's University of Montpellier II in 1995 with a PhD in optoelectronics, electronics and systems, Wintrebert-Fouquet worked in Macquarie's electronics department (gaining experience in precision engineering with semiconductor components as well as modeling, designing and fabricating resonant tunneling diodes and transistors) and in the physics department (growing and characterizing thin nitride films of GaN and InN). Her expertise lies in overseeing and maintaining the integrity of characterization, and ensuring that material development is targeted at LED devices.

Martin graduated in 2001 with a degree in Experimental Physics and a Masters in High Performance Computing from Trinity College Dublin in Ireland. After five years in Europe in the Product Design and Development Department of a major semiconductor equipment maker, he joined BluGlass in January 2007. His expertise lies in product design and development, particularly the use of computational fluid dynamics to optimize BluGlass's equipment and RPCVD process (speeding up development time and cutting time to market for the firm's products). Martin provides hardware and process development support for BluGlass's equipment as well as technical support for sales & marketing.

www.bluglass.com.au

Oxford Instruments-TDI develops technique for HVPE growth of InGaN

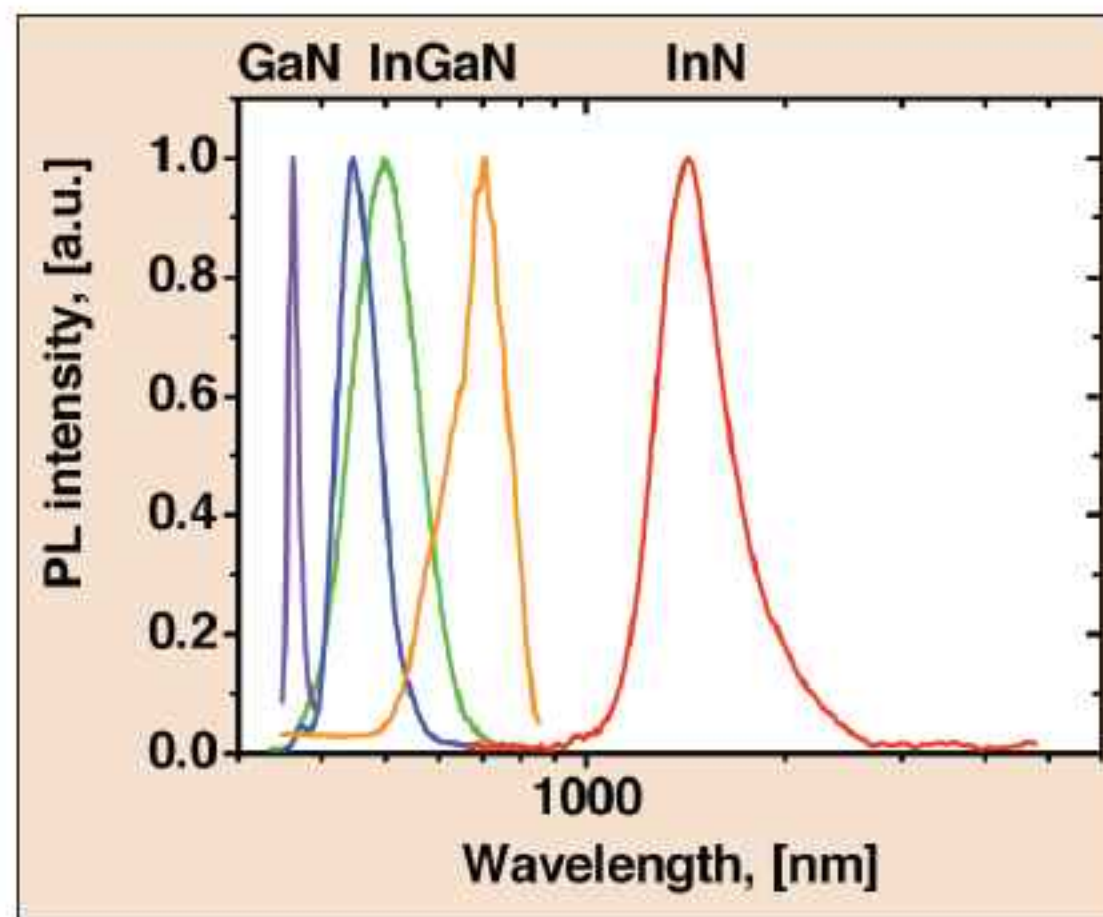
UK-based equipment maker Oxford Instruments plc says that its subsidiary TDI (which was acquired in April) has extended hydride vapor phase epitaxy (HVPE) technology to the growth of indium gallium nitride (InGaN).

The InGaN alloy materials typically forming the active region of green-blue-violet light-emitting optoelectronic devices based on III-nitride compounds are normally grown using metalorganic chemical vapor deposition (MOCVD) or molecular beam epitaxy (MBE).

In contrast, HVPE is best known for its capability to grow low-defect, crack-free, high-quality quasi-bulk gallium nitride (GaN) and aluminium nitride (AlN) materials at a high growth rate of up to 100 μ m/hour. TDI uses its patented HVPE technology to manufacture nitride materials (including GaN, AlN, AlGaN, InN and InGaN epi-wafers), mainly for applications in solid-state lighting (high-brightness LEDs), short-wavelength optoelectronics (laser diodes) and RF power electronics (high-electron-mobility transistors).

But, based on the GaCl₃-InCl₃-NH₃ (trichloro-gallium, trichloro-indium, ammonia) system of precursor materials, the new HVPE technique developed by Oxford Instruments-TDI can precisely control the growth rate of InGaN at 1-2 μ m/hour with indium content of up to 43%.

The x-ray diffraction reciprocal space mapping (RSM) technique has been used to study the strain relaxation of the InGaN layers. The studies show that low-indium-content layers (In_xGa_{1-x}N with x~0.08-0.15) were either fully strained or partially relaxed, with



Room-temperature photo-luminescence spectra of HVPE-grown materials: GaN, InN, and InGaN with various compositions.

relaxation strongly depending on the layer thickness and full relaxation for higher-indium-content layers (x~0.2-0.4).

The results were presented at July's 2nd International Symposium on Growth of III-Nitrides in Izu, Japan and at the International Workshop on Nitride semiconductors (IWN 2008) in Montreux, Switzerland on 6 October.

"This study further confirms the ability of HVPE to grow high-quality InGaN layers and extend its capability for blue-green LED production in the near future," says Dr Alexander Syrkin, who is deputy director and team leader for the InGaN project at TDI.

Recently, the study of InGaN growth by HVPE at Oxford Instruments-TDI was rewarded with substantial funding from a US government agency. "We strongly believe that we are just at the edge of discovering the substantial potential of HVPE technology for the solid-state lighting industry in the near future," comments Oxford Instruments-TDI's general manager Bernard Scanlan.

www.oxford-instruments.com

IN BRIEF

Crystal IS appoints CEO to spearhead commercialization of deep UV LEDs

Crystal IS Inc of Green Island, NY, USA, which manufactures single-crystal aluminium nitride (AlN) substrates, has appointed Dr Steven Berger as its new president and CEO.

Berger spent 10 years at electron microscope manufacturer FEI Company, where he held several roles including chief operating officer and chief technology officer. His key role

at FEI was to bring new products to market profitability. Previously, Berger was a technical manager at AT&T's Bell Labs. He



also taught at Cambridge University, UK, following his PhD from the Cavendish Laboratory. Berger holds a dozen US patents and is widely published in the fields of electron beam lithography, microscopy and analysis.

Crystal IS is using its low-dislocation AlN substrates to develop deep ultraviolet LEDs at 265nm (the peak germicidal wavelength, targeting water and air disinfection) and, after demonstrating significant performance improvements, says it has reached the point where it is about to take the devices to market (for availability in 2009). Crystal IS says that Berger's experience of bringing new products to market will therefore help greatly as it makes the transition to becoming a commercial supplier of deep UV LEDs, adds the firm.

www.crystal-is.com

NSF funds Smart Lighting Center

The US National Science Foundation has granted \$18.5m over five years to Rensselaer Polytechnic Institute (RPI) of Troy, NY along with partners Boston University and the University of New Mexico (UNM) as the three primary research universities forming a new 'Smart Lighting Center' ERC (Engineering Research Center).

The Smart Lighting Center (SLC) aims to develop LED technologies that, along with energy savings for lighting homes and offices, can also impact a diverse range of applications including bio-imaging, high-efficiency displays and illumination devices, safer transportation and novel modes of networking (e.g. free-space optical communications coexisting with LED illumination).

The new center will be staffed by 30 faculty (20 from RPI and 10 from Boston and UNM), plus students, postdoctoral researchers, and visiting industry engineers.

Led by E. Fred Schubert (RPI's Wellfleet senior constellation professor of future chips), at RPI a multi-disciplinary team will focus on three main research thrusts: novel materials, device technology, and systems applications, in order to further the understanding and proliferation of smart lighting technologies.

UNM will focus on nanomaterials and devices, supporting testbeds in bioimaging and displays.

As well as nanomaterials and photonic crystals, Boston's main contribution will be on LED communications and computer networking systems. "As we switch from incandescent and compact florescent lighting to LEDs in the coming years, we can simultaneously build a faster and more secure communications infrastructure at a modest cost along with new and unexpected applications," says professor Thomas Little, ERC associate director and SLC/Boston University site coordinator. The SLC presents unique opportunities, especially related to ubiquitous computing and sensor networks, giving traditional lighting vendors an

entry into the telcom and service provision business, he adds.

"Smart lighting offers the potential to reshape and advance wireless communications technology," comments Kenneth R. Lutchen, dean of Boston's College of Engineering.

Including a possible five-year renewal (also \$18.5m), in the next 10 years the project is expected to receive up to \$50m. First-year funding (from September) includes \$3.25m from the NSF (which should rise over the next several years), \$700,000 from New York State, \$500,000 from RPI, and almost \$1m from 18 industrial partners (lighting firms to start-ups, enlisted to help guide strategic planning, spur innovation and provide students with first-hand experience in entrepreneurship as well as corporate R&D). Innovations will be commercialized through industrial partners while securing intellectual property. To facilitate and stimulate technology transfer, the center will also partner with the Center for Economic Growth in Albany, NY, the Optoelectronics Industry Development Association (OIDA), and small business incubators at each partner university.

The SLC joins four other new ERCs in 2008, the start of a third generation of over 50 ERCs set up since 1985. "The SLC is the first in our extensive portfolio of ERCs in optics and electronics that focuses on advancing LED technology for new lighting systems that will have the capacity to deliver increased functionality in displays, transportation, and communication systems with significant savings in energy use," says Lynn Preston, leader of the ERC Program.

"Not only will this help the state and nation achieve our energy efficiency objective, it will also advance our economic objectives by establishing a technology leadership position in an area with tremendous commercial opportunities," says Edward Reinfurt, executive director of the New York State Foundation for Science, Technology and Innovation.

"This program will have a strong focus on outreach... the new field of smart lighting will increase the number and diversity of students entering science, math, and engineering education," says UNM president David Schmidly.

Outreach partners for the SLC are Washington's Howard University, Baltimore's Morgan State University and Rose-Hulman Institute of Technology in Terre Haute, IN. Also, Korea's Chonbuk National University, Taiwan's National Chiao Tung University, the Taiwan National University, and Lithuania's Vilnius University will support the ERC with expertise and international perspectives.

As well as widening the knowledge base of smart lighting, Schubert

SLC will also be a catalyst for developing and realizing new, yet unexpected applications for photonics

expects the SLC to be a hub for commercializing related technology, where students and researchers work alongside companies to test, validate, and bring new products to market. "The SLC will also be a catalyst for developing and realizing new, yet unexpected applications for photonics," Schubert says. With recent breakthroughs in the first true anti-reflective coating, nano-emitter growth, in the unprecedented control of the refractive index of materials, and the demonstration of the first viable polarized LED-based light sources, researchers are now better able to control almost every aspect of light. "The capabilities of smart lighting surpasses and transcends the abilities of conventional lighting," Schubert continues. "We have absolute control over every aspect of the light, from polarization to temporal modulation and spectral composition... We can custom tailor a light source for nearly any imaginable scientific or commercial application."

www.erc-assoc.org/centers.htm

Osram's colored Advanced Power TopLED Plus boosts light by 15% for large LCD displays

Osram Opto Semiconductors GmbH of Regensburg, Germany claims that its new Advanced Power TopLED Plus is the brightest-colored LED in its class, providing 15% more light for direct display backlighting than its predecessor, as well as beating other LEDs in terms of efficiency. The Advanced Power TopLED Plus is also suitable for backlighting tasks in buildings, position lights on automobiles, and displays in industry, says Osram.

Depending on the display, versions emitting at wavelengths in the usual combination of red (623nm), green (527nm) and blue (457nm) cover more than 125% of the NTSC color gamut, and are suitable for all directly backlit displays, particularly for large formats of 24 inches and more. The new LEDs also offer an optimized ratio of display brightness to display thickness with the minimum number of LEDs necessary, the firm claims.

Osram says that the greater brightness of its Advanced Power TopLED Plus comes mainly from the special lens designed for backlight-



Osram's red, green and blue Advanced Power TopLED Plus LEDs.

ing. At an operating current of 100mA, the LEDs now achieve 14lm (red), 24lm (green) and 28mW/sr (blue). The new lens ensures absolutely uniform display backlighting, it is claimed.

The chips used in the LEDs have an edge length of 500µm and are fabricated using Osram's latest ThinGaN or Thinfilm technology, so that the light sources achieve the highest efficiency in their class: 65lm/W (red), 59lm/W (green) and 27% overall efficiency (blue), the firm reckons. A life of more than 50,000 hours is compatible with

the lifespan of displays and monitors. Also, the LEDs' low height of only 2.25mm means that the backlighting can be very thin.

Osram says that the Advanced Power TopLED Plus is suitable for all display sizes, with a focus on screen diagonals of 24 inches and more. Also, projects are already under way with key customers for use in 46 inch monitors, for which 1200 LEDs are sufficient. Before now, about 600 more LEDs were needed to produce the same brightness.

"Close relations with our customers and extensive application support enable us to ensure that the special requirements of each and every display are met in full," says Winfried Schwedler, marketing manager for LED Backlighting. "This includes not only the selection of suitable LEDs but also the logistical support for module manufacture based on the latest simulation methods," Schwedler adds. "The result is extremely homogenous display backlighting"

www.osram-os.com

Osram offers engineering kit on LED Light for You platform

Osram Opto Semiconductors is offering the LED Engineering Kit for sale on the LED Light for You (LLFY) platform to provide a way of gaining practical knowledge of LED lighting.

The kit is a tool for testing LEDs, accessories and applications, and includes components from LLFY partners. As well as Osram's OSTAR high-power LED, there are various lenses and reflectors, a power supply, a thermal interface and a selection of heat sinks. A brochure is also included for technical assistance.

Lighting designers, luminaire makers and architects can use the Engineering Kit as a simple way of gaining insight into LED technology and testing different LED lighting solutions, says Osram. Different



reflectors, lenses and heat sinks can be combined to create variations and provide an idea of what the new light sources can achieve and what their special features are.

The kit contains the OSTAR LED, two reflectors from Fraen with medium and narrow beam angles, and three lenses from Ledil:

one with a wide angle, a spot lens and a cat's eye for side deflection. A thermal interface from Laird that provides optimum heat dissipation, two heat sinks (an aluminum plate and one from CoolerMaster) and an Osram Optotronic power supply for the European/Asian or NAFTA market round off the kit.

The kit demonstrates the options offered by LED light sources and indicates the accessories that are needed. "Our kit provides a quick and simple means of understanding the new LED technology," says LLFY network manager Sebastian Lyschick. "It can be used as the basis for developing projects and products with network partners."

www.ledlightforyou.com/led-kit

IN BRIEF

Zumtobel to sell Cree's recessed LED downlights throughout Europe

Cree Inc of Durham, NC, USA has announced a long-term strategic agreement to supply European versions of its recessed LED downlights to lighting provider Zumtobel Group of Dornbirn, Austria, to be sold exclusively under the Thorn and Zumtobel names in more than 40 countries throughout Europe and selected export markets. The minimum first-year sales target is 50,000 LR6-230V luminaires. This accelerates the firms' business relationship, which is expected to expand into other high-volume lighting categories in 2009.

"By integrating this innovative LED luminaire into our portfolio, we are securing a significant technological edge," says Zumtobel Group's CEO Andreas Ludwig. "LED technology is changing the industry, and they [Zumtobel] want to help lead the change," adds Cree's chairman & CEO Chuck Swoboda. "This strategic agreement is targeted to accelerate the LED lighting revolution across Europe by providing customers with energy-efficient and long-lasting products that save energy, save money and help protect the environment."

The LR6-230V consumes just 12W of power, while delivering light of equivalent output and color quality to a 75W incandescent lamp and lasting up to 50 times longer (more than 20 years in homes and 10 years in businesses under normal use). Compared to compact fluorescent (CFL) lamps, Cree claims that its downlight uses 50% less energy, lasts up to five times longer, and contains no mercury.

www.zumtobel.com
www.CreeLLS.com

Cree expands distribution network with Digi-Key and Premier Farnell

Cree has signed electronic component distributor Digi-Key Corp of Thief River Falls, MN, USA to distribute its high-performance LEDs. In 2007, Cree signed Digi-Key to distribute its energy-saving power components.

"The addition of Digi-Key widens Cree's ability to reach growth markets for our LEDs," says Mark Despotes, Cree VP of global channels. "Digi-Key has the expertise and the commitment to help accelerate the adoption of LEDs — including the fast-growing lighting-class and high-brightness markets."

Digi-Key president and COO Mark Larson said: "We're seeing increasing market demand for high-quality LEDs, and the Cree LED products are a key addition to our portfolio."

The global agreement covers Cree's LED portfolio, including the XLamp LEDs and the broad high-brightness portfolio, which includes round, oval, SMD and P4 LEDs. Cree's LEDs are available via Digi-Key's website and will be added to future print catalogs.

Cree has also signed a global distribution agreement for Premier Farnell plc of London, UK to distribute its full standard portfolio of

LEDs, including the latest technology solutions in the high-brightness and lighting-class XLamp families. These products will be distributed throughout Premier Farnell's global network of companies, Newark, Farnell, Premier Electronics and Farnell-Newark.

"Premier Farnell has an extensive global customer base, reaching those who are both designing and already using high-brightness LEDs, along with a reputation for excellent customer service," said Despotes. "Distributing our products through Premier Farnell is targeted to add tremendous value to our global network of customers to service the fast-growing LED markets."

Marianne Culver, head of global supplier management at Premier Farnell, said: "The addition of Cree's high-performance LEDs will significantly enhance our technology line card, and we are very excited about partnering with this forward-thinking manufacturer to provide new, innovative solutions for our customers, in the high-growth LED lighting market."

www.digikey.com

www.PremierFarnell.com

KIPT invalidates second Nichia patent

Korean LED maker Seoul Semiconductor Co Ltd says that the Korea Intellectual Property Tribunal (KIPT) has ruled that the LED-related patent KP 491482 owned by Japanese LED maker Nichia Corp is invalid, based on lack of inventiveness. This follows a ruling in July when KIPT invalidated Nichia's Korean patent 406201 for lack of novelty (see our September issue, page 44).

A year ago, in October 2007, Nichia brought a lawsuit against Seoul Semiconductor alleging infringement of the 491482 patent. Subsequently, this March, Seoul asked KIPT to examine its validity. Now, after extensive examination,

KIPT has determined that the patent lacks an inventive step and has therefore declared it invalid.

"Following another invalidation of Nichia's patents, which were asserted against Seoul, Seoul is in a stronger position and feels confident that we will prevail in all the patent infringement lawsuits pending against Nichia," says a spokesperson for the firm. "As a company which respects patent rights, we will continue to sincerely evaluate the valid scope of all patents relating to our products, and where necessary will not hesitate to verify the facts in patent disputes."

www.seoulsemicon.com

Cree's recessed down-lights win design competition

LED maker Cree has again won the top prize for recessed down-lights in the 2008 Lighting for Tomorrow solid-state lighting (SSL) competition (after its LR6 LED down-light won 2007's Lighting for Tomorrow grand prize). Organized by the American Lighting Association, the US Department of Energy (represented by Pacific Northwest National Laboratory) and the Consortium of Energy Efficiency, Cree says that the contest has now recognized its complete LED lighting family for their efficacy and design.

Cree's LR4 recessed architectural LED down-light won the top prize for LED recessed down-lights. Entrants in this category must meet the Department of Energy's solid-state lighting Energy Star criteria, which is due to go into effect later



Cree's LR4 recessed architectural LED down-lights.

this year. Selected from 56 entrants, the LR4 underwent independent laboratory testing, under the direction of the Department of Energy, as part of the award selection. The judges praised its "superior

energy efficiency and color quality".

Also, the Cree LR24, a 24-inch square recessed LED light, was honored for superior efficacy in the 'Other Applications' category, which is reserved for general illumination products not covered by Energy Star that exceed device efficacy of 50 lumens per watt. The LR24 (available this fall) is designed for use in suspended ceilings and features the same color rendering, long lifetime and best-in-class efficacy as other Cree LED lights.

Cree's LED lighting has previously won other awards, including a 2008 silver International Design Excellence Award (IDEA), a 2008 PCBC Cool Product designation, and BuildingGreen's Top 10 Green Building Products for 2007.

www.CreeLLS.com

Multi-chip XLamp MC-E LEDs become commercially available

Cree Inc of Durham, NC, USA has announced the commercial availability of its XLamp MC-E LED, which is the highest-lumen LED in its award-winning XLamp family.

The multi-chip MC-E retains the same 7mm x 9mm footprint as Cree's existing XLamp XR family LEDs while providing four times the light output of the XR-E, the highest lumen output commercially available for a package of this size. This combination is designed to enable new applications and reductions in overall system cost compared to other LED packages. At 9.8W, the MC-E provides up to 790 lumens at 6000K and up to 605 lumens at 3000K.

"The XLamp MC-E LED is a lighting-class solution for applications that require high lumen output in a small footprint," says Norbert Hiller, VP & general manager for lighting LEDs. "Imagine the design implications for something like a street light — if you could reduce the size by roughly 75% without compro-



Cree's multi-chip MC-E LED.

missing on lumen output," he adds. "Or consider the efficiencies that could be gained in an MR16 bulb application."

Cree says that the MC-E has already been designed into a number of products and applications, as customers can benefit from increased design flexibility and reduced overall system cost over other, lower flux-output LED packages, without compromising on quality.

www.cree.com/MCE

IN BRIEF

SDK establishes Taiwan LED sales subsidiary

Tokyo-based chemical manufacturer Showa Denko KK (SDK) has established a subsidiary Taiwan Showa Denko Electronics Co Ltd in Taipei, with capital of NT\$10m, to strengthen sales and customer support for its LED chips.

SDK says that demand for LED lamps is growing rapidly worldwide, reflecting progress in commercializing LED-containing products. In particular, due to their international price competitiveness, Taiwanese LED lamp makers are expanding their operations. Correspondingly, demand for SDK's LED chips is growing steadily in Taiwan for incorporation into LED lamps.

SDK says that the new Taiwan subsidiary will begin operations in November.

www.sdk.co.jp

Luminus' LEDs used in Samsung & LG portable projectors

Luminus Devices Inc of Billerica, MA, USA, which makes solid-state light sources for illumination applications (including high-definition TVs, video projectors, avionics displays, and lighting systems), says that its PhlatLight (Photonic Lattice) LEDs are powering two of the newest portable LED-based projectors: the Samsung P400 Pocket Imager and LG Electronics' HS-102 Ultra-Mobile Projector. Both are lamp-free, weigh less than 2 pounds and fit in the palm of a hand.

The PhlatLight PT54 LEDs used in both enable brightness to exceed 150 lumens, a breakthrough for pocket projectors, Luminus claims. Their pure RGB color produces a brighter, more vivid image than the ANSI brightness specs would suggest, yielding a picture that's easily viewable when projected to a 40 inch size even in a well lit office.

In addition to PhlatLight LEDs being free of hazardous materials such as mercury or lead, the projectors consume about one-third the power of comparable lamp-based projectors and produce an instant-on image at full brightness without the cost and inconvenience of lamp replacement. Both projectors were demonstrated at the Internationale Funkausstellung IFA 2008 consumer electronics trade fair in Berlin, Germany (29 August to 3 September). The Samsung P400 is now shipping in the USA.

"The HS-102 offers consumers superior picture quality for presentations, games or movies anywhere you want it thanks to the brightness and long-life of PhlatLight LEDs," said LG's marketing manager Sean Uhm.

Luminus began making patented PhlatLight LEDs for TVs in 2006. They are larger than conventional LEDs and are designed to operate at much higher intensity. The firm claims that they remain the only LEDs bright enough to replace arc lamps, and that projectors illuminated by PhlatLight LEDs produce more than 50% wider color gamut than the NTSC standard.

Also at IFA was a new prototype home theater projector from DLP projector maker Delta Electronics, demonstrating a collaboration that has brought together Luminus' PhlatLight LEDs with the technology of Texas Instruments (TI) DLP Products to yield high-quality, long-lasting solid-state illumination for mainstream projection applications.

Luminus and TI have been working together to increase brightness in LED-based DLP projectors by creating brighter and more efficient PhlatLight LEDs and through improvements in the DLP processing algorithms, enabling projection manufacturers such as Delta to introduce DLP home theater projectors later this year. Future developments should lead to the launch of lamp-free projectors for corporate and education markets.

Luminus says that PhlatLight LED performance and reliability has been proven with hundreds of thousands of DLP TVs and ultra-portable projectors shipped over the last several years. Increased brightness should allow manufacturers to create lamp-free projectors delivering much improved picture quality, superior reliability, convenience and environmental friendliness by eliminating the need for lamp replacement, adds the firm.

"These projectors can produce outstanding images with far superior contrast and deeper blacks than lamp-based projectors," says Christian Hoepfner, Luminus' VP of products. "PhlatLight LEDs give DLP projectors a pure RGB light source, producing vivid, accurate, stable color images that will not shift or fade over time."

"Delta engineers recognized very early the reliability, value and astounding performance of this new platform," said Kirk Chang, the firm's manager of technology development. Delta adds that it is expanding the use of PhlatLight LEDs across its DLP product range to further grow its projector business.

Ellen Richstone joins Luminus as executive VP & CFO

Ellen Richstone has joined Luminus Devices as executive VP & chief financial officer, with responsibility for implementing and managing worldwide finance, administrative, human resources, legal and IT operations.

Prior to Luminus, Richstone was CFO at Sonus Networks Inc of Chelmsford, MA. Previously, she was president & CEO of Entrepreneurial Resources Group, a global professional services firm. Richstone also served as CFO & senior VP, finance and administration at Brooks Automation of Chelmsford, MA, a hardware and software provider to the semiconductor industry.

Luminus develops solid state light sources for a variety of lighting applications, including high-definition TVs, video projectors, avionics displays, as well as illumination systems for entertainment, architectural, medical, and industrial purposes. Its patented PhlatLight LEDs are the brightest and most versatile solid-state light sources available, claims the firm.

"I am delighted to join Luminus Devices as the company enters its next stage of growth," said Richstone. "I look forward to working with our customers, investors, and executive management team, and being part of the company's long-term success."

In addition, Richstone currently serves on the board of directors at Blue Shift Technologies and is the non-executive chairman of the Entrepreneurial Resources Group. She also served on the board of American Power Conversion as that firm's SEC Financial Expert.

www.luminus.com

IMEC and Nippon Sanso collaborate on green LED manufacturing

Nanoelectronics research institute IMEC of Leuven, Belgium and industrial gas manufacturer Taiyo Nippon Sanso Corp (TNSC) of Osaka, Japan have agreed to jointly develop manufacturing technology for indium gallium nitride (InGaN) high-efficiency green LEDs based on IMEC's compound semiconductor device technology. The majority of the research will be conducted at IMEC, where the development will build on IMEC's expertise in strain engineering on large-diameter wafer as well as in-situ growth monitoring.

The collaboration with Taiyo Nippon Sanso, which supplies metal-organic materials, gas supply, purification and abatement systems as well as MOCVD tools, enables IMEC to

accelerate the development of high-efficiency green LED manufacturing technology, says IMEC's president & CEO professor Gilbert Declerk. IMEC stresses that there is increasing demand to develop brighter green LEDs for future applications such as back-lights for high-definition LCD TV.

The agreement marks the first time that Taiyo Nippon Sanso has collaborated with a research center based in Europe. "This relationship with IMEC will enable Taiyo Nippon Sanso to position itself as a leading MOCVD tool maker in the LED compound semiconductor market," reckons TNSC's senior managing director Mike Hara.

www.tn-sanso.co.jp/en
www2.imec.be

Opnext launches 640nm/60mW red laser, targeting miniature displays

Optical module and component maker Opnext Inc of Eatontown, NJ, USA has launched what it claims is the first 640nm/60mW red laser diode, accelerating the firm's entry into the miniature display market. The new HL6387TG can be built into miniature display systems, including those in personal computers, mobile phones and other mobile devices.

Tadayuki Kanno, Opnext's senior VP, Device Business Unit, claims that the new laser can provide better color reproducibility on a cell phone or other portable device, helping to meet consumer demand for new applications in the miniature display market.

The single-longitudinal-mode laser allows continuous operation at a power output of 60mW in the 640nm wavelength band. Its reliability remains high despite the HL6387TG's small (3.8mm) package. The output power also remains constant despite a



Opnext's HL6387TG 640nm/60mW red laser diode.

decrease in the ratio of the stem area by 50%. The wavelength band of the red area is 642nm, which is optimal for red light display.

The single longitudinal mode also enables higher resolution of the displayed images by focusing the laser light into a small spot, says the firm.

www.opnext.com

IN BRIEF

Everlight ships high-power LEDs for micro-projectors

Taiwan-based LED packaging firm Everlight Electronic Co Ltd has started shipping high-power LED orders to be used in micro-projectors, according to Digitimes. Although initial order volumes are limited, Everlight is the first firm in Taiwan to enter the market for micro-projectors.

Micro-projectors are a newly developed product and most vendors are still using LEDs from worldwide first-tier makers such as Philips, Lumileds or Osram. Everlight is the first Taiwan-based LED maker to provide high-power LEDs to micro-projector vendors.

Everlight indicates that micro-projectors require better color saturation, hence RGB LEDs will be used as the light source. Initial monthly shipment estimates are for about 10,000 units, but orders are expected to grow as the market for micro-projectors matures in 2009.

Industry players estimated that the market for micro-projectors and micro-projectors built into handsets may reach 2.34 million units in 2010. However, Taiwan-based Lite-On Technology remains conservative about the new market, noting that LEDs typically deliver only one-sixth the brightness of alternative projector light sources. Lite-On said it believes the growth of the micro-projector market is limited and it is not considering joining the market at this time.

Optoma introduced its first micro-projector using DLP technology from Texas Instruments (TI) and LEDs as the backlight source. The device is able to project a 20-inch diagonal image from a distance of 50cm. This product is expected to start shipping in October.

www.everlight.com

IN BRIEF

Advanced Photonix raises credit facility

Advanced Photonix Inc of Ann Arbor, MI, USA, a vertically integrated manufacturer of silicon, InP- and GaAs-based photodetectors, subsystems, and terahertz instrumentation, has established a new credit facility with The PrivateBank and Trust Company of Chicago, IL. As part of this new banking relationship, it has repaid the short-term note and line of credit previously held by Fifth Third Bankcorp Trust.

The new credit facility consists of a four-year-term note of \$1.8m at prime plus 1%, and a three-year \$3m revolving line of credit at prime plus 1%.

"We have replaced our previous one-year line of credit with one that extends for three years and increases the available credit to the company from \$2.5m to \$3m," says president & CEO Richard Kurtz.

"Given the current state of the financial industry, having close proximity to banking partners is important in our rapidly changing business environment."

www.advancedphotonix.com

Intense's 630–690nm laser driver systems receive CE mark approval

Laser manufacturer Intense Ltd of Glasgow, UK has received CE mark approval for its Series 7400 laser drivers, which are turnkey systems designed to provide current control and temperature compensation of the firm's high-power, free-space or fibered visible laser components.

Unlike traditional laser drivers, they are complete, integrated systems that include current driver, temperature controller, as well as a choice of high-power red laser diodes with wavelengths of 630–690nm and power levels up to 4W.

Series 7400 systems are designed specifically for medical research applications in rapidly growing areas of photo-dynamic therapy (PDT) and low-level laser therapy (LLLT).

"Obtaining the CE mark was in direct response to EU customer demand for high-brightness, high-power, 'ultra-red' devices," says Kevin Laughlin, VP HPL global business development. "CE mark approval now clears the way for use of these systems by leading research institutes, hospitals, and medical OEMs throughout the EU," he adds. Standard systems are available in turnkey configurations. OEMs can also integrate subassembly modules



Series 7400 laser driver system.

into their own medical systems.

Series 7400 systems are available in three versions: the 7401 portable, turnkey laser driver system; the 7403 OEM ruggedized version for easy integration into the front panel of OEM medical systems; and the smaller 7404 system (weighing only 5 pounds) with its own front-panel controls (allowing easy adjustment of power and temperature).

Both the 7401 and 7403 can be fitted with an optional in-line power monitor and integrating sphere. All units offer timers and closed-loop constant power control features. The systems can be fitted for a variety of industry-standard fiber connection options on the front panel. Custom power levels and wavelengths are available on request.

www.intenseco.com

Intense appoints VP global product & market development

Intense Ltd of Glasgow, UK, a provider of single- and multi-mode monolithic laser array products and high-power laser diodes, has appointed Dr Berthold Schmidt as VP global product & market development, to spearhead the firm's drive into new products and market areas globally.

Over the last 10 years, Schmidt has held senior management positions at JDS Uniphase and Nortel Networks and joins Intense from Bookham (Switzerland) AG, where he was on the executive board. Schmidt received his PhD from the Technical University at Munich,

Germany and an MSc degree from the State University of New York. He also holds a Bachelor's degree in business administration from GSBA in Switzerland.

"Intense has experienced considerable growth over the past three years underpinned by its core QWI technology and its wide product range serving the print, industrial, defense and medical markets," says CEO Scott Christie. "As our



Berthold Schmidt.

technology continues to develop and we increase our rate of new product introductions, Berthold will bring great experience to the team, ensuring we focus all of our resources to maximize return for both our customers and our shareholders."

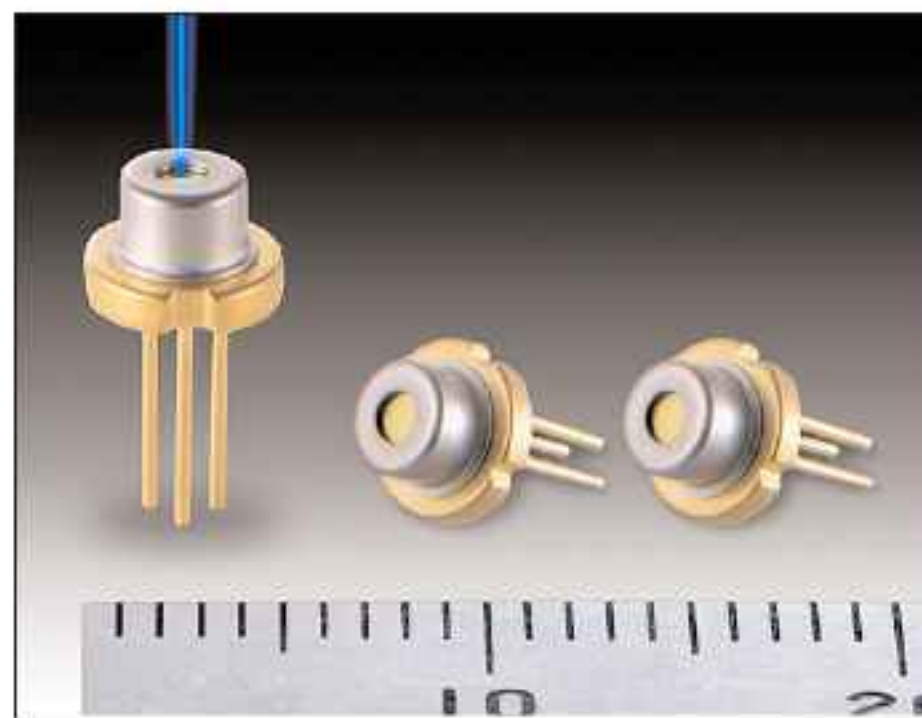
Intense is at an important stage in its growth, says Schmidt. "Intense's robust diode laser technology combined with device integration and volume manufacturing capabilities, puts us in a unique position to offer high-quality laser diodes and integrated solutions."

Sanyo develops record 450mW blue-violet laser for 12x writing

Japan's Sanyo Electric Co Ltd has developed a blue-violet (405nm-wavelength) laser diode that can deliver what is claimed to be a record maximum optical output of 450mW under pulsed operation for Blu-ray Disc products (about double the power of Sanyo's current highest-power Blu-ray laser). Under continuous operation, the output is 200mW and the operating current is 200mA.

Compared to the current maximum recording speed of six times faster than real time (6x) on dual-layer Blu-ray Discs (with a data capacity of 25GB per layer), the new laser is powerful enough to write at 12x speed on four-layer discs. As well as doubling total capacity to 100GB, this would allow copying of either 8 hours of SD (standard-definition) or 2 hours of HD (high-definition) film in just 10 minutes.

Sanyo says that, to increase the laser's optical output, it has made three major improvements. First, improved material and a new 'LASTECT' (Low optical Absorption



Sanyo's 5.6mm-diameter 450mW 405nm Blu-ray laser diode.

Structure by Endurable Coating Technology) structure has reduced the amount of light absorbed by the end-face protective film (which acts as a mirror). So, about 95% of the light is passed through the multi-layer front end face and stability is increased. Operation for 1000 hours at 80°C has been confirmed (a criterion for practical use). With the existing end-face structure, the device would fail in about 500 hours, says Sanyo.

Second, to increase the optical conversion efficiency, Sanyo

reduced the loss from light absorption in the optical waveguide's cladding layer by more than halving the amount of impurities incorporated during layer growth, boosting optical output by 10%.

Third, to ensure a more stable beam position and optical output, Sanyo says that it used simulations to optimize the shape of the waveguide and also improved the precision of the dry etching technique used to form the structure. The new laser has beam divergence angles of 8.5° and 19° in the horizontal and vertical directions, respectively.

The laser also has a compact size, with a diameter of just 5.6mm. The Blu-ray Disc Association has not yet standardized 12x recording or four-layer Blu-ray Disc systems, but Sanyo says that it will continue development and optimization of the laser, targeting mass production in the next 2-3 years (when the new drives and media to match the laser are expected to become available).

www.sanyo.co.jp

First high-power surface-emitting eye-safe laser demoed

QPC Lasers Inc of Los Angeles suburb Sylmar, CA, USA, which makes high-power lasers for consumer, industrial, defense and medical markets, has completed its initial Department of Defense contract to develop and deliver high-power eye-safe surface-emitting diode pumps for directed-energy weapons applications. The firm has been invited to submit a proposal for a much larger follow-on contract.

QPC claims to be the first firm to demonstrate such technology, which marries a unique surface-emitting laser design with capabilities in high-power long-wavelength 'eye-safe' diode arrays.

"Battlefield lasers using conventional diode pump technologies are prohibitively expensive and present hazards to the eyes of friendly personnel, severely limiting their utility," says co-founder & CEO Dr Jeffrey Ungar. QPC says the development is key to the future of DoD high-energy laser applications since the technology enables fabrication to be wafer-based and extremely cost effective. "QPC's demonstration points the way to a new generation of laser weaponry which combines the low cost of 'wafer-scale' manufacturing with beams that are 100,000-1,000,000 times less hazardous to our soldiers," Ungar adds. "Besides directed-

energy weapons, these chip-based lasers have great promise for other defense applications, including range-finding, covert/active illumination for surveillance, and remote sensing."

Beyond these military applications, QPC is already shipping eye-safe-wavelength lasers to medical customers for dermatological and vein treatment applications. The firm also sees great promise for eye-safe lasers in commercial applications such as welding and cutting by eliminating the safety concerns and costs associated with industrial lasers such as YAG and fiber lasers.

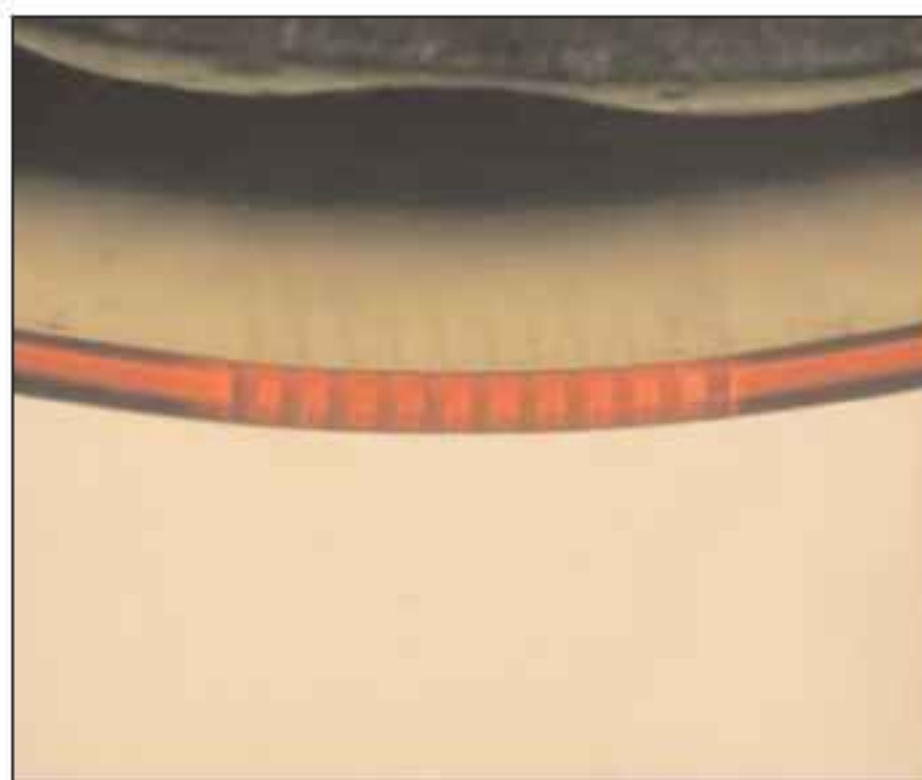
www.qpclasers.com

Functional optical links embedded in flexible substrates

Nanoelectronics research center IMEC of Leuven, Belgium says that INTEC, its associated laboratory at Ghent University, has made the first functional optical links embedded in a flexible substrate. The links include optical waveguides, light sources, and detectors. The technique makes it possible to fabricate foils that sense changes in pressure. Such skin-like foils could be used for monitoring irregular or moving surfaces, for example in robots, pliable machinery, or as an artificial skin.

Integrated optical interconnections have the advantage that they are insensitive to electromagnetic interference, applicable in harsh environments, and highly sensitive. Already, last year, IMEC reported embedded optical links on rigid surfaces. The current research takes optoelectronics a step further.

Standard, commercially available gallium arsenide photodetectors and VCSELs (vertical-cavity surface-emitting laser) are thinned down to 30 microns. Next, they are embedded into a flexible foil of optically transparent material and optically coupled with embedded waveguides and out-of-plane micro-mirrors. The resulting structure shows good adhesion and flexible behavior, IMEC claims.



Optical foil, bent with radius of curvature of 1cm.

Using this technology, IMEC is working on two types of sensors: array waveguide sensors and optical-fiber sensors. Both can be used for sensor foils.

Array waveguide sensors rely on the change in coupling between arrays of crossing waveguides. Two layers of polymer waveguides are separated by a thin layer of soft silicone. When no pressure is applied, no crosstalk is detected. But when pressure is applied to the foil, the distance between the waveguides in the separated layers decreases and light is transmitted from one layer to the other.

IMEC says that the low-cost sensor is suited to use in high-density pressure sensors on small areas.

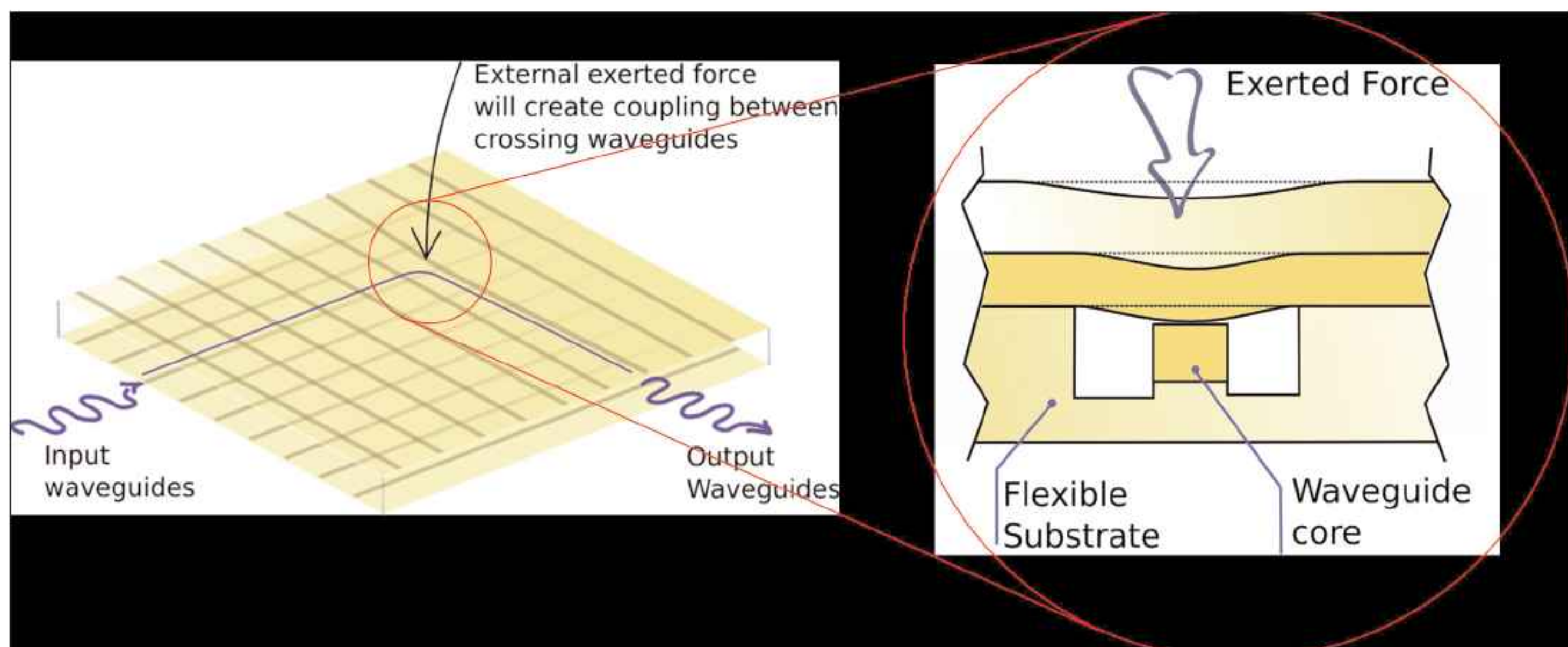
Optical sensing foils combine two technologies that have lately seen growing interest: integrated optical interconnections and flexible, stretchable electronics. The aim of researchers is to create a flexible and stretchable skin-like foil sensitive to touch, pressure, or deformation. Such artificial skin could be used in medical and industrial environments.

To this end, a group of European research institutes, including IMEC, are collaborating in the three-year 7th Framework project PHOSFOS (Photonic Skins For Optical Sensing), which started in April and aims to develop photonic foils based on optical-fiber sensors.

These foils are targeted at applications in civil engineering and medicine. They will, for example, continuously monitor the integrity and behavior of buildings, dams, bridges, roads, or tunnels. Other uses include monitoring aircraft wings, helicopter blades, or wind-mill blades. They will enable early warning of failure or anomaly.

Skin-like PHOSFOS membranes can also be used in long-term monitoring of respiration and cardiac activity, as well as the detection of pressure points under bed-ridden patients, says IMEC.

www.imec.be



Crossing waveguides: principle of the array waveguide sensor.

IQE joins European-funded VISIT program

Epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK has become a member of the €3.5m European program 'Vertically Integrated Systems for Information Transfer' (VISIT). Funded under the EU's Seventh Framework Program (FP7), VISIT lasts up to three years (from June 2008) and focuses on developing strategic, high-value photonic components and subsystems for scalable economic broadband access and local-area networks.

Demand for media-rich content and high-definition video services is increasing consumer bandwidth requirements by over 30% per annum, which in turn is expected to drive a compound annual growth rate (CAGR) for the optical component market of more than 12%, according to industry forecasts. The central objective is research on, development, test and exploitation of system-enabling optical transmitters with a completely novel

design and/or largely improved functionality compared to current technology.

Other members of the VISIT program (which is coordinated by Technische Universitaet Berlin) include the University College Cork as well as Intel Performance Learning Solutions Ltd in Ireland, VI Systems GmbH in Germany, Chalmers Tekniska Hoegskola AB in Sweden, the University of Cambridge in the UK, and the Ioffe Physico-Technical Institute of the Russian Academy of Sciences.

Epitaxial growth of the structures, processing and design of high-frequency modules is challenging and demands detailed modelling. "The unique ability of IQE to supply material developed both by MBE and MOCVD technologies will further strengthen our project," says professor Dieter Bimberg of Technische Universitaet Berlin.

"IQE brings a wealth of experience in the growth of both edge-emitting

lasers and VCSELs [vertical-cavity surface-emitting lasers] for optical communications networks," claims Andrew Joel, product director for Optoelectronic Materials at IQE's Cardiff facility.

"The materials will operate at a range of wavelengths, including 850nm (local-area networks and storage-area networks), 980nm (very short links) and 1.3µm (local-area networks and access networks)."

Upon completion of the program, a full supply chain from production of epitaxial wafers to test beds for measurements and prototype systems should be established. "The economic impact of this work will be systematically enhanced by contributing directly to international standardization activities and roadmaps of this area," adds Bimberg.

www.visit.tu-berlin.de/v-menue/projekt_visit
www.iqep.com

Quantum dot laser manufacturer Innolume receives Frost & Sullivan Award for Innovation of the Year

At the 2008 Growth Excellence Awards Banquet on 16 September in San Francisco, CA, Innolume received the 2008 North American Technology Innovation of the Year Award from market research and consulting firm Frost & Sullivan.

Innolume was originally spun-out of the Ioffe Physico-Technical Institute in St Petersburg, Russia, and now has a fabrication plant in Dortmund, Germany and a marketing/testing office in Santa Clara, CA for laser chips and modules targeted at medical, industrial, communications and computer markets.

"Innolume's unique laser technology is based on quantum dots (QDs), which provide a wide operational spectrum covering 1064–1310nm as well as broad optical gain," says Frost & Sullivan research analyst Avinash Bhaskar. "The company's

technological innovation promises inexpensive yet highly efficient light sources for emerging applications, including silicon photonics for optical interconnect systems and lasers for niche medical applications such as optical coherence tomography (OCT)."

Each year the Frost & Sullivan Award for Product Innovation is presented to the company that has demonstrated excellence in new products and technologies within its industry. Frost & Sullivan's analysts track all new product launches, R&D spending, products in development, and new product features and modifications. Product criteria include significance, competitive advantage, innovation, acceptance, value-added services, and number of competitors with similar product(s).

Innolume says that the award comes at a technological tipping point for the firm. In March, it launched a unique QD comb laser (InnoComb), a single Fabry-Perot semiconductor laser that emits many wavelengths, each of which can be modulated at high speed and combined into an optical fiber or silicon photonic network. Innolume claims that the comb laser is an enabler for future computer optical interconnects, allowing the low-cost migration of telecom wavelength-division multiplexing (WDM) technology into the computer. For the first time, a comb diode laser is making WDM a practical option for short-reach signaling in commodity computer applications.

www.awards.frost.com
www.innolume.com

3S launches 750mW 980nm terrestrial pump laser module for next-generation EDFAs and fiber-laser applications

At the European Conference and Exhibition on Optical Communication, telecom laser chip and module maker 3S Photonics of Nozay, France said it is sampling what it claims is the most powerful pump module available on the market, an enhanced version of the 1999 CHP series (its most powerful 980nm pump module series for terrestrial applications).

Key features include:

- maximum operating drive current of 1050mA for an operating power of 680mW;
- low-profile hermetically sealed 14-pin butterfly package with polarization-maintaining fiber (PMF) or standard single-mode fiber (SMF) pigtail;
- fiber Bragg grating (FBG) stabilization;
- multiple wavelength availability;
- an integrated thermo-electric cooler (TEC), precision NTC thermistor, and back-facet monitor photodiode;
- high polarization extinction ratio (PER);



- fully qualified in accordance with Telcordia GR-468-CORE specifications.

By delivering kink-free fiber-coupled output power of 750mW (from -5°C to $+75^{\circ}\text{C}$), the cooled 1999 CHP 980nm pump laser module forms a cornerstone for next-generation erbium-doped fiber amplifiers (EDFAs), says the firm. "This new 980nm terrestrial pump is obviously powered by our in-house chip technology, which has been fully qualified for submarine applications, ensuring an unparalleled level of performance and reliability," explains Yannick Bailly, VP of marketing. The new ultra-high output

power pump incorporates 3S' 1999 LCv2 laser chip, which is designed and produced internally and is fully qualified for submarine applications (thus exceeding Telcordia recommendations).

Also, for not just the 750mW model but all 3S' 1999 CHP 980nm cooled terrestrial pump laser modules (350–750mW), the low-profile hermetically sealed 14-pin butterfly package is offered with not only the existing polarization-maintaining fiber (PMF) pigtail but now also a standard single-mode fiber (SMF) pigtail. "This new feature has been developed to support our customers, making their life easier, by allowing them to easily splice our pumps to the WDM couplers with very low insertion losses," says Bailly.

Applications of the new product include low-noise EDFAs, next-generation dense wavelength division multiplexing (DWDM) EDFAs, cable TV (CATV) applications and fiber-laser systems.

www.3Sphotonics.com

Smaller, higher-efficiency pump doubles power for FTTH

JDSU of Milpitas, CA, USA has launched the 4900 Series pump laser, which provides twice the power, improved efficiency and a package that is 70% smaller than the firm's previous pump laser platform (freeing up valuable data-center real estate), for deployment in fiber-to-the-home (FTTH) networks.

According to a Fiber-To-the-Home Council study released in September, the annual growth rate for FTTH deployments in North America is 76%, the highest of any country or region in the world. The total number of North American subscribers that have chosen FTTH networks as their technology of choice for receiving high-bandwidth Internet and video services now stands at 3.76 million.

JDSU pump lasers power optical amplifiers that enable high-definition

TV (HDTV), internet, phone, and video-on-demand FTTH services between a service provider's central office and consumers' homes. The pump laser increases an optical amplifier's signal power so that it can split a signal to travel over multiple fibers and reach the maximum number of homes, helping to decrease signal generation costs for network equipment manufacturers (NEMs) and service providers.

Based on JDSU's telecom-grade L4 diode laser platform (released in December 2007), the 4900 Series doubles laser pump power from 4W to 8W, allowing NEMs and service providers to replace two pump lasers with a single pump laser within optical amplifiers for FTTH deployments. It is also designed to improve pump laser efficiency by

20%, reducing customers' power and cooling requirements.

"We have leveraged our innovative diode laser technology to create a much more powerful and efficient pump," says Toby Strite, marketing director of High Power Lasers in JDSU's Optical Communications business segment. "With twice the power, our customers can service twice as many homes from the same amplifier, helping them to control costs as voice, video and on-demand services continue to grow in popularity among consumers."

Previous generations of JDSU's FTTH pump laser have accumulated more than 150 million field deployment hours, with an accumulated figure rate below 250 Failures in Time (FIT).

www.jdsu.com

Santur gives live demo of InP-based 100Gb/s PIC technology

At September's European Conference on Optical Communications, integrated photonic device maker Santur Corp of Fremont, CA, USA gave a live demonstration of 100Gb/s transmitters and receivers based on indium phosphide (InP) laser and detector arrays.

The devices are based on a transmitter that integrates a distributed feedback (DFB) laser array with a matched planar lightwave circuit (PLC) multiplexer, and a receiver that integrates a photodiode array with a matched PLC demultiplexer. The high level of integration eliminates the need for multiple single-channel discrete devices and fiber couplings found in traditional photonic components. Santur says that, unlike parallel 10x10Gb/s technologies based on ribbons of multi-mode fiber (MMF), its transmitters and receivers operate over one conventional single-mode fiber (SMF) with longer reach. Compared to other 100Gb/s SMF optic links,

the technology being demonstrated does not require complex modulation schemes or gearbox ICs for conversion to intermediate 25Gb/s lanes.

Santur says that, as a result of its focus on integrated InP devices, there are currently nearly 200,000 of its tunable lasers based on integrated laser arrays deployed in long-haul and metro networks around the world. The firm adds that its ability to make low-cost devices in array form has allowed it to develop a robust photonic integrated circuit (PIC) platform that delivers from 40Gb/s to 400Gb/s, and that such devices deliver the value of photonic integration (including increased density, lower cost, reduced power consumption and enhanced reliability) to system integrators.

Based on 10 electrical lanes operating at 10.3Gb/s, the live demonstration showcased wavelength division multiplexing (WDM) transmission of 100Gb/s protocol compli-

ant data streams over up to 10km of SMF. The technology simplifies the upgrade of 10Gb/s channels in access networks, enterprise core networks, and addresses fiber exhaustion in data centers, Santur says.

"The economics of integrating multiple optical devices onto a single chip gives us very significant opportunities to continue to drive performance while keeping cost down," says chief technology officer Bardia Pezeshki. "This solution is optimized to address the near-term need for higher data rates for a wide variety of high-growth applications."

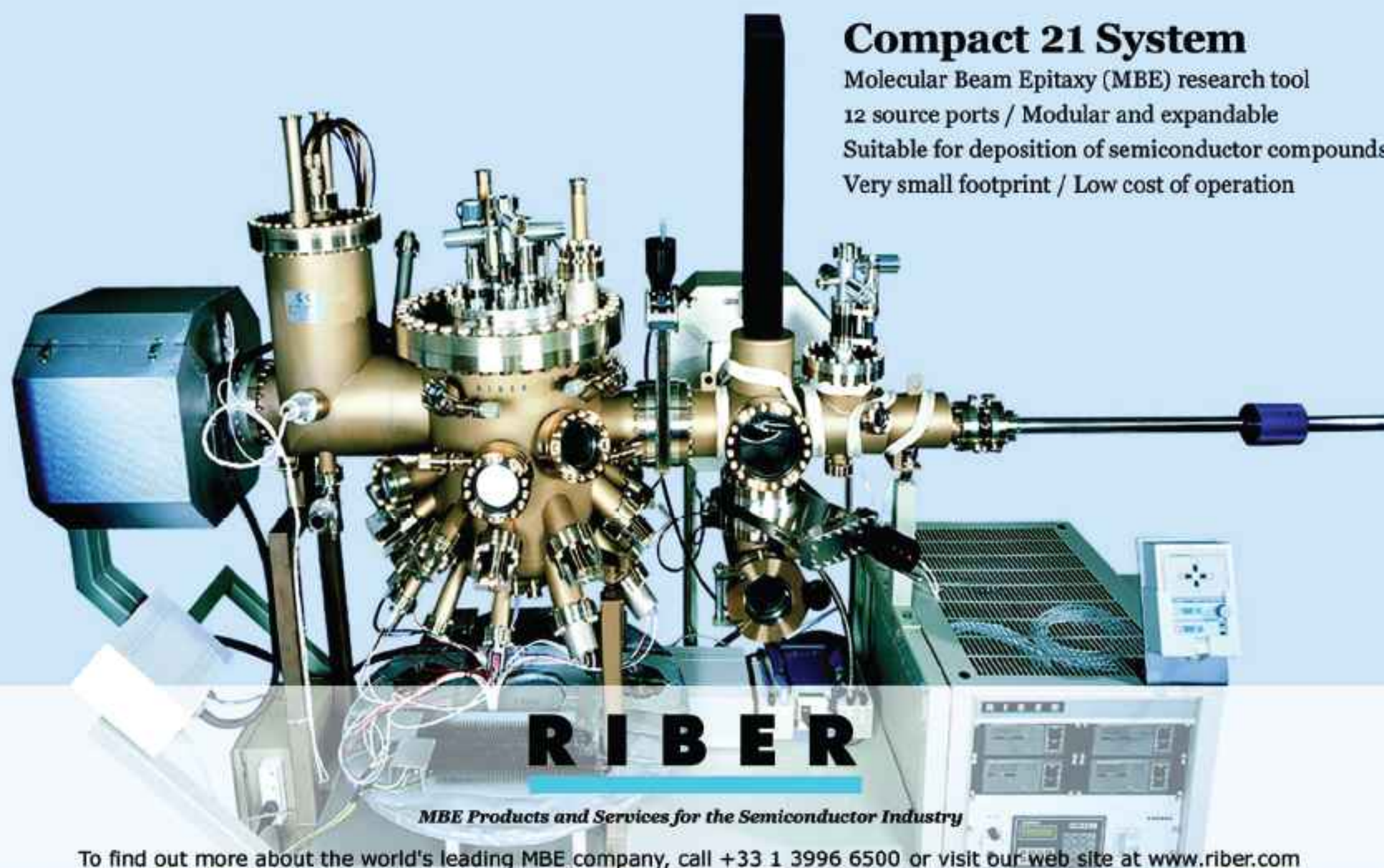
In addition to the live demonstration of 100Gb/s PIC technology, Santur is showcasing its broad portfolio of solutions including narrow-linewidth tunable laser solutions for 40Gb/s and 100Gb/s networks and highly integrated low-profile tunable transmitters.

www.santurcorp.com

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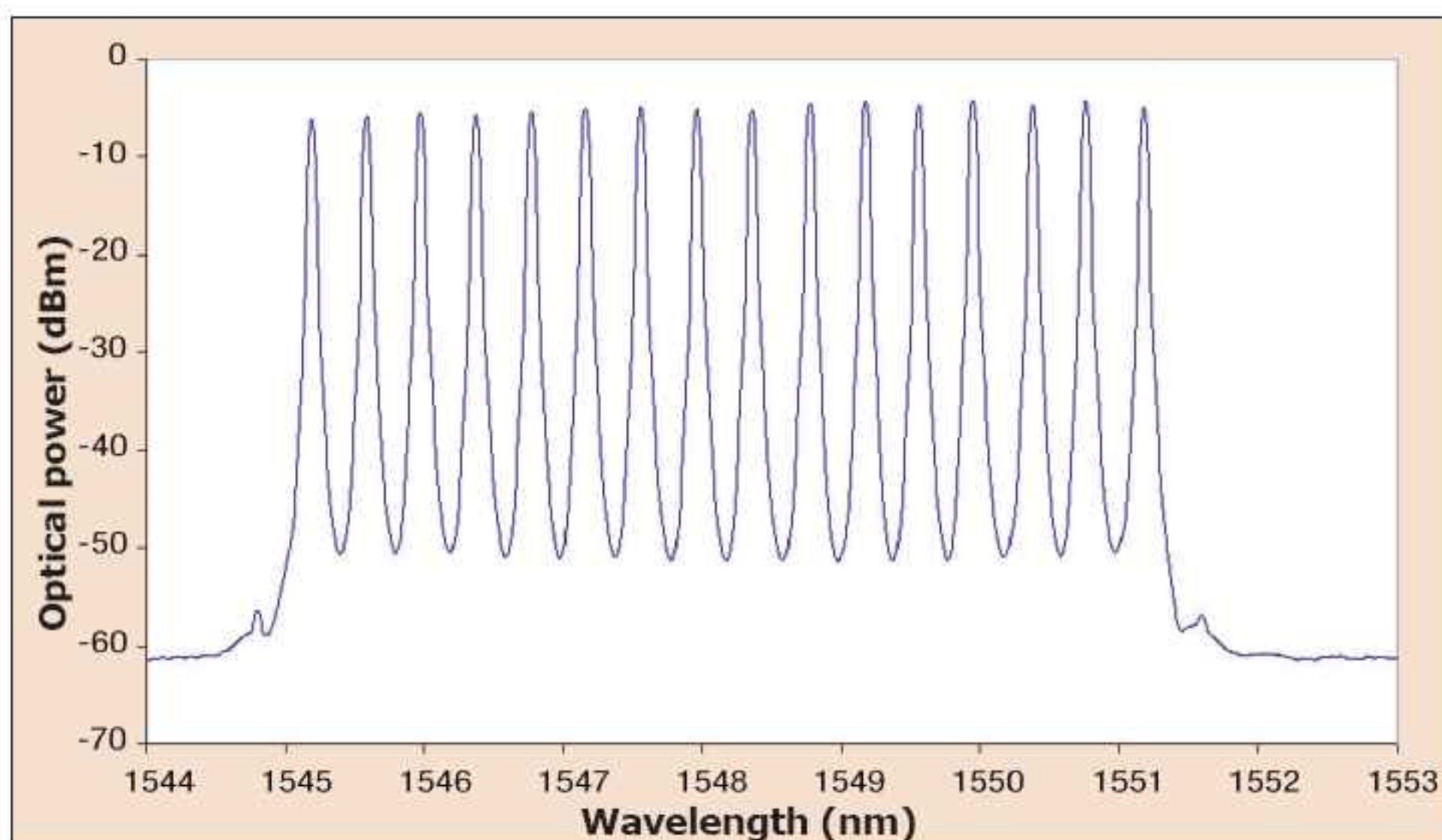
CIP launches hybrid photonic integrated circuit platform

At September's European Conference and Exhibition on Optical Communications, CIP Technologies of Martlesham Heath, Ipswich, UK launched its HyBoard hybrid photonic integrated circuit (PIC) platform with a live demonstration of its flexibility via a proof-of-concept multi-channel dense wavelength division multiplexing (DWDM) laser module producing 16 independent wavelengths on a 50GHz grid.

HyBoard brings together three main elements: indium phosphide active/passive optoelectronic device arrays, single-mode planar silica waveguides, and micromachined silica submounts. These are cost-effectively combined, as required, to create a hybrid integrated PIC with low optical losses. HyBoard can also be extended to accommodate optical isolators, thin-film filters and polarization elements, as well as customizable channel spacings and a wide range of different active/passive component arrays, including tunables.

The prototype multi-wavelength laser source being demonstrated incorporates multiple InP optoelectronic device arrays aligned to silica planar waveguides and other passive optical elements, including an arrayed waveguide grating (AWG) on the optical motherboard. The 16 lasers within the multi-wavelength source can each provide >0dBm output power and are individually addressable to enable channel power control and switching. The particular module, aimed at WDM-PON (passive optical network) headends and metro WDM, is one variant of a range of compact, cost-effective hybrid integrated designs now available to system integrators.

CIP says that the hybrid integration platform enables systems integrators to offer high-performance, highly functional, custom PICs at telecoms production volumes and competitive cost points, and provides assembly and form factor advantages over traditional multiple gold box solutions, as well as delivering a degree of



Optical spectrum of a 16-channel, 50GHz-spaced multi-wavelength laser.

flexibility, performance and functionality that is not possible with full monolithic integration.

"The HyBoard price point and value proposition offers a route for systems integrators to gain access to sophisticated integrated photonics technology and start addressing the growing gap between traffic growth and revenue," claims chief technology officer David Smith. "CIP has developed a range of building blocks including semiconductor optical amplifier (SOA) arrays, lasers and modulators, all designed to integrate within the HyBoard platform, providing a new and highly versatile capability to the system designer in core, metro and access applications."

HyBoard is designed for volume manufacture and can deliver bespoke, scalable and cost-effective PICs, optimized to the end-user's requirements at realistic yields, as well as permitting a wide range of integrated optical functionality, says

HyBoard provides the advantages of reduced assembly cost and footprint reduction over discretes but without the yield and performance challenges of full monolithic integration

Graeme Maxwell, VP of hybrid integration. "HyBoard provides the advantages of reduced assembly cost and footprint reduction over discretes but without the yield and performance challenges of full monolithic integration," he adds. This offers all systems integrators a proven and available route to develop and deliver sophisticated custom PICs that are complementary to their own architectures.

"Recent consolidations and joint venture announcements within the optical components industry show that hybrid integration is being taken seriously as a route to next-generation integrated photonic modules," Maxwell continues. "Both the markets and the systems integrators recognize the advantages of photonic integration, but are agnostic about what type of integration is used, as long as the device meets performance and price targets. HyBoard leverages our long experience of research, process development and manufacturing, and our extensive IPR portfolio to deliver a customizable, scalable and cost-effective offering to the telecoms industry for customer-driven commercial applications."

CIP says that it is already working with commercial customers to realise integrated, bespoke and application-specific modules.

www.ciphotonics.com

JDSU unveils first photonic integrated amplifier platform

JDSU of Milpitas, CA, USA has used erbium-doped fiber amplifier (EDFA) capabilities, combined with planar lightwave circuit (PLC) technology, 980nm pump lasers and optical component technology, to develop the first photonic integrated amplifier (PIA) platform, which can replace up to 50 discrete components with a single chip and be up to 50% smaller than current solutions.

JDSU claims the new PIA platform is the first reconfigurable amplifier solution for a variety of functions, enabling network equipment manufacturers (NEMs) to use it either as a booster at transmit locations, as a pre-amplifier at receiver sites, or as an in-line amplifier in between locations that transmit and receive optical signals within a network.

The PIA platform's smaller size will allow NEMs to put more functionality

into a single network element, saving real estate, reckons JDSU. Having an interchangeable product should also simplify product sparing, ordering, and tracking previously required to support different network amplification needs. The PIA can also be used as a critical building block for the AON Super Transport Blade, JDSU's all-in-one single-slot blade solution for optical transport.

JDSU reckons that the improved functionality of the PIA platform will extend the reach of transponder technology 15–35% further than current amplifier solutions, cutting the amount of costly regenerators needed to sustain optical signals as they travel throughout a network.

"Integration has long been touted as a possible path to lower costs in optical communications, but most resulting products have fulfilled either

technology or performance needs," says Daryl Inniss of market research firm Ovum. "The JDSU PIA platform appears to be based on applying integration to lower the cost of amplifiers, along with providing higher performance and flexibility," he adds.

"The basic technology for optical amplifiers hadn't changed significantly over the past decade," says Jy Bhardwaj, VP & general manager of Agile Optical Networks in JDSU's Optical Communications business. "JDSU has leveraged its functional integration approach at the photonic level to create the new PIA platform," he adds. "It opens the door for JDSU and its customers to think of new ways to apply the solution and add even more functionality."

The PIA platform is being sampled, and should be available in 2009.

www.jdsu.com

Newly developed features contribute to performance of platform

JDSU has created several features contributing to the PIA platform's reduced size, improved cost savings, increased performance and reconfigurability. "Network equipment makers have been asking for more flexible, low-cost and higher-performing solutions to optimize their networks," says Bhardwaj. "We've had to break down traditional ways of building amplifiers that have resulted in these six new technology breakthroughs."

JDSU says the new features will contribute to performance unavailable in existing optical amplifiers:

- A new optical isolator component, can reduce the number of discrete isolator components from as many as six down to a single component. Isolators are key discrete components that prevent light signals from reflecting back within an optical amplifier and causing damage or disturbing the quality of transmission signals in DWDM networks. To achieve high performance, JDSU will edge mount the isolator onto the PLC chip within the PIA platform

so that it can function seamlessly with the integrated optical amplifier elements on the chip. This should improve performance, as light signals will no longer need to travel on and off chip through separate and discrete isolators, which weakens the transmission signal's strength.

- New waveguide technology has been demonstrated that simplifies routing, splitting and recombining of light signals within the platform. Together with the new isolator, this should provide light management capability previously unavailable in optical amplifiers, JDSU reckons.

The waveguide technology allows both 980 and 1550nm wavelengths to combine and travel through a single PLC chip within the platform. This removes a range of fibered bulk components that are typically required to manage light signals within an amplifier, and replaces them with a single PLC chip.

- JDSU's photodetector arrays will reduce the number of discrete devices typically needed from up to nine down to a single array.

Photodetector arrays monitor feedback loops to control each part of the amplifier and also provide alarm functionality.

- A variable pump splitter provides improved noise performance over a wider dynamic range by allowing a single amplifier to be tuned to accommodate both low- and high-input applications, improving the noise figure at low-input conditions.

- A tunable gain flattening filter, when used with an optical channel monitor, can actively compensate for common system link impairments, such as unequal channel power levels caused by transmission fiber and by other components. This allows the amplifier to provide output with consistent power levels for each channel that is amplified.

- A tilt filter provides more predictability in amplifier performance with an active tilt adjustment when a channel load or total signal power changes. It is more linear than current solutions and more closely matches typical network characteristics.

Full-band tunable pluggable transceiver in XFP-E format

At the European Conference and Exhibition on Optical Communications, optical component, module and subsystem maker Bookham Inc of San Jose, CA, USA launched the TL8500, a full-band tunable pluggable transceiver in the XFP-E format, targeted at long-haul links and metro/regional networks at rates up to 11.3Gb/s.

The XFP-E format is an industry-recognized MSA (multi-source agreement) and, by adding full-band tunability, Bookham says it can now offer a 'universal' 10Gb/s transceiver with the following qualities:

- maximum faceplate density for all links, including high-performance long-haul;

- flexibility for 'pay as you grow' capability and in-service accessibility;
- reliability, via field-proven technology;
- the security of an MSA format for ease of procurement;
- economically competitive compared to alternative technologies and formats.

The module is underpinned by Bookham's fully Telcordia qualified indium phosphide Mach-Zehnder (MZ) modulator and DSDBR (digital supermode distributed Bragg reflector) laser — the key building blocks of Bookham's range of high-performance tunable modules.

"We have already established a clear commercial lead in tunable

pluggable devices with the success of our TL8000, and delivering high-end 300-pin capability in the XFP-E format extends that leadership — we are showing that there is a real market for tunable pluggables in a variety of formats," says Adam Price, director of product management. "We are now bringing our performance standards into the pluggable arena," he adds.

"With our proven, high-performance optical components and decade of field history with indium phosphide Mach-Zehnders, we are perfectly placed to expand the current tunable pluggable portfolio to include a variety of tunable formats, including X2, XENPAK and XFP."

Bookham demonstrates increased density and deployment flexibility of InP MZ-based tunable pluggable module

At ECOC 2008, Bookham gave a live demonstration of its TL8000 tunable pluggable module, showing its capability in chromatically dispersed links and high-noise environments as well as highlighting the increased density and deployment flexibility benefits of the firm's tunable pluggable technology.

The demonstration followed July's announcement that Bookham had begun supplying the TL8000 to telecom network equipment maker Ciena Corp of Linthicum, MD, USA.

The TL8000 featured the first use of electronic dispersion compensation (EDC) chips in a Bookham product, and delivers high optical output power (+4dBm). The module was being operated in conjunction with Bookham's TL9000 small-form-factor tunable transponder, which has been shipping in volume to tier 1 customers for almost 12 months.

Bookham says that the demonstration illustrates the spectral and RF properties of the tunable transmitter,



enabled by its DS-DBR tunable laser and its indium phosphide Mach-Zehnder (InP MZ) modulator. The receiver performance is showcased by real-time bit error rate measurements in varying dispersion and optical signal-to-noise ratio (OSNR) environments, with up to 800ps/nm of dispersion and 15dB OSNR being configured.

"The live demonstration highlights high-end optical interface capability equal to 300-pin transponder products, in a front faceplate pluggable, full-band tunable module," says Adam Price, director of Product Management.

"This is a high-end product designed into a pluggable format that increases faceplate density and flexibility, and enables customers building both long-haul and metro networks to immediately take advantage of the cost-reduction benefits of wideband-tunable pluggable technology," he adds.

Price says that Bookham is building on its proven tunable laser, MZ modulator and APD receiver technologies to deliver long-reach modules that meet customer demand in a variety of formats, including the TL5000 iTLA source, the TL7000 tunable transmitter assembly, TL9000 small-form-factor transponder, and the TL8000 and TL8500 front faceplate pluggable transceivers. "This vertically integrated approach is allowing us to serve all the major network equipment manufacturers, and play a key role in helping them drive down costs and improve performance," he claims.

www.bookham.com

Avago launches long-reach extended-temperature 10G SFP+ transceivers

Avago Technologies of San Jose, CA, USA says that it is sampling the latest addition to its 10Gb/s Ethernet SFP+ optical transceiver product family (for general availability by the end of 2008).

Based on its 1310nm DFB laser and PIN detector technology, Avago says that the AFCT-701SDZ/AFCT-701ASDZ 10Gb/s SFP+ LR (long-reach) optical transceiver offers extended temperature support and brings new levels of high speed and high port density to next-generation networking equipment, targeting campus and access networks.

With digital monitoring interface (DMI), Avago's new 10Gb/s SFP+ transceivers operate over single-mode fiber at distances of up to 10km in compliance with the opti-

cal interface specifications per IEEE 802.3ae 10GBASE-LR. With support for RoHS 6 and China RoHS, the ACFT-701SDZ operates at temperatures of 0–70°C and features a typical power dissipation of less than 1W. The extended-temperature AFCT-701ASDZ version supports 0–85°C. The new optical transceiver follows the SFF-8431 specification for enhanced 10Gb/s SFP+ as well as the SFF-8472 specification for DMI in optical transceivers.

The emerging SFP+ form factor for optical transceivers enables network equipment manufacturers to build products with greater port density to effectively support the growing demand for data-intensive applications, says Avago.

www.avagotech.com/fiber

Bookham samples 5Gb/s DWDM SFP transceiver as alternative to 10Gb/s

Bookham is sampling what it reckons is the fastest dense wavelength division multiplexing (DWDM) SFP transceiver module available, with a transmission speed of 5Gb/s. The firm says that the new high-speed module should enable the performance of SFP-based board designs to be expanded, and offers a readily available, cost-effective alternative to 10Gb/s DWDM XFP transceivers.

The 5Gb/s transceiver is designed to operate in high-noise, amplified environments, and is targeted at multi-span links for metro networks. It can deliver output power from +3dBm to +6dBm, has channel spacing of 100GHz, and offers full C- and L-band coverage.

Bookham has also continued the evolution of its pluggable products by achieving an uncompensated reach of 400km at 2.5Gb/s with a multi-rate DWDM SFP transceiver. The portfolio offers DWDM solutions for all transmission speeds and net-



**Bookham's
5Gb/s DWDM
SFP transceiver.**

work protocols, including Ethernet, Fiber Channel and SONET/SDH. All designs are underpinned by the same optical engines: Bookham's avalanche photodiode receiver and buried-heterostructure directly modulated laser.

Bookham claims the highest speed and the longest reach in SFP WDM pluggable optics, coupled with stability and tolerance to low-OSNR [optical signal-to-noise ratio] links.

The WDM SFP portfolio also offers standard optical power devices in both multi-protocol (SONET, Ethernet and 4Gb/s Fiber Channel) and multi-rate (100Mb/s to 2.7Gb/s) variants as well as equivalent versions with higher optical power levels (5.5dBm typical).

www.bookham.com

IN BRIEF

Avago first to market with 8Gb/s SFP+ LR transceiver for Fiber Channel

Avago Technologies has launched what it claims is the first 8Gb/s SFP+ LR (long-reach) optical transceiver for Fiber Channel applications. The AFCT-57D5ATPZ is complementary to the firm's AFBR-57D5APZ multimode optical transceiver (launched in early 2008), which has a 150m reach.

The AFCT-57D5ATPZ operates over single-mode optical fiber at signaling rates of up to 8.5GBd for distances up to 10km. The new transceiver also enables the production of high-port-density, standards-based 8Gb/s storage-area network (SAN) applications, such as inter-switch links, storage replication, and other long-reach networks.

Based on Avago's 1310nm distributed feedback (DFB) laser, the AFCT-57D5ATPZ is compliant with industry 8.5/4.25/2.125GBd Fiber Channel specifications. The new transceiver supports RoHS requirements and provides real-time monitoring of transmitted optical power, receive optical power, laser bias current, temperature and supply voltage information. Its digital diagnostic interface also adds the ability to disable the transmitter, monitor for transmitter faults, and monitor for receiver loss of signal.

"Avago continues to demonstrate its commitment to the growing Fiber Channel market with the introduction of our high-performance long-reach transceivers," says Randy Clark, product marketing manager for Avago's fiber optic products division. "We remain very involved with the industry standard organizations that define the direction of the storage networking industry," he adds.

www.avagotech.com/fiber

IMEC and CEA-LETI extend ePIXfab silicon photonics prototyping service with PhotonFAB

Microelectronics research center IMEC of Leuven, Belgium and CEA-LETI of Grenoble, France have launched the joint initiative PhotonFAB, a continuation of their existing ePIXfab multi-project wafer silicon photonics prototyping service started in 2006 to offer a cost-effective way for researchers and SMEs (small- and medium-sized enterprises) to develop photonic integrated circuits in silicon.

Co-funded by the European Union via the 7th Framework Program (FP7) and coordinated by IMEC, ePIXfab aims to shrink the barriers for access to and market take-up of silicon photonics technology by focusing on reduced cost, risk and design effort, education, and roadmapping.

ePIXfab had been started as the silicon photonics platform within the framework of ePIXnet, the FP6 Network of Excellence on photonic integrated components and circuits.

The silicon platform is one of the six technology platforms in ePIXnet (which has two other integration technology platforms — for InP circuits and for nanostructuring — accompanied by three supporting platforms on packaging, high-speed characterisation and modelling).

ePIXfab organizes shuttle (multi-project wafer) fabrication runs with IMEC and LETI wafer-scale technologies, including 193nm deep-UV lithography-based processes. Since 2006, over 25 academic and SME groups have been able to develop IC technology in a fabless way with reduced costs, by joining many IC designs in a single fabrication run.

Now, to enable a broader market take-up of silicon photonic IC technology, the ePIXfab service is being extended by the three-year project PhotonFAB (Silicon Photonic IC Fabless Access Broker) to include a more extensive technology portfolio,

new design libraries, education and training for the clients, a shuttle service roadmap and a more streamlined operation. Dedicated prototyping and small-volume manufacturing is also possible based on IMEC or LETI technology.

Funded by the EU as a FP7 Support Action, PhotonFAB should hence lower the design effort, risk and bare costs for clients. In addition, clients from countries fully associated to the FP7 program will be able to obtain additional cost reductions for the shuttle service and training activities.

In September, ePIXfab presented information sessions on its fabrication service and on PhotonFAB at the IEEE Group IV Photonics conference in Sorrento, Italy and at the European Conference & Exhibition on Optical Communication (ECOC) in Brussels, Belgium.

<http://photonfab.org>

SEI launches 10Gb/s 80km transceiver with built-in EDC circuit and direct modulation laser diode

Tokyo-based Sumitomo Electric Industries Ltd (SEI) has expanded its 10Gb/s transceiver portfolio by launching an integrated direct modulation laser diode (DML) with a built-in electronic dispersion compensation (EDC) feature for use in 80km transceivers. SEI demonstrated the new 10Gb/s technology at the European Conference and Exhibition on Optical Communication.

Previously, DMLs were used in transceivers up to data rates of 2.5Gb/s. For 10Gb/s ZR applications, DMLs did not provide a reliable light source, says the firm, because transmission distance was limited by chromatic dispersion due to optical spectrum chirping. As a result, such light sources had to be combined with an expensive external modulation laser diode (EML) for this application.



SEI claims that the new design is the first product to integrate a DML and an EDC circuit internally to the transceiver. By providing improved chirp characteristics in the DML and combining it with a receiver having a built-in EDC capability, the new product offers a low-cost integrated solution for long-distance applications. This combination enables 10Gb/s transmission over 80km using a low-cost DML, and benefits system designers by eliminating an

external modulator and wasted board space, says the firm.

In addition to enhanced packaging, another design feature is that EDC is based on the maximum likelihood sequence estimation (MLSE) technique. The EDC circuit has not only an electronic dispersion compensation function, but also a digital signal processing function.

"Sumitomo Electric's DML technology has been tested with the performance of MLSE PHY," says Terry Fujitani, head of SEI's Lightwave Technologies department. "Together, these technologies provide a very compelling value proposition to the optical networking market."

Sumitomo Electric plans to launch 10Gb/s transceivers such as X2, XFP and SFP+ using this technology, starting in 2009.

www.sei.co.jp

Hitachi and Opnext achieve first 43Gb/s transmission over 10km fiber using uncooled laser

At ECOC 2008, Japan's Hitachi Ltd and Opnext Inc of Eatontown, NJ, USA (which was spun-out of Hitachi in 2001) announced the development of an uncooled 1300nm-range electro-absorption (EA) modulator integrated laser for 40Gb/s optical transmission that does not require temperature control and has achieved the first 10km single-mode fiber transmission at a speed of 43Gb/s (achieved during a test trial over a wide temperature range of 25–85°C).

Compared to directly modulated lasers, using external electro-absorption (EA) modulators results in less degradation of the signal waveform, enabling higher-speed longer-distance optical transmission.

Past cooperation between Hitachi and Opnext on developing EA modulator monolithically integrated lasers resulted in a product capable of 40Gb/s transmission, but its operating wavelength was 1550nm and transmission distance was limited to 2km due to fiber dispersion. Hence, a 40Gb/s high-speed modulator structure was developed that is capable of operating at a wavelength of 1300nm, reducing fiber dispersion and enabling 10km long-distance transmission.

Also, using temperature-tolerant indium gallium aluminum arsenide (InGaAlAs) in the EA modulator has expanded the operational temperature range. Using an uncooled laser and eliminating the need for temperature control can reduce power consumption by 10–20%.

In addition, a process was developed for this material to allow the fabrication of a monolithically integrated modulator and laser structure similar to the conventional 1550nm device.

The development is key to achieving energy-efficient, low-cost

Eliminating the need for temperature control can reduce power consumption by 10–20%

40Gb/s ultra-high-speed optical transceivers, claims Dr Masahiro Aoki, manager of the Nanoelectronics Research Department at Hitachi's Central Research Laboratory.

"Uncooled lasers are a key component, as they contribute to the handling of larger data volumes, as well as the lowering of costs in optical transmission equipment," he adds.

www.opnext.com

Extended-reach SFP+ module with uncooled EA-DFB

Opnext says that its extended-reach small-form-factor pluggable (SFP+ER) module with uncooled EA-DFB (co-developed with Hitachi's Central Research Laboratory) will be commercially available from Q2/2009. The 10Gb/s optical transceiver expands the firm's 10Gb/s portfolio of 40km reach modules, such as SFP+ and XFP. The module is also the first 40km SFP+/XFP with uncooled EA-DFB, claims Opnext.

"It offers more capacity, enables higher density systems, and it will help our customers realize thermal and power consumption system requirements," says executive VP Tadayuki Kanno. "It will also provide a pluggable form factor for easy system maintenance and reduces power consumption by eliminating the need of a TEC."

Opnext says its new extended-reach SFP+ module expands its reach in the high-capacity switching, storage and transmission systems market, which is forecast to grow to \$150m in 2010. The uncooled EA-DFB is suitable for either SFP+ ER or XFP-IR2 applications.

The product is MSA-based and pin-to-pin compatible. It keeps the 40km capability in SFP+ form factor with $P_c < 1.25W$, while keeping the same characteristics as a conventional cooled EA-DFB.

Opnext first to reach 750,000 10G transceiver milestone

At ECOC 2008, Opnext announced that it has shipped over 750,000 10G transceivers to its global customer base, coming less than a year after the firm achieved half a million transceiver shipments in December 2007.

"The demand for bandwidth continues to expand industry wide, hence the need for 10Gb/s in telecom and enterprise networks," stated Daryl Inniss, vice president and practice leader at market

research firm Ovum. "Opnext, a leading 10G supplier, continues to support this market by delivering both new and legacy products notwithstanding the broad range of transmission protocols, form factors and electrical connectors required," he added.

"Reaching 750,000 10G transceivers shipped continues to validate our position as an industry-leading technology provider of 10G solutions," said

Tadayuki Kanno, senior VP in Opnext's modules business unit.

Opnext's 10G module transceivers fully comply with industry standards from ITU-T G.691, G.709, and IEEE 802.3, and OIF recommendations, supporting a variety of electrical interfaces, including SFI-4, XAUI and XFI. Opnext transceivers meet or exceed standards established by industry multi-source agreements (MSAs), claims the firm.

Avanex cutting 8% of workforce and closing Florida facility

In a report filed with the US Securities and Exchange Commission (SEC), optical communications component and module maker Avanex Corp of Fremont, CA, USA said that, in order to reduce costs, streamline operations, and improve its cost structure, by the end of October it will cut staffing worldwide by about 47 (8% of the workforce that it had at the end of June).

The cuts include closing the firm's facility in Melbourne, FL, USA, which was acquired in July 2007 along with the MSA 300-pin transponder and XFP transceiver business of the Commercial Communication Products Division (CCPD) of Essex Corp (which is now a subsidiary of Northrop Grumman Corp).

The product lines, inventory and fixed assets will be transferred to Avanex's facilities in either Shanghai, China (originally intended as a product development center, but now an interface for the Chinese design centers of customers including Alcatel-Lucent, which represented 25% of Avanex's fiscal 2008 revenue) or Villebon Sur Yvette, France (where transponder and transceiver transmission products, e.g. 40Gb/s tunable transponders, are made), near Alcatel-Lucent's European base.

Avanex's revenues fell from \$213m in fiscal 2007 to \$208m in fiscal 2008 (which ended in June). For the September quarter, Avanex expects revenue to fall from \$51.8m to \$44-48m and gross margin to fall from 32% to 20-23%. July saw the departure of chief financial officer Marla Sanchez and CEO Jo Major (who was replaced by Giovanni Barbarossa).

As part of the cost cutting, all of Avanex's executive officers have voluntarily agreed to a 10% cut in their salaries from October onwards.

www.avanex.com

Civcom debuts long-reach tunable 10Gb/s SFF transponders with LiNbO₂ or InP modulator

Optoelectronic component, module and subsystem manufacturer Civcom of Petach Tikva, Israel has announced the availability of a new line of tunable small-form-factor (SFF) 10G transponders, designed for long-reach dense wavelength division multiplexing (DWDM) applications. The transponder contains both a wide-band receiver and a 10Gb/s widely tunable transmitter, with a laser covering the entire C-band over distances up to 80km. Civcom's 10G SFF interface is compatible with the 300-pin MSA and I2C interface.

Civcom says that the new products expand its existing Free Light family of tunable transponders, offering equipment makers the high performance in a cost-effective SFF device. Production devices have already been supplied to customers for evaluation purposes, Civcom confirms.

The new SFF transponders are available in two models, using either a lithium niobate (LiNbO₂) or indium phosphide (InP) modulator, giving manufacturers the flexibility to choose the optimal option in accordance with their customers' performance and budgetary requirements, explain Civcom representatives. In addition, the new transponders can be used in



Civcom's 10G SFF transponder.

conjunction with Civcom's Free-Path family of manageable dispersion compensation modules (M-DCM) as a complete optical offering for any distance.

"Our recently launched Tunable SFF 10G transponders line meets market demand for cost-effective, small footprint optical equipment," contends Yair Itzhar, vice president of sales & marketing at Civcom. "These high-performance products, together with Civcom's complete line of optical components and modules, provide our customers with everything they need to build the best carrier and enterprise network solutions for a wide variety of applications," he continues. "Our track record for delivery features a rapid customization and production cycle to assure optimal integration of our equipment into the complete solution design, enabling our customers to enjoy fast time to market and ROI."

www.civcom.com

Emcore secures \$25m credit facility

Emcore Corp of Albuquerque, NM, USA, which makes components and subsystems for the broadband, fiber-optic, and solar power markets, has closed an asset-backed \$25m revolving credit facility with Bank of America that can be used for working capital, letters of credit and other general corporate purposes.

The credit facility, which incorporates both LIBOR and Prime-based borrowing alternatives, is subject to certain financial covenants and a

borrowing base formula. The agreement matures in September 2011.

"Given the current state of the credit markets, we are very pleased to enter into this agreement with Bank of America and appreciate the bank's confidence in our future," says chief financial officer John M. Markovich. "This facility will serve to further strengthen our financial flexibility as we continue to pursue the company's growth strategy."

www.emcore.com

Finisar expands in China with new high-volume plant

Finisar Corp of Sunnyvale, CA, USA, which makes fiber-optic communications components and subsystems as well as network test & measurement systems, has opened its new manufacturing and R&D facility in Shanghai in the presence of company executives and local dignitaries.

Finisar says that the opening reaffirms the importance of the China market to the firm as well as its commitment to strengthening customer relationships in Asia.

Designed specifically for high-volume, cost-effective optics production, the plant also furthers development efforts and enables lower-cost manufacturing of Finisar's optical components including lasers and passive devices.

The \$3m investment supports Finisar's ongoing R&D efforts and enhances volume manufacturing capabilities for active and passive components used in its own transceivers as well as the merchant market. With a local staff of 650, the new site provides 15,000m² of manufacturing, cleanroom, and office space (nearly three times the capacity of the previous site). The firm has completed product qualification and the new plant is now in full operation.

China represents a very important market in the fiber-optics industry, says Joe Young, senior VP and general manager of Optics at Finisar. "By being vertically integrated with our other manufacturing sites

around the globe — Fremont, CA and Ipoh, Malaysia, for example — this facility is now a part of a larger operation committed to the volume production of high-quality optical components," he adds.

Finisar says that, over the last two decades, it has focused on developing high-volume manufacturing capabilities to create cost-effective optical communication products for the data networking and telecom markets. The firm claims that this strategy has established it as the volume-leader in fiber-optics communications. Finisar ships nearly one million optical transceivers per month and 1.5 million free-space isolators annually.

www.finisar.com

Products demonstrated at Fibre Channel Over Ethernet Plugfest

At September's Fibre Channel over Ethernet (FCoE) Plugfest hosted by the Fibre Channel Industry Association (FCIA) at the University of New Hampshire Interoperability Laboratory (UNH-IOL), Finisar demonstrated its 10G SFP+ short-reach transceiver, Xgig protocol analyzer, Laserwire active optical cable, and Medusa Labs Test Tool Suite in a live FCoE environment.

The event is the first industry interoperability test of FCoE technology. FCoE is intended to provide IT professionals with a simple migration path from their existing SAN infrastructure onto a converged Ethernet based network, combining both Fibre Channel and Ethernet fabrics. This technology should provide greater efficiencies by reducing cables and hardware equipment and simplifying data-center management, while maintaining their investment in native Fibre Channel and Ethernet products and training.

At the Plugfest, Finisar demonstrated test and analysis tools including:

- Xgig, a powerful unified multi-function platform used for design, test, verification and compliance of the FCoE protocol; and
- Medusa Labs Test Tool Suite, a series of benchmark speed, data integrity and application based stress test tools that allow test and interoperability engineers to better develop and validate quality products in real SAN environments in a shorter time frame, for faster time to market.

Finisar also provided optics for connecting the FCoE network. The optics, which enabled high-port-density and low-power FCoE solutions, included:

- 10G SFP+ short-reach (SR) transceivers that played a key role in transporting 10GBASE-SR Ethernet traffic (the underlying foundation of FCoE) between switches and adapters; and

- Laserwire, the first serial 10Gb/s active optical cable product designed to accelerate and support 10G Ethernet server and FCoE connectivity. Laserwire is a plug-and-play datacenter cable solution that provides lightweight, flexible, low-power consumption connectivity from 3m to 30m. It does not require host-board receiver equalization compared to alternative solutions.

FCoE, the standard for transporting Fibre Channel frames over Ethernet, is designed to make converged networks possible for data centers. With converged networks now on the way to becoming a reality, servers will no longer require separate interfaces for data and storage networking. Finisar says that IT professionals will be able to increase functionality while reducing cost and complexity by using a single set of cables and switches.

www.fibrechannel.org

CPV Consortium launched

The launch has been announced of the CPV Consortium, a global industry organization focused on supporting the development of concentrating photovoltaics (CPV), with the goal of providing low-cost, reliable renewable energy.

Founding members include CPV module maker Concentrix Solar GmbH of Freiburg, Germany (spun off from the Fraunhofer Institute for Solar Energy Systems in February 2005); component and subsystem maker Emcore of Albuquerque, NM, USA; Spain's Isofoton S.A. (spun off from the Polytechnic University of Madrid); ISFOC (the Institute of Concentration Photovoltaic Systems) of Puertollano, Spain; and SolFocus of Sunnyvale, CA, USA.

"CPV is on the cusp of delivering on its promise of low-cost, reliable solar-generated electricity that will be cost competitive with traditional energy sources," reckons CPV Consortium director Nancy Hartsoch, VP of marketing for SolFocus (which in July completed an initial 200kW phase of ISFOC's 3MW CPV project). "The challenge now is to assure that a proper foundation and infrastructure is in place to support CPV." Consortium membership is open to the whole CPV supply chain, including solar cell and material suppliers, mirror and lens suppliers, panel suppliers, solar tracker companies, integrators, power generators, uni-

versities and government organizations, as well as other institutions with an interest in advancing the CPV industry. Equipment and materials suppliers Veeco and 3M have joined the consortium as charter members.

The consortium gathers all key industrial and R&D players, says ISFOC's director general Dr Pedro Banda. "It is with this type of commitment that we all can ensure the future of this technology, becoming a major trend and providing global solutions for the deployment of renewable energies," he adds.

"ISFOC is committed, together with the industrial players, to support their technology and product developments and serve as their test bed. This consortium will help bring CPV up to the pace at which the PV market is growing across the world," Banda predicts.

"With its outstanding efficiencies, CPV technology has an immense potential for lowering costs of solar electricity," believes Hansjorg Lerchenmuller, CEO of Concentrix (which earlier in September started up a 25MW CPV module manufacturing line). "To fully exploit the potential of the technology, we need to join forces throughout the whole CPV industry," he adds.

"It is crucial for the companies participating in the CPV industry to collaborate and ensure that this technology meets and exceeds the

cost and performance requirements of the global energy market," explains David Danzilio, VP and general manager for Emcore's Space and Terrestrial Solar Products. "The CPV Consortium is the mechanism where the industry leadership will partner to ensure concentrating PV systems reach their full market potential," he continues. "CPV technology means a cost-effective and reliable product in the PV sector," adds Isofoton's CPV business manager Vincente Diaz. "The mature technologies present in CPV allow big improvements in terms of system efficiencies. It is the right moment for joining in a powerful team that could boost CPV technology market presence in the short term," Diaz concludes.

Now that it has launched, the CPV Consortium has begun a membership drive. Membership is available at several levels including charter membership (which includes a seat on the steering committee), general membership, and informational membership. Governmental, university and non-profit memberships are available on an invitation-only basis.

In October, the consortium held informational meetings at Solar Power International '08 in San Diego, CA, and led a pre-conference workshop ('CPV 101').

www.cpvconsortium.org

MOCVD system maker Veeco joins CPV Consortium

Veeco Instruments Inc of Plainview, NY, USA has become a charter member of the CPV Consortium.

Along with other process tools and metrology systems, Veeco manufactures MOCVD systems that can be used to make CPV cells. "We look forward to continued development of CPV cell manufacturing equipment and process improvements to further reduce the cost and ease of manufacturing, while improving the efficiency and reli-

bility of CPV cells," says Sudhakar Raman, VP marketing of Veeco's MOCVD operations.

Raman adds that, compared to conversion efficiencies of 13-18% for traditional silicon solar cells, CPV cells provide much higher efficiencies — about 35%, moving to the 45% range over the next few years, it is planned. "Veeco is aligned today with all of the leading CPV manufacturers to help pursue these future efficiency gains."

Veeco claims that its TurboDisc As/P MOCVD tools offer the highest yields and lowest cost of ownership for the high-volume production of multi-junction III-V CPV cells. The systems have proprietary RealTemp 200 in-situ metrology (aiding material quality and process efficiency via direct real-time wafer temperature control), fast gas switching for control of interface abruptness, and vacuum loadlock automation.

www.veeco.com

SolFocus first to complete ISFOC CPV installation

After installing 200kW of concentrator photovoltaic (CPV) systems at a power plant in Puertollano, Spain in July, Palo Alto Research Center spin-off SolFocus Inc Mountain View, CA, USA has installed 300kW of CPV systems in Almoquera (making 500kW in total).

SolFocus becomes the first of three CPV system makers to complete its installations as part of a first, 1.7MW phase of the 3MW CPV project of Puertollano-based Instituto de Sistemas Fotovoltaicos de Concentración S. A. (ISFOC).

The project represents SolFocus' first commercial deployment. The two other CPV makers supplying systems for the first phase are Isofoton and Concentrix. Also, last November, ISFOC awarded contracts for the second phase (which is expected to have a capacity of 1.3MW) to Sol3g, Concentración Solar La Mancha, Emcore Corp and Arima Eco.

The 3MW ISFOC project was initiated in 2006 by the Castilla-La Mancha regional government's Department of Education and Science and the Institute of Solar Energy (IES) of Universidad Politécnica de Madrid (UPM), and is financed by Spain's Ministry of Education and Science.

The plants have been created both as municipal power production facilities (to generate electricity for the local power grid) and as a proving ground for CPV technology (incorporating different concentrator technologies becoming available on the market from several firms). The project aims to demonstrate that CPV technology, with higher efficiency and the potential for cost reduction, is an attractive alternative to other solar technologies in key high solar resource regions worldwide.

ISFOC sought the most promising CPV technologies approaching the

electrical generation market, and selected SolFocus for a contract in late 2006 (in advance of commercial production by the firm).

SolFocus says that it has now entered the industrial, commercial and utility markets, having fine-tuned its design and technology development to emphasize reliability and overall system performance at the ISFOC installation. In September, the California Energy Commission (CEC) approved SolFocus' SF-1000P panel as the very first CPV product eligible to participate in the state of California's solar incentive program for commercial deployment, meaning the panels have met the CEC's safety and reliability standards.

ISFOC has performed initial testing and analysis, which have confirmed that, in SolFocus' flagship product (the SF-1000P CPV panel), each panel is performing as designed at specified power levels (205W). SolFocus says that, in some cases, their panels are producing 10-15% more than their rated amount.

"While we are just now beginning to evaluate performance results from the installed systems, initial results look excellent and validate our belief that the high-efficiency capability of CPV technology is going to provide high energy yields," comments Dr Pedro Banda, ISFOC's director general. "SolFocus has done an excellent job of progressing its technology from R&D into commercially ready product," he adds.

"Working with ISFOC has allowed us to deploy our technology faster and in a more supportive environment than would have otherwise been possible," says SolFocus' president Mark Crowley. SolFocus expects its ISFOC installation to be connected to the grid in the next few weeks.

www.solfocus.com

IN BRIEF

SolFocus first CPV systems maker to get CEC approval

SolFocus of Mountain View, CA, USA says that its SF-1000P concentrator photovoltaic (CPV) panels have been approved by the California Energy Commission (CEC) to be placed on the Eligible California Solar Initiative (CSI) Photovoltaic Modules Renewables Equipment List. The listing assures customers that the solar equipment has been tested for safety and performance and meets the requirements of both the CEC and California Public Utility (CPUC), says SolFocus.

CEC listing is required for residential, commercial, and large-scale utility buyers to qualify for rebates against the cost of installing new solar equipment as part of the CPUC's CSI incentive program and CEC's Solar Homes Partnership. Only equipment listed by the CEC is eligible for incentives. SolFocus adds that it is the first CPV systems manufacturer to be CEC listed.

"Not only is this an important achievement for SolFocus as we have reached the phase of commercialization of our CPV systems, but the thumbs up from the CEC is another proof point that CPV technology is a serious, scalable source of clean, renewable electricity," says SolFocus president Mark Crowley.

SolFocus' CPV technology uses reflective optics to magnify sunlight 500 times onto small, highly efficient, III-V-based solar cells (which have an efficiency approaching 40%). The firm claims that its systems use just one thousandth of the active, expensive solar cell material compared to traditional photovoltaic panels.

www.energy.ca.gov

IN BRIEF

GreenVolts wins \$250,000 grant for CPV installation

GreenVolts has been awarded a \$250,000 grant from the California Energy Commission's Public Interest Energy Research (PIER) Program for its proposal 'Low Cost Installation of Concentrating Photovoltaic' (rating highest among all applicants to the the PIER Renewables Solar PV RD&D Grant Solicitation). The PIER program supports energy research, development and demonstration (RD&D) projects that aim to bring environmentally safe, affordable and reliable energy services and products to the Californian market.

Founded in 2005, GreenVolts' CPV technology integrates optics (an off-axis micro-dish aluminum reflector mirror) as well as solar tracking into a system that aims to produce the lowest-cost utility-scale solar energy for wholesale distributed generation.

GreenVolts was previously awarded a PIER grant for R&D on its 3kW two-axis CarouSol tracker, which tracks the sun as it moves across the sky and concentrates 625 times the sun's energy onto its CPV system's GaAs-based triple-junction solar cells. The firm completed its work as part of that grant in advance of its second proposal. "This PIER grant is continued validation of our technology and our approach to the marketplace," says founder & CEO Bob Cart.

"GreenVolts is demonstrating that smart, reliable solar projects can help the state reach its goals of generating 33% of our electricity from renewable sources and reducing our greenhouse gas emissions by 2020," says California Energy Commission chairman Jackalyne Pfannenstiel.

www.energy.ca.gov/pier

GreenVolts secures \$30m Series B funding

CPV system maker GreenVolts Inc of San Francisco, CA, USA has secured \$30m in Series B funding from Oak Investment Partners. GreenVolts says it will use the funds to continue to build out its organization, accelerate its R&D, and scale capacity for anticipated 2009 deployments.

A portion of the funds will also be used for the firm's GV1 project (which broke ground earlier this year in Byron, CA, and is being built as part of the company's agreement with Pacific Gas & Electric). The first megawatt of GV1 will be delivered later this year, says GreenVolts.

"We will soon be generating energy from the sun at what will be the world's largest non-silicon CPV power plant," said Bob Cart, founder and CEO of GreenVolts. "Having a partner like Oak that

shares our vision for CPV is a great asset as we make the long-term decisions necessary to meet existing demand while continuing to innovate for the future," he adds.

The plant will consist of the firm's 3kW two-axis CarouSol trackers, which track the sun as it moves across the sky and concentrate 625 times the sun's energy onto the firm's GaAs-based triple-junction solar cells. When completed in Q4/2009, the generating capacity is expected to be 3MW.

Brian Hinman, venture partner of Oak Investment Partners, added: "We believe that, over time, the GreenVolts system can produce solar energy more efficiently and at a lower levelized cost than competing photovoltaic technologies, dramatically accelerating the adoption timeline for CPV systems."

www.greenvolts.com

General counsel hired to deal with utilities

GreenVolts has recruited Richard Raushenbush as its vice president & general counsel. Raushenbush's experience working with public utilities and government agencies makes him suited to help guide GreenVolts' continued growth and new utility-scale solar projects around the world, the firm reckons.

"Richard is the perfect match for GreenVolts, someone who can hit the ground running and help speed even the imminent deployment of our GV1 project," says founder & CEO Bob Cart. "His addition to our executive team will not only help facilitate future planned projects, but his expertise and devotion to this industry speaks volumes about our own efforts as a company."

Raushenbush spent the previous 20 years in the Environment, Land & Resources Department and

Litigation Department at Latham & Watkins, where his practice was centered on environmental, land use and administrative litigation. He has extensive experience representing public utilities before the California Public Utilities Commission and in court regarding electric transmission, electric generation, and natural gas transmission. He also has extensive experience in judicial and administrative actions regarding environmental issues.

Raushenbush has litigated environmental cases throughout California's federal and state courts, as well as federal courts in Texas, Indiana and Maryland. He has also dealt with the EPA and California state agencies in both court and administrative enforcement proceedings. Raushenbush holds a JD from the University of Virginia School of Law.

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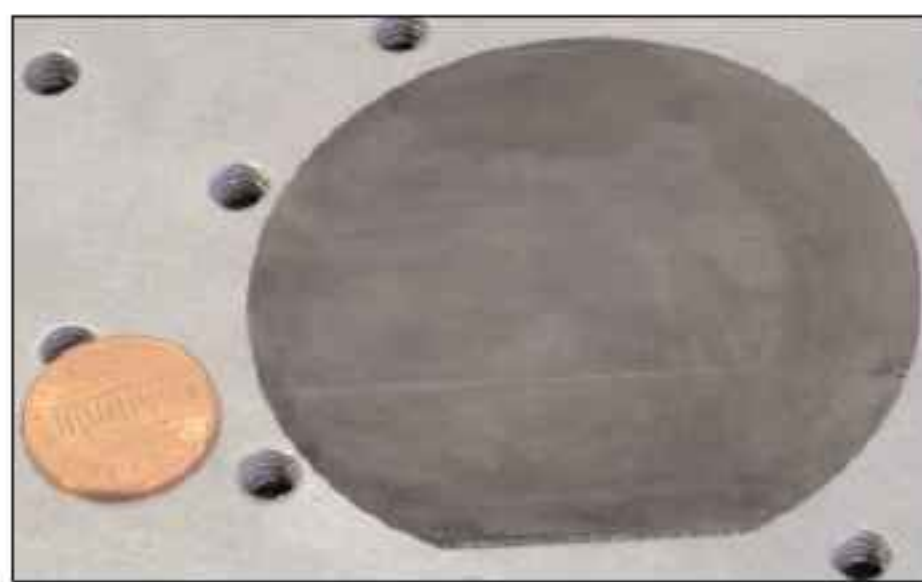
Wafer slicing method cuts waste in making Ge-based PVs

Following work funded by the US National Science Foundation, the University of Utah Research Foundation and germanium wafer maker Sylarus Technologies of St George, UT, University of Utah researchers have reported a new method for slicing thin germanium wafers that could lower the cost of solar cells by reducing the waste and breakage of the brittle substrate.

Germanium is used as both the substrate and the bottom of multi-junction solar cells, upon which layers of GaInAs and GaInP are grown to produce the other junctions. Such cells are currently used mainly on spacecraft, but the idea is to make germanium-based, high-efficiency solar cells for uses where cost is now a factor, particularly for terrestrial (e.g. roof-based) solar power, says assistant professor of mechanical engineering Eberhard 'Ebbe' Bamberg.

Bamberg says that Ge-based cells are used on most spacecraft since they are more efficient and lighter than silicon-based solar cells. Silicon-based terrestrial solar cells have maximum efficiency of 20%. In space, Ge-based cells typically have an efficiency of 28%, but on Earth (e.g. in solar concentrators) this can be more than 40%, and theoretically 50%. But, despite the efficiency, a 2005 survey found that 94% of solar cells made for non-space uses were silicon-based, because silicon is much cheaper and less fragile than germanium.

"We're coming up with a more efficient way of making germanium wafers for solar cells – to reduce the cost and weight of these solar cells and make them defect-free," says doctoral student Dinesh Rakwal. The new method may make Ge-based cells competitive with less efficient but less expensive Si-based cells for terrestrial applications, believes Bamberg. By making it more attractive economically to use Ge cells on rooftops, the weight and size of solar panels can be reduced, he adds.



Germanium wafer cut from an ingot.
Credit: Eberhard Bamberg.

Traditionally, brass-coated, steel-wire saws are used to slice Ge wafers from cylindrical single-crystal ingots. However, since germanium is brittle, it cracks easily, requiring broken pieces to be recycled. Also, the saw's width means that much germanium is lost during slicing. The method was developed for silicon wafers, which are about 100 times stronger.

The new method — wire electrical discharge machining (WEDM) — wastes less germanium and yields more wafers by cutting even thinner wafers with less waste and cracking. The method (used previously to machine metals in tool-making) uses an extremely thin molybdenum wire with an electrical current running through it, forming an electrode.

This is connected to a pulsed power supply that charges the wire. Thin, synthetic oil is injected along the wire to increase electrical charge on the wire and to flush away material that melts during cutting.

Wire electrical discharge machining takes 14 hours to cut a single wafer. The electrified wire method has to be conducted gently to avoid cracking the germanium, but Bamberg hopes to increase the speed to the 6 hours it now takes to cut a wafer using a wire saw.

Compared to wire saws made of brass-coated steel with a thickness of about 170 or 180 μm , the molybdenum wire is just 75–100 μm thick, so less germanium is wasted during slicing. The study found that a 100 μm -thick electrified wire greatly reduced the waste and increased the number of wafers that could be made from a germanium ingot.

A thinner 75 μm -wide wire did even better. "At the current standard wafer thickness of 300 μm , you can produce up to 30% more wafers using our method with a 75 μm -wide wire," says Bamberg. "Since we produce them crack free, we can also make them thinner than standard techniques. So if you go down to a 100 μm -thick wafer, you can make up to 57% more wafers [from the same germanium ingot]." Making the wafers thinner should reduce their cost, because more can be made from the same ingot.

The new study found that the kerf (the amount of germanium wasted during slicing) was 22% less when a 75 μm -wide electrified wire was used, compared with the conventional wire saw method. The researchers cut 2.6 inch-diameter wafers with a thickness of 350 μm .

The study also showed that less germanium was wasted not only using the smaller wire size, but also if the charge on the electrified wire was lower.

Germanium-based solar cells are used mainly on NASA, military and commercial satellites because of the high expense (raw germanium costs about \$680 per pound). The 4-inch diameter wafers that are used cost \$80–100 each. The new cutting method may reduce the cost by more than 10%, says Sylarus' chief technology officer Grant Fines. Lowering this cost will ultimately lower the cost of solar power per kilowatt-hour and encourage wider use of solar power, he adds.

Sylarus is considering using the new method, but must determine if it can be scaled up so wafers can be mass-produced in a commercially viable manner, Fines says. Bamberg's method would "reduce the amount we have to recycle and increase the yield," he adds.

A patent is pending on a way of using the new method so that multiple, parallel electrically charged wires can be used to cut germanium wafers in mass-production.

www.unews.utah.edu

Fraunhofer ISE raises Euro PV efficiency record to 39.7%

After in mid-July announcing a European record of 37.6% for solar cell efficiency, in late September the Fraunhofer Institute for Solar Energy Systems (ISE) of Freiburg, Germany achieved a new European record of 39.7% (closer to the world record of 40.8% set in August by the US Department of Energy's National Renewable Energy Laboratory). The work is supported by the European Union research project Fullspectrum (SES6-CT-2003-502620).

Like July's record, the new cell uses the same metamorphic (lattice mismatched) triple-junction structure — grown on a germanium substrate by MOCVD using a reactor from Aixtron — consisting of more than 30 layers (including $\text{Ga}_{0.35}\text{In}_{0.65}\text{P}$, $\text{Ga}_{0.83}\text{In}_{0.17}\text{As}$ and Ge), which divide the solar spectrum into three wavelength ranges in order to convert it efficiently into electrical energy.

The 37.6% efficiency was reached under very high radiation intensities with a concentration ratio of 1700. Up to now such solar cells have been used primarily for space applications. ISE's current developments aim to facilitate more cost-efficient use of these types of cells for terrestrial applications. For this purpose, sunlight is concentrated up to 2000 times and focused onto a multi-junction solar cell having an area of only a few square millimeters. Concentrator photovoltaic (CPV) technology promises that the costs of generating electricity from sunlight can be considerably decreased, especially in countries with a large fraction of direct solar radiation.

However, for CPV systems, optimal efficiency of multi-junction solar cells must often be achieved at a concentration factor of 300–600 suns.

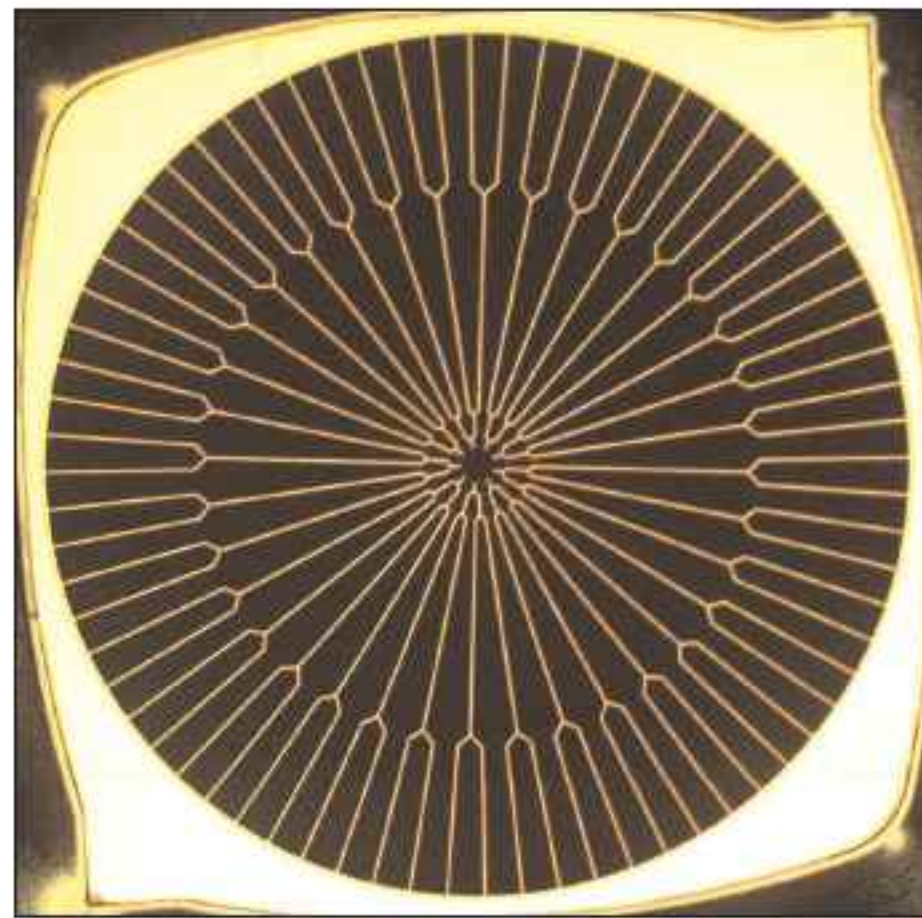


Figure 1. Typical metal finger structure on the front side of a GaInP/GaInAs/Ge concentrator solar cell with a diameter of 2mm.

In the latest, 39.7%-efficient cell, the higher efficiency has been achieved at 326 concentration.

At different concentration factors, the metallization on the front side of the solar cell makes a major difference. Hence, the solar cell's contact structures were improved through using a front-side network of thin metal wires that transport large currents but with low resistance, according to Frank Dimroth, head of Fraunhofer ISE's III-V-Epitaxy and Solar Cells Group.

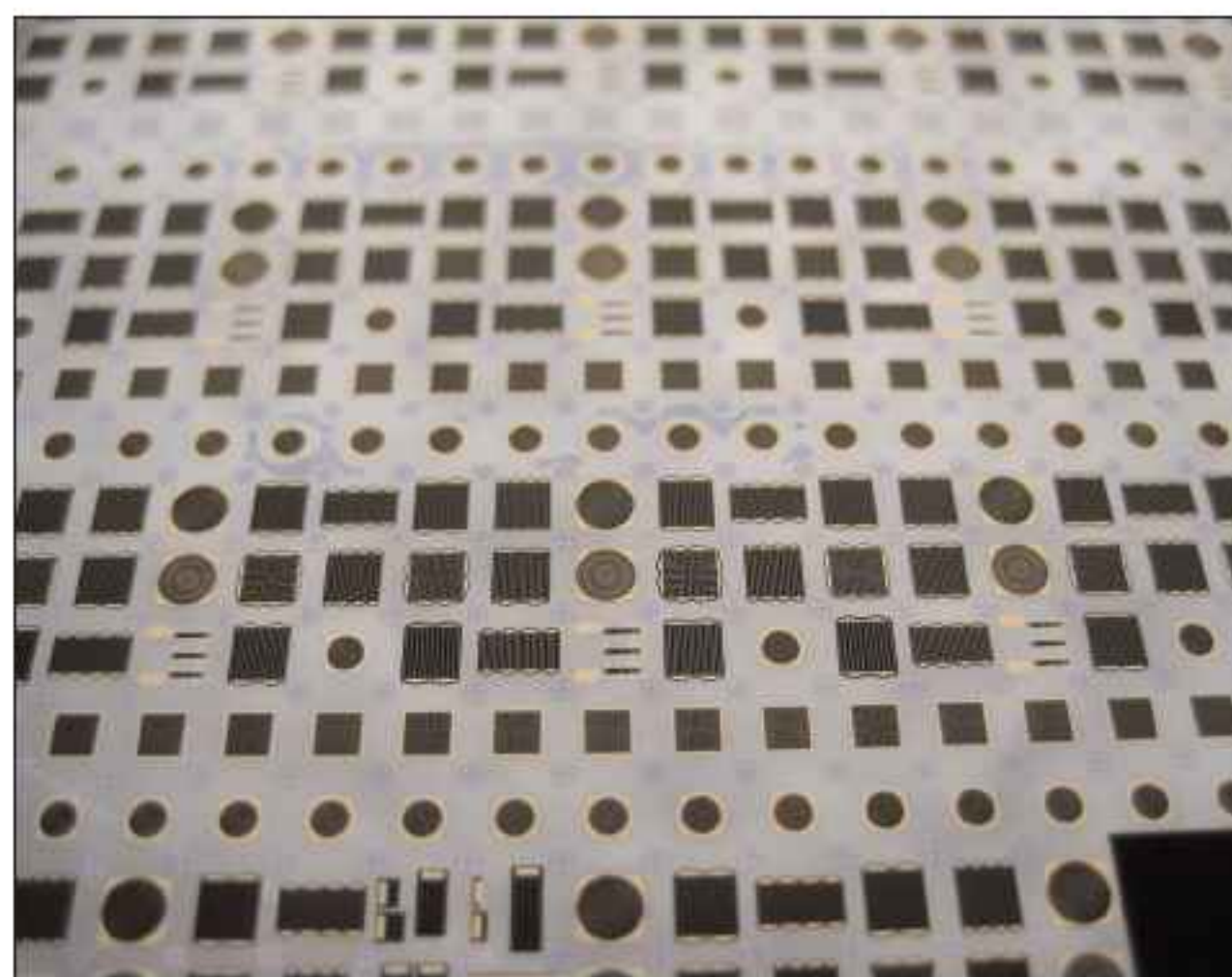


Figure 2. Photo of a solar cell wafer with different concentrator solar cell structures.

In the front grid, current is conducted through a network of thin wires (see Figure 1) from the middle of the solar cell to the edge, where it is then picked up by a 50 μm gold wire. Under concentrated sunlight in particular, the structure of this metal network is critical. On the one hand, the metal wires must be big enough to transport, with low resistance, the large currents that are generated under concentrated sunlight. On the other hand, the wires must be as small as possible, since sunlight cannot penetrate through the metal and thus the cell area covered by the metal cannot be used for converting sunlight to electricity.

For the past two years, sponsored by Fullspectrum, Fraunhofer ISE has been working on a program for the theoretical calculation of the optimal contact structures. Based on this work, the new cells are especially suited to inhomogeneous radiation, e.g. for concentration factors of 300–600 suns. The solar cells have been installed in concentrator modules of FLATCON type, both at Fraunhofer ISE and at spin-off firm Concentrix Solar GmbH, among others.

"We are very pleased to have advanced a further decisive step in such a short amount of time," says Dr Andreas Bett, department head at ISE. Higher efficiencies will help the technology to be market competitive and cut the cost of solar electricity generation, he adds.

ISE aims to transfer the technology to its manufacturing partner Azur Space in Heilbronn, Germany

www.ise.fhg.de

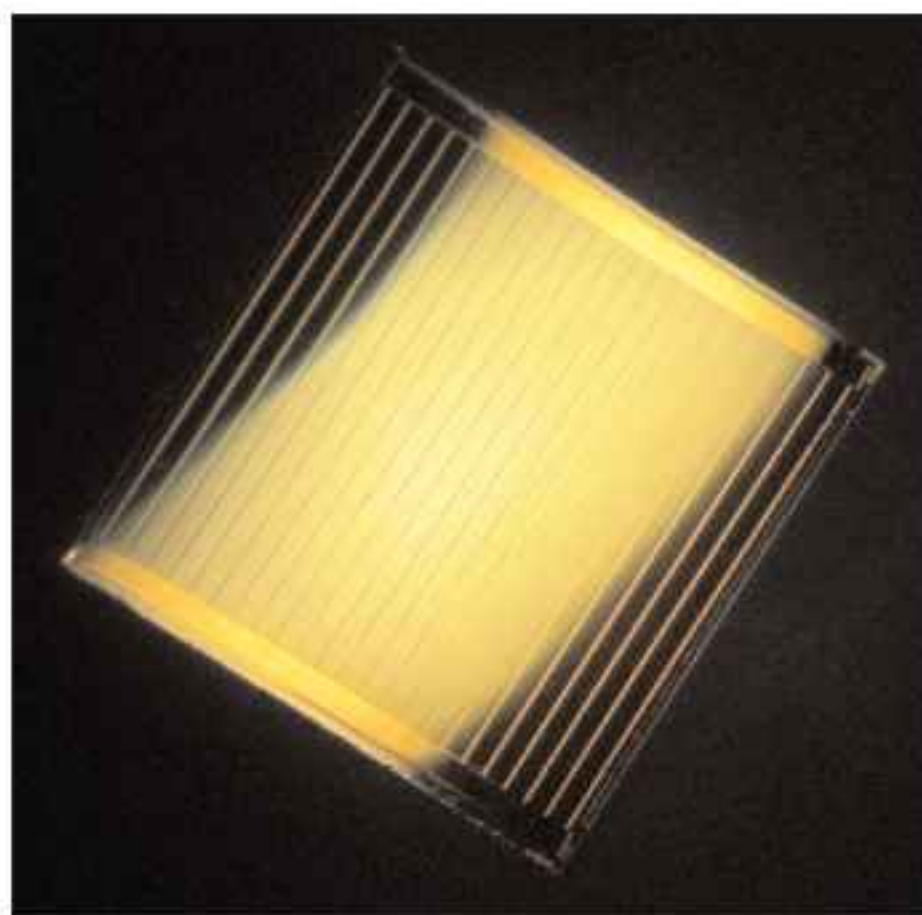
InP boosts thermo-photovoltaic efficiency record to 12%

A three-year collaborative research project, funded partially by the UK's Technology Strategy Board and the Engineering and Physical Sciences Research Council (EPSRC), has delivered first-generation thermo-photovoltaic (TPV) cells with energy conversion efficiencies of up to 12% (versus 9% for existing, commercially available devices).

The consortium partners in the project are CIP Technologies of Martlesham Heath, Ipswich (which makes photonic hybrid integrated circuits and indium phosphide-based optoelectronic chips, devices, arrays and modules for the communications and defence markets), III-V substrate maker Wafer Technology Ltd of Milton Keynes (a member of the IQE plc group of companies), and the University of Oxford's Physics Department.

On the TPV project, CIP is responsible for epitaxial growth and the fabrication of both devices and fully packaged TPV modules, Wafer Technology has developed a new range of low-cost InP substrates, and the University of Oxford performs cell design and device testing.

TPVs are similar to solar cells, but operate at infrared rather than



Thermo-photovoltaic (TPV) cell.

visible wavelengths, generating electricity directly from heat. Applications include waste heat recovery from industrial plant such as blast furnaces, combined heat and power (CHP) generation and domestic boilers, as well as silent mobile power generation.

Rather than the more traditional gallium antimonide (GaSb), the new, record single-junction TPV cells are based on indium phosphide (InP), which offers higher efficiency, low-cost growth, and fabrication using industry-standard processes, combined with the potential to fabricate highly integrated and complex cells.

"CIP's expertise in InP growth and fabrication continues to demonstrate successful application to new markets and products, and builds on its III-V solar cell expertise to continue to address areas of environmental importance," says TPV project manager Dr David Rogers.

The consortium is now working on a second-generation cell design with a more complex, multi-layer construction that should improve infrared capture further and boost efficiency beyond 15% (widening the range of viable applications for the technology).

"The advanced technology that has emerged from this project complements solar photovoltaic cells, and significant efficiency gains from the second-generation product are expected," says CIP's commercial & contracts manager, Andrew Bridges. "CIP is leading the commercial exploitation and volume manufacture of this technology and is actively seeking partners and end users to develop its full market potential," Bridges adds.

www.ciphotonics.com
www.wafertech.co.uk
www.physics.ox.ac.uk

First Solar breaks ground on Ohio CdTe PV expansion

First Solar Inc of Tempe, AZ, USA, which makes thin-film photovoltaic modules based on cadmium telluride (CdTe), has held the official groundbreaking ceremony for the expansion of its facility in Perrysburg, OH, officiated by president Bruce Sohn and attended by Ohio Governor Ted Strickland, US Senators George Voinovich and Sherrod Brown, and guests representing state and local governments.

The groundbreaking puts First Solar on track to complete plant

construction by first-half 2009, with full volume production expected by second-quarter 2010.

The expansion (announced in August) will add about 500,000ft² of manufacturing, R&D and office space, and increase annual capacity to about 192MW by bringing it to the same four-line configuration as the firm's five other plants in Germany and Malaysia.

The firm will also construct a separate facility to support increased development activities

associated with its thin-film solar module manufacturing technology.

The new investment will add at least 134 new jobs to the current workforce of 700. First Solar has collaborated with the State of Ohio and local leaders on a comprehensive incentive package for the two projects.

"Our growing capacity allows us to continue reducing the cost of solar electricity to a level competitive with conventional sources," says Sohn.

www.firstsolar.com

First high-output normally-off GaN HEMT

Fujitsu has unveiled what it claims is the first gallium nitride HEMT that needs no negative voltage in standby mode, while boosting output power to 100W.

At the International Symposium on Compound Semiconductors (ISCS) in Rust, Germany (21–24 September), Tokyo-based Fujitsu Laboratories Ltd presented what is claimed to be the first gallium nitride-based high-electron-mobility transistor (HEMT) with a structure that achieves high output of over 100W while also enabling power to be cut when the device is in standby mode. Fujitsu says the

advance should contribute to higher output and lower power consumption in amplifiers for high-speed wireless communications at microwave (30MHz to 30GHz) and millimeter-wave (30GHz to 300GHz) frequencies.

As transmission speeds in next-generation wireless communications have increased, wireless base-stations that operate in the microwave frequency range at several gigahertz consume an ever-increasing amount of power. In addition to the fact that the millimeter-wave frequency range above 30GHz has a large amount of available bandwidth that is currently unused, its potential for use in high-speed transmissions is significant since it delivers high speed and good directionality, says Fujitsu. However, because millimeter-wave frequencies are higher than frequencies used for conventional wireless transmissions, it has been difficult to develop amplifiers for practical use that are both compact and economical, so the millimeter band has so far not been widely used.

Amplifiers based on silicon have low breakdown voltages, making it difficult for them to achieve both high frequencies and high power output, so attention has shifted to compound semiconductors with higher breakdown voltages. GaN-based compounds have innately high breakdown voltages, suiting high-output applications. The development of high-output power amplifiers enables microwave and millimeter-wave transmissions to be used in high-speed wireless communications.

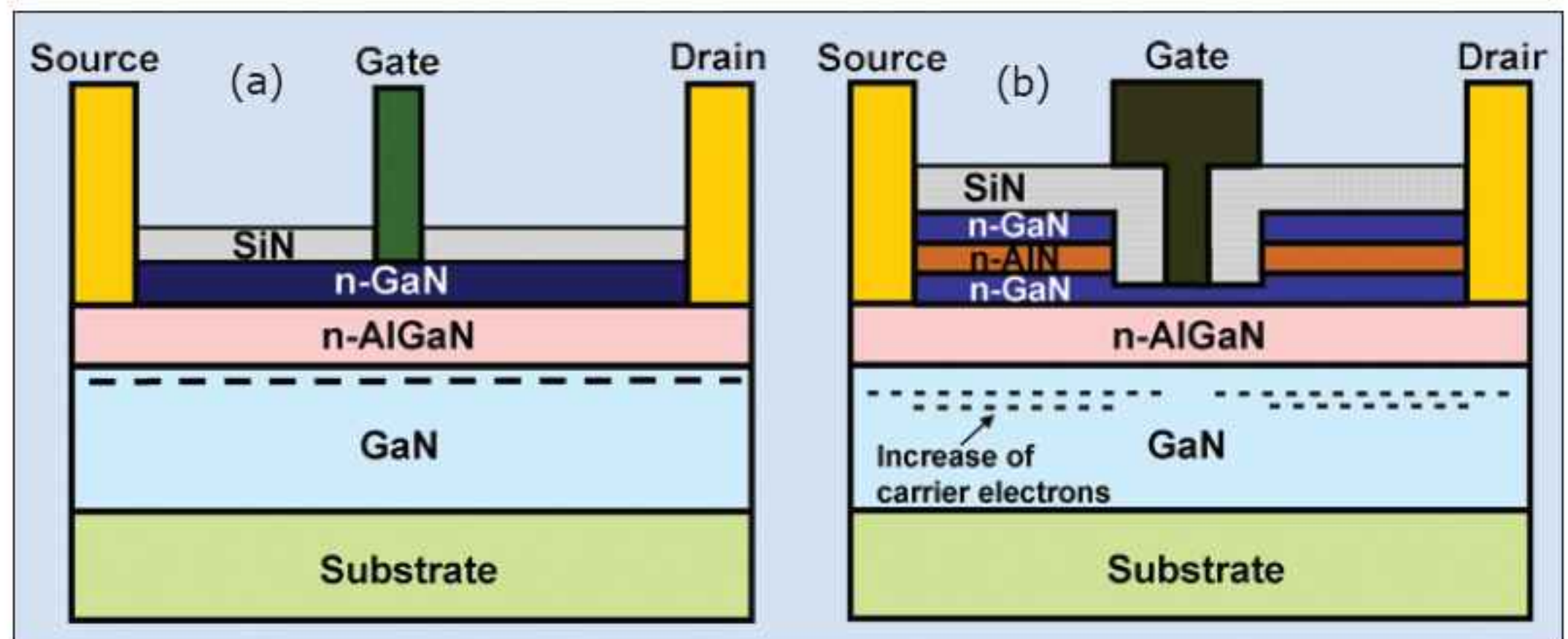


Figure 1: GaN HEMT: (a) conventional structure; (b) structure of Fujitsu's new HEMT.

Previous amplifiers based on compound semiconductors have required a negative voltage to be applied continuously to the gate electrode (see Figure 1a), even when the circuit is in standby mode (enabling the electron density just below the gate to be zero, allowing

Previous amplifiers based on compound semiconductors have required a negative voltage to be applied continuously to the gate electrode, even when the circuit is in standby mode... The new three-layer cap structure obviates the need for a negative voltage across the gate electrode to turn off the device

the transistor's current flow to be turned off). This results in high power consumption. Until now, no compound semiconductor transistor had been able to both generate 100W of power output and cut power consumption without requiring the addition of a negative voltage. Also, because the design of the control circuits used in previous transistors has been very complex, they required more power to be consumed.

Figure 1b shows the structure of Fujitsu's new GaN HEMT transistor, which it claims is the first that does not require a negative

voltage to turn off the circuit's power.

Key features include the following:

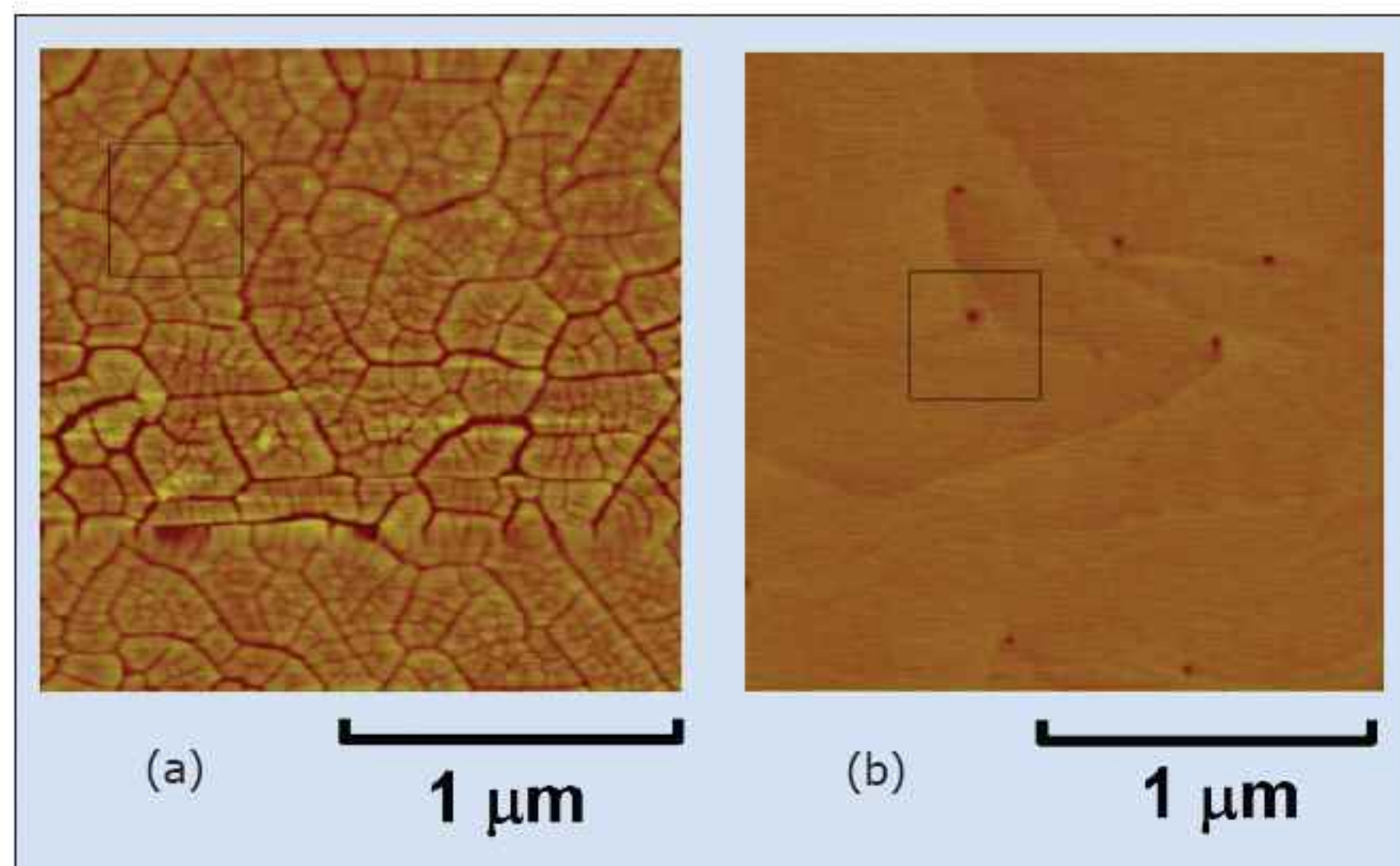


Figure 2: Atomic-scale surface roughness on GaN HEMTs for:
(a) a two-layer cap structure without an uppermost layer; and
(b) the new three-layer cap structure.

- The addition of an aluminium nitride (AlN) layer on top of the n-type GaN layer increases the density of charge carriers in the two-dimensional electron gas on the GaN side of the GaN/n-AlGaN interface when the transistor is switched on. In a HEMT transistor, a high electron density makes the design naturally amenable to higher power output.
- The design of the gate electrode, formed after removing the AlN layer, decreases the density of carrier electrons in the region below the gate electrode, preventing current from flowing even in the absence of a negative voltage.
- Making the topmost layer from AlN results in a micro-cracked surface (see Figure 2a), which degrades the breakdown voltage. So, an n-type GaN-based top

layer was added, resulting in a three-layer GaN-AlN-GaN cap structure that improves the surface roughness (see Figure 2b) as well as raising output and reliability.

The new three-layer cap structure obviates the need for a negative voltage across the gate electrode to turn off the device and results in a GaN HEMT that allows power to be cut during standby. Fujitsu also verified that the addition of the AlN layer increases the volume of electrons transmitted by 60% (Figure 1b). This results in the transistor's characteristic of being able to sustain high current densities when on, but cut power when on standby (see Figure 3a).

The three-layer structure permits a breakdown voltage of 336V, resulting in what Fujitsu claims is an unprecedented combination of achieving high current densities and high breakdown voltages (see Figure 3b).

This enables high-efficiency power amplification with low resistance and low power consumption. Implementation of the new transistor structure eliminates the need for power during standby, and has realized output of 126W (the first time that both breakdown voltages exceeding 300V and output powers exceeding 100W have been achieved together, claims the firm).

Fujitsu intends to pursue commercialization of the GaN transistor technology, aiming to apply it in high-capacity wireless communications systems by 2010.

Aspects of the research were conducted as part of the Research and Development Project for Expansion of Radio Spectrum Resources, sponsored by Japan's Ministry of Internal Affairs and Communications.

www.fujitsu.com

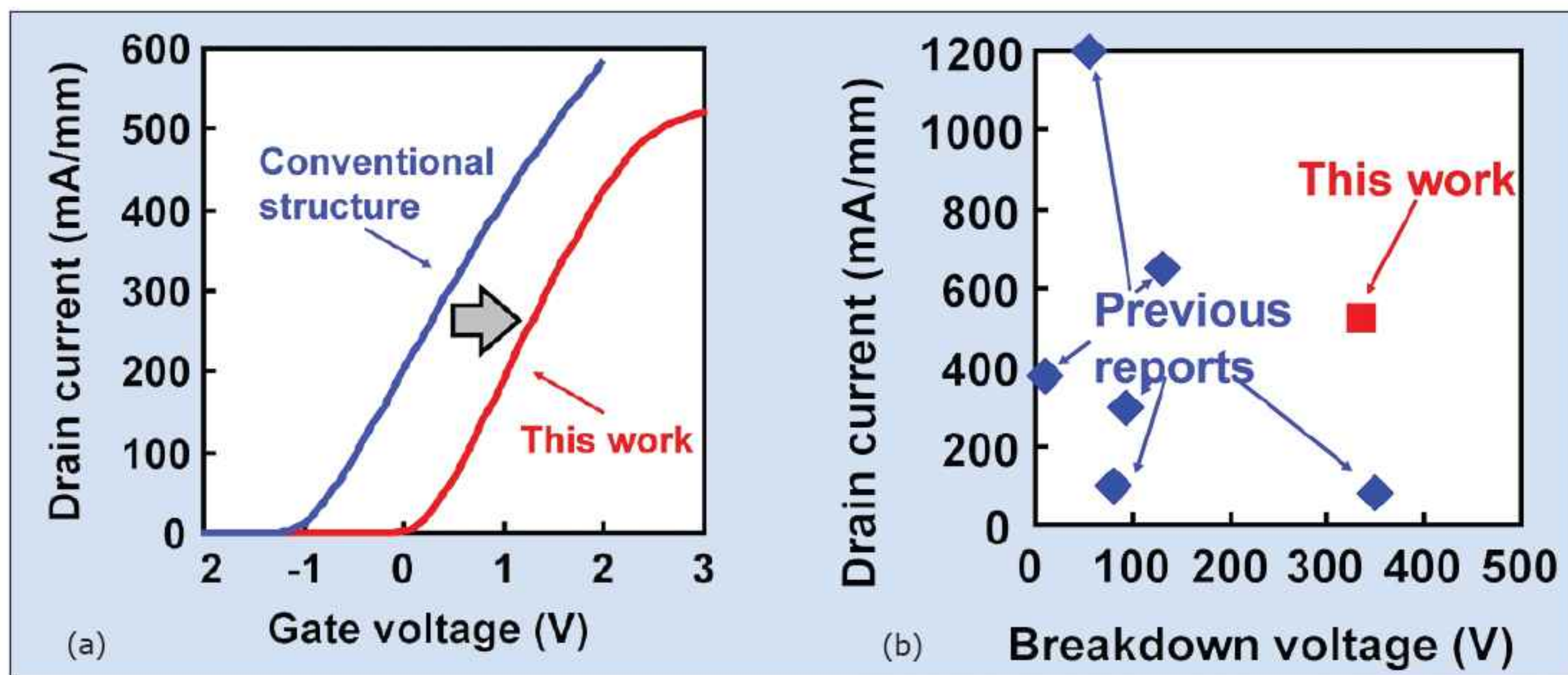


Figure 3: (a) Carrier transfer characteristics; and (b) maximum drain current and breakdown voltage benchmarks (enabling current to be turned off without applying a negative voltage).

Powering up GaN MOSFETs

In the past few years a new application for nitride semiconductors has been developing for high-power radio/microwave frequency amplifiers based on high critical field and carrier mobility properties. However, the transistors that have been produced have high gate leakage, leading to severe power losses, and it is desirable to develop suitable insulated gate structures. Recently, this work has been making progress, reports Dr Mike Cooke.

For some 20 years, there has been a drive to research and develop gallium nitride and related III-N compound semiconductor materials for electronic applications. The attractive properties of GaN include a wide direct energy bandgap of 3.4eV, a large critical electric field of 3MV/cm, carrier mobility comparable to that of silicon, and good thermal conductivity.

Until recently, nitride semiconductor development has been propelled forward by the ability, in principle, to emit light in the wavelength range 590–190nm, corresponding to photon energies of 2.0–6.2eV. This spectral range covers orange, yellow, green, blue, violet and ultraviolet light, based on various mixtures of aluminium (AlN, for which the bandgap is $E_g \sim 6.2\text{eV}$), gallium and indium (InN, $E_g \sim 2\text{eV}$) with nitrogen.

Now, due to its critical field and carrier mobility properties, GaN is being used to produce high-power-density transistors for radio frequencies up to tens of gigahertz. The smaller size of the resulting devices enables better impedance matching and hence better signal power transmission into and out of the device. These components are being marketed for base-stations used for mobile phone to network communications ($\sim 2\text{GHz}$).

So far, the GaN devices produced for power applications have been high-electron mobility transistors (HEMTs) with the gate operating through a reverse-biased Schottky junction with the semiconductor material. However, HEMTs suffer from high power losses from gate leakage and normally-on characteristics compared with components with an insulated gate, such as metal-oxide-semiconductor field effect transistors (MOSFETs). This is where silicon integrated device technology has been so successful in creating effective MOSFET structures that have been difficult to produce in other technologies. The basis for silicon MOSFETs has been the ease of growing silicon dioxide insulator on silicon with low densities of charge trap states and fixed charges near semiconductor-insulator interfaces.

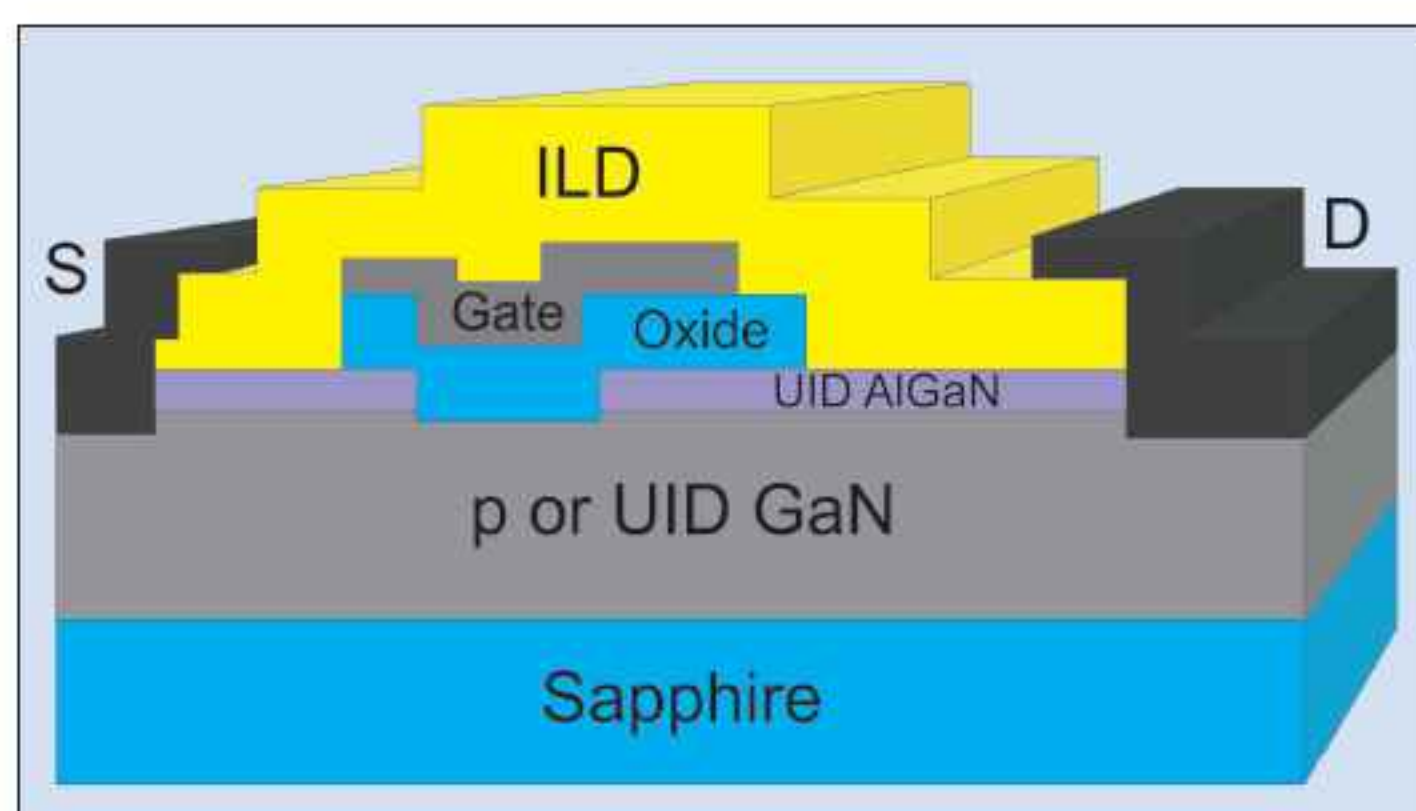


Figure 1. Schematic of hybrid MOS-HEMT device investigated in [2].

Further, polysilicon on silicon dioxide is an effective low-cost solution for gate electrodes.

Recently, there has been progress in developing suitable insulators for metal-insulator-semiconductor transistors based on III-V materials such as gallium arsenide, after some 20 years of stagnation in the area [1]. These renewed efforts have benefitted from the struggle of the mainstream silicon industry to move beyond the traditional SiO_2 gate insulation that is now becoming too thin for reliable devices. Different deposition techniques have been developed, with some coming from the compound semiconductor industry such as metal-organic chemical vapor deposition (MOCVD).

Among the groups researching oxides/insulators for III-V devices, a number have been developing materials for use in GaN gate stacks. For example, a group working under the direction of professor T Paul Chow at Rensselaer Polytechnic Institute (RPI) researches GaN MOSFETs using SiO_2 as the gate oxide, with one application target being power switching. The devices are made using standard tools from a silicon CMOS environment, says Chow. The GaN MOSFET process was developed by Chow's former PhD student Weixiao Huang. Chow sees such devices being used to implement

'smart power' in power supplies for low-voltage and battery-powered equipment. Chow has also worked on GaN MOSFETs with researchers at GE's Global Research center in New York State.

MOS-HEMT

At this May's International Symposium on Power Semiconductor Devices & ICs (ISPSD), an enhancement-mode hybrid MOS-HEMT built on GaN-on-sapphire was reported by a joint RPI/Furukawa Electric group [2]. The structure is designed to have a lightly doped drift region with a reduced surface field (RESURF) between the gate and drain to optimize the trade-off between the breakdown voltage and on-resistance of the device (Figure 1). An AlGaIn/GaN heterostructure is incorporated into the RESURF region so that the drift occurs in a high-mobility two-dimensional electron gas (2DEG), while the current flow is controlled by a MOS gate stack. Using the AlGaIn/GaN heterostructure instead of an ion implant to create the RESURF region avoids the need for extremely high-temperature annealing to activate the implant. The new arrangement results in a specific on-resistance as low as $20\text{m}\Omega/\text{cm}^2$ for a $20\mu\text{m}$ -long RESURF region.

First of all, the researchers carried out simulation work on the design concept to find appropriate parameters and dimensions for experimental devices. For example, the 2DEG carrier density was varied to find the maximum breakdown voltage. The model's optimum density for an unintentionally doped combination of AlGaIn/GaN was found to be $5 \times 10^{12}/\text{cm}^2$. However, this level creates too high a field in the oxide at the gate corners, making it difficult to create depletion and hence blocking current in the channel when the transistor is off. Balancing these contradictory needs limits the 2DEG carrier density to $2 \times 10^{12}/\text{cm}^2$. A higher carrier density means lower resistance, and hence higher current flow. For a higher carrier concentration, a model with p-type GaN (with a doping concentration of $3 \times 10^{16}/\text{cm}^3$) under the unintentionally doped AlGaIn was considered. The 2DEG carrier density for maximum breakdown voltage was found to be $1.2 \times 10^{13}/\text{cm}^2$. Taking into account the limitations from gate depletion, the 2DEG carrier density is found to be limited to $8 \times 10^{12}/\text{cm}^2$ or less. Varying the p-type doping for the GaN layer was also considered, with a doping density of $2\text{--}3 \times 10^{16}/\text{cm}^3$ found to be the best range in terms of long-term oxide reliability.

Actual devices were grown on 30nm of unintentionally doped $\text{Al}_{0.22}\text{Ga}_{0.78}\text{N}$ on a $3\mu\text{m}$ carbon-doped p-GaN buffer on sapphire. The general silicon dioxide insulation was 500nm thick, while the gate oxide was 100nm. The oxide was annealed at 900°C for 30 minutes in an N_2 ambient. The temperature was lowered from the usual 1000°C to protect the AlGaIn/GaN heterostructure. Polysilicon was used for the gate electrode. The source/drain contacts were 20nm of titanium on

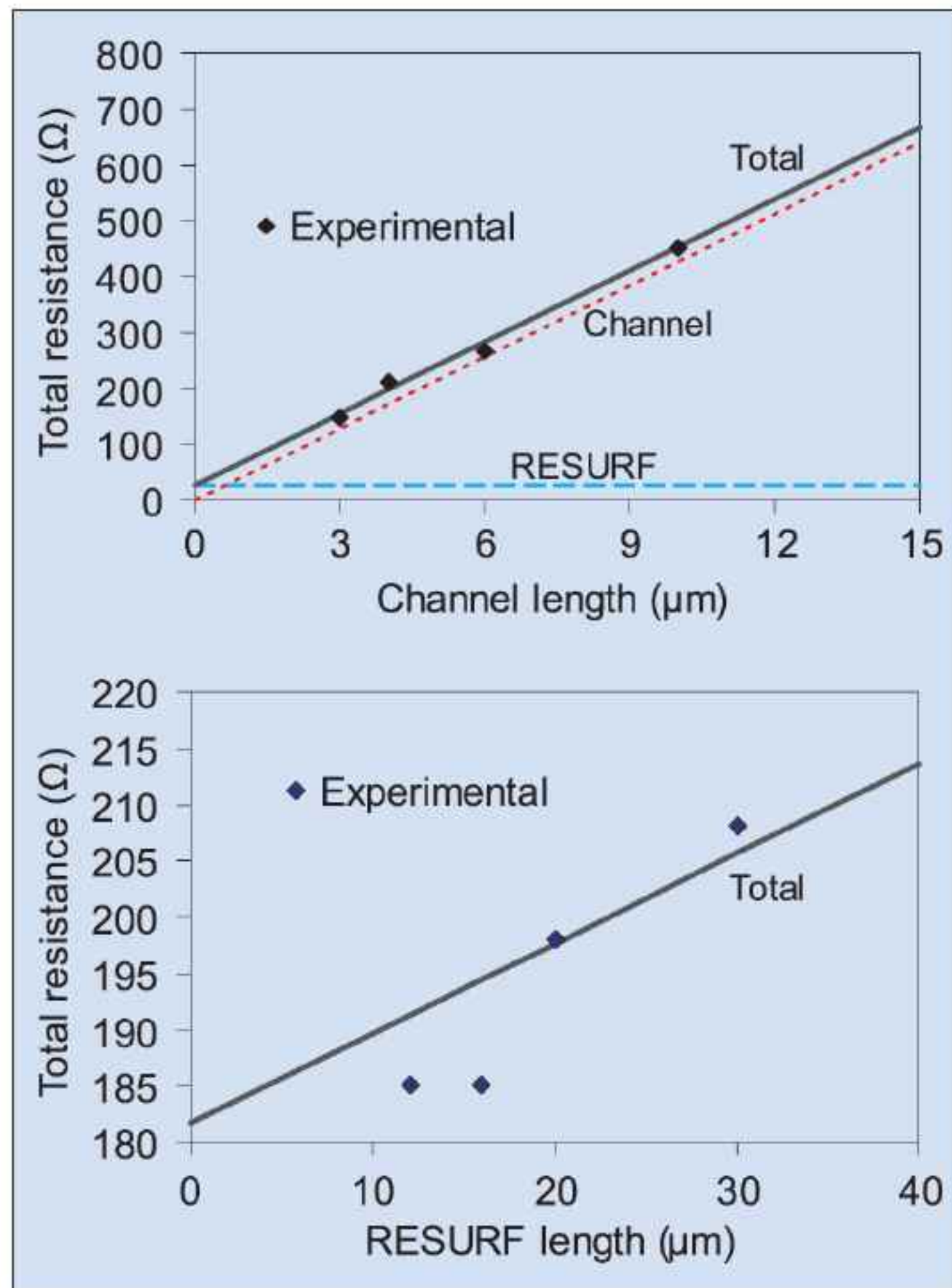


Figure 2. Experimental and model fit for on-resistance as function of channel and RESURF length for device in Figure 1.

300nm of aluminium. A Ti/Mo bilayer was used for the probe pads. Various RESURF region lengths were implemented in the range 8– $30\mu\text{m}$, with channel lengths of 2– $10\mu\text{m}$.

The model for the MOS-HEMT devices was tested by extracting parameters such as maximum field-effect mobility from circular GaN MOSFETs that were formed on the same wafer. The circular MOSFET devices were found to have a sub-threshold swing higher than previously obtained by the group. This poor performance was attributed to the wet etch step not completely removing damage from the more aggressive inductively coupled plasma (ICP) etch used to form the devices. CV measurements suggest that the lower anneal temperature also plays a role in the poorer performance. One result is that the maximum field-effect mobility of $79\text{cm}^2/\text{V}\cdot\text{s}$ is about half the value for as-grown GaN MOSFETs.

With these values for the relevant parameters, it was found that the MOS-HEMT devices performed close to the model in terms of on-resistance dependence on channel and RESURF region lengths (Figure 2). A device with a $3\mu\text{m}$ channel, $20\mu\text{m}$ RESURF length and $600\mu\text{m}$ width was found to have a specific

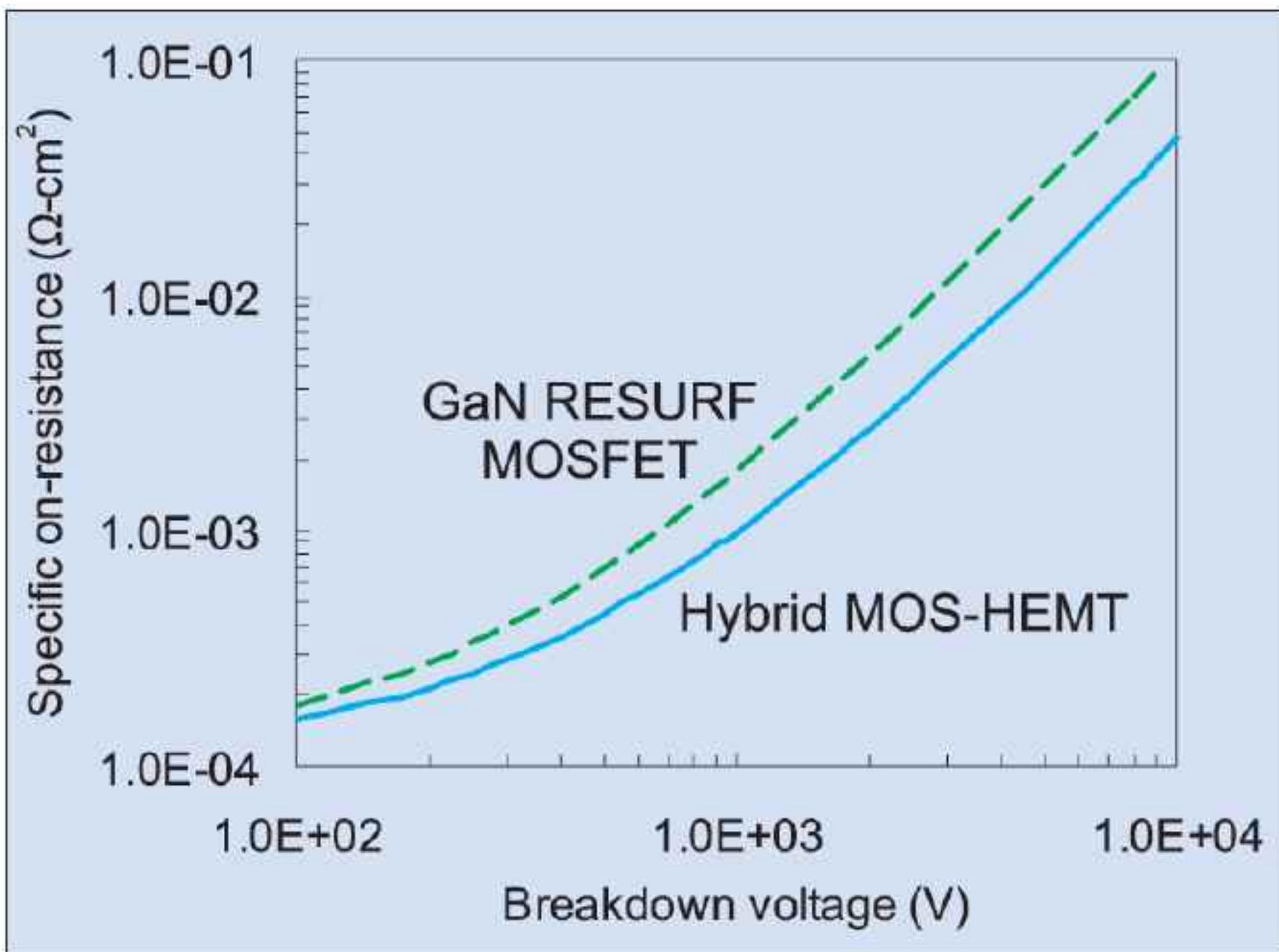


Figure 3. Specific on-resistance vs breakdown voltage for the device in Figure 1.

on-resistance of $20\text{m}\Omega/\text{cm}^2$ for a 30V gate voltage. For a $4\mu\text{m}$ channel and $20\mu\text{m}$ RESURF drift region, it is estimated that the channel contributes 84% of the resistance due to the poor mobility of p-GaN compared with the 2DEG in the drift region. The breakdown voltage of this device was 200V, which was attributed to oxide failure. However, it is thought that this can be improved by a better-quality p-GaN underlayer.

Using these results, it is found that the MOS-HEMT configuration has lower on-resistance over GaN RESURF MOSFET devices, both in devices with low breakdown voltage (BV) and even more so at higher BV ratings (Figure 3). For example, a 1200V MOS-HEMT device would have a specific on-resistance of $1.3\text{m}\Omega\text{-cm}^2$, a value that is 53% that of the equivalent MOSFET with just GaN in the RESURF region.

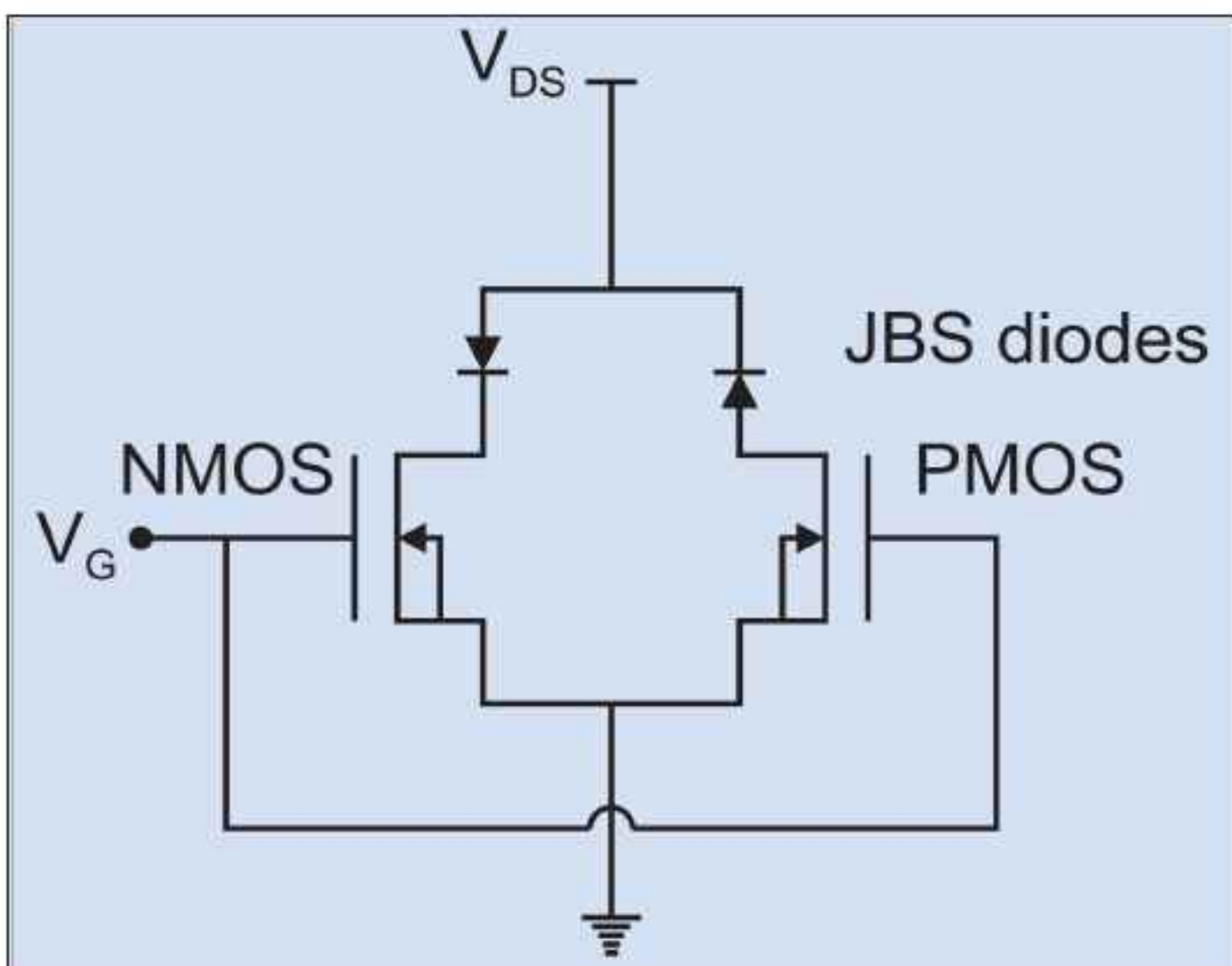


Figure 4. Bi-directional switch circuit structure.

GaN RESURF

Last year, a GaN RESURF region device was reported that integrated a MOSFET with an integrated Schottky diode [3]. The RESURF length dependence was studied up to $18\mu\text{m}$. DC performance includes a blocking voltage of 770V in the forward direction and 1040V in the reverse direction. The device is designed to be half of a GaN bidirectional switch (Figure 4), realized as a pair of MOSFETs connected with a complementary pair of junction barrier Schottky diodes. In the half circuit, the current is blocked in the forward direction by the RESURF region and in the reverse direction by the Schottky diode (Figure 5). Again, simulations preceded the building of actual devices.

Devices were built on a $3\mu\text{m}$ unintentionally n-doped GaN epilayer on sapphire grown using MOCVD. Silicon ion implantation was used to create source/drain n doping.

Annealing was carried out at 1100°C to activate the silicon doping. Circular devices were created with a channel length of $4\mu\text{m}$ and a channel width of $800\mu\text{m}$. The length of the RESURF drift region was varied between $6\mu\text{m}$ and $18\mu\text{m}$.

From the experimental results, the forward voltage drop in the on state for a given breakdown voltage device was predicted to give an indication of the on-resistance. Beyond a breakdown voltage of 1000V the forward voltage drop rises rapidly from 1.2–1.3V, reaching $\sim 10\text{V}$ at 10,000V (Figure 6). Beyond 5000V breakdown, bipolar structures would be needed to reduce on-resistance and hence bring power losses down to an acceptable level. Further problems would arise from integrating the p-channel half of the bi-directional switch due to the lower hole mobility in GaN.

Over a number of years, the RPI group [4] has reported on the properties of silicon dioxide deposition on GaN using different (and often unspecified) precursor recipes and process temperatures ($300\text{--}900^\circ\text{C}$).

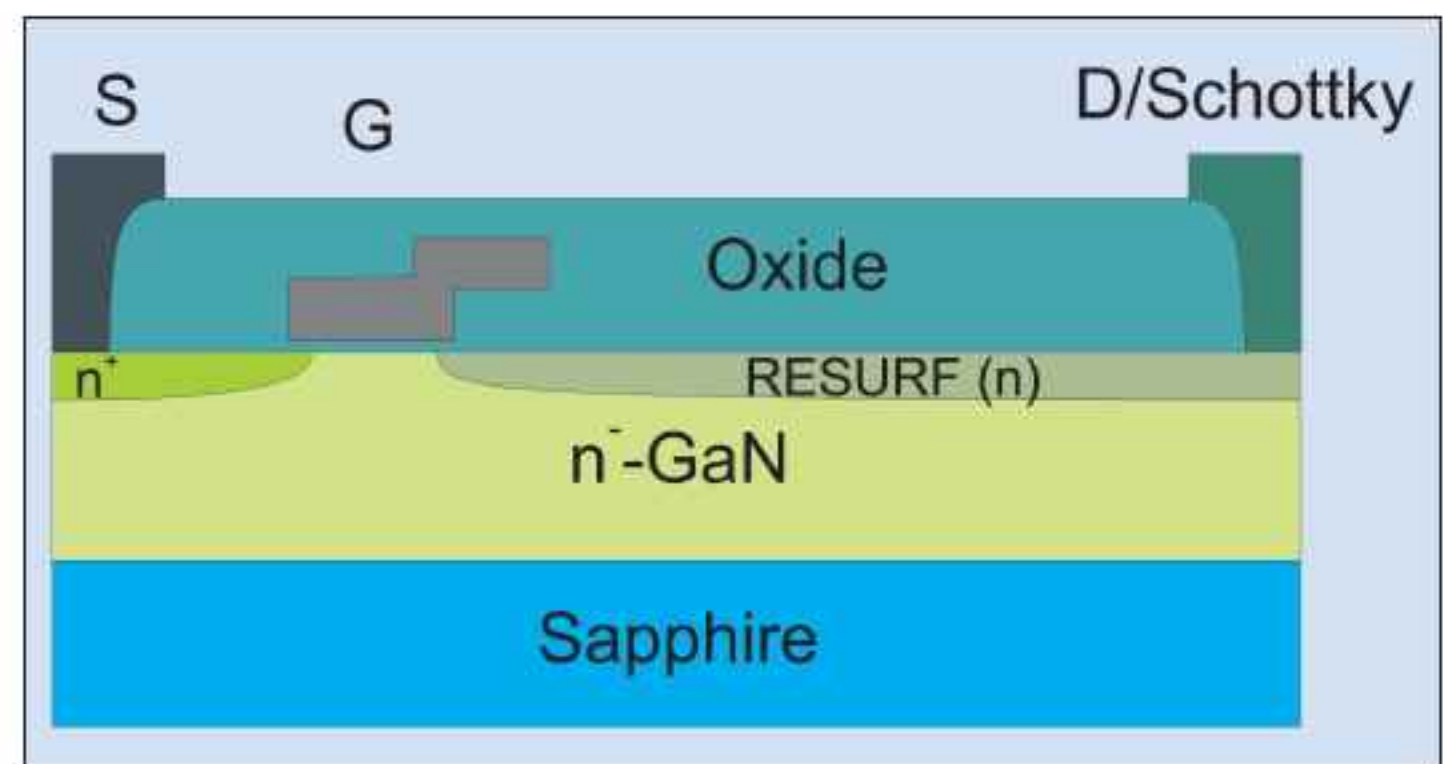


Figure 5. Schematic of half bidirectional switch of GaN MOSFET with integrated Schottky diode.

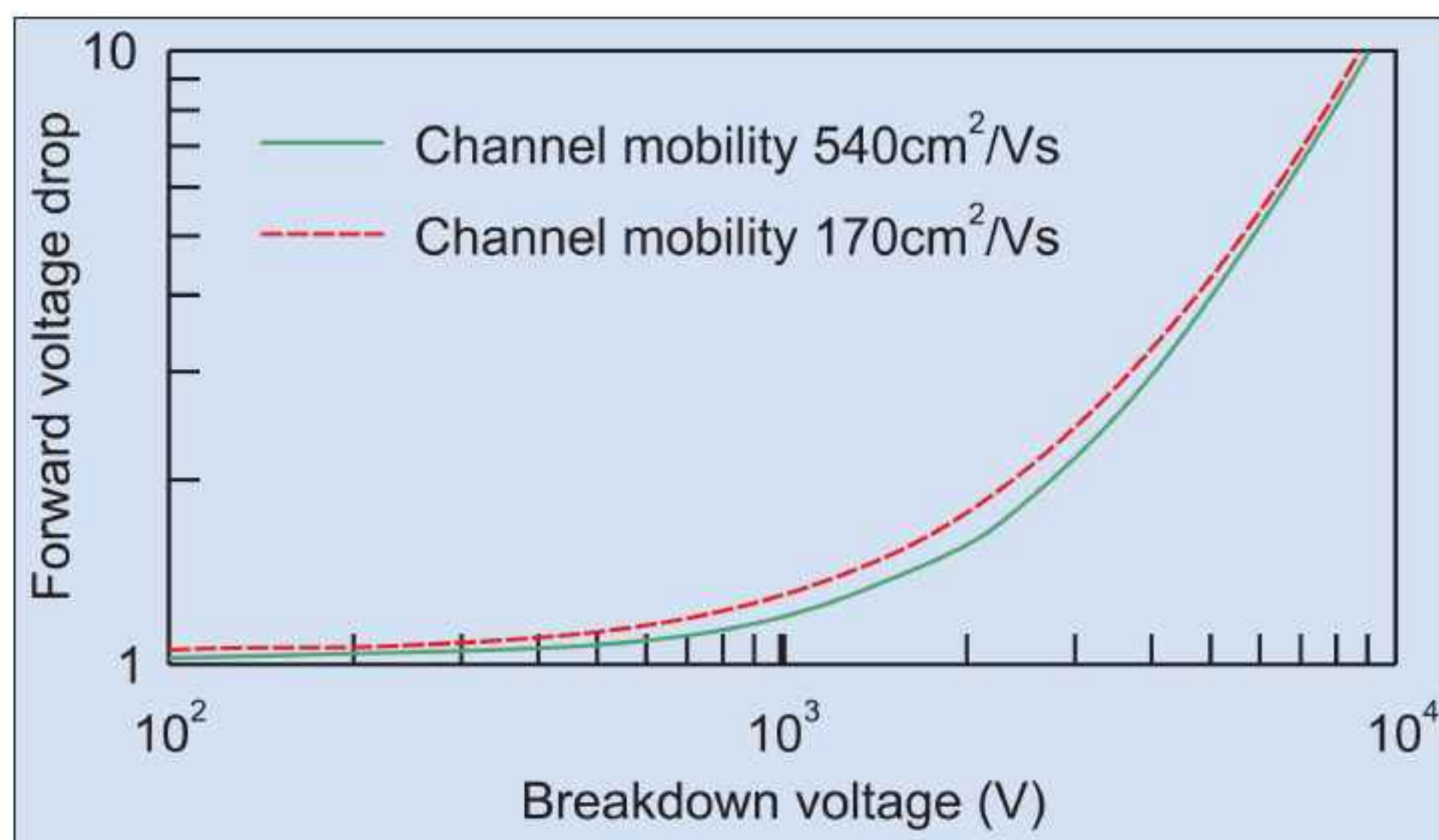


Figure 6. Predicted forward voltage drop for current density of $100\text{A}/\text{cm}^2$ and given breakdown voltage for two channel mobilities and RESURF region mobility of $600\text{cm}^2/\text{Vs}$. RPI achieved a mobility of $167\text{cm}^2/\text{Vs}$.

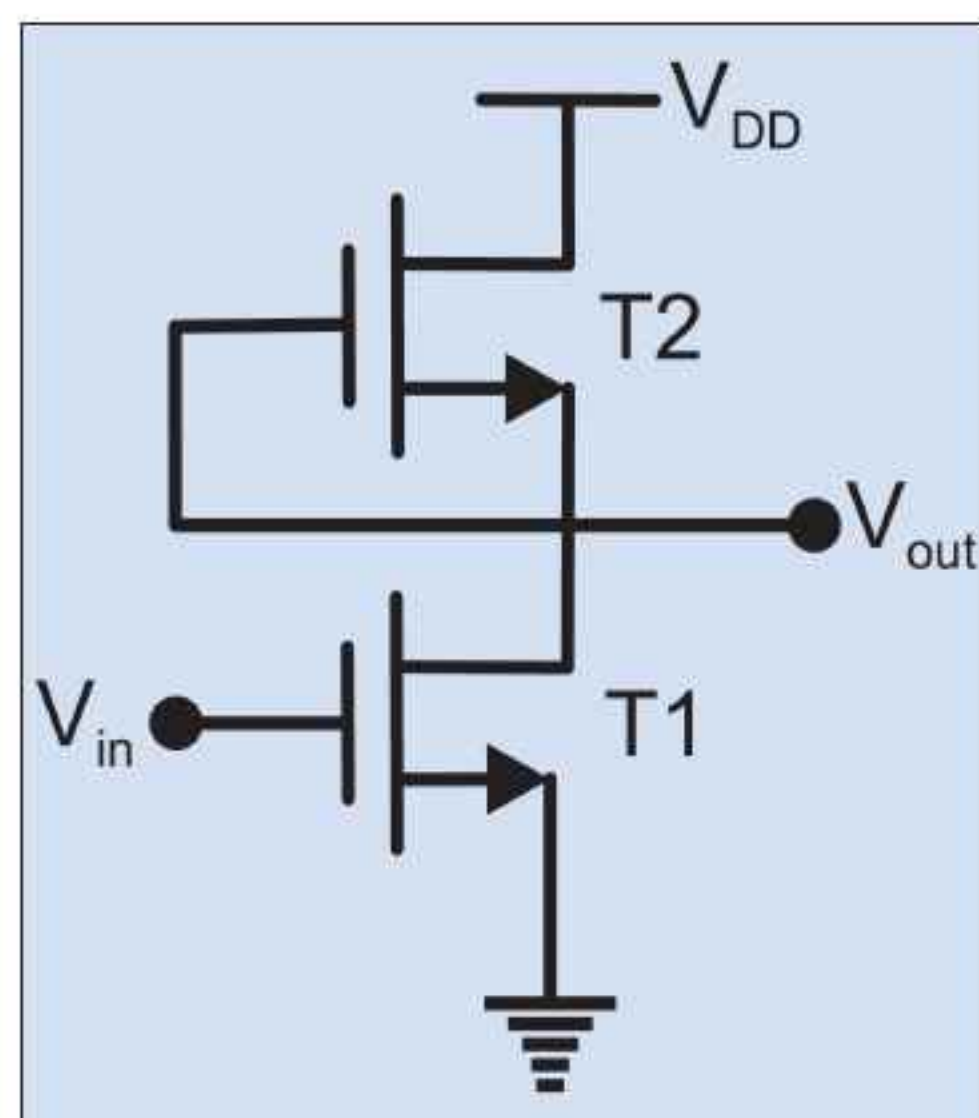


Figure 7. Schematic circuit diagram for a gallium nitride inverter device.

Measurements (CV, flat-band voltage shift) on GaN MOS capacitor formations to determine the levels of interface trap states and fixed charge in the oxide layer have resulted in one process (OX3 in [4]) that showed a low level of traps that decreases into the bandgap and a positive 1.5V flat-band voltage shift. Ultraviolet-induced flat-band voltage shift measurements on OX3 indicated a net interface charge of $1.6 \times 10^{12} \text{q}/\text{cm}^2$ and fixed charge of $1.0 \times 10^{12} \text{q}/\text{cm}^2$ (where q represents the elementary charge). The maximum field-effect mobility in circular MOSFETs was found to be $167\text{cm}^2/\text{V-s}$, which is about 20% of the bulk value of $\sim 900\text{cm}^2/\text{V-s}$. However, even 20% was a world best for GaN MOSFETs, according to the researchers' knowledge.

A common problem in GaN HEMTs is the collapse of current at high source/drain voltages. Testing for current collapse in the GaN MOSFETs with pulsed gate voltages instead found increased currents. It is thought that the pulsed gate voltage creates less heating than a DC gate condition.

A common problem in GaN HEMTs is the collapse of current at high source/drain voltages... pulsed gate voltage creates less heating than a DC gate condition

An inverter circuit (Figure 7) built using the GaN MOSFETs showed good transfer characteristics.

The University of Florida has also been doing basic research on improved gate dielectrics for GaN MOSFETs over the past decade or so, under the direction of professors Steve Pearton and Fan Ren. Oxides with interface state densities as low as $1\text{--}3 \times 10^{11} \text{cm}^{-2}$ have been produced. Among the materials that were tried as an insulator on GaN at Florida (individually and in alloy form) are Ga_2O_3 , Gd_2O_3 , Sc_2O_3 , MgO , MgCaO , SiO_2 , SiNx , and even low-temperature-deposited GaN.

Other work

Florida has used its GaN MOS technology to create MOS-HEMT hydrogen detectors. A variety of these devices have been deployed in the field for hydrogen sensing at a Ford dealership in Orlando, where a fleet of hydrogen-fueled cars are stored. Florida has also collaborated with researchers at Taiwan's National Cheng Kung (NCKU) and National Central (NCU) universities and at Toyota's central lab in Japan.

Florida, together with NCU and French epiwafer firm Picogiga International, has also investigated using GaN-on-silicon substrates to produce GaN MOSFETs [5]. GaN-on-silicon opens up possibilities of large-scale, low-cost production, perhaps even on the largest 300mm diameter wafers. Although silicon's lattice mismatch with GaN ($\sim 17\%$) is worse than sapphire's ($\sim 15\%$), the thermal conductivity of silicon is much better, which is an important consideration for power devices. Silicon carbide is another material that is used for GaN MOSFET growth — it has a much smaller lattice mismatch ($\sim 3\%$) and even better thermal conductivity than silicon. However, it is extremely expensive and is available only in diameters of up to 100mm.

The group at NCKU [6] has used SiO_2 to make a MOSFET with $13\mu\text{m}$ source-to-drain distance and a gate area of $8 \times 40\mu\text{m}$. The transconductance was $48\text{mS}/\text{mm}$ with a drain current of $250\text{mA}/\text{mm}$ at a 4V gate voltage. The gate voltage could also go up to 20V. More recently, an oxide layer containing Ga_2O_3 and Al_2O_3 was used to produce an AlGaN/GaN MOS-HEMT with a threshold voltage of -5V . The gate leakage was 50pA at a forward bias of 10V and 2pA at a reverse bias of -10V [Huang et al, IEEE Electron Device Letters, vol.29, p284, 2008]. A maximum transconductance of $50\text{mS}/\text{mm}$ was found at -2.09V .

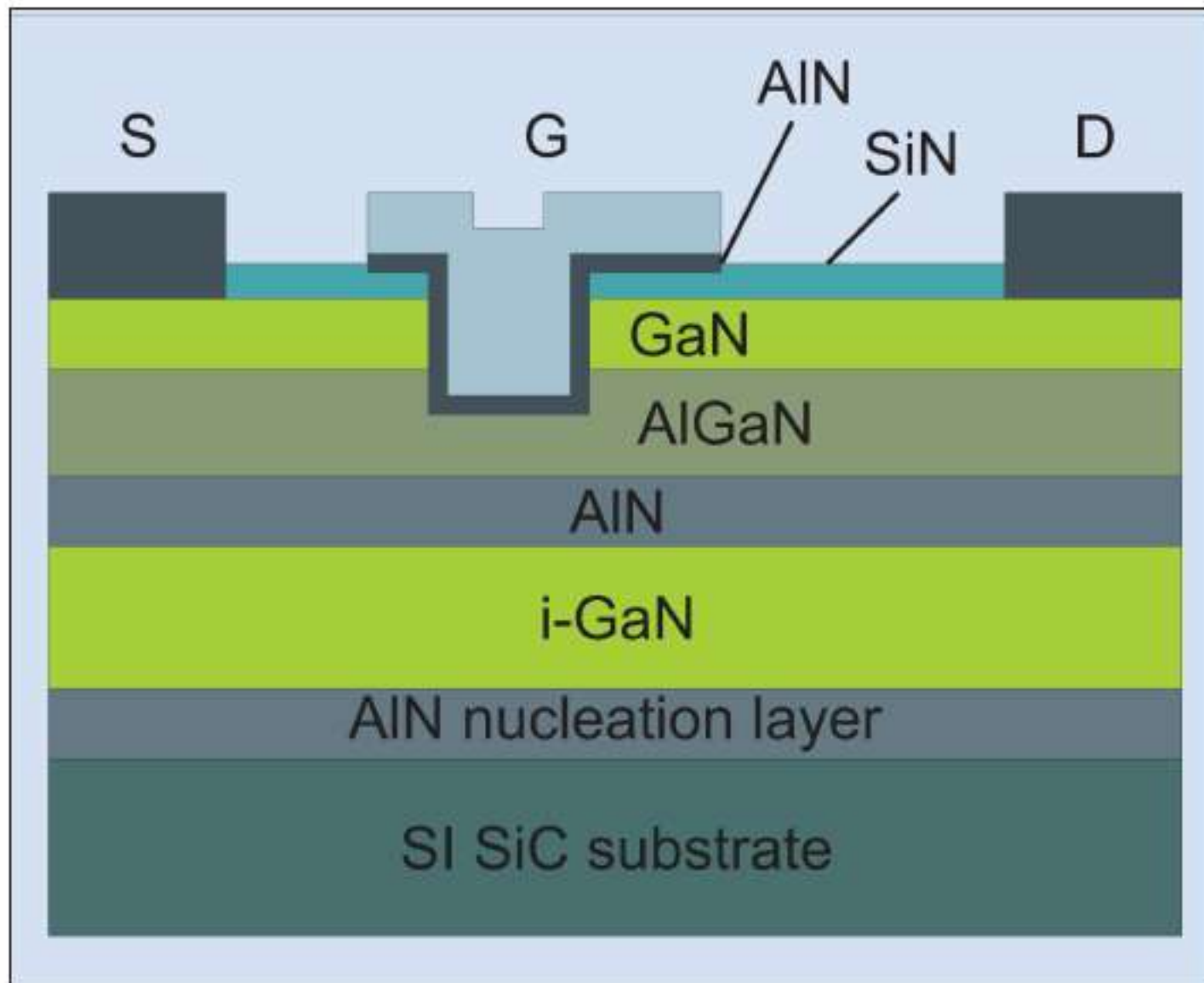


Figure 8. GaN MOSFET with AlN insulator on semi-insulating SiC substrate.

In 2000, researchers at China's Nanjing University [7] reported a GaN/AlGaIn/GaN double-heterojunction structure with SiO_2 insulator and a gate that was 6mm long and 100mm wide. The DC transconductance was 0.6mS/mm and the maximum drain-source current was 5mA/mm. The gate leakage was less than

1 μ A at a bias of -10V and the gate breakdown was more than 20V. In 2006, the Nanjing team reported a 0.4 μ m AlGaIn/GaN MIS-HEMT that used AlN as the insulator layer (Figure 8) [8]. The gate leakage at -80V was \sim 0.1mA/mm, which compares with a current in excess of 1mA/mm for a traditional Schottky gate GaN HEMT. The gate leakage also falls off faster for lower gate potentials.

A Yale University team [9] used jet vapor deposition (JVD) to investigate a $\text{SiO}_2/\text{Si}_2\text{N}_3/\text{SiO}_2$ (ONO) stack in a MOS capacitor structure (i.e. without source and drain regions), which is often the first stage in demonstrating a gate stack for later use in a MOSFET structure. The gate leakage was described as 'very low', while interface traps and fixed oxide charge were 'low'. The hard-breakdown strength was 'extremely high'. ■

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 Fax: +44 1933 227814
www.MCP-group.com

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50 Simms Avenue,
 Providence, RI 02902,
 USA
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 Fax: +1 401 421 2419
www.thinfilmproducts.umicore.com

United Mineral & Chemical Corp

1100 Valley Brook Avenue,
 Lyndhurst,
 NJ 07071,
 USA
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 Fax: +1 201 507 1506
www.umccorp.com

2 Bulk crystal growth equipment

MR Semicon Inc

PO Box 91687,
 Albuquerque,
 NM 87199-1687,
 USA
 Tel: +1 505 899 8183
 Fax: +1 505 899 8172
www.mrsemicon.com

3 Substrates

AXT Inc

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 CA 94538,
 USA
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 Fax: +1 510 683 5901
www.axt.com

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 Fax: +1 518 271 7394
www.crystal-is.com

The Fox Group Inc

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 Canada
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 Fax: +1 514 630 0227
www.thefoxgroupinc.com

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 CA 94539, USA
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 Fax: +86 755 89724120
www.epistone.com

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 Germany
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 Fax: +49 3731 280 106
www.fcm-germany.com

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Tel: +1 919 789 8880
Fax: +1 919 789 8881
www.kymatech.com

Nikko Materials

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Chandler, AZ, USA
Tel: +1 480 732 9857
Fax: +1 480 899 0779
www.nikkomaterials.com

SiCrystal AG

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D-91058 Erlangen, Germany
Tel: +49 (0) 9131 / 73 33 97
Fax: +49 (0) 9131 / 73 22 37
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sp3 Diamond Technologies

2220 Martin Avenue,
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Tel: +1 877 773 9940
Fax: +1 408 492 0633
www.sp3inc.com

**Sumitomo Electric
Semiconductor Materials Inc**

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www.sesmi.com

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www.spirecorp.com

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Fax: +44 (0)1223 352444
www.camchem.co.uk

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(see section 3 for full contact details)

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Fax: +33 (0)1 69 31 61 79
www.picogiga.com

SemiSouth Laboratories Inc

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Fax: +1 662 324 7997
www.semisouth.com

5 Deposition materials

**Akzo Nobel High Purity
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Fax: +1 312 544 7188
www.akzonobel-hpmo.com

Cambridge Chemical Company Ltd

Unit 5 Chesterton Mills, French's
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Tel: +44 (0)1223 352244
Fax: +44 (0)1223 352444
www.camchem.co.uk

Matheson Tri-Gas

6775 Central Avenue
Newark, CA 94560, USA
Tel: +1 510 793 2559
Fax: +1 510 790 6241
www.mathesontrigas.com

Mining & Chemical Products Ltd
(see section 1 for full contact details)**Power + Energy Inc**

(see section 8 for full contact details)

Praxair Electronics

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Orangeburg, NY 10962, USA
Tel: +1 845 398 8242
Fax: +1 845 398 8304
www.praxair.com/electronics

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6 Deposition equipment

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Tel: +1 617 965 5511
Fax: +1 617 965 5818
E-mail: sales@microchem.com

www.microchem.com

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

Praxair Electronics
(see section 5 for full contact details)

8 Wafer processing equipment

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Oxford Instruments Plasma Technology

(see section 6 for full contact details)

Power + Energy Inc

(see section 8 for full contact details)

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Fax: +1 408 734 0961
www.samcointl.com

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9 Materials & metals

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Fax: +44 (0)1954 786818
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www.cscleansystems.com

EMF Semiconductor Systems Ltd

(see section 6 for full contact details)

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www.iemtec.com

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Tel: +1 215 942-4600
Fax: +1 215 942-9300
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4175 Santa Fe Road,
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11 Process monitoring and control

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k-Space Associates Inc

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Fax: +1 734 668 4663
www.k-space.com

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Optical Reference Systems Ltd

OpTIC Technium, St Asaph
Business Park, St Asaph, LL17 0JD,
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Fax: +44 (0)1745 535 186
www.ors-ltd.com

WEP (Ingenieurbüro Wolff für Elektronik- und Programmentwicklungen)
Bregstrasse 90, D-78120
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Germany
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Fax: +49 7723 9197 22
www.wepcontrol.com

12 Inspection equipment

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Fax: +49 (0)721 595 4587
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Fax: +1 510 456 2498
www.kla-tencor.com

13 Characterization equipment

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Fax: +1 402 477 8214
www.jawoollam.com

Lake Shore Cryotronics Inc
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Fax: +1 614 818 1600
www.lakeshore.com

14 Chip test equipment

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www.suss.com

15 Assembly/packaging materials

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Fax: +1 512 231 8183
www.epak.com

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Fax: +1 510 576 2282
www.gelpak.com

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www.jpsalaser.com

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www.kns.com

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17 Assembly/packaging foundry

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Tel: +1 858 674 4676
Fax: +1 8586 74 4681
www.quikicpak.com

18 Chip foundry

Compound Semiconductor Technologies Ltd
Block 7, Kelvin Campus,
West of Scotland, Glasgow,
Scotland G20 0TH, UK
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Fax: +44 141 579 3040
www.compoundsemi.co.uk

United Monolithic Semiconductors
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BP46, Orsay, 91401,
France
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www.ums-gaas.com

19 Facility equipment

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www.marlerenterprises.net

20 Facility consumables

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21 Computer hardware & software

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Crosslight Software Inc

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Semiconductor Technology Research Inc

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www.semitech.us

22 Used equipment

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www.wsr-ods.com

25 Resources

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http://spie.org/innovation.xml

10–13 November 2008

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University of Nottingham, UK

E-mail: M3-Academic-Support@nottingham.ac.uk

www.[nottingham.ac.uk/~epzgk/nanoproduction-workshop.php](http://www.nottingham.ac.uk/~epzgk/nanoproduction-workshop.php)

19–20 November 2008

Optoelectronics Industry Development Association's 17th Annual Forum

Baltimore, MD, USA

E-mail: iams@oida.org

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

24–28 November 2008

International PV Trade Mission China

Shanghai, China

E-mail: info@solarplaza.com

www.[solarplaza.com/event/pvtourschina](http://www.solarplaza.com/event/pvtourschina)

1–5 December 2008

MRS Fall Meeting 2008

Boston, MA, USA

E-mail: info@mrs.org

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

2–4 December 2008

Searching for the 'Second Solar' USA, including PHOTON's 1st PV Thin-Film Conference

San Francisco, CA, USA

E-mail: ticket@photon-expo.com

www.[photon-expo.com/en/usa_2008/sss_2008.htm](http://www.photon-expo.com/en/usa_2008/sss_2008.htm)

3–5 December 2008

Semicon Japan

Chiba, Japan

E-mail: jeventinfo@semi.org

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

11–13 December 2008

IEEE 39th Semiconductor Interface Specialists Conference (SISC 2008)

San Diego, CA, USA

E-mail: kaczer@ieeesisc.org

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

13–17 December 2008

Photonics 2008: 9th International Conference on Fiber Optics and Photonics

New Delhi, India

E-mail: bppal@physics.iitd.ac.in

http://web.iitd.ac.in/~photonics2008

14–17 December 2008

IEEE International Electron Devices Meeting (IEDM 2008)

San Francisco, CA, USA

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www.[ieee.org/conference/iedm](http://www.ieee.org/conference/iedm)

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9–11 January 2009

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http://theledexpo.com

20–22 January 2009

SEMICON Korea 2009

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www.semiconkorea.org

24–29 January 2009

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San Jose, CA, USA

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http://spie.org/photonics-west.xml

18–20 February 2009

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Santa Clara, CA, USA

E-mail: tcarli@strategies-u.com

http://sil09.events.pennnet.com

25–27 February 2009

2nd International Photovoltaic Power Generation Expo (PV Expo 2009)

Tokyo, Japan

E-mail: pv@reedexpo.co.jp

www.pvexpo.jp/2009_eng

28 February – 3 March 2009

LED CHINA 2009

Guangzhou, China

E-mail: Led@TrustExhibition.com

www.LEDChina-gz.com

4–6 March 2009

PHOTON's 4th Photovoltaic Technology Show 2009 Europe

Munich, Germany

E-mail: ticket@photon-expo.com

www.photon-expo.com/en/pts_2009_europe/pts_2009.htm

8–11 March 2009

15th European Molecular Beam Epitaxy Workshop (Euro-MBE 2009)

Zakopane, Poland

E-mail: mbe09@unipress.waw.pl

www.unipress.waw.pl/mbe09

13–15 April 2009

6th China International Solar PV Exhibition

Shanghai International Exhibition Center, China

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www.ch-solar.com

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Photonics '09: 4th International Specialized Exhibition for Laser, Optical and Optoelectronic Technologies

Moscow, Russia

E-mail: es@expocentr.ru

www.photonics-expo.ru

3–7 May 2009

LightFair International 2009

New York, NY, USA

E-mail: info@lightfair.com

www.lightfair.com

18–20 May 2009

OPTOmism: Photonics for the Green Revolution

Santa Clara Convention Center, CA, USA

E-mail: OPTOmismAbstract@oida.org

http://opt09.events.pennnet.com

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