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COMPOUNDS & ADVANCED SILICON

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Solar power focuses on compounds

GaAs-on-Ge and CIGS PVs get down to earth

LED developments

Lighting at the crossroads

Taiwan consolidates

WiMAX market & product launches • Further SiC investments
NIST's AlGaAs epi standard • HVPE for GaN quantum wells

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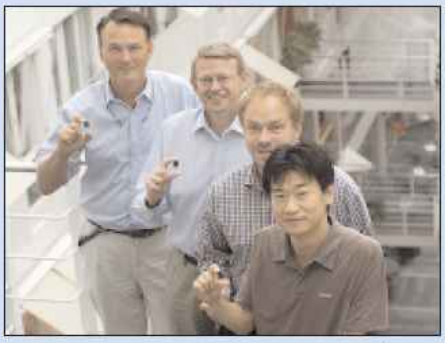
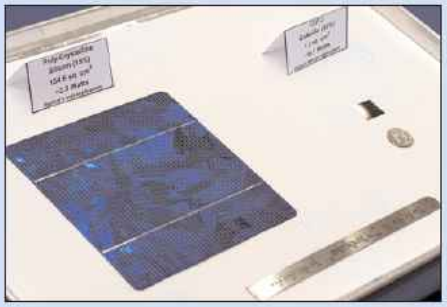


p13 KTH spin-off TranSiC is sampling its first product, a 6 Amp SiC BJT.

p27 Osram's new side-emitting LEDs for low-profile display backlighting.



p34 A small GaAs/Ge concentrator-based terrestrial solar cell (right) can produce over five times the power of a much larger polysilicon cell (left).

Cover: A SolFocus terrestrial solar panel. Each dish contains a Spectrolab concentrator photovoltaic cell with an average conversion efficiency of 35%. Spectrolab is to make and supply 600,000 cells to SolFocus, capable of generating more than 10MW of electricity (enough to power about 4000 US homes). **p25**

editorial

Renewed energy in compound interest

In this issue of *Semiconductor Today* we focus on the topic of photovoltaic cells, specifically those using compound semiconductor materials rather than silicon. But, as indicated by other developments reported in the news pages, there are several types of materials and devices that are attracting attention for applications that aim to use electrical energy more efficiently, in the interests of both global ecology and national economies.

On pages 12–14 we report further launches of both new silicon carbide manufacturing plants (epiwafer and substrate maker Norstel) and products (bipolar junction transistors of KTH spin-off TranSiC, both of Sweden), as well as funding for Microsemi to develop new products for defense applications and yet more funding for SemiSouth. This follows recent new facility openings by SemiSouth and II-VI Inc, Microsemi and Cree (reported in the August issue, pages 24–27). Many of the applications of silicon carbide electronics are for power devices that aim to improve efficiency, such as inverters in hybrid electric vehicles.

On page 25 we report how Sandia has been chosen to be the new home of the US National Laboratory Center for Solid-State Lighting Research and Development, as well as increases by Osram (page 26) and Cree (page 28) of their white-light LED luminosities. However, the solid-state lighting industry is at a 'critical crossroads', according to market research firm iSuppli as adoption of solid-state lighting in new applications has been slower than expected and LED suppliers must target new applications while LEDs slowly start to penetrate general lighting.

Such market growing pains are partly behind Emcore's decision at the end of August to sell its stake in the LED lighting joint venture GELcore (see September issue, page 17). However, Emcore's main motivation is to refocus its business on broadband, optical communications and photovoltaic markets (see this issue, page 32). Emcore, like Spectrolab (page 34), has exclusively III-V-based photovoltaic technology, but is now adapting what has previously been dedicated to space application to terrestrial applications, allowing the use of concentrator cells to boost efficiency well beyond what is possible using established silicon solar cell technology.

Although III-V solar cell technology is more expensive, while polysilicon is in short supply, compound semiconductors have an opportunity to capitalize on their advantages. None more so than copper indium gallium diselenide (CIGS), which has the benefit of competitive efficiency and potentially much lower manufacturing costs (see page 24). Indeed, even major silicon solar cell makers such as Sharp and Shell are investigating III-V and CIGS solar cell technology. The key issue is whether these technologies can get a permanent foothold before silicon shortages ease. But, in the meantime, the opportunity for compounds is there. As the saying goes, make hay while the sun shines!

Mark Telford

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

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

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WLAN and WiMAX to grow to 23% of GaAs market by 2010

The reports "GaAs Device Demand from WLAN Market: 2005-2010" and "WiMAX Market Forecast: 2005-2010" from Strategy Analytics demonstrate that GaAs device demand from these two applications will show significant growth, with overall demand of nearly $1bn by 2010, second only to demand from the cellular handset market.

● WLAN GaAs demand growing 76% in 2006

The WLAN market continues to ramp. GaAs device demand for WLAN will grow by over 76% from $138m in 2005 to $243m in 2006. Demand for GaAs components such as PAs and switches will grow at a compound average annual growth rate (CAAGR) of 46% through to 2010, driven by the move to multi-mode and multi-band architectures that play to the advantages of linearity, efficiency and high-frequency capabilities offered by GaAs, requiring higher levels of complexity and multiple PAs and switches.

"The adoption of MIMO and 802.11n, which require multiple PAs, transceivers and more complex front-end modules, will have a big impact on GaAs demand," adds Chris Taylor, director of the Strategy Analytics RF & Wireless Components service. Strategy Analytics believes that SiGe will gain ground in 802.11g systems, but will fail to penetrate 5GHz applications through 2010 as 802.11n replaces 802.11g and 802.11a/g systems.

Amplifiers and switches will be the primary market for GaAs technology, with silicon dominating the transceiver and baseband markets

● WiMAX market to grow at 67% through to 2010

While the WiMAX market will remain in its early stages, semiconductor demand for WiMAX will grow at a CAAGR of 67% through 2010, though overall demand will remain low comparative to other wireless markets.

"While WiMAX will still be in an early stage of roll-out in 2010, certification of WiMAX equipment has started and coverage areas have begun to expand beyond basic trials, providing a real target market for GaAs suppliers," says Taylor.

Strategy Analytics says that it expects silicon technologies to account for 75% of the overall radio chip market in this early rollout of WiMAX technologies, but GaAs will dominate specific functions in the RF module, especially in mobile applications, with demand growing at a CAAGR of 69%. Strategy Analytics does not expect GaN to be a significant threat to silicon or GaAs during this early rollout; the potential to upset the status quo will only start to emerge from 2008 onwards.

"In terms of GaAs demand, the WiMAX and WLAN markets will emulate the cellular handset market," says Asif Anwar, director of the Strategy Analytics GaAs and Compound Semiconductor Technologies service. "Without expecting all-GaAs solutions, we do predict that amplifiers and switches will be the primary market for GaAs technology, with silicon technologies dominating the transceiver and baseband markets."

www.strategyanalytics.com

WLAN chip market to grow 17% to $3bn by 2010

The WLAN semiconductor market continues to look strong and will grow at a 17% compound annual growth rate (CAGR) to $3.2bn by 2010, says IDC in its 'Worldwide WLAN Semiconductor 2005–2010 Forecast'. IDC says that this growth is due to technology advancements in 802.11, such as single-chip low-power devices, production of pre-N and draft-N chipsets, and burgeoning end-market applications.

While industry-wide competition has continued to force pricing down, opportunity continues to abound for WLAN chip suppliers. The primary growth opportunity is in embedded applications such as mobile phones and in select consumer electronic designs.

"To remain viable players in this space, chip vendors must think about WLAN as a portfolio technology that can complement products in broadband, wired networking, consumer devices, PC, or mobile device designs," says Celeste Crystal, who is senior research analyst for IDC's Semiconductors group. "By focusing on end markets and the ecosystem, WLAN chip vendors will differentiate products and drive pricing and product differentiation in the industry," she adds.

www.idc.com

Mobile sales 970m in 2006, says Nokia

In Q3/2006, top cell-phone maker Nokia shipped a record 88.5m handsets (up 13% sequentially and 33% year-on-year), increasing its market share to 36%, from 34% in Q2/2006 and 33% a year ago. It estimated total industry shipments of 243m units, up 6% sequentially and 22% year on year.

However, Nokia's cell-phone revenues rose just 14% year-on-year. Average selling price fell from €102 in Q2 to €93, mainly due to a lower proportion of sales in high-end products and a higher proportion in entry-level products. This was driven by strong growth in emerging markets Latin America, Asia-Pacific and China (with unit sales up 32%, 65.9% and 62.4% year-on-year) and market share gains in those regions, more than offsetting share declines in Middle East & Africa and, to a lesser extent, Europe and North America (where unit sales grew 11.2% and 0%).

"Our entry-level device business performed extremely well, driven by outstanding volume growth and a solid product portfolio," said CEO Olli-Pekka Kallasvuo. "We expect the device industry to experience value growth in 2006, but expect some decline in industry ASPs, primarily reflecting the increasing impact of the emerging markets and competitive factors in general."

The mixed results highlight Nokia's strength at the top and bottom of the market, and its mid-range weakness, where Motorola and Samsung are making gains.

For the seasonally strong Q4, Nokia expects industry shipments to grow 15% to 279m, and its market share to stay at 36% (growing to over 100m). Nokia has raised its forecast for total 2006 shipments to 970m units (up 22% on its estimate of 795m for 2005). This compares with Gartner's forecast in late August of 960m (up 18% on its estimate of 816.6m units in 2005).

www.nokia.com

Sony Ericsson overtakes Motorola as fastest-growing mobile vendor

A record 256m mobile phones were shipped in Q3/2006, up 22% on Q3/2005, says Strategy Analytics in its report 'Vendor Market Share: Sony Ericsson the World's Fastest-Growing Mobile Vendor in Q3 2006'.

For the first time since Q1/2005, Motorola has been overtaken as the fastest-growing top-six mobile vendor, amid signs that demand for its Razr phone has peaked. Helped by strong demand for its Walkman and CyberShot ranges, Sony Ericsson grew 43% annually, compared with Motorola's 39%. Nokia was third-fastest growing, its highest rank for three years, with unit sales of 89m (a 35% market share).

Samsung gained 1% of market share sequentially, due to healthy sales of its new Ultra Edition portfolio of slim-phones. In contrast, despite the popular Chocolate family, LG's mobile phone sales grew just 6% annually; its slowest rate since Strategy Analytics' records began. BenQ–Siemens continues its almost inevitable movement to market exit, the market research firm adds.

With 716m units shipped in the first nine months of 2006, Strategy Analytics maintains its forecast of 1bn units for full-year 2006, up 22% on 2005.

www.strategyanalytics.net

Mobiles top 245m in Q3; 1bn by year end

Although Q2/2006 shipments and prices were softer than expected, 245m handset were shipped in Q3, and Q4 will be a boom quarter, so 2006 should reach 1bn in total, says ABI Research. "Handset vendors are pulling out all the stops to get their slickest, flat-test, largest music memory, biggest mega-pixel camera phones onto the shelves in time for the Q4/2006 holiday," says research director Jake Saunders.

The big five — Nokia (36%), Motorola (23.3%), Samsung (12.5%), Sony Ericsson (8.1%), and LG (6.7%) — all gained market share at the expense of smaller vendors due to economies of scale and marketing. "Initiatives such as super thin phones have helped manufacturers such as Samsung and Motorola gain market share, but Nokia's ability to pump out phones for the emerging markets, cut handset average selling prices (ASPs), and exploit its brand image have served to maintain, and even boost, Nokia's market-share," said principal analyst Stuart Carlaw.

The market share competition has led to lower ASPs. "The global weighted ASP dropped a steep –7.8% in Q3 compared to a 1.6% rise in Q2," said Saunders. "Q4 is unlikely to fare any better."

In Q3, 3G handset shipments were a bit soft. 2.75G EDGE (rolled out by a number of operators) has made the perceived performance gain of owning a 3G phone over a 2G GSM phone less distinct. Also, a some vendors and operators are planning a big overhaul of their 3G phone line up for Q4. Vodafone will be unveiling 10 new phones for the festive season, six with capabilities for 3.5G HSDPA (which will enhance downloading music, games, etc). But, ABI questions, will HSDPA kick in quickly enough?

www.abiresearch.com

Jazz acquired by Acquicor

Wafer foundry Jazz Semiconductor of Newport Beach, CA, USA, which specializes in high-voltage CMOS, SiGe BiCMOS and RFCMOS for analog and mixed-signal devices, has been acquired by private equity firm Acquicor Technology Inc of Newport Beach, CA, USA for $260m.

Acquicor was formed in August 2005 by Apple Computer co-founder Steve Wozniak as CTO, Ellen M. Hancock (ex-CTO of Apple and COO of National Semiconductor) as COO and president, and Gilbert F. Amelio (ex-chairman and CEO of Apple and National Semiconductor) as chairman and CEO. Amelio was also president of the Rockwell Communications Systems semiconductor manufacturing division of Rockwell International (later spun-off as Conexant Systems), responsible for operating what is now Jazz's plant.

Acquicor raised $172.5m in an initial public offering in March, aiming to invest in technology businesses and lend its management skills and technology expertise to help them capitalize on market opportunities. Jazz is Acquicor's first investment.

Acquicor is funding the purchase and providing further capital for the expansion of Jazz's business through its $164.3m trust account plus third-party funding. Wachovia Capital Finance (Western) has provided a $65m credit facility. The selling shareholders have agreed to provide up to $80m to complete the transaction, if necessary.

"Jazz is poised to take advantage of growth opportunities for innovative specialty foundry services," said Amelio. "We are very excited about leveraging Jazz's specialty process technologies and working with Jazz to optimize operations and expand fabrication capacity."

On completion in Q1/2007 (subject to approval by Acquicor's stockholders), Jazz will become an Acquicor subsidiary but still operate as Jazz, with Shu Li, president and CEO since its formation, continuing.

Jazz was formed in March 2002 as a joint venture between Conexant Systems Inc (which contributed its Newport Fab LLC wafer fab, becoming a fabless company) and a $52m, 55% controlling stake by private equity firm The Carlyle Group. The aim was to change it from captive manufacturing within Conexant to an independent foundry. Initial customers comprised just Conexant and Skyworks Solutions Inc (formed from Conexant's wireless business merged with Alpha Industries in June 2002). The transition, mostly completed, has expanded Jazz and diversified its customer base, resulting in over 300 design wins with over 95 new customers, including Marvell Technology Group, Texas Instruments, Freescale Semiconductor, and RF Micro Devices. Jazz also maintains manufacturing partnerships with HuaHong NEC Electronics Company (HHNEC) and Advanced Semiconductor Manufacturing Corporation (ASMC) in Shanghai, China.

The merger is expected to provide a diversified stockholder base and facilitate the management's long-term goal of growing through access to capital and broader exposure to public markets

"Over the past four years, our specialty process capabilities and customer base have grown considerably," said Li. "This merger reinforces Jazz Semiconductor's long-term strategic focus on a successful specialty foundry business model," said Li. The merger is expected to provide a diversified stockholder base and to facilitate the management's long-term goal of growing through access to capital and broader exposure to public markets. As Acquicor is already publicly traded, Jazz will no longer pursue its initial public offering plans and has withdrawn its registration statement filed with the Securities and Exchange Commission. "As part of a public company, we will have enhanced opportunities to build on the strong foundation we have already established," says Li.

On completion of the merger, Conexant expects to receive about $100m from its 42% stake in Jazz. "Our share of the proceeds from this transaction will significantly strengthen our balance sheet and provide us with improved liquidity," said chairman and CEO Dwight W. Decker. "Jazz has been an important supplier for Conexant since its inception, and I expect our relationship to continue," he added.

RF Micro Devices Inc of Greensboro, NC, USA expects to make $24–27m from selling its equity stake in Jazz, bought in 2002 for about $60m.

"RFMD and Jazz have worked together since 2002 developing state-of-the-art silicon process technologies targeted for next-generation mobile devices," said RFMD's co-founder and CTO Bill Pratt. "RFMD's next-generation single-chip EDGE transceiver, which we expect will ramp at Jazz in the first half of calendar year 2007, utilizes a specialized CMOS process jointly developed between the two companies. Additionally, our existing agreements with Jazz regarding supply, wafer credits and joint development activities remain intact, and we expect to continue a mutually beneficial partnership following the merger."

Li added: "We look forward to the continued evolution of this relationship as RFMD launches new highly integrated mixed-signal products built on Jazz silicon and as we continue our development efforts in advanced RF silicon semiconductor processes."

www.acquicor.com
www.jazzsemi.com

Skyworks exits baseband business and focuses on GaAs

Skyworks Solutions Inc of Woburn, MA, USA has ceased silicon-based baseband operations to focus on growing core business (GaAs linear products, power amplifiers, front-end modules and radio solutions).

Skyworks' baseband business developed complete reference designs, including the digital signal processor and software functionality, in support of tier-three handset makers. It says the initiative was complex, R&D intensive and generated substantial operating losses. As tier-one OEMs have increasingly dominated, the addressable market for its baseband solutions has 'significantly contracted'.

Meanwhile, masked by declining baseband sales (together with the conclusion of a non-strategic assembly and test services contract), Skyworks' core business revenue has grown 17% annually over the past four years (from $396m at Skyworks' launch in fiscal 2002 to an estimated $730m in fiscal 2006). This has been driven by the launch of the Linear Products business, gains in power amplifier market share, the ramp of Helios EDGE radios, and capturing increasing dollar content through highly integrated solutions.

Given the diverging profitability and growth profiles of the baseband and core businesses, Skyworks has implemented a strategic restructuring to eliminate all baseband-related infrastructure, while strengthening R&D, marketing and sales efforts in the core business.

"We are focusing exclusively on our high-growth and profitable analog and RF core business," says David J. Aldrich, president and CEO. "We will partner with, rather than compete against, leading baseband suppliers such as Texas Instruments, Qualcomm, Freescale and Infineon.

"We began our transition away from developing baseband designs nearly two years ago, but continued to support existing customers with legacy products. Throughout this timeframe, our portfolio of linear products, ultra-compact power amplifiers, Intera front-end modules and Helios EDGE radios has demonstrated design win momentum and an accelerating growth trajectory," says Aldrich. "We are implementing a strategic restructuring to build upon our leadership franchise and to realize our vision of becoming the global leader in semiconductors enabling mobile connectivity."

Skyworks will eliminate nearly $70m in annual costs through the narrowing of product development, closure of certain international design centers and a reduction in staffing by about 425 (10% of its workforce). However, this should result in charges of $85–95m for asset impairments, severance and shut-down costs, mostly in its fiscal Q4/2006 (to end-September).

Skyworks says it will consequently enter fiscal 2007 with an intensified focus on its analog, mixed-signal and RF design competencies across three strategic product areas:

- **Linear Products**

– New designs supporting medical, automotive, industrial and broadband applications;
– 802.11n solutions as part of Broadcom reference designs and cellular infrastructure subsystems led by Ericsson, Alcatel, and Nortel;
– sequential growth and record bookings in the past four quarters.

- **Power amplifiers and front-end modules**

– 42% market share, up from 30% in 2002, supporting all key worldwide standards;
– Increasing dollar content through higher levels of integration;
– Design wins with all tier-one handset OEMs.

- **Highly integrated radio solutions**

– Helios EDGE architecture powering Samsung and LG;
– DigRF radios for Motorola in 2007;
– WEDGE and WCDMA multi-mode solutions.

"Skyworks' business transformation is now complete. We've evolved from a system-level baseband supplier targeting new market entrants at the time of our launch, to a developer of highly specialized analog and RF solutions," says Aldrich. "Accordingly, we plan to substantially improve our financial performance, beginning in the current quarter."

Skyworks has also affirmed its fiscal fourth-quarter 2006 revenue guidance of $197–200m. Excluding restructuring charges, for fiscal first-quarter 2007 Skyworks expects pro-forma earnings per share of $0.12–0.14, with revenue growth in the core business offsetting the elimination of baseband revenue. It aims to deliver fiscal 2007 revenue of $820–840m, an increase in the core business of nearly 15% year-on-year. On a pro-forma basis, gross margin is expected to expand to 38–40%, while operating expenses decrease to $215m, yielding operating income in excess of $100m and EBITDA (earnings before interest, taxes, depreciation and amortization) of more than $150m. It also expects record pro-forma diluted earnings per share of $0.55–0.60, roughly twice the pre-restructuring consensus estimate of $0.29.

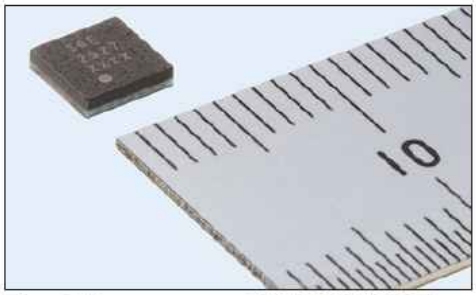
* A day after Skyworks announced it was exiting its baseband operations and restructuring, the company's shares rose by about 39% to $7, its largest percentage gain since June 1998.

www.skyworksinc.com

InGaP HBT PAs for WiMAX terminals

In mid-December, Mitsubishi Electric will begin sample shipments of the MGFS36E2527 high-output InGaP HBT amplifier, which operates at 2.5-2.7GHz for WiMAX terminals in mobile and domestic markets. To date, it has sold a pre-WiMAX transmission module for business services developed in the USA.

For strong wireless communication (i.e. reducing signal distortion while also strengthening output), by using InGaP HBTs often used in mobile handsets but with device structure optimized to fit the WiMAX orthogonal frequency division multiplexing (OFDM) modulation method, Mitsubishi has reduced the error vector magnitude (EVM) by 2.5% while maintaining a competitive output of 27dBm (502mW). It also claims that it is unique in its application to both IEEE802.16-2004 (fixed line communication) and IEEE802.16e-2005 (mobile communication) specifications.



The 4.5mm square MGFS36E2527.

Mitsubishi says it is the world's smallest high-output amplifier (4.5mm x 4.5mm) due to embedding the power detector and step attenuator in the module. Height has also been kept to 1mm for use in PC card terminals. External matching circuitry is unnecessary, since input/output port impedance is the wireless device standard 50Ω, reducing the number of parts and the mounting area.

Mitsubishi will also make amplifiers for the 3.5 and 2.3GHz bands.

http://global.mitsubishielectric.com

Power switch and diode co-pack

Cree Inc of Durham, NC, USA has made available samples of its first power-device combination pack (co-pack), designed specifically to reduce costs and increase efficiency of inverters used in solar, UPS and motor-drive power applications.

The CID150660 combines a 6A/600V Cree SiC Schottky diode with a 15A silicon insulated gate bipolar transistor (IGBT) from International Rectifier. It comes in a standard TO-220-3 package.

The co-pack provides the potential to achieve new levels of efficiency at power levels up to 3kW, says Stuart Hodge, manager of applications engineering for power devices. "This is the first in a series of co-pack products targeted to reduce IGBT switching losses up to 50% and reduce overall inverter losses up to 25%. Compared with traditional Si-based pn diodes, Cree's SiC-based Schottky diodes and co-pack solutions provide lower switching losses, higher-frequency operation, and higher power densities."

www.cree.com

Ultra-wideband short-range automotive radar sensors

M/A-COM of Lowell, MA, USA has introduced a new range of 24GHz ultra-wideband (UWB) short-range radar sensors for driver-assistance systems that incorporate GaAs pHEMTs as well as silicon application-specific integrated circuits (ASIC) chips.

The highly integrated 'smart sensor' is designed to improve safety and comfort functions in automotive applications by providing object detection and tracking, and to be resistant to inclement weather and harsh environmental conditions more than other sensing technologies such as infrared devices.

The sensors can be customized for the following applications:

- parking assistance — rear-mounted sensors, with a range of 1.8m, can detect small objects in front of large objects and measure the direction of arrival;
- pre-crash sensing — the sensors scan out up to 30m to provide advanced warning of an imminent collision, arm the airbags, pre-tension seat restraints etc;
- blind spot detection — short-range sensors detect objects in critical zones;
- obstacle detection — with up to a 30m operating range, the radar sensor can be used to warn of unseen objects.

M/A-COM's 24GHz ultra-wideband short-range radar sensor for driver-assistance systems.

The UWB technology enables the system to measure objects located within centimeters of the sensor, says M/A-COM. Also, compared to narrow-band sensors, short-range sensors can detect and distinguish between objects as close as 15cm from each other.

M/A-COM adds that the radar sensors can also be deployed in security, military and unmanned vehicle operations, as well as mining and industrial sensing applications.

www.macom.com

Filtronic expects loss despite compounds

At an extraordinary general meeting in Shipley, UK on 29 September, Filtronic plc's shareholders passed a resolution announced in June (see July issue, page 7) to dispose of most of its Wireless Infrastructure division to base-station RF product supplier Powerwave Technologies Inc of Santa Ana, CA, USA for $185m (£96.9m) in cash and 17.7m new Powerwave shares (about $319.5m in total, revised from $150m in cash and 20.7m shares to reflect Powerwave's shrinking share price).

The division generated about 80% of total sales last year and operating profits of £5.5m compared to total losses of £4.2m. Following the disposal, the scale of the group's activities will be substantially reduced, said chairman John Poulter. "This will result in operating losses pending the development and reshaping of the group."

Of the three remaining activities, compound semiconductors has the greatest potential. "With the growth in capacity at Compound Semiconductors it is expected that there will be substantial revenue growth in the current financial year." However, in August Filtronic announced a reduction in the investment it planned to make in the Newton Aycliffe, County Durham GaAs foundry.

"Underlying trading performance for Compound Semiconductors and the Point to Point activity are currently in line with expectations. The recovery of Defence Electronics is proceeding more slowly than anticipated", said Poulter.

www.filtronic.co.uk

IN BRIEF

Anadigics reaches 750m shipments

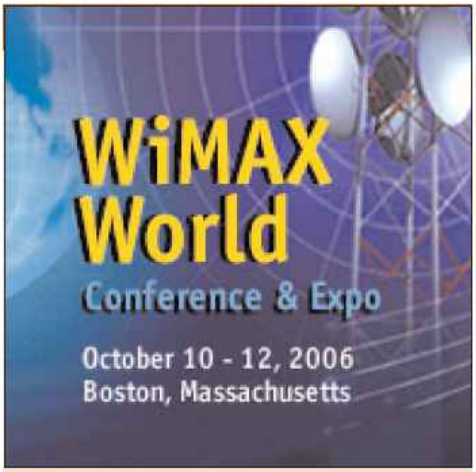
Anadigics of Warren, NJ, USA has surpassed 750m unit shipments since its launch in 1985 (supported by its 6" fab since 1999). Applicationsof i ts RF ICs include mobile handsets, smart phones, data cards, WLAN notebook computers, CATV set-top boxes, and CATV infrastructure systems.

www.anadigics.com

UMS opens Asia office in Shanghai

In September UMS opened a United Monolithic Semiconductors Asia sales office in Shanghaï, managed by Xavier Taltasse. It aims to develop closer relationship with Asian customers and to 'take into account the transfer of several industrial activities in Asia'.

www.ums-gaas.com



WiMAX is a standards-based wireless technology that provides high-throughput connections over long distances. It can be used for multiple applications, including last-mile broadband access, hotspots, cellular backhaul, high-speed enterprise connectivity, and non-line-of-sight mobile connectivity.

Now in its third year, WiMAX World takes place in both the USA and now Europe.

The first annual WiMAX World Europe Conference & Expo, in Vienna last May, drew over 1200 attendees, 45 exhibitors and over 100 sponsors. WiMAX World USA is the largest event in the world on wireless and mobile broadband with a focus on WiMAX.

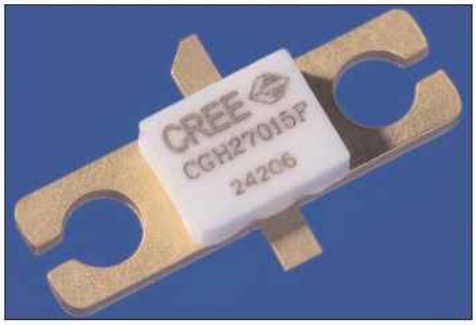
This October's WiMAX World USA Conference & Expo had a three-day conference program that included five tracks on WiMAX and wireless mobile broadband trends, featuring over 175 speakers. The event drew over 4500 attendees and 140 exhibitors, well up on the expected 4000 attendees and 200 sponsors and exhibitors, and a significant increase on WiMAX World 2005 (over 3000 attendees and 140 sponsors and exhibitors).

Such rapidly growing interest in WiMAX is being driven by new commercial and military applications, attracting a growing number of device makers.

Cree samples 15W GaN-on-SiC HEMT

In conjunction with October's WiMAX World event in Boston, Cree Inc of Durham, NC, USA announced that it is shipping sample quantities of its CGH27015 15W packaged GaN HEMT (first demonstrated at June's IEEE MTT-S International Microwave Symposium 2006).

Optimized for high efficiency, high gain and wide bandwidth, Cree says the CGH27015 is designed for North American WiMAX and broadband wireless access applications and operates at 2.3–2.9GHz, at which it typically produces 2.5W of average output power and 24% drain efficiency. This is an improvement of up to 30% in device efficiency compared with technologies such as silicon LDMOS or GaAs under WiMAX signals and requirements (802.16-2004), claims Cree. The CGH27015 also features 14.5dB of small-signal gain and 2% error vector magnitude (EVM) under orthogonal frequency-division multiplexing (OFDM) modulation when operated at 28V.



Cree's CGH27015 15W GaN HEMT.

"Release of the CGH27015 demonstrates Cree's continued commitment to provide a comprehensive line of high-performance GaN RF products for the WiMAX and broadband wireless access markets," says Jim Milligan, product manager for wide bandgap radio frequency products. "GaN is an ideal material for applications that operate under high-power conditions and must meet high efficiency and stringent linearity requirements, like WiMAX and other applications operating between 2.5 and 6GHz."

www.cree.com

GaN HEMT WiMAX set for take off

Cree's GaN HEMT WiMAX devices are being used in the new Powerlinear power amplifiers of Array Wireless Inc.

Cree claims the GaN HEMTs help to deliver a solution 25% smaller and twice as energy efficient as other systems. Such smaller, lighter and more efficient power amplifiers are being used in applications such as airborne high-definition broadcasting.

The Powerlinear amplifiers are used in blimps and aircraft that provide TV broadcast feeds for sports events. "With the new Cree GaN HEMT devices, our amplifiers use half the power of competing systems and are significantly smaller in size, both of which are critical benefits for wireless applications where space and weight are at a premium," says Ed Takacs, president of Array Wireless.

Powerlinear PAs are designed to work with the rigorous requirements of digital modulation formats, such as coded orthogonal frequency division multiplexing (COFDM). They operate in a variety of bands from UHF to C and are optimized for the Nextel BAS (Broadcast Auxiliary Service) frequency relocation programs that are underway.

Other targeted communications applications include unmanned aerial vehicles, law enforcement, unmanned ground vehicles, WiMAX base-stations and secure mobile military communications.

Improved GaN-on-Si process yields WiMAX transistor launch

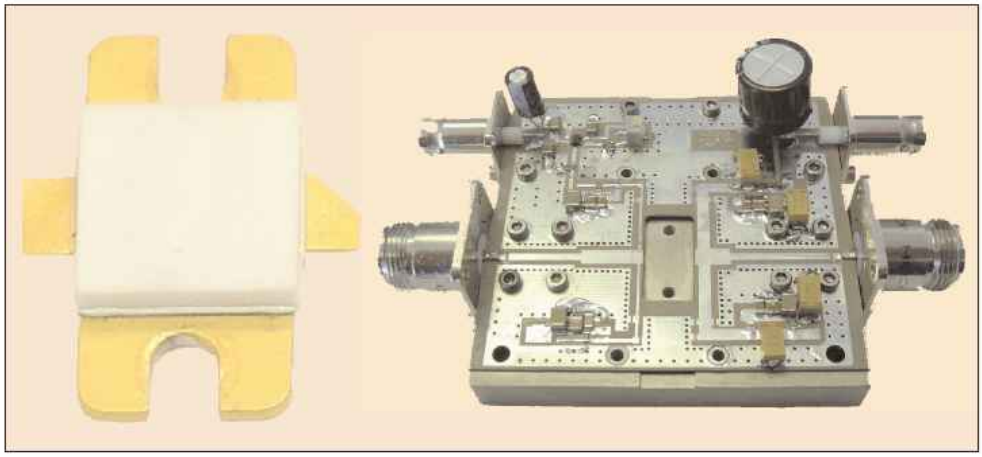
At October's WiMAX World event in Boston, Nitronex of Raleigh, NC, USA announced that its SIGANTIC GaN-on-silicon manufacturing process is now fully qualified for volume production following the completion of all reliability testing.

Chris Rauh, VP sales & marketing, says the new NRF1 process is an improvement on the earlier process used to develop the first WiMAX samples, made available in October 2005 when Nitronex announced that it was entering the WiMAX RF power transistor market. In the interim, the company decided to improve the process and finish the productization and qualification only on the new process, adds Rauh.

Also, the first three members of its family of discrete high-performance RF power transistors for power amplifiers in WiMAX infrastructure are now available, offering high gain, high efficiency and high linearity, along with broadband operation, Nitronex claims.

The 50W/28V NPT35050 has an average output power of 6W from 3.3–3.8GHz (offering 10.5dB of gain) and a saturated power output at 3.5GHz of 65W. It offers error vector magnitude (EVM) of less than 2.5% and a drain efficiency of 18%. The device is packaged in an air-cavity plastic package with a copper-moly-copper flange for enhanced thermal performance.

The 15W/28V NPT35015 and NPT25015 operate at 3.3–3.8GHz and 2.3–2.7GHz, respectively. Both deliver 1.5W of average power at 2% EVM during OFDM operation. The parts take advantage of small, cost-effective plastic overmold packaging, common in other semiconductor segments but relatively new to RF power transistors says Nitronex, and are running in high-volume packaging production at Amkor Technology without any modification to Amkor's standard processes.



Nitronex's 50W/28V NPT35050 GaN HEMT RF power transistor for 3.3–3.8GHz WiMAX applications (left) and its application board (right).

"The WiMAX market requires combinations of power, efficiency, frequency and bandwidth that are beyond the specs of the current cellular market," says Rauh. "In addition, considerable pressure is being applied to smaller form factors and to total cost of WiMAX infrastructure hardware."

100mm Si wafers allow us the scale to produce statistically significant and compelling reliability data, use proven packages from the Si industry, and quickly scale up volume production

GaN-on-Si field-effect transistor technology enables base-station OEMs to optimize bandwidth, power and efficiency at attractive sizes and costs, he adds. "The use of 100mm silicon wafers allows us the scale to produce statistically significant and compelling reliability data, to use proven packages from the silicon industry, and to quickly scale up volume production."

After agreeing a deal to supply GaN-based power amplifier products for WiMAX applications to a Korean customer late last year, in June Nitronex closed a $21.8m venture capital funding round led by Silicon Valley-based Alloy Ventures. Other new investors Intersouth Partners of Durham, NC and Reston, VI, ARCH Venture Partners, and Diamondhead Ventures were joined by returning investors VantagePoint Venture Partners and Contender Capital.

Nitronex said it would use the funds to complete the development and expand manufacturing of several new products; accelerate hiring in operations, engineering, sales and marketing and finance; expand into new global markets; and take advantage of emerging opportunities in cellular and WiMax, broadband markets.

"GaN-on-Si based products offer significant advantages over existing LDMOS and GaAs solutions for the WiMAX, cellular, and broadband wireless markets," claims CEO Charles Shalvoy. "We plan to accelerate our efforts to introduce a broad family of innovative RF power transistor products for these markets," he adds.

www.nitronex.com

Norstel inaugurates SiC plant

Semiconductor Today's August issue (pages 24-27) reported the opening of facilities for SiC power semiconductor manufacturing by SemiSouth Laboratories (joined in the same fab in Starkville, MS, USA by substrate maker II-VI Inc), Cree (at its new Advanced Device Cleanroom in Research Triangle Park, NC, USA), and, after its late 2005 acquisition of Advanced Power Technology Inc, Microsemi (in Bend, OR, USA, for first wafer runs in mid-2007).

In addition, at the end of August, Norstel AB opened its new 2000m^2 (22,000ft^2) SiC substrate and epiwafer manufacturing plant, located on a green-field site 4km from the center of Norrköping, Sweden.

Construction began in February 2005, when Norstel was spun off from silicon wafer maker Okmetic of Vantaa, Finland, with Nordic venture capital companies Eqvitec Partners, Northzone Ventures and Creandum as major shareholders.

"Norstel is a result of a long period of intensive R&D at Linköping University, partially funded by Swedish government agencies," said Thomas Östros, Minister for Industry and Trade, at the opening. Through the Swedish Energy Agency and VINNOVA (the Swedish Governmental Agency for Innovation Systems), the state is funding product development with SEK60m (€6m) over three years, raising funding to more than SEK200m (€20m). "It is my pleasure to welcome the industrial phase of advanced SiC materials manufacturing to strengthen the Swedish infrastructure of the advanced electronic industry," added Östros.

Norstel already has a major contract to deliver SiC to Sweden's Defense Materiel Administration (FMV), which is co-ordinating the Swedish part of a large project for a Western European Union defensive radar system. Norstel is the only European source of SiC high-frequency material able to meet the stringent demands, claims CEO Asko Vehanen.

Norstel's SiC substrate- and epiwafer-making plant near Norrköping, Sweden.

"Our technology is based on the patented high-temperature chemical vapor deposition (HTCVD) technique," said Vehanen. HTCVD-grown crystals are formed directly from gases at more than 2000°C. The technique was developed from a collaborative SiC project (part of the Swedish national SiC program, funded by the Swedish Foundation for Strategic Research and various European projects) initiated in 1993 between Linköping University (led by professor Erik Janzén), Okmetic and ABB. This led to crystal growth in 1995 and commercial deliveries of wafers from HTCVD-grown SiC crystals in 2000.

In November 2005, the European Patent Office confirmed the validity of two of Norstel's HTCVD patents (numbers 835,336 and 859,879) which had been opposed by LPE S.p.A of Milan, Italy. "The filing of these oppositions reflects the growing interest in HTCVD and related gas-phase crystal growth technologies for SiC and group III nitrides," claimed Vehanen.

Thomas Östros, Minister for Industry and Trade, throws the switch to open Norstel's new SiC plant.

Norstel's operations had been sited at Linköping University, where it developed SiC ingots, wafers and epi. "We are now taking a major step towards establishing Norstel as a significant supplier of SiC materials," Vehanen adds. "Making this method truly industrial will enable Norstel to produce high-quality, large-diameter SiC crystals and wafers cost-efficiently, opening up new markets and applications."

Norstel's product range includes both semi-insulating and nitrogen-doped 4H-SiC substrates, grown by HTCVD. It also provides epi services using hot-wall CVD, which, Norstel claims, is widely regarded as the method of choice for depositing very uniform thin layers of SiC on polished SiC wafers.

Norstel anticipates demand for power and high-frequency electronic devices for hybrid cars, cell-phone base-stations, microwave power systems such as radar, and high-voltage power transmission and distribution. "We see SiC expanding in a growing number of applications," says Vehanen. Future needs to increase capacity have been taken into account; the building is easily expandable, he adds.

HTCVD is also suited to making III-nitride crystals, Norstel claims.

www.norstel.com

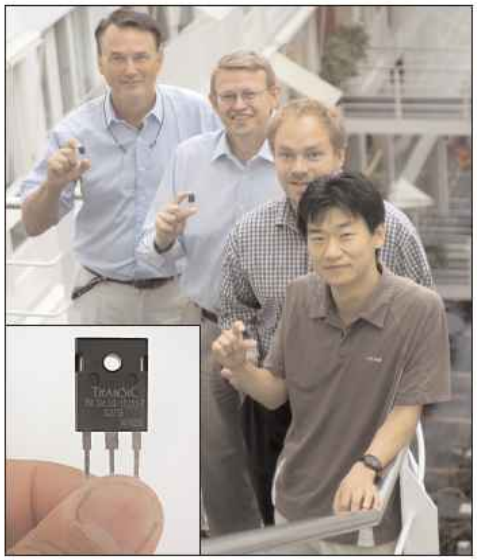
KTH spin-off targets Q2/2007 BJT launch

One company dedicated to bringing SiC bipolar junction transistors (BJTs) to market in 2006 is fabless SiC power transistor manufacturer TranSiC AB of Kista, Sweden.

TranSiC was spun off from KTH (Royal Institute of Technology) in Stockholm, Sweden in October 2005 by professor Mikael Östling, CEO Bo Hammarlund, and CTO Martin Domeij. TranSiC's advisory board includes Hans Peter Nee, a professor of Electrical Machines and Power Electronics at KTH, and Carina Zaring, a specialist in production planning.

In November 2005, TranSiC signed up with Stockholm Innovation & Growth (STING) of Kista, an incubator focusing on early-stage high-tech start-ups. In December, it received funding from both VINNOVA (the Swedish Governmental Agency for Innovation Systems) and Statens Energimyndighet (the Swedish Energy Agency), which had been supporting the BJT SiC power transistor project at KTH, aiming to take such energy-saving technology to market. In April, TranSiC received funding from NUTEK and Innovationsbron to continue development of its BiTSiC bipolar transistors for higher current ratings. So far, only 'soft seed' Goverment money has been invested (a mix of free support and loans, re payable after 5 years), but Hammarlund is expecting venture capital funding in November that will cover operation for the next 2 years plus hiring of skilled staff.

During TranSiC's first year, chips are being fabricated on a 4" silicon wafer processing line in the Electrum Laboratory in Kista (operated by KTH in collaboration with microelectronics and optics research institute Acreo), using subcontractors for SiC epitaxy and packaging. However, TranSiC can provide short-run packaging for pilot customers



Bo Hammarlund, Mikael Ostling, Martin Domeij, and Hyung-Seok Lee. Inset: BiTSiC 1206 bipolar transistor.

where process development speed is a trade-off with package price.

In Q4/2006, TranSiC made available engineering samples of its first product (plus an evaluation circuit board with driving circuitry). The BiTSiC 1206 (in a TO-220 package) is designed for power applications at V_{max} = 1200V, 6A and a maximum operating temperature of 175°C. Target applications include power electronic systems for motor drives, welding and power supplies. Next for BitSiC 1206 is wider customer sampling by end-2006.

During 2007, more BJTs will be developed for higher currents (up to 20A), packaged for operating at over 200°C. TranSiC aims to make commercial products available in Q2/2007. "Our goal is to have a 30A prototype device by the end of 2007, plus a packaged prototype able to handle 225°C junction temperature," Hammarlund says. Yet higher-current devices are on the longer-term development path.

TranSiC has not yet decided if it will develop products other than BJTs.

www.transic.se

ITME turns to SiC

In late September, the Institute of Electronic Materials Technology (ITME) in Warsaw, Poland ordered an VP508GFR MOCVD system from Sweden's Epigress, a member of the Aixtron Group of Aachen, Germany, for delivery in Q4/2006.

The reactor will be used for research and pilot production. In particular, it will play a key role in ITME's plan to further expand its compound semiconductor activities into SiC by developing epitaxial growth of n- and p-type SiC layers for high-power and high-frequency devices, said Dr Wlodek Strupinski, who is president of ITME's III-V Epitaxy Laboratory.

ITME is a research, development and consultancy institution offering a combination of scientific and technological capabilities. The organization was founded in 1979 through the merger of the research laboratories of the Electronic Materials Research and Production Centre as a separate organization. Since then, it has become the leading centre in Poland devoted to the R&D of advanced semiconductor materials and devices. Activities cover not only R&D and small-scale production of electronic and optoelectronic materials but also R&D of electronic and optoelectronic components based on such materials. Customized versions of these products are manufactured on request.

ITME already has an AIX 200 and an AIX 200/4 system, both for GaInAsP applications, and an AIX 200RF-S for the growth of GaN. ITME says that, with these systems, it is able to cover virtually all the principal compound semiconductors, such as multilayer epitaxial structures based on GaAs/AlGaAs/GaInAsN, InP/InGaAs/InAlAs and GaN/InGaN/AlGaN.

www.itme.edu.pl

Microsemi to develop SiC RF power chips for military avionics

Microsemi Corp of Irvine, CA, USA, which makes analog and mixed-signal ICs and high-reliability semiconductors for power regulation, has been awarded $1.8m by the US Congress as part of the Fiscal Year 2007 Defense Appropriations Act.

The funding will allow its Power Products Group (formerly Advanced Power Technology, of Bend, OR) to develop SiC technology for military avionics applications, supporting the design of lighter and more efficient jet fighter communications systems. The program will be administered by the Air Force Research Laboratory, and should enable substantial growth of operations in Bend.

The award follows a contract in February for Microsemi to provide SiC products to defense contractor Northrop Grumman.

Microsemi says that SiC's benefits for avionics include increased reliability, extended battlespace coverage, point-of-use power conversion, and reduced size and cooling requirements. Also, SiC plays a key role in expanding bandwidth and high duty (power) operation required by increasingly networked battlefields.

Oregon senators Ron Wyden and Gordon Smith announced the funding in Washington. "This commitment reaffirms the status of Central Oregon as a haven for high-technology research, development, and production, particularly as it relates to aerospace," says Wyden. Smith attended the launch of the Bend SiC fabrication facility in April.

"Microsemi is committed to be a technology innovator in the development of next-generation SiC products for defense and commercial applications," says president and CEO James J. Peterson.

www.microsemi.com

SemiSouth raises $5m and wins contract

Within a week of opening its new high-volume SiC epiwafer and power semiconductor fabrication plant in Starkville, MI, USA in late August (which is also home to II-VI Inc's new SiC substrate plant — see August issue, page 24), SemiSouth Laboratories Inc raised $5m through Series A1 venture capital financing (funded in two stages over three months) and received a five-year Small Business Technology Transfer (STTR) Phase III contract from the US Air Force Research Laboratory that could be worth up to $22.5m.

The financing round was led by Southern Farm Bureau Life Insurance Company of Jackson, MS, and included Delta Capital Management of Memphis, TN and Southern Appalachian Fund of Knoxville, TN (which both participated in June 2005's Series A financing, led by Delta Capital). New investors included: Starkville Technology Investments LLC led by Mississippi State University graduate Frank Brumfield; Mississippi Angel Fund of Jackson, MS; Gulf South Capital of Jackson, MS; and Schneider Electric Ventures of Paris, France.

"This new financing is a strong endorsement of SemiSouth's innovative silicon carbide semiconductor technology, its business plan, and its management," said SemiSouth's president and CEO Dr Jeff Casady. "This financing success also demonstrates the strength of Momentum Mississippi — the Governor's approach for drawing in investment capital for high-tech Mississippi businesses." Mississippi Governor Haley Barbour visited SemiSouth's new SiC manufacturing facility for the announcement.

Also, the Air Force Research Laboratory at Wright-Patterson Air Force Base in Dayton, OH, USA has awarded SemiSouth Laboratories a five-year Small Business Technology Transfer (STTR) Phase III contract (to be complete August 2011) that could have a maximum valuation of $22.5m.

The Ralph E. Powe Center for Innovative Technology, adjacent to Mississippi State University's campus, and home to SemiSouth and II-VI Inc's new SiC plants.

The objective of the contract is to extend the design, fabrication, and reliability testing of advanced SiC power devices toward military qualification and reproducible manufacturability for product development and commercial sale.

The type of contract is 'indefinite delivery, indefinite quantity with cost plus fixed-fee (completion) type task orders': funds are received under 'task orders' when needed, and with differing periods of performance and amounts of work, explains SemiSouth's vice president of sales and marketing, Keith Nootbaar. Each task has a budget, and typically involves work lasting about one year and for a few million dollars.

Task Order 1 (awarded at the same time as the overall contract) is valued at $3.95m and represents SemiSouth's current backlog with the Air Force under this contract. Nootbaar says SemiSouth is confident that, over the next 60 months, it will be able to win additional task orders up to the specified ceiling of $22.5m.

www.SemiSouth.com

COMPOUND SEMICONDUCTOR WEEK 2006

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The 2006 Compound Semiconductor IC Symposium

We cordially invite you to the 2006 Compound Semiconductor IC Symposium being held November 12–15 in beautiful, historic San Antonio, Texas, USA. The high-performance wireless and high-speed digital communications markets are thriving due to impressive strides in new materials and devices, greater integration levels, novel circuit implementations, and ever-changing systems partitions. Over the last 28 years the Compound Semiconductor IC Syposium (CSICS — formerly named the GaAs IC Symposium) has been and continues to be the preeminent international forum in which advances in semiconductor circuit and device technology are presented, debated, and discussed. The scope of the Symposium encompasses devices and circuits in GaAs, SiGe, InP, GaN, and InSb as well as sessions targeting the fields of RF CMOS and high-speed digital CMOS to provide a truly comprehensive conference. This is the ideal forum for presentation of the latest results in high-speed digital, analog, microwave/millimeter wave, mixed mode, and optoelectronic integrated circuits.

This year's 2006 CSIC Symposium will be co-located with the Key Conference. The co-location is referred to as Compound Semiconductor Week and is comprised of 2 short courses and a primer course, a full 3-day technical program, and a joint technology exhibition. The technical program consists of 58 high-quality state-of-the-art technical papers, 4 panel sessions, 2 Short Courses on 'GaN Circuits and Applications' and 'RF and High Speed CMOS', and an Industry Exhibit. The Symposium will also be offering the popular annual introductory level Primer Course on 'Basics of Compound Semiconductor ICs'. This year the Symposium will feature 16 invited papers on a wide range of important topics encompassing device engineering to circuit application using advanced compound and other related semiconductor technologies. In addition, the Symposium will continue the tradition of including important 'late breaking news' papers.

The joint technology exhibition will be held on Monday and Tuesday. The exhibition will feature informative and interesting displays with corporate representatives on hand. The list of exhibitors can be found in the CSICS advance program which will be published and distributed in late June.

To complement the Symposium, there are several social events. Events include the Sunday Evening CSICS Opening Reception, Monday's CS-Week Exhibition Opening Reception, the CS-Week Tuesday evening Theme Party to be held at the Rio Cibolo Ranch providing an authentic and memorable Texas experience, and the CS-Week Exhibition Luncheon on Tuesday. Additionally, a breakfast will be served on Monday, Tuesday and Wednesday.

The 2006 CSICS will be held in San Antonio, Texas in the Marriott Riverwalk Hotel located in downtown San Antonio. Now the eighth largest city in the USA, the city has retained its sense of history and tradition, while carefully blending in cosmopolitan progress. Close to 20 million visitors each year delight in the discovery of San Antonio's charms. Amidst the daily hubbub of the busy metropolitan downtown, sequestered 20 feet below street level, lies one of San Antonio's jewels — the Paseo del Rio. Better known as the 'River Walk', these cobblestone and flagstone paths border both sides of the San Antonio River as it winds its way through the middle of the business district. The River Walk is quiet and park-like in some stretches, while other areas are full of activity with European-style sidewalk cafes and specialty shops. The River Walk stretches for approximately 2.5 miles from the Municipal Auditorium and Conference Center on the north end to the King William Historic District on the south. Rio San Antonio Cruises, the river's floating transportation system, provides a novel method of sightseeing and people-watching in downtown San Antonio. Groups can also dine aboard open-air cruisers as they wind their way along the scenic waterway.

For registration and further information, please visit the CSICS website at http://www.csics.org. Further questions may be addressed to the Symposium Technical Program Chair: Mohammad Madihian, Ph: +1-609-951-2916, Email: madihian@nec-labs.com

We hope you can attend,
IEEE CSIC Organizing Committee

Aviza granted £1.2m for Newport facility by Welsh Assembly

Aviza Technology Inc has received a multi-year grant of about £1.2m ($2.2m) from the Welsh Assembly Government's Regional Selective Assistance (RSA) program.

Aviza plans to invest £6.4m over several years to enhance R&D and engineering capabilities at its Newport, Wales facility (formerly Trikon Technologies, before 2005's merger with Aviza), where it manufactures single-wafer equipment and process technologies. The grant will create over 30 technical positions and support expanded responsibilities for 50 further positions in Newport.

"The grant will enable Aviza's Newport operations to further develop and strengthen its presence here in Wales, in addition to complementing the company's R&D efforts at its Scotts Valley, CA global headquarters," said Andrew Davies, Minister for Enterprise, Innovation and Networks. "Aviza is already one of the flagships of the advanced technology sector of the Welsh economy."

Jerry Cutini (left) and Andrew Davies, Welsh Minister for Enterprise, Innovation and Networks (right).

"This grant is an important component to our ongoing commitment to support business in Wales," said president and CEO Jerry Cutini. "Aviza will continue to work closely with the Welsh government to highlight the technical accomplishments achieved by the company and to identify cooperative programs for future collaborations," he adds.

www.avizatechnology.com

Nanometrics launches rapid PL mapping system and expands R&D in UK as production is outsourced to Asia

Metrology equipment manufacturer Nanometrics Inc of Milpitas, CA, USA has introduced VerteX, a rapid photoluminescence (PL) mapping system for production control during volume manufacturing of optoelectronic devices. The automated system accurately predicts emission wavelengths for green LEDs at the wafer level, the company claims.

VerteX's control of laser excitation conditions allows the accurate matching of PL data to electroluminescence (EL) test information, resulting in faster run-to-run epitaxial layer growth feedback, Nanometrics says. Unlike conventional means, where the exact emission wavelength of a green LED can only be measured by an electrical test after wafer processing is complete, VerteX can forecast diode performance during the process, providing data that can be used to adjust process controls for optimal epitaxial layer growth.

"As production volumes increase and tolerances tighten for epitaxial layers, customers demand a metrology tool that not only provides accurate measurements but that can provide the processing data required to accelerate time to yield. VerteX answers these requirements and more," claims Tom Ryan, product manager for compound semiconductors. "VerteX makes possible accurate predictive processing metrics of green, blue and UV LED emission wavelengths at the wafer level, a capability that is unmatched in the industry." The system can also be used to manufacture optoelectronic materials, including ultraviolet diode lasers, it is claimed.

VerteX is the company's first product launch since it acquired Accent Optical Technologies Inc in July. Nanometrics gained a facility in York, UK, which has been in existence for over 300 years and once even provided instruments for Sir Isaac Newton. Established by John Worgan, the facility became Vickers Instruments, then Bio-Rad and, in 2000, Accent Optical Technologies. Recently, York-based media source *The Press* reported that jobs in York would be outsourced to Asia. In response, Nanometrics confirmed that about 25 positions would be lost, but that R&D would remain in York and be expanded.

Redundancies will take place "over the next six to nine months up to the middle of 2007", said executive vice president Douglas McCutcheon. However, the company plans to create a centre of excellence for R&D and customer support at the site, on which the lease has already been extended. "We aim, over the next few years, to employ highly skilled R&D staff to build on the 80-plus employees who will remain after next summer," McCutcheon told *The Press*.

www.nanometrics.com

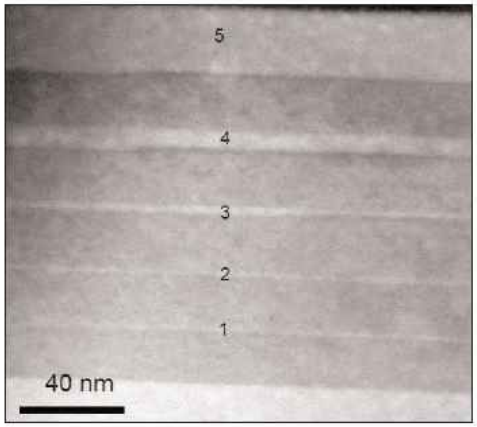
HVPE for GaN quantum wells

Technologies and Devices International Inc of Silver Spring, MD, USA has developed the first hydride vapor phase epitaxy (HVPE) process capable of depositing GaN quantum well (QW) structures.

HVPE is TDI's core technology, which it uses to produce GaN-based epitaxial products. "TDI has perfected the growth of very thick GaN layers, which is typical of the HVPE process [capable of deposition at up to 1μm per minute, much higher than MBE and MOCVD], along with very thin layers and multi-layer structures, in the same epitaxial process," claims Vladimir Dmitriev, president and CEO.

"TDI engineers and scientists have successfully developed a novel HVPE growth machine and process which allows us to reduce the materials deposition rate by more than two orders of magnitude and control the growth of GaN, AlN, and AlGaN layers to a thickness of about 1nm," said Dmitriev.

Professor Subhash Mahajan and staff at Arizona State University have characterized TDI's GaN single and multiple quantum well structures. "HVPE is a well-known method for fabricating thick GaN layers. We never expected this technology to produce nanometer-thick GaN layers and multi-layer structures," they comment. Their transmission electron microscopy measurements confirm that this is achieved. "This is definitely the first HVPE-grown AlGaN/GaN structure that clearly shows a quantum well signature in photoluminescent characterization," adds professor Michael Reshchikov of Virginia Commonwealth University.



TEM image of five GaN layers (2, 3, 4, 8, and 25nm thick) sandwiched between 20nm-thick AlGaN layers (courtesy of S. Mahajan).

"This proprietary HVPE process opens up a completely new path for the formation of low-defect substrate materials and device structures," says Dmitriev. QW structures are the key elements for devices including high-brightness LEDs and laser diodes. Multi-layer structures with nanometer-scale layers are important to reduce defects and control strain in GaN-based materials, to improve doping, and to open new device possibilities.

TDI reported results on HVPE grown GaN-based QW structures at the International Workshop on Nitride Semiconductors 2006 in Kyoto, Japan (22-27 October), and featured MQW epiwafers at the workshop's exhibition.

With continued support for the developments from the US Department of Energy (DoE) and the Defense Advanced Research Project Agency (DARPA), TDI plans to release epitaxial products based on HVPE-grown superlattice structures and quantum wells in early 2007.

www.tdii.com

Riber and Kwansei Gakuin to co-develop MBE-litho

In September, MBE system maker Riber of France acquired the exclusive rights to a family of patents filed by Japan's Kwansei Gakuin University relating to processing, in situ, three-dimensional patterns with compound semiconductor materials by means of MBE and electron-beam writing.

The process can produce nano-features of precisely selected geometrical shape and organized nanometric dots or wires on the wafer surface, and could lead to a variety of nano-devices for new applications.

Riber, Kwansei Gakuin University, and several Japanese industrial companies have agreed to partner on developing new research equipment for in-situ processing. The new MBE-Litho system will have several process step stations, including an MBE machine coupled with an electron-beam writer.

A prototype MBE-Litho will be installed at Kwansei Gakuin University, where it will be used to demonstrate the capabilities of the process in terms of patterning conformation, resolution, and the electronic characteristics of the semiconductor materials processed.

- Riber has reported sales of €7.3m in first-half 2006, up 35% year-on-year and marking a return to consolidated profit.

Gross profit was €3.7m (yielding a margin of 51%), up 16% on €3.2m a year ago, mainly due to a variation of provisions for inventory depreciation, which was recorded as cost of sales. Excluding the reversal of these provisions, gross profit would have been €1.2m, compared with €1.3m a year ago.

Sales and Administrative expenses fell by €0.4m and net R&D expenses by 30% to €1m.

Operating profit reached €0.2m, compared to a loss €1.1m a year ago. The net result improved to breakeven from a loss of €1.1m.

For full-year 2006, Riber forecasts sales of €19-22m.

www.riber.com

First order for ALD/AVD system

A year after buying Genus, in July Aixtron received the first system order for its combined Genus 300mm Atomic Layer Deposition StrataGem and Atomic Vapor Deposition technologies, from "a leading Asian memory manufacturer". This represents a further step into next-generation solutions for high-k dielectrics in DRAM capacitor sub-45nm high-volume production. Installation at the customer's 300mm R&D fab started in Q3/2006.

Process modules combining ALD and AVD can overcome many limitations of current film deposition techniques, says Aixtron, and are a driving force into mainstream/HV semiconductor processing.

The initial work will focus on:

- Evaluation of various high-k dielectrics and metal gate materials for large-scale production purposes;
- Integration into high-k gate stacks and advanced DRAM capacitors;
- Optimization of DRAM and CMOS device structures sub-45nm.

"Many of Genus' primary customers are major chip manufacturers in the memory (DRAM and FLASH) segment of the semiconductor industry," said Dr William W. R. Elder, the executive board member responsible for Aixtron's silicon business interests. "The process modules are based on a patented process chamber concept and have achieved a leading position for the deposition of tungsten silicide (WSi_x) and high-k materials, primarily used in memory and capacitor applications. With ALD, AVD technologies and the company's core tungsten silicide CVD platform, we are now able to offer our customers a full and comprehensive portfolio of semiconductor process technologies."

www.aixtron.com

STS sales up 37%

Plasma etch and deposition system manufacturer Surface Technology Systems plc of Newport, Wales, UK has reported interim results for first-half 2006.

Year-on-year, sales rose 37% to £10.2m and gross margin rose from 24% to 32%. EBITDA improved by £1.2m to a loss of just £0.1m.

Of system sales (68% of total sales), 45% were to North America, 21% to Europe, and 34% to the rest of the world (mainly Asia). While 62% of sales were for MEMS, wireless sales rose from 6% in 2005 to 16%.

"The order book for the period was strong largely due to widespread interest in the Pegasus system [£7.9m at end-June, up from £6.5m a year before]," said chairman Nigel Randall. Order intake has continued to grow, with two large orders, worth together over £3m, in September (for delivery this year). Backlog at end-September was £9.1m. "The directors expect the group to trade profitably in second-half 2006," adds Randal.

www.stsystems.com

OIPT appoints sales and customer support director

Oxford Instruments Plasma Technology (OIPT), which supplies tools for plasma-enhanced deposition and etch, ion-beam deposition and etch, molecular beam epitaxy, and atomic layer deposition (ALD), has appointed Mark Vosloo as sales and customer support director.

Vosloo was formerly sales and marketing director for Photonic Materials, and president of the UK and US sales subsidiary for LINOS, which makes electro-optical subassemblies and components.

"I am keen to drive growth within OIPT," says Vosloo, "especially during a time in which Oxford Instruments is geared towards launching innovative new products for nanostructure growth and semiconductor device engineering, as well as consolidating the recent launch of the FlexAL atomic layer deposition tool [in June, after beta testing at the Eindhoven University of Technology]".

OIPT's Mark Vosloo.

FlexAL enables low-temperature deposition, high-density films and high film purity, while giving thermal ALD processing capability in the same system to maximize the range of processes and materials. Processes developed include TiN, HfO_2 high-k dielectric, Al_2O_3 deposition down to room temperature, and single-metal Ru. The systems can handle small sample size materials through to 200mm wafers.

ALD applications specialist Chris Hodson says the ability to deposit highly dense, pinhole-free and conformal thin films at low temperatures by plasma ALD enables not only semiconductor applications but others such as the encapsulation of organic and temperature-sensitive devices such as organic LEDs and wear-resistance coating of MEMS. "Very low-resistivity nitride and metal films have been achieved, and the use of plasma ALD allows us excellent control of material stoichiometry," he adds.

www.oxford-instruments.com

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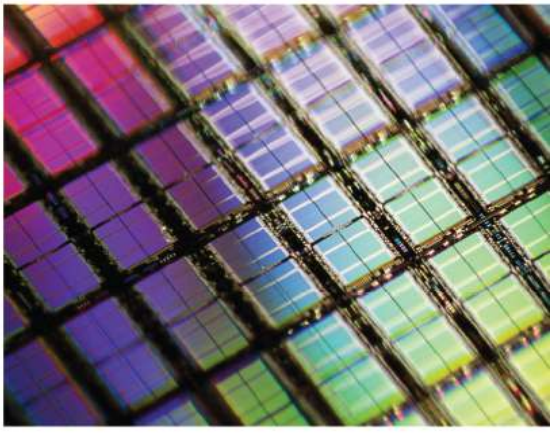

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IN BRIEF

VPEC expands foundry capacity

Taiwan-based epiwafer foundry Visual Photonics Epitaxy Co Ltd (VPEC) says that it is expanding capacity after ordering two AIX 2600 G3 MOCVD systems from Aixtron in Q3/2006, for installation at its plant in Ping-Jen City, Taoyuan. The systems have the flexibility for 12x4" or 7x6" wafer configurations for the production of HBTs and HEMTs or 49x2" for LEDs.

Founded in 1996, VPEC's main products are HB-LED epiwafers and chips for industrial and commercial applications, and HBT, HEMT and PIN epiwafers for communication applications.

www.aixtron.com

FOREPI orders hydrogen purifiers

InGaN LED wafer and chip maker Formosa Epitaxy Inc (FOREPI) of Taoyuan, Taiwan has placed an order with Johnson Matthey Gas Purification Technology (GPT) group of West Chester, PA, USA for three Model GPT-40 hydrogen purifiers which are capable of flowing 30Nm/hr for its growing number of MOCVD reactors.

Founded in 1999, FOREPI claims to be the only LED company in Taiwan able to offer a full spectrum of products including high-power InGaN blue, green and near-UV LEDs.

Johnson Matthey says that its bulk hydrogen purifiers are capable of providing 99.9999999% pure hydrogen for wafer fabrication. With facilities in North America, Japan, South Korea, Singapore, Taiwan, China and Hong Kong, Johnson Matthey GPT reckons it has installed over 5000 gas purification units worldwide.

www.pureguard.net

Standard launched for AlGaAs epilayers

The US National Institute of Standards and Technology (NIST) has issued its first standard for the chemical composition of thin-film semiconductor alloys.

Standard Reference Material (SRM) 2841 'Semiconductor Thin Film: $Al_xGa_{1-x}As$ Epitaxial Layers' (with Al mole fraction x near 0.20) is intended for use as a reference to calibrate equipment either for making the material or for measuring thin-film composition using analytical methods such as electron microprobe analysis (EMPA), photoluminescence (PL), auger electron spectroscopy (AES) and x-ray photoelectron spectroscopy (XPS).

As well as government and university labs, NIST expects buyers of SRM 2841 to include firms that grow or characterize AlGaAs thin films or that use them to make devices, including high-speed circuits for wireless communication; lasers for optical disk drives, bar-code scanning, xerography, and laser surgery; and LEDs for remote controls, traffic lights, and medical instruments.

SRM 2841 consists of a 3μm-thick epilayer of $Al_xGa_{1-x}As$ with a certified Al mole fraction x, grown on a 1cm x 1cm GaAs substrate mounted on a 2.5cm diameter stainless-steel disk. Each unit is sealed in a Mylar envelope containing a nitrogen atmosphere.

The standard should increase the accuracy of characterizing the chemical composition of AlGaAs films by an order of magnitude over the current state of the art. Improved accuracy should reduce wasteful duplication of reference wafers, increase the free exchange of thin-film materials between vendors and their customers, and ultimately improve the accuracy of data on relationships between material composition and properties.

SRM 2841 can be ordered at:

http://ts.nist.gov/ts/htdocs/230/232/232.htm

RF chip foundry makes IQE preferred external epi supplier

Epiwafer foundry IQE plc, which has plants in Cardiff and Milton Keynes, UK and in Bethlehem, PA, USA, has signed a Memorandum of Understanding to become the preferred external supplier of epiwafers to a 'leading European RF wireless chip foundry' (complementing its in-house epi capacity) for use in its RF wireless switch products.

IQE says it has worked closely with the customer over the last 12 months to achieve fully 'qualified supplier' status. As the customer's own product demand increases, any increase in epi requirements beyond the customer's internal capacity should flow directly to IQE.

"We will be working closely with the customer to fully realize all the benefits of such an outsource arrangement to enable significant commercial benefits to accrue to both parties," says CEO Drew Nelson. "This demonstrates the strength of the outsource model, which is now becoming a key part of customers' strategic considerations."

In August, IQE completed its acquisition of Emcore Corporation Inc's Electronic Materials Division for $16m (an initial payment of $13m, plus $3m payable in four equal quarterly payments subject to 7.5% interest per annum).

www.iqep.com

Non-polar GaN substrates funded

Kyma Technologies Inc of Raleigh, NC, USA has been chosen for Phase I funding under the US Army's Small Business Technology Transfer (STTR) Program to develop native crystalline non-polar GaN substrates.

Kyma will focus both on improving the current method of manufacturing non-polar GaN and on developing alternate manufacturing methods, with the goal of establishing a cost-effective supply of non-polar GaN.

Kyma's engineers will work with academic research groups led by professor April Brown at Duke University and professor Mark Johnson at North Carolina State University (Kyma was founded in 1998 by researchers from NCSU's Department of Materials Science and Engineering).

NCSU has already investigated the electrical and structural properties of Kyma's GaN materials and has worked with Kyma on novel approaches to manufacturing non-polar GaN. Brown will extend her current programs in advanced epitaxial growth and characterization of non-polar GaN materials to Kyma's low-defect-density substrates. The collaborators hope to gain new understanding of the physical properties of Kyma's non-polar GaN substrates, including the ability to deposit high-quality device layers on them.

"This program enables us to accelerate the development of non-polar GaN materials with ultra-low dislocation densities and zero stacking faults," said Kyma's co-founder and CTO Drew Hanser. "Kyma's non-polar GaN offers new possibilities in terms of device design and the potential to enable better device performance across several different device types, including FETs, HBTs, and visible and ultraviolet emitters and detectors."

Non-polar GaN has "strong potential to impact a broad range of military and commercial applications," says president and CEO Keith Evans. According to Kyma, the substrates enable the deposition of improved device active regions that can be used to realize new and improved high-performance devices. It is predicted that non-polar GaN will enable higher quantum efficiencies and improved electrical characteristics for LEDs and laser diodes and will enable the development of very high performance enhancement mode (e-mode) HEMTs.

While such predictions have been partially corroborated by experiment, previous attempts to fabricate devices on non-polar GaN were severely hampered by very high defect densities in the active regions which had origins in the substrates and which derived from the heteroepitaxial approaches used in the non-native approach to their fabrication. Kyma says its native boule growth approach provides a direct route towards slicing and polishing non-polar GaN and provides benefits in terms of lower defect densities, process scalability, and manufacturing cost structure.

In March, Kyma signed a formal co-operative research and development agreement (CRADA) with the Naval Research Laboratory focused on low-defect-density native GaN substrates for high-power RF FETs. In August it signed a CRADA with the Air Force Research Laboratory to further understand how low-defect-density native GaN substrates might positively impact GaN FET device performance and reliability (see August issue, page 19). The focus is to perform advanced characterization analyses of native GaN materials and native GaN FET devices for RF electronic applications.

www.kymatech.com

SGR to develop BluGlass substrates

Australian GaN-on-glass specialist BluGlass Ltd has signed an 18 month joint development agreement to work with France's Saint-Gobain Recherche (SGR), the main corporate research center of materials supplier Saint-Gobain Group.

SGR focuses on specialty glass formation, glass processing, and thin-film deposition technologies, and will develop specifically engineered substrates for BluGlass' GaN layers and devices.

BluGlass was spun off from the III-nitride department of Macquarie University in Sydney in October 2005. This September it raised $7.7m in an initial public offering and listed on the Australian Stock Exchange. CEO David Jordan says that strategic alliances with global companies such as Saint-Gobain are an integral part of the development and commercialization of its technology. "Working with a technology leader such as SGR makes sense for BluGlass, given their ability to engineer substrates optimally suited to the BluGlass deposition process," he adds.

"We are already a major supplier of high-quality LED substrates in sapphire and a leader in the glass industry," claims Saint-Gobain's chief technology officer Dr Didier Roux. "We believe BluGlass has promising breakthrough technology and that Saint-Gobain can contribute to its development and commercialization by developing specifically engineered substrates," he adds.

Substrate development will take place in SGR's facilities in Paris, followed by GaN deposition at BluGlass' pilot production plant in Sydney. Semiconductor material characterization and device quality will be assessed in both France and Australia.

www.bluglass.com.au
www.saint-gobain-recherche.com

UK III-Vs relocates

Supported by the Science Research Investment Fund (a joint initiative by the UK Government's Office of Science and Technology and the Department for Education and Skills) and the European Regional Development Fund, in October the UK's University of Sheffield invested £10m to create a Nanoscience and Technology Centre. This incorporates the UK's largest cleanroom lab for research into semiconductors, nano-magnetics and other devices, as well as incubator offices to support high-tech businesses in the region and foster links with industry.

The center includes the new home of the UK's National Centre for III-V Technologies, which was set up 25 years ago by the UK government's Engineering and Physical Sciences Research Council (EPSRC).

"Relocating to this new facility will give us the expansion capacity, not only to maintain and expand our existing research, but to accelerate new areas such as biophotonics and to form stronger links with industry," said professor Peter Houston (co-director of the III-V Centre, together with professor Maurice Skolnick). "We're looking forward to being located on the university's new North Campus [which also includes the Kroto Research Institute] where the multidisciplinary environment is already proving beneficial as we rub shoulders with colleagues in areas such as tissue engineering and biological remediation."

Cleanroom of the UK National Centre for III-V Technologies' new home.

www.shef.ac.uk

Hypersound in solid materials

Physicists at France's Institute des Nanosciences de Paris and Argentina's Centro Atomico Bariloche and Instituto Balseiro have generated hypersound (acoustic pulses at frequencies of 200GHz) in a solid made of thin GaAs and AlAs layers excited by a femtosecond laser (Huynh et al., *Phys. Rev. Lett.* (2006) **97**, 115502). Further layers with different acoustic impedance reflect the phonons, forming a nanocavity.

The hope is to reach the terahertz acoustic range, where wavelengths are just nanometers and the acoustic properties of semiconductor nanodevices could be more prominent. Such THz phonons and nanocavities could be used to modulate the flow of charges or light at high frequency and in small spaces. THz sound might also help in developing powerful 'acoustic lasers' or tomography for imaging the interior of opaque solids.

www.insp.upmc.fr

Improved magnetic–semiconductor bilayer for room-temperature spintronics operation

Funded by the US National Science Foundation, researchers at Ohio University and Ohio State University have created an improved magnetic–semiconductor bilayer that they claim solves a problem spintronics scientists have been investigating for years (Lu *et al* (2006) *Phys. Rev. Lett.* **97**, 146101).

Unlike classic or vintage electronics that operate on electronic charges, spin-based electronics focuses on the spin of electrons to carry and store information. Spintronics make devices faster, improve storage capacity and reduce the amount of power needed to run them. However, the technology has not yet been widely applied, due to difficulty controlling, manipulating and measuring the electrons.

Led by postdoctoral fellow Erdong Lu, together with Arthur Smith and David Ingram, of Ohio University and J W Knepper and F Y Yang of Ohio State University, the team has created an effective interface between a semiconductor and ferromagnetic metal. Formed from binary ferromagnetic manganese gallium (MnGa) crystalline thin films grown epitaxially on wurtzite GaN (0001) surfaces using RF plasma MBE, the two-layer sandwich nearly eliminates any intermixing of the two layers and allows the spin to be 'tuned'.

"We found a way to grow the metal on the semiconductor. The crystalline match between the two materials was nearly perfect," said Smith, associate professor of physics and astronomy and director of Ohio University's Nanoscale & Quantum Phenomena Institute. "The advantage of this finding is in the growth process. By adjusting the conditions of the growth, we can tune the spin."

The magnetic moments were found to depend on the Mn/(Mn+Ga) flux ratio and can be controlled by observation of the surface reconstruction during growth. By monitoring the process, researchers could predict the spin properties.

The researchers also found that the magnetic–semiconductor bilayer will operate at room temperature. Other materials have only worked at very low temperatures, which makes them impractical for commercial applications.

www.phy.ohiou.edu/~asmith

Advanced substrates more than half of market for GaN in 2010

Over the last 10 years, the availability of high-quality sapphire and silicon carbide substrates has enabled rapid growth of the gallium nitride device market (mainly high-brightness LEDs) to over $3bn. However, according to Strategies Unlimited's recent report 'Substrates for GaN-Based Devices: Performance Comparisons and Market Assessment', increasing demand for blue–violet laser diodes, ultraviolet LEDs, and high-power, high-frequency electronic devices will present significant market opportunities for advanced substrates such as gallium nitride and aluminum nitride. These substrates will be needed to provide the lattice matching and thermal characteristics necessary to produce high-performance devices at high yields.

Based on the forecast demand for high-brightness LEDs, blue–violet laser diodes, and high-power, high-frequency electronic devices, worldwide demand for substrates for GaN devices is forecast to grow from $340m in 2006 to $880m in 2010. Advanced substrates such as GaN and AlN are predicted to comprise more than half of the market in 2010.

AlN and GaN substrates are available, but only as small-diameter wafers. The effort to develop advanced substrates, as well as to improve conventional substrate properties (e.g. 3" and larger diameter sapphire and silicon carbide) includes 48 companies and 118 universities and research centers worldwide, reckons Strategies Unlimited.

Companies that can provide such substrates as the market expands include larger, established firms such as Japan's Sumitomo Electric Industries Ltd, Cree Inc of Durham, NC, USA and Korea's Samsung Corning, as well as smaller, technology-focused start-up companies such as Crystal IS Inc of Green Island, NY, USA, The Fox Group Inc of Deer Park, NY, USA, Kyma Technologies Inc of Raleigh, NC, USA (like Cree, a spin-off from North Carolina State University), Lumilog of Vallarus, France (a spin-off from CRHEA-CNRS), TDI Inc of Silver Spring, MD, USA, and TopGaN Ltd of Warsaw (founded in 2001 by the High Pressure Research Center UNIPRESS of Polish Academy of Sciences).

www.strategies-u.com

LED solid-state lighting at a crossroads as applications shift

In 2005, the growth rate for the solid-state lighting (SSL) industry decelerated dramatically after three consecutive years of double-digit expansion to just 5.8% and led to a slowdown in the total LED market (which grew to about $5bn), said iSuppli in its report 'Light Emitting Diodes (LEDs) 2006'.

The slowdown was mainly due to:

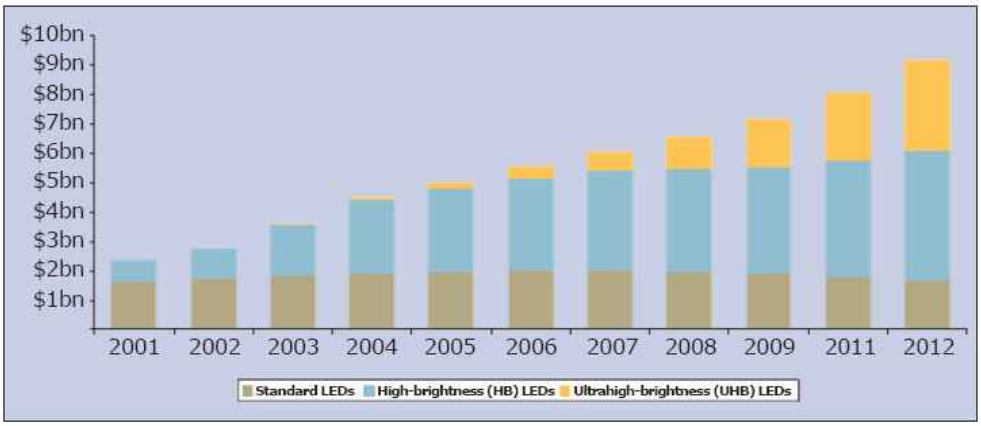
- aggressive erosion in average selling prices (ASPs) of 26% for blue HB-LEDs used in keypad backlighting and about 20% for white LEDs used in handset backlighting offsetting unit shipments. In 2005, backlighting of LCDs and handset keypads accounted for 25% of total SSL industry revenue. The aggressive ASP erosions are continuing in 2006.
- a significant slowdown in the growth of mobile phone shipments 25-30% in 2003 and 2004 to 15%.
- slower adoption of SSL in new applications.

In 2006, the SSL industry finds itself at a critical crossroads, says Jagdish Rebello, director and principal analyst with iSuppli. LED suppliers must aggressively target new applications in order to regain their momentum.

iSuppli says that the growth drivers for the SSL industry will shift from the backlighting of small-size LCDs to new applications requiring high-flux LEDs, i.e. ultrahigh-brightness (UHB) LEDs."

iSuppli projects that the market for LEDs will have a compound annual growth rate (CAGR) of 10.6% through 2011, when it will exceed US$9.1bn. A significant portion of this growth will be driven by UHB-LEDs, which will rise from 4% of the total LED market in 2005 to about 33% in 2011.

The backlighting of large-size LCDs, new signage and decorative illuminations and exterior automobile lighting will fuel future growth, iSuppli predicts. Several LED suppliers, backlight unit (BLU) manufacturers, LCD panel makers and TV/monitor OEMs are actively investigating the use of LEDs for backlighting of large-size LCDs. Several designs are being investigated and prototypes are being demonstrated, iSuppli notes.



Worldwide market for through-hole and SMD LED lamps. (Source: iSuppli.)

While LED BLUs offer the advantages of richer color gamut, better contrast, lower power consumption and reduced thickness, they are still significantly more expensive than cold-cathode fluorescent lamp (CCFL) BLUs.

iSuppli projects that commercial shipments of large-size LCDs with LED BLUs will start in 2007. However, penetration rates will be small, at less than 10% through 2009. As progress continues to be made in improving the performance of LEDs, while driving down pricing, high-power LEDs will slowly start to penetrate general lighting applications, which represents a $16bn market for light bulbs and a further $25bn market for lighting fixtures, drive circuitry and accessories.

Applications such as LED flash lighting and garden lighting are slowly creating awareness among customers and reducing the educational barrier to the adoption of LEDs in lighting. iSuppli projects that LED light bulbs will begin to address the residential and enterprise general illumination market in 2010.

Also, as LED technologies advance, new applications will emerge that traditional lighting sources such as incandescent lamps and fluorescent bulbs will not be able to address. The near-monochromatic emission of LEDs and their resultant capability to tune their spectral characteristics will culminate in dramatic lighting applications that have not yet been conceived, reckons iSuppli.

If all LEDs do is replace traditional lighting sources in existing applications, the success of LEDs will be limited. However, iSuppli believes that, just as the replacement of vacuum tubes with solid-state transistors revolutionized the electronics industry with dramatic new applications, so too will the LED for the lighting business.

Lighting designers, OEMs and module manufacturers are striving to harness the power of LEDs in new lighting applications and to advance the overall lighting industry. The market is expanding and investments in innovative designs and creative solutions can be well justified, iSuppli concludes.

www.isuppli.com

Sandia to be center for lighting R&D

At a conference at Sandia National Laboratories in Albuquerque, NM, US Department of Energy secretary Samuel W. Bodman announced that it is the new home of the National Laboratory Center for Solid-State Lighting Research and Development. Sandia will conduct research and coordinate related efforts at several other national laboratories.

The DOE's Office of Energy Efficiency and Renewable Energy will provide funding of $5m for seven research projects, including $2.6m for four at Sandia: $599,757 for a project to develop white LEDs; and $795,000, $616,000 and $605,000 for three projects looking into ways to make more energy-efficient LEDs. Los Alamos National Laboratory will receive $800,000 for a project to establish high-efficiency, low-voltage stable hybrid organic LEDs (used in the small screens of mobile phones, for example).

"The research will be conducted at the new nanotechnology centers at our national laboratories," Bodman said, including the new Sandia/Los Alamos Center for Integrated Nanotechnologies (CINT). "This is part of nearly $20m we are committing this year to support R&D efforts in this rapidly emerging technology."

Bodman noted that 18% of all US energy generated ($55bn) goes to lighting homes, offices, and factories. He believes solid-state lighting offers excellent prospects for meeting future lighting needs in a less costly, more efficient way than incandescent and even fluorescent fixtures.

"We at the Department of Energy want to see it fully developed as quickly as possible," Bodman said. "We also believe that solid-state lighting presents an excellent opportunity for the US to assume a leadership role in an emerging industry that can generate thousands of high-paying, high-quality jobs."

"It makes sense that this research will be done right here at Sandia, where scientists are already hard at work developing this technology," said senator Jeff Bingaman, who singled out Jerry Simmons, senior manager of Sandia's Energy Sciences Department, for his "many years of working in the vineyards" of solid-state lighting research.

"There will be spin-offs from this research," added senator Pete Domenici. The labs involved will find "the longest waiting list they've ever seen" for partners from industry and academia eager to collaborate.

www.sandia.gov

Pictured (from left): Jerry Simmons, senior manager of Sandia's Energy Sciences Department; DOE secretary Samuel Bodman; senator Pete Domenici; representative Heather Wilson; Los Alamos National Laboratory director Michael Anastasio; Sandia president and Laboratories director Tom Hunter; and senator Jeff Bingaman at the new Center for Integrated Nanotechnologies. (Photo courtesy of Randy Montoya.)

IN BRIEF

Dalian expands opto with multiple MOCVD systems

Dalian Meiming Epitaxy Technology Co Ltd has ordered multiple Aixtron MOCVD systems for high-volume production of LED and laser epiwafers in both Dalian, China and California, USA.

The new order follows its recent purchase of an Aixtron 24x2"-wafer AIX 2400G3 HT and a 24x2"-wafer AIX 2600G3 HT, which are to be installed soon.

"We have great plans for the expansion of our optoelectronics manufacturing capacity to meet the present and future needs of our customer base," said president Xiao Zhiguo.

"Taken together, this is one of the biggest single orders we have so far received from a China-based customer," said Dr Bernd Schulte, Aixtron's executive VP and chief operating officer. "These MOCVD tools will meet all the requirements for Dalian Meiming Epitaxy Technology in growth capacity, flexibility and productivity."

Dalian Meiming Epitaxy Technology is establishing both horizontal as well as vertical flow regime systems for epitaxial deposition, says Schulte.

SemiLEDs expands for GaN-based LEDs

In October 2006, Silicon Valley-based SemiLEDs Corp ordered a 24x2"-wafer Aixtron AIX 2600G3 HT mass-production MOCVD system (to be installed at its plant in Hsinchu Science Park, Taiwan, alongside several existing AIX-TRON reactors), providing additional production capacity for its high-performance GaN-based LEDs, which it claims are the only commercial metal-base-vertical-structure LED chips.

www.aixtron.com

Photolith clusters chosen for HB-LEDs

Osram Opto Semiconductors of Regensburg, Germany recently placed follow-on orders with Munich-based Suss MicroTec for LithoFab200 cluster systems, used specifically for volume production of high-brightness LEDs.

The LithoFab200 enables streamlining of the LED production process by automating and integrating all photolithography process steps (coat, bake, expose and develop) in a modular cluster system, says Rolf Wolf, managing director of Suss MicroTec Lithography Division. As well as its high productivity and high yield at lowest possible cycle times, the LithoFab200 has been chosen for its ability to safely handle fragile substrates, says Suss.

Based on the MA200Compact Mask Aligner, a newly designed exposure cell optimizes alignment accuracy, widening the process window for a variety of applications. The DirectAlign option allows an alignment accuracy down to 0.5μm (3σ), the highest performance available for a mask aligner, Suss claims.

"The new generations of advanced HB-LEDs are sold in a highly competitive market environment, and we therefore demand the best possible quality, precision and cost of ownership from our production equipment," says Gerhard Maihöfner, VP Osram Opto Semiconductors. "Our work with the LithoFab200 System is a vital part of our continuing efforts to provide our customers with cutting-edge LED solutions. In order to meet the aggressive schedules for cost control in all aspects of the LED manufacturing process we have to rely on suppliers with trusted manufacturing capacity and performance records in the field of production."

www.suss.com

Osram launches 30lm/W LED

Osram Opto Semiconductors of Regensburg, Germany has launched the Platinum Dragon, the brightest single-chip high-power LED in its Dragon series, producing 75lm of white light at 700mA (30lm/W).

In terms of its design and dimensions, the package is the same as for the Golden Dragon but can withstand twice the output and therefore a higher operating current, due to the high-power thin-film chip, better thermal connection between the chip and the package, and optimum heat dissipation of the SMT package. Because the operating current can be higher — up to 1A depending on the colour — there is more light from the same unit area.

OSRAM says that the Platinum Dragon is suitable for applications that need high brightness in a small space, such as torches, bicycle lamps and flashing blue lights for emergency vehicles. Existing applications such as traffic lights, flashing warning lights on building sites, reading lights in cars and aircraft, and medical lamps can be made brighter without design modifications. OSRAM claims that, at a price of less than three dollars, the Platinum Dragon offers more lumens per dollar than any other LED.

Osram's 30lm/W Platinum Dragon.

www.osram-os.com

Osram forms North American partnership for Nu Horizons

Osram Opto Semiconductors Inc of San Jose, CA, USA, the US arm of the German parent company, has announced a partnership agreement throughout the USA, Canada and Mexico for the distribution of its LEDs, silicon photodetectors, optical sensors, infrared emitters, high-power laser diodes, organic LEDs (OLED) and intelligent display products via Nu Horizons Electronics Corp, a global distributor of semiconductor, display and system solutions. The aim is to "broaden our opto semiconductor products reach and allow greater penetration into our key target markets," says president and CEO Tom Shottes.

Osram Opto Semiconductors says it focuses its product offering on growing markets such as general illumination, projection, LCD display backlighting, automotive interior and exterior lighting, and mobile communications with organic and classic light emitting diodes used as innovative light sources.

"This partnership provides Nu Horizons an entry into the lighting market and allows our company to synergistically work with multiple partners across our line card to satisfy diverse customer requirements," says Dave Bowers, president of Nu Horizons' Distribution Division. "We are particularly excited about OSRAM's innovative OLED offering. It's a great addition to our flat panel display business."

www.nuhorizons.com

New-generation side-emitting LEDs to extend battery life

Osram Opto Semiconductors has launched a new generation of its side-emitting MicroSIDELEDs that has 30% higher luminous intensity and is 0.6mm tall compared to 0.8mm for the previous generation, suiting low-profile display backlighting applications. Thanks to further advances in ThinFilm technology, output from a single LED has been raised from 0.9cd to 1.6cd. The new MicroSIDELEDs help to reduce the costs of display backlighting and also maximize battery life in mobile terminals, says Ellen Sizemore, director of LED/IR Marketing.

Osram's MicroSIDELEDs for displays.

Producing the required luminance of almost 220cd/m^2, the LEDs also operate with a lower current. For a comparison value of 60cd/m^2, consumption is reduced to 1W.

Along with 50 other companies, Osram is participating in a project to extend the battery life of mobile devices by identifying areas where energy consumption can be reduced. In support of this initiative, at *Display Fair* in Yokohama, Japan, Intel's 'Extended Battery Life' exhibit demonstrated a laptop display using 60 MicroSIDELEDs to backlight a 15" screen. It consumes just 4.4W, and achieves a maximum luminance of about 220cd/m^2, outperforming higher-wattage displays equipped with cold-cathode fluorescence lamps (CCFLs).

www.osram-os.com

LSG puts OSTAR LED lighting products in the spotlight

Osram Opto Semiconductors' OSTAR lighting products are being used in the new LED-based R-16 compact floodlights of Dallas, TX-based Lighting Science Group Corp, for industrial and commercial applications (especially in elevators) and for flood, track and spot lighting.

"Elevator lighting represents a substantial market opportunity for us, and we view the LED R-16 as key to our development of this market," said LSG's chairman and CEO Ron Lusk. Most elevators are lit continuously, so the application presents important opportunities for energy conservation and labor cost savings, he adds.

Osram is providing OSTAR six-chip series LEDs for LSG to incorporate in its Optimized Digital Lighting technology. The complete lamp yields easy-to-install, long-life, efficient and high-output solid-state lighting, LSG says.

The LED R-16 lamp uses a single OSTAR six-series chip design with lens. The OSTAR's chip design is suited to down-lighting, as it delivers high brightness from a small source. Its hexagonal shape enables more LEDs to be linked together in space-saving, high-intensity packages. At 420lm and an operating current of 700mA, a single OSTAR with lens is brighter than a 20W low-voltage halogen lamp and generates far less heat, says Osram.

Osram's OSTAR LED and (inset) LSG's new LED-based R-16 lamp.

According to LSG's current testing of the combined technologies, the LED R-16 offers a lumen output maintained at 70% capacity over an estimated life of 30,000 hours (about three years), suited to use in difficult-to-reach applications.

As part of its Green Building effort to reduce the use of mercury containing lamps, Merrill Lynch says it is installing the R-16 where the application may be appropriate.

● It was previously announced in July that OSTAR lighting products were to be used for LSG's new LED-based MR-16 and R-30 lamps for industrial, commercial and consumer applications, as an alternative to its MR-16 metalized reflector halogen lamp. The LED MR-16 also contains a single OSTAR six-series chip design with lens; the R-30 contains three. "This synergy with Osram is sure to open new doors that will benefit our customers as well as expand the market adoption of LED lighting," said Lusk.

The collaboration also extends the use of Osram's advanced LED technology and components from the automotive sector into the industrial, commercial, and consumer down lighting markets," says Osram's president and CEO Tom Shottes.

www.lsgc.com

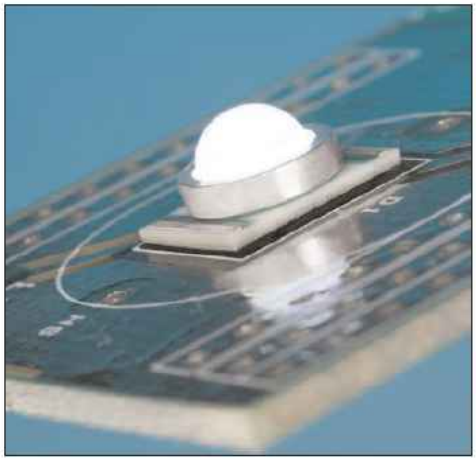
White power LED hits 160lm; efficiency exceeds fluorescent

The luminous efficacies of established light sources are 10-20lm/W for incandescent light bulbs and 50-60lm/W and, in some cases, up to 100lm/W for compact fluorescent lamps (CFLs). Most white LEDs in production have an efficiency of about 40lm/W. Now, the performance of white-light LEDs has progressed to such an extent that they can match the efficiencies of halogen lamps and are starting to rival CFLs as a cost-effective alternative to traditional technologies in general lighting applications.

In October, Cree Inc of Durham, NC, USA launched its latest XLamp 7090 power LED, which has luminous flux of up to 160lm at 700mA and 95lm at 350mA (a record luminous efficacy of 85lm/W), and typically 80lm at 350mA (70lm/W) — 350mA operation is the benchmark for most solid-state lighting applications, says Mark McClear, director of marketing for lighting LEDs.

Mike Dunn, general manager and VP, lighting and backlighting LEDs, says the XLamp 7090 offers the efficiency and reliability needed to make LEDs cost-effective for more general lighting applications, such as street lighting, retail high-bay lighting and parking-garage low-bay lighting, as well as improved consumer applications such as flashlights, camera flash and projection displays. Cree's goal is to "aggressively increase the brightness and efficacy of our LEDs to ensure that LEDs become a cost-effective, energy-saving alternative for all lighting applications."

"To replace the light bulb cost effectively with solid-state technology, LED manufacturers have to maximize the efficacy (lumens/watt) of their high-power LEDs," notes Manuel Lynch, Permlight Products president and CEO. "Energy savings is the most important metric as we build the business case for the residential lighting fixtures of today."



Cree's latest 160lm XLamp 7090 LED.

Cree's LED R&D is enabled in part via funding from the Department of Energy's Building Technologies Program, within the Office of Energy Efficiency and Renewable Energy, and from the Department of Commerce's National Institute of Standards and Technology's Advanced Technology Program. Cree is also a charter member of the Department of Energy's Solid-State Lighting Partnership with the Next Generation Lighting Industry Alliance, an organization of lighting manufacturers that provides input to enhance the manufacturing and commercialization focus of the Department's solid-state lighting portfolio.

"The Department of Energy is pleased to have been a contributing partner in the Cree R&D efforts that have achieved a new level of performance for power LEDs," says Alexander Karsner, Department of Energy assistant secretary for Energy Efficiency and Renewable Energy. "Now, more than ever, our nation needs energy-saving technology that is top-quality and cost-effective. The Department will continue to work with Cree and other lighting-industry partners to turn advanced energy-saving technology into commercially available and successful products that save energy for consumers."

The work is part of a three-year project focused on demonstrating that white LED electrical input/optical output power can be scaled up to levels suitable for general illumination applications, with superior energy efficiency, requiring improvements in chip efficiency, optical design, and thermal management.

The XLamp 7090 is Cree's first power LED based on its EZBright 1000 chip (released at the end of August — see September issue, page 19). It is also the third product based on its InGaN-based EZBright LED chip platform, which was launched in March with the EZBright290, which typically measure 0.29mm x 0.29mm and are available in both green and blue colors for white backlighting applications in LCD screens on mobile phones, PDAs, TVs and monitors, as well as for indoor and outdoor LED display, camera flash, gaming and indicator applications. The 7090 is also twice as bright as the second EZBright chip, the EZR LED launched in April for industry-standard side-view packages in mobile LCD backlight applications. The 7090 is rectangular, allowing thinner packages than square-shaped chips, extending the use of white LEDs to mobile phones, PDAs, DST cameras, MP3 players, and laptop PCs.

The easy-to-die-attach EZBright chip can be assembled into LED packages using industry-standard epoxy die attach processes, which broadens applications. A proprietary optical design delivers an optimal Lambertian radiation pattern, reducing emission losses and significantly increasing efficiency, which scales well with the chip size.

"These chips should enable solid-

state lamp makers to challenge the efficacy of not only incandescent, but also fluorescent lamps," says chairman and CEO Chuck Swoboda. "The EZBright1000 LED power chip is one of several advancements we are working on to help drive LEDs into more mainstream lighting applications." Measured as a bare die, the blue LED has power output of up to 370mW at 350mA drive current and 800mW at 1A.

"The LED industry is advancing brightness at a far greater pace than anticipated," says Swoboda. "Power LEDs are rapidly moving up the performance curve, similar to advances we continue to make with small LED chips". XLamp LEDs have larger chips (1 x 1 mm), designed to operate at 350mA, and hence have lower efficacy than the smaller-chip devices.

In February Cree launched a white XLamp 7090 power LED with then record typical efficacy of 47lm/W and luminous flux of 57lm at 350mA.

Using a pre-production prototype chip in Cree's standard, commercial XLamp 7090 power LED package, Cree's Santa Barbara Technology Center demonstrated white LEDs with efficacies of 65lm/W at 350mA (on a par with some compact fluorescent lighting systems and up to 10 times as efficient as incandescent sources).

A key modification to Cree's experimental blue-emitting LED chip design resulted in a 17–20% increase in brightness and record performances for 1W-class blue LEDs operating at 350mA. Then, with a commercial yellow phosphor, packaged white LEDs using Cree's XLamp 7090 power LED platform gave average output over 65lm/W, and up to 70lm/W for a 0.9mm x 0.9mm chip at 350mA.

This June Cree reported prototype white LEDs with record 131lm/W efficacy at 20mA (as confirmed by NIST), using a prototype EZBright-based cool-white device with a correlated color temperature of 6027K. This points the way to commercial LEDs soon with typical efficacies exceeding 100lm/W, claims Cree. The 'holy grail', adds Steve Johnson (head of the Lighting Research Group at Lawrence Berkeley National Laboratory) is 150lm/W.

www.cree.com

Cree profits hit by falling LED prices

Cree, which makes LEDs, SiC- and GaN-based power-switching and RF/wireless devices, and SiC substrates, has reported revenue for its fiscal Q1/2007 (to 24 September) of $103.9m, within its forecast of $102–106m but up just 1% on a year ago. Net income from continuing operations fell from $21.7m to $13.3m. Gross profit was 41% and operating profit 16% of revenue.

LED unit shipments were up 10% sequentially and 32% year on year. But the average selling price of Cree's LEDs fell 11% sequentially and 26% year on year, so LED revenue fell from $85.1m the previous quarter and $84.6m a year ago to $82.6m (the lowest for several quarters). Sales of high-power devices such as SiC Schottky diodes rose to $4.5m, up more than 35%. Wafer revenue was $6.6m, up nearly 30%.

"While short-term market conditions remain challenging, we continue to make outstanding progress towards our goal of enabling LEDs to become a cost-effective, energy-saving alternative for lighting applications," said CEO Chuck Swoboda. "The recently introduced EZBright 1000 LED power chip and the latest XLamp 7090 power LED have established a new class of performance by dramatically increasing the light output and efficiency provided by LEDs," he claims. "We are on track with our strategy to broaden our product lines into higher-value components for the tremendous markets in lighting and power."

For its fiscal Q2/2007, Cree is targeting revenue of $105–109m.

IN BRIEF

Cree counter-sued by BridgeLux over GaN LED patents

LED chip maker BridgeLux Inc of Sunnyvale, CA, USA (founded in 2003 as eLite Optoelectronics Inc) has filed a motion to dismiss the lawsuit filed against it by Cree Inc and Boston University in September that alleged infringement of US patents 6,657,236 and 5,686,738 and sought monetary damages and injunctive relief (see September issue, page 19).

The '236 patent, 'Enhanced Light Extraction in LEDs through the Use of Internal and External Optical Elements' (assigned to Cree Lighting Company), relates to light extraction structures used in LEDs. The '738 patent, 'Highly Insulating Monocrystalline Gallium Nitride Thin Films', relates to semiconductor devices manufactured using a GaN-based buffer technology, comprising a GaN layer and one or more doped GaN layers.

"We reiterate our belief that Cree's lawsuit is without merit, and we will vigorously defend against the claims that have been brought," said BridgeLux's CEO Robert C Walker.

Furthermore, in response to Cree's lawsuit, BridgeLux has commenced an action seeking declaratory relief against Cree and Boston University, declaring that BridgeLux does not infringe the '236 and '738 patents, as well as certain other Cree patents. In addition, BridgeLux has filed suit against Cree for infringement of its US patent 6,869,812.

"We believe in the importance of respecting the intellectual property rights of others, just as we expect that others will respect our rights," added Walker.

www.bridgelux.com

Taiwan's LED makers consolidate and grow

Epistar's acquisition of Epitech and Highlink at the end of September is just the latest in a series of consolidations of Taiwanese LED epiwafer and chip makers. The remaining players are among the biggest in the world and have recently been committing to further capacity expansions.

The LED epiwafer and chip manufacturing sector in Taiwan is continuing to undergo consolidation, with profit-making high-volume manufacturers taking over loss-making, less established rivals. Meanwhile, after some postponements for market trends to become apparent and the settlement of patent litigation between the biggest firm Epistar and Japan's Nichia, Taiwanese LED manufacturers have recently been committing to planned capacity expansions.

At the beginning of 2004 there were at least 11 Taiwanese manufacturers of high-brightness LEDs (HB-LEDs), including: Advanced Epitaxy Technology (AET), Arima Optoelectronics, Epistar, Epitech, Formosa Epitaxy (FOREPI), Highlink Technology, Huga, South Epitaxy, Tekcore, Uni Light Technology, and United Epitaxy Company. But some of the smaller players have recently been taken over by the larger players, which are now challenging the 'big five' LED chipmakers: the USA's Cree, Europe's Philips Lumileds and Osram Opto Semiconductors, and Japan's Nichia and Toyoda Gosei.

In August 2005 LED epiwafer and chip maker South Epitaxy acquired rival Epitech Technology Corp, both founded in Tainan's Science-based Industrial Park in 2000 (though the merged company retains the name Epitech in English). This doubled capacity for AlGaAs and blue LEDs to at least 300m chips per month each, according to Taiwan's Digitimes.com.

In late 2005, Taiwan's Epistar Corp, a leading supplier of ITO (indium tin oxide) high-brightness blue and green LED epiwafers and chips, acquired the world's largest maker of red-orange-yellow AlGaInP HB-LED chips, United Epitaxy Company (UEC). Both companies, founded in Hsin-Chu Science-based Industrial Park in 1996 and 1993 respectively, benefitted from technology transfers from the Opto-Electronics & Systems Laboratories (OES) of the Industry Technology Research Institute (ITRI). For first-half 2006, Epistar's sales doubled year-on-year to nearly NT$3bn ($91m), and net profit was up 370% to NT617m.

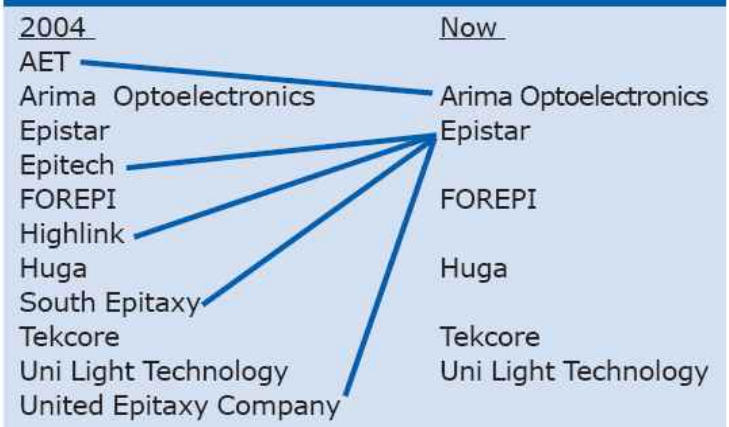
Earlier this year, in March, Arima Optoelectronics Corp (founded in 1998 in Taoyuan, as a subsidiary of the Arima Group) boosted its AlGaInP LED-making capacity from 550m units per month by acquiring a majority 67% stake in AET of Hsinchu (also founded in 1998), which has 13 MOCVD production machines for growing AlGaInP and InGaN LED wafers. The additional capacity should help Arima to fulfill its target for 2006 LED revenue of $98m (up $17m on 2005). Previously, in 2004, Arima had already expanded capacity for AlGaInP-based LEDs through acquiring Kingmax Optoelectronics Inc of Hsinchu (another company founded in 1998).

FOREPI, which was founded in Taoyuan in 1999 and claims to be the only company in Taiwan able to offer a full spectrum of products including high-power InGaN blue, green and near-UV LEDs epiwafers and chips, was also said to be seeking a strategic alliance, to strengthen its market presence. Meanwhile, in May, Chi Mei Optoelectronics, Taiwan's second-biggest TFT-LCD flat-panel display maker and a manufacturer of backlighting units, acquired a 25% stake in FOREPI, becoming its largest shareholder. This was driven by AU Optronics Corp, Taiwan's biggest and the world's third biggest maker of TFT-LCDs, already having a stake in Highlink via its cold cathode fluorescent lamp (CCFL) making subsidiary Wellypower Optronics, and possibly looking to buy Uni Light or Tekcore, which makes green, blue and UV LEDs but aims to also develop AlGaInP LEDs.

But most recently, at the end of September, Epistar said it was acquiring both Tainan-based AlGaInP and InGaN HB-LED epiwafer and chip maker Epitech Technology Corp and Hsin-Chu-based InGaN-focused blue/green HB-LED epiwafer and chip maker Highlink Technology Corp (both founded in 2000). In first-half 2006, Epitech reported sales of NT$1.28bn but a net loss of NT$567m, and Highlink reported sales of NT$311m but a net loss of NT$140m.

With the merger expected to complete by March 2007 (subject to shareholder approval and regulatory clearance in Taiwan), Epistar will undergo share swaps with Epitech (at a ratio of 1:3.08) and Highlink (1:5.5). United Microelectronics Corp (UMC), which is the

Consolidation of Taiwan's LED makers.



world's second biggest silicon wafer foundry after TSMC (also of Hsin-Chu), has a 12.55% stake in Epitech and a majority 30.6% stake in Highlink via affiliated venture capital firms, and hence will gain shares in Epistar. UMC says it is 'confident' about the potential of the LED industry.

According to Digitimes.com, Epistar has over 80 MOCVD reactors, Epitech 60, and Highlink 19. The combined blue and green InGaN LED chip-making capacity of Epitech and Highlink is the largest in Taiwan and twice that of Epistar. Overall, this makes Epistar one of the top-four GaN LED chip-makers worldwide in terms of capacity, along with the likes of Nichia and Cree . The client portfolios of Epitech and Highlink are complementary, with just one or two clients among their combined top-10 overlapping, says Highlink's chairman Semi Wang, adding that Epitech also has strong channel distribution experience in China.

Through cooperation and integration in sales, production and R&D, the merger will enable synergies in new product development and cost reduction, as well as increasing revenue and profitability, claims Epistar.

Following the successful merger of UEC, Epistar reckons it is well prepared to cope with the challenge of the latest consolidation in a fast and efficient way, keeping pace with the rapid development of the HB-LED market. "Combining the production capacity of the three companies, the new Epistar will have complete resources to satisfy fast-growing market demand," says Epitech's chairman Stan Hung. In addition to existing applications in mobile handsets, with emerging applications in backlighting for notebook PCs, LCD monitors and TVs, autos, outdoor displays and many new lighting fields on the horizon, the demand for HB-LEDs will boom over the next few years, Hung reckons.

"With the integration of technology and patent portfolio, the new Epistar will have all the capabilities to be a major player in the global LED industry and offer integrated and high-quality products to meet the needs of customers worldwide," adds Epistar's president B.J. Lee. "The combined number of LED patents from the three firms will total more than 800, facilitating patent partnerships with international makers."

Taiwan is the biggest manufacturing region for blue LEDs. However, patents for the phosphor technology that needs to be added to turn them into white LEDs are mainly held by established white LED makers Osram, Toyoda Gosei and Nichia, hampering development of white LEDs in Taiwan. In particular, Nichia filed a lawsuit in both Korea and Japan against Epistar's representative E&E Japan alleging infringement of patent relating to its phosphor intellectual property. However, in April, emphasizing Epistar's merger with UEC (which had maintained a good business relationship with Nichia for years) and acknowledging Epistar's promise to respect Nichia's IP rights, Nichia decided to settle all pending IP litigations between the companies.

Also, Toyoda Gosei has signed LED cross-licensing agreements with both Nichia and (in April) Philips Lumileds. Epitech has since signed a supply deal with Toyoda Gosei, and in July purchased a new 30 x 2"-wafer Thomas Swan Crius MOCVD reactor from Aixtron for GaN-based HB-LEDs, for delivery in Q3/2006.

Following these patent developments, Epistar, Arima and FOREPI have all scheduled capacity expansions.

Epistar ordered five more Aixtron MOCVD systems (one 42x2"-wafer AIX 2800G4 and four 24 x 2"-wafer AIX 2600G3s) for growing GaN-based LED wafers, aiming to raise blue LED capacity from 150m to 350m chips per month in 2006, although it said second-half 2006 expansions would take place only after the market stabilized; despite strong demand for handset-use LEDs, demand for LEDs used in large-sized applications remained uncertain.

Arima also said it would not expand until early 2007. However, in September, Arima received a large order for AlGaInP red LEDs used in brake lights and outdoor bulletin boards, for shipment from Q4/2006, and hence ordered three of Aixtron's latest 49x2"-wafer AIX 2600G3 MOCVD reactors, for installation in Q4 at its facilities in Dashi and Houko. "The plan is to increase the volume to 40m units per quarter by next year," said president P J Wang. "We also intend to begin shipping blue HB-LEDs this year." This requires installation of extra growth capacity to meet a target of 100m units per month by end-2006. The contribution of HB-LEDs to Arima Opto's revenues is hence expected to rise from a single-digit percentage to more than 30% in 2007.

At the end of August, Digitimes reported that FOREPI had received approval from the Southern Taiwan Science Park's administrators to establish a new plant, costing US$16.3m, to meet demand for customers in southern Taiwan. The plant is due to start production in December at the earliest, with monthly capacity of 250m units adding to its existing capacity of 1.5bn.

So, while the number of HB-LED makers in Taiwan is shrinking, the volume output continues to increase. ■

Emcore refocuses

The cost of III-V photovoltaic cells has limited them largely to satellite use, but the shortage of polysilicon, the high price of terrestrial solar cells, and advances in concentrator cell efficiencies has seen Emcore focus more on III-Vs solar cells.

Emcore Corp of Somerset, NJ, USA has traditionally been a broad-ranging vertically integrated manufacturer of MOCVD deposition equipment; epitaxial wafers, components and subsystems for broadband, wireless and fiber-optic communications; III-V photovoltaic cells; and, via its GELcore joint venture formed in 1999 with General Electric, high-brightness LED solid-state lighting systems (e.g. for traffic lights, channel letters, and other signage and display products). However, in recent years Emcore had been undertaking an ongoing strategy to consolidate activities and focus on broadband infrastructure, optical communications, and solar power.

In late 2003 Emcore sold its MOCVD tool-making division to Veeco, and in recent months it has also shed its epiwafer division and its stake in GELcore.

This August, Emcore also sold its Electronic Materials Division, which provides MOCVD-based RF transistor epiwafer foundry for high-bandwidth wireless communications, for $16m to pure-play epiwafer foundry IQE. The sale aimed to "lower Emcore's cost base, improve gross margins company-wide and permit further consolidation of operations", and should save about $3m annually, said CEO Reuben F. Richards Jr.

At the end of August, Emcore also sold its 49% stake in its joint venture GELcore LLC of Cleveland, OH, USA for $100m in cash to the lighting operation of GE Consumer and Industrial, a division of joint venture partner General Electric. GELcore had slumped from a $2.5m profit in 2004 to a net loss of $0.8m last year and $1.3m for first-half 2006. Emcore said its cumulative share of losses in GELcore since its formation (to the end of June 2006) totaled $16.1m.

Emcore's divestiture of EMD and its stake in GELcore improved its cash balance by a net gain of about $100m, from $25.3m at the end of the June quarter (which was down by $8.6m on the prior quarter) to about $125m. "This sale provides us with one of the strongest balance sheets in our industry and positions us extremely well to advance our industry-leading technology in both fiber-optics and photovoltaics," said Richards.

Emcore is benefitting from a strong recovery in the fiber-optic market. In the April quarter, revenue from the fiber-optic sector of $25.9m drove Emcore's total sales to $41.2m, up 35% year-on-year.

In the June quarter, Emcore's gross margins for photovoltaic products rose due to increased volumes, product mix and better yields, helped by completing the consolidation of solar cell assembly and panel manufacturing from its now-closed facility in City of Industry, CA into the solar cell fabrication plant in Albuquerque, NM, USA (expecting annual savings of $3m).

Emcore's Photovoltaic division has developed and made solar cells in Albuquerque since its formation in 1998. Emcore says it has commercialized several advanced solar cell technologies, focusing initially on the demanding requirements of satellite-based solar power systems for communication, navigation, earth observation, and science applications. It claims to be the leading supplier of GaAs multi-junction solar cell technology for satellite power-generation applications.

However, the increased demand for III-V PVs is coming from not just the traditional III-V market for satellites but, increasingly, for terrestrial solar cells too. Until recently, most terrestrial solar cells have been silicon-based, with high-efficiency but more expensive compound semiconductor solar cells confined to satellite applications.

Demand is being driven by the prolonged shortage of polysilicon used in conventional solar panels (and consequently their continuing high price), the high efficiency of III-V-based PV cells, and advances in concentrator cells to adapt them from space to terrestrial applications. A silicon-based PV cell has a large area for the electrical conversion of light that falls on it directly. In contrast, III-V-based cells have a small-area chip. However, the light can be focused onto the cell area via an optical concentrator lens. Although thin-film multi-junction GaAs-on-Ge cells are more expensive than conventional silicon solar cells, their higher efficiency (up to 38%, compared to 18% for silicon) and improved performance under high light concentration means that far fewer cells are needed to achieve a specific power output. Because only a small area of material is needed, overall system cost can be reduced compared with the large volumes of silicon needed in conventional solar cells.

Also, a concentrator can also track the movement of the sun throughout the day, yielding higher electrical output power. These designs may not be suited to residential use, but could be used in commercial markets.

Emcore Photovoltaic's fab in Albuquerque, NM.

Emcore and Sandia develop terrestrial CPVs

In late July, Emcore said it was teaming with its long-standing technology development partner, Sandia National Laboratories (also based in Albuquerque) to co-develop next-generation grid-tied, utility-scale (10–100MW) concentrator PV power systems, as part of both their ongoing efforts to apply compound semiconductor-based high-efficiency solar cells to terrestrial systems. As well as being a pioneer in PV research, Sandia has worked on the development of PVs for grid-tied, utility-scale power generation for over 25 years. It will provide technical support for Emcore's terrestrial solar systems products.

Emcore is adapting its solar cell technology as a base for the development of large-scale, concentrator PV power systems. "Emcore, with its advanced solar cell technology, provides an excellent path for the commercialization of this [concentrator] technology," added Dr Jeff Nelson, manager of the Sandia Solar Technologies Group.

Emcore invests $10m to expand PV production capacity

The cash from the EMD and GELcore sales will help Emcore to invest in the terrestrial PV making. In September, Emcore said it is spending at least $10m on expanding and developing its terrestrial solar cell manufacturing capacity through purchasing equipment (e.g. MOCVD reactors) and an increase in staffing (the remaining cash from the disposals is being retained for general working capital).

Emcore is in negotiations for the first wave of potential 40MW contracts. "We have bids out on approximately 40MW of [planned projects], with contracts to be awarded in 2006 and installation beginning in 2007," said Richards in May. These would be the largest ever deployments of multi-junction GaAs solar cells.

"Our goal is to become the leader in solar energy power systems," said Richards. "We have a very successful track record in commercializing next-generation technologies, as we have done in the satellite market," he claims.

www.emcore.com

DARPA contract to develop 50%-efficient terrestrial solar cells

In February, Emcore's Photovoltaic division was subcontracted by prime contractor University of Delaware to join 21 other institutions in the Very High Efficiency Solar Cell (VHSEC) project, which was launched by the Advanced Technology Office of the US Defense Advanced Research Projects Agency (DARPA) in November 2005. Emcore says it is the only compound semiconductor manufacturer participating in the program. The aim is to develop cells with at least 40% efficiency by mid-2007 and to deliver 1000 prototype 10cm^2 modules with a minimum efficiency of 50% and an output power of 0.5W by 2009.

The program will provide up to $53m in funding (the largest in the history of solar energy research, according to Rhone Resch, president of the Solar Energy Industries Association), awarded to participants in phases over the next several years. In Phase I, Emcore will develop advanced III-V multi-junction solar cells. In later phases, it expects to develop a technology roadmap for enabling significantly lower fabrication costs.

Reducing the cost of the cells is critical if they are to cross over from high-value satellite to low-cost terrestrial applications. In connection with the sub-contract, Emcore also joined a consortium formed by the University of Delaware to meet the VHSEC program's requirements for a high-efficiency and low-cost terrestrial solar product. The consortium is led by Department of Electrical and Computer Engineering professor Allen Barnett as principal investigator and associate professor Christiana Honsberg as co-principal investigator.

"Emcore will use its core expertise and technology base [the development and high-volume production of III-V solar cells using GaAs alloys and MOCVD] for the demonstration of very high efficiency, as a common theme in the transition to low-cost fabrication," said David Danzilio, VP and general manager of the Photovoltaic division. "In addition to leveraging the solar cell technologies that we have developed for space applications, we also will contribute our experience in deploying high-efficient solar cells for terrestrial markets, where we are achieving excellent results in the concentrator solar power market."

Emcore's highest efficiency InGaP/InGaAs/Ge triple-junction solar cells currently operating on-orbit can have a maximum conversion efficiency of 37% in terrestrial applications, so the technology can outperform other solar approaches. However, typical efficiency in manufacturing is more like 20%.

JV formed for full-spectrum solar cells

RoseStreet Labs LLC of Phoenix, AZ, USA and Sumitomo Chemical Co Ltd of Tokyo have formed a 50:50 joint venture, RSL Energy Inc (starting operation in Phoenix in November and capitalized at $6.6m) to develop and manufacture full-spectrum solar cells.

RSL has exclusive patent licenses from both Lawrence Berkeley National Laboratory and Cornell University for devices that use a much larger fraction of the solar spectrum compared to existing products, and is commercializing full-spectrum technology that could achieve efficiencies above 48% in both single- and multi-junction devices.

RSL will commercialize Berkeley's multi-band technology, which incorporates a "new semiconductor material" developed by CTO Wladek Walukiewicz that can achieve triple-junction efficiencies with single-junction manufacturing cost and simplicity.

RSL is also commercializing the InGaN multi-junction technology of Cornell and Berkeley, which is expected to provide outstanding thermal and radiation properties required for concentrator-based photovoltaics (CPV) in distributed energy power generation. RSL will perform R&D and product development during 2007 and expects to field test prototypes in 2008 in CPV distributed energy, flat-panel, space and architectural applications.

RSL will use RoseStreet's R&D Lab and its high-volume bumping foundry, FlipChip International. "Sumitomo plans to use its US subsidiary, Sumika Electronic Materials Inc, also of Phoenix, to participate directly in the development of InGaN," adds Sumitomo Chemical executive VP Masami Nakamoto.

www.rosestreetlabs.com

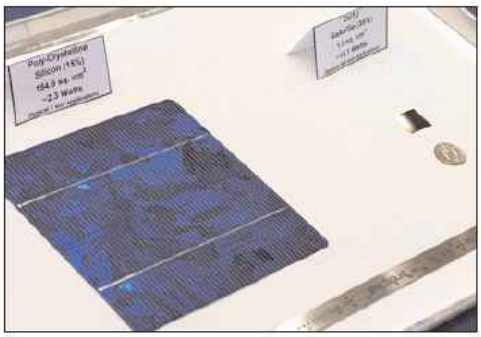
Two-millionth multi-junction solar cell

Spectrolab Inc of Sylmar, CA, USA (acquired by Boeing in 2000 as part of the El Segundo satellite factory of Hughes Electronics) has made its two millionth multi-junction GaAs solar cell in its 50th anniversary year.

Spectrolab pioneered this type of cell in 1983, putting it into production several years later. In the 1990s, Spectrolab licensed solar cell technology from the Department of Energy's National Renewable Energy Laboratory. layered to absorb light at various parts of the solar spectrum, increasing efficiency. Spectrolab mass produced that technology and innovated it to increase the layers of light absorption and efficiency to 28% for space, much higher than for silicon.

"I'd like to thank the US Air Force and NASA for their visionary support of Spectrolab and early adoption of the multi-junction solar cell technology," said president David Lillington. "Spectrolab's on-orbit products are creating more than 575kW of total power for agencies like NASA and the National Oceanic and Atmospheric Administration, and high-performance commercial spacecraft for customers such as DIRECTV and Thuraya," adds Howard Chambers, VP and general manager of Boeing Space and Intelligence Systems. Spectrolab also supplies the US government and national security programs. Its cells power 60% of all satellites, as well as the International Space Station. Also, six of the seven programs on or in orbit around Mars have Spectrolab solar cells and panels. In total, Spectrolab's products have powered over 525 satellites and interplanetary missions.

Spectrolab expects to offer 30%-efficient triple-junction solar cells in 2007 and 33% efficient by 2009 or 2010. It is already working on 40%-efficient cells, says Lillington.



GaAs/Ge concentrator-based terrestrial solar cell (right) can produce five times the power of a much larger polysilicon cell (left).

Since the bluer sunlight in space is not absorbed so well, a terrestrial solar cell is about 10% more efficient. Multi-junction solar cells for use in terrestrial solar concentrators have record efficiencies of 39%. But space cells still win out because satellites get 100% of the sun's energy, while the atmosphere filters out about 20%.

However, terrestrial solar panels can use relatively inexpensive mirrors and lenses to concentrate the light on the cell by as much as 500 times, increasing the energy produced. This allows a 1cm^2 cell (costing about $10-20 to make) to produce 16W. Spectrolab has already developed a 40%-efficient concentrator-based cell and thinks a 45% efficient cell can be made by 2009, 'probably the limit' of what can be produced with current technology and materials.

Spectrolab produces about 700kW worth of non-concentrated GaAs solar panels annually, but this could be 200MW using concentrators. Spectrolab thinks it could deliver 120MW of concentrator cells.

Spectrolab says it is working with several domestic and international solar concentrator manufacturers.

Sharp focus on III-Vs

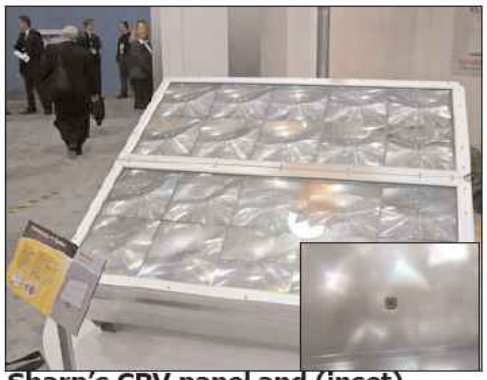
At the Solar Power 2006 Conference and Expo in San Jose, CA, USA on 16–20 October, Sharp Electronics, the first Japanese company to enter mass production of solar cells in 1963 and the world's biggest solar cell manufacturer since 2000, exhibited a prototype concentrating photovoltaic (CPV) solar panel which combines a III-V-based solar cell beneath a Fresnel lens that concentrates the sunlight. Sharp also presented a paper at the conference, 'Concentrating Photovoltaics on the Path to Grid Parity'.

Because of the higher cost of the III-V material compared to silicon, the cell is just a quarter of an inch square (7mm x 7mm). By contrast, the much less costly lens measures a few inches across. The cell is expensive if you use it as it is, without the lens, acknowledges Ron Kenedi, VP of Sharp's solar-energy solutions group, "but it will outperform traditional solar cells in the right conditions", The lens concentrates the energy, making it seem as if 700 suns are pointing at the solar cell, he adds. Sharp says that the panel can convert 36% of the sunlight that strikes it into electricity, far more than the 13–22% of commercial silicon solar cells.

The panel contains 270 lenses, measures 12.5 feet by 16 feet and can produce 2.9kW. It also rotates with the sun, further maximizing efficiency.

Unlike traditional solar panels, the panels require direct sunlight and cannot, for example, harvest energy from light reflected off snow, says Sharp. So, they work best in dry areas with lots of sunlight, such as the southwestern United States.

The system, which may come to market in the next year or two, is suited to use for solar power plants — large installations in a field that would pass power onto the grid — rather than on suburban rooftops, as different types of panels are required for different applications, says Kenedi. "You can't use the same product on the ground as on the roof," he adds. "In the last 20 years, thin film has been the hope [for terrestrial applications]. We think it is getting closer and closer, and we think in two to three years it will become mainstream. Concentrators also make a lot of sense for large fields. We expect that will happen in three to four years."



Sharp's CPV panel and (inset) solar cell beneath the Fresnel lens. Credit: M. Kanellos/CNET News.com

Sharp has also developed prototype solar cells that combine a layer of amorphous silicon and a layer of conventional, crystalline silicon, said Kenedi. These solar cells are nearly transparent, so they could potentially be used in windows. Sharp has installed some of these cells at its latest LCD plant in Kameyama, Japan, which obtains much of its power through various clean energy sources.

In another experiment, Sharp has inserted a layer of LED lights between the two layers of the experimental combo cells. The solar cells power the LED lights, which can then light a room at night. Sharp says that it is also experimenting with solar cells made from organic materials and different types of silicon.

http://solar.sharpusa.com

The Solar Power Conference and Expo, the largest solar event in the USA, has grown from 1100 attendees and 60 exhibitors in San Francisco, CA in 2004 to 1300 attendees and 66 exhibitors in Washington DC in 2005, then over 4000 attendees and 160 exhibitors at mid-October's Solar Power 2006 in San Jose, CA.

The 'Thin Film Solar Electric Technologies' panel session highlighted the status of thin-film solar technologies, amorphous silicon (a-Si), cadmium telluride (CdTe) and copper indium gallium diselenide (CIGS), regarding solar cell efficiencies, module efficiencies, R&D issues, technology pathways, major global players and various applications.

Moderated by Harin Ullal of the US National Renewable Energy Laboratory, speakers included: Jeff Britt, Global Solar ('Progress Towards Commercialization of CIGS Thin Film Photovoltaics'); Subhendu Guha, United Solar Systems ('Thin Film Silicon Solar Cells and Modules'); Craig Hunter, Applied Materials ('Leveraging Mature Platforms: Benefits of Thin Film PV Production Using LCD Equipment'); and Dave Pearce, Miasole ('High Volume Roll-to-Roll Manufacturing').

The session 'Concentrating PV: Ready for Market?', moderated by Roland Winson of University of California Merced, included speakers Bill Gross, Energy Innovations ('Maximizing Onsite Electricty Production Through Rooftop CPV'); Gary Conley, SolFocus ('Toward $1 per Watt Through CPV Designed for Manufacturability and Reliability'); Raed Sherif, SpectroLab ('The Multijunction Solar Cell: An Enabler to Lower Cost Electricity for Concentrating Photovoltaic Systems'); Jason Bobruk, Sharp Electronics ('Concentrating Photovoltaics on the Path to Grid Parity').

www.solarpowerconference.com

Silicon shortage opens window for CIGS PVs

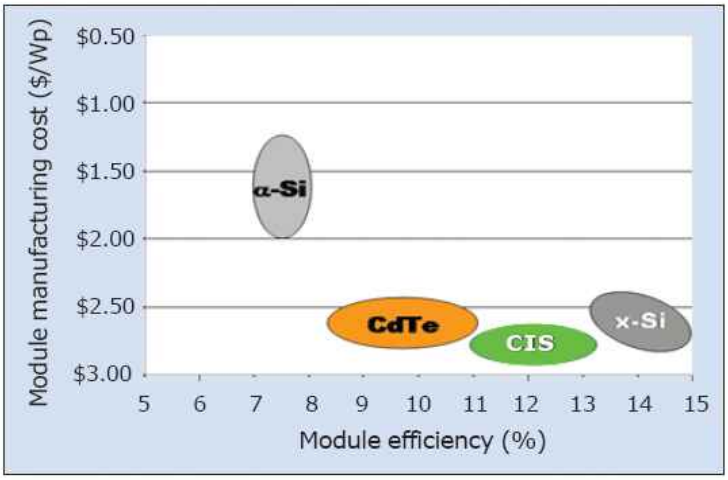
The shortage of polysilicon is constraining uptake of solar power, driving some recent large investments to speed less costly thin-film copper indium gallium diselenide (CIGS) solar cells on flexible substrates into production.

The solar energy industry has grown with a compound annual growth rate averaging 40% over the past eight years. About 90% of solar panels are made of crystalline silicon. However, demand has led to a prolonged shortage of refined polysilicon raw material since 2004 (especially since builders have begun to incorporate solar panels into new homes). This has severely limited sales growth, and may not ease until at least 2008 and possibly beyond.

Given the high cost of oil and instabilities in oil-producing states, President Bush's 'Solar America Initiative' (SAI) calls for an acceleration of US solar cell manufacturing capacity to 5–10GW of generating capacity by 2015 (enough to power 1–2 million households). The US has lagged Japan and Europe in solar production, and is now a distant third, with about 10% of the global market (75% of which is in California). Currently, the world's largest solar factories are run by Sharp and Kyocera in Japan. However, the US has the largest potential for growth, with incentives for photovoltaic (PV) installation in over 20 states.

However, silicon solar panels are made with processes similar to those for ICs, so a solar factory capable of producing 30MW worth of panels a year can cost as much as $70m. A solar-produced kilowatt can cost 35 cents, while a kilowatt straight from the grid can cost 25 cents, says Ron Kenedi, general manager of solar systems at Sharp. Hence, governments are still having to subsidize the cost of solar equipment.

Also, crystalline silicon has an indirect bandgap and is inefficient at photoelectric conversion. In contrast, copper indium gallium diselenide (Cu(In,Ga)Se_2 or CIGS) has a direct bandgap and generates far more electricity. A film as thin as 1μm produces a photoelectric effect equal to that of crystalline silicon over 100 times thicker (200-300μm). Hence, CIGS cells use less than 1% of the material required — an inherent cost advantage.



Module efficiencies versus manufacturing costs in practical application (source: HelioVolt).

According to the US Department of Energy's National Renewable Energy Lab (NREL) of Golden, CO, USA, CIGS solar cells have efficiencies for converting solar energy into electricity of up to 19.5% theoretically and 10–15% in high-volume manufacturing. This is higher than other commercially available thin-film technology, but less than silicon, which has a maximum of 30% theoretically but only 10–20% commercially (although CIGS has an R&D roadmap for improvement to 20%).

However, CIGS solar cells have several advantages (eliminating three problems that have slowed adoption of silicon solar cells — cost, fragility, and availability):

- unlike bulky, rigid silicon, CIGS can be either vacuum sputtered or printed as a thin film onto many carrier substrates including thin, flexible foils such as stainless steel only 50μm thick (100 times thinner than a silicon cell) or polymer sheets, cutting material costs;
- CIGS cells weigh correspondingly less than silicon;
- panels cost five to ten times less to manufacture;
- manufacturing equipment and plants cost less;
- flexibility to conform to small-radius curves;
- easier use in PV modules or direct incorporation into roof tiles and materials such as cement in a building's entire exterior;
- higher efficiency in low-angle and low-light conditions;
- stable and reliable in use (unlike some other thin-film technologies in the past), even being self-healing.

These advantages are further enhanced when incorporated with rugged, flexible encapsulants (rather than glass) into flexible photovoltaic modules.

Table 1: Solar cell technology comparison (source: DayStar Technologies).

Technology	Efficiency	Degradation	Flexibility	Comments
Thin Film				
CIGS	+++	++++	+++	Highest non-silicon efficiency Low material and processing cost Highly flexible Clear roadmap to efficiency improvement
Amorphous silicon	++	++	++	Moderate performance Exhibits instability High cost No clear path to efficiency improvement
Cadmium telluride	++	++++	Rigid	Requires rigid packaging No pathway to efficiency improvement
Crystalline silicon				
Single-crystal silicon	+++++	++++	Rigid	Fully mature technology, Difficult to reduce price or increase performance High material costs & processing cost Fragile, high shipping costs
Polycrystal silicon	++++	++++	Rigid	Similar to single-crystalline silicon

CIGS modules have been tested for over 15 years and produced commercially in modest volumes for experimental installations for nearly a decade. However, high-volume manufacturing technology has been lacking.

But now, given the shortage of polysilicon, CIGS' potential for high module efficiencies and low cost has begun to attract large companies such as Shell and has also led to several recent cases of large investments in specialist CIGS-based companies. The effect is to accelerate development of high-volume manufacturing by years to volume delivery just next year.

Companies ramping up production of CIGS solar cells include Miasolé, DayStar, HelioVolt and Nanosolar.

Miasolé raises $35m for volume production

Miasolé (formerly Raycom Technologies) of Santa Clara, CA, USA has developed a continuous, high-throughput roll-sputtering process to vacuum deposit CIGS over large areas of stainless-steel foil, using proven low-cost thin-film coating process technology used by Miasolé's staff previously in the disk-drive and optical industries. Each production run delivers square miles of product.

"We have the enabling technology to reduce the cost of PV modules from today's $3 per Watt to less than $1 per Watt, making solar-generated electricity competitive with conventional energy sources," claims CEO David Pearce. In 2010, the costs of generating a watt of electricity from a CIGS panel — including installation and other expenses and considering its lifetime — should be about $2.50, roughly equal to grid power, he adds.

After raising $25m over 2004–2005 from investors including Kleiner Perkins Caufield & Byers, Vantage-Point Venture Partners, Bessemer Venture Partners, Firelake Strategic Technology Fund, Garage Technology Ventures and Nippon Kouatsu Electric, and Venture Banking Group, in October Miasolé raised another $35m (bringing the total to $58m).

"We are now able to accelerate our ramp to high-volume production," says Pearce. In May, he said Miasolé was building a production facility with annual capacity of 50MW of solar panels (two lines of 25MW each) by Q4/2006. It has since procured material to build two more 25MW lines. It aims to have 200MW of capacity by end-2007. Pearce adds that Miasolé can erect a 100MW/yr factory for $25m (in contrast, silicon solar cell maker Evergreen Solar spent $75m this year to build a 30MW facility in Germany). The goal for 2007 is $100m in revenue and profitability. Pearce is targeting an initial public offering of stock in 12–18 months.

DayStar targeting 100MW capacity

Also using vacuum sputtering deposition on flexible metal foil is DayStar Technologies, co-founded in Grass Valley, CA, USA in 1997 by president and CEO Dr John Tuttle, a former senior scientist at NREL.

In February 2004 an IPO on NASDAQ raised $10.5m. That June, DayStar accepted an $11.1m incentive package from the New York State Department of Economic Development to locate its 'Gen I' R&D and 'Gen II' pilot lines in Halfmoon (Albany Tech Valley), contingent on plans to invest $40m over five years and grow to 250 staff. This came after New York legislation mandated that, by 2013, at least 25% of the electricity sold to consumers is generated from renewable resources. The package includes a series of tax credits and access to grant programs: in January 2005 the New York State Energy Research and Development Authority awarded DayStar a $1m Renewable Energy Technology Manufacturing Incentive Grant — $600,000 based on production capacity milestones (targeting a 1MW/yr production capability), then $400,000 based on product sales coupled with a commitment to expand in 2007 into a new 'Gen III' roll-to-roll factory at the Saratoga Technology + Energy Park in Malta, NY.

Shell Solar CIGS PV installation in Wales, UK (left) and roll-printing at Nanosolar (right). Credit: NREL.

In May 2005 DayStar started pilot manufacturing of TerraFoil cells, and in the June signed its first client, European PV system integrator Blitzstrom GmbH of Mainbernheim, Germany, for monthly delivery to end-2008 of 30m 1W TerraFoil solar cells (30MW), worth at least $60m, for Blitzstrom's contract module manufacturer Titan Energy in India. At September 2006's 21st European Photovoltaic Solar Energy Conference in Dresden, the agreement was expanded to 130MW through to end-2010. July 2005 also saw the first sale of TerraFoil-SP small-power cells when Micro Energy Group Inc of China agreed to buy up to 500kW for flat-plate PV modules and specialty consumer electronic products. This October, DayStar received a $1m US Air Force award to develop its LightFoil cells (CIGS on titanium foil) for lighter-than-air vehicles.

After transitioning from pilot- to commercial-scale production of Terrafoil on the Gen II line in Q2/2006 and in response to evolving market conditions, in May DayStar raised $15m from selling 12% of its stock to Castlerigg Master Investments Ltd. This will enable it to start up its Gen III line earlier than planned, installing equipment in early 2007 for a capacity 10MW per year, increasing to at least 20MW per year by end-2007. The first target is to fill the facility with 100MW of capacity, then expand through duplication at other plants worldwide, while developing an expanded platform for greater economies of scale.

GSE selling CIGS to silicon PV panel makers

Global Solar Energy Inc (GSE) of Tucson, AZ, USA (established in 1996) uses roll-to-roll manufacturing of CIGS cells on flexible materials to make 6.5–55W foldable, portable solar panels.

This March, module manufacturer Solon AG of Berlin, Germany acquired a 19% stake in GSE (the balance being privately owned by a German investor). At October's Solar Power 2006 conference, Solon launched 130–220W modules based on GSE's cells, for delivery in North America in Q2/2007. GSE also said it had begun selling CIGS cells in power strings to established silicon module manufacturers, as a replacement for traditional silicon cells.

"We are going up to 4.2MW by January 2007 and 40MW by January 2008 to keep up with the demand for our current flexible, foldable, portable solar panel line as well as this new demand for our cell strings", said president Michael S. Gering.

HelioVolt seeking funding

HelioVolt Corp of Austin, TX, USA was founded in 2001 by president and CEO Dr Billy J. Stanbery. He argues that the vacuum deposition in conventional thin-film production can be capital intensive, and is difficult for CIGS films over large areas with the precision necessary to achieve both high performance and low cost, compared to his patented non-vacuum deposition 'FASST' process. A two-year Cooperative Research and Development Agreement (CRADA) with NREL indicated that FASST enables simpler, faster manufacturing and improved flexibility. Greater controllability allows it to be adapted; FASST can also print CIGS directly onto construction materials, including architectural glass, steel, roofing and polymers.

In June 2005, HelioVolt raised $8m in a Series A round from New Enterprise Associates, and is using the funding to build prototypes of commercial-scale manufacturing equipment. This September, the CRADA was extended to optimize FASST for commercialization. HelioVolt is now aiming to raise $50m.

Nanosolar raises $100m for 430MW/yr fab

Nanosolar Inc of Palo Alto, CA, USA was founded in 2002 by president Brian Sager and CEO Dr Martin Roscheisen (a Stanford University engineering graduate who sold Internet firm eGroups to Yahoo for $432m in 2000). Seed funding came from Google co-founders Sergey Brin and Larry Page.

After Nanosolar re-focused in 2003 from organic technology to CIGS, in 2004 it was awarded a $10.3m R&D contract by DARPA, and has also received funding from the California Energy Commission as well as the US National Science Foundation.

In 2004 it recruited director of process engineering Craig Leidholm (who, at International Solar Electric Technology Inc, developed CIGS thin-film processes). By using its all-solution-based coating process to embed nanostructured CIGS into thin polymer films, Nanosolar was first to roll-print a CIGS-based solar cell. It claims that its technology allows roll-to-roll printing with more than an order of magnitude faster throughput over the best in conventional silicon or vacuum technology, as well as being very inexpensive and quick to scale to production volume.

After completing its initial R&D phase and moving into commercial production with a pilot manufacturing facility, in May 2005, Nanosolar appointed the following staff:

- VP of engineering Dr Chris Eberspacher, former head of R&D at ARCO Solar (now Shell Solar), where he developed the first commercial CIGS cells, before co-founding Unisun Corp and pioneering printed CIGS cells;
- Executive VP of operations Werner Dumanski, former manufacturing executive for Hitachi/IBM's $4.5bn storage components business;
- independent director Dr Siva Sivaram, COO of Matrix Semiconductor, a former general manager of Intel's IC Procurement and Enabling Division.

After receiving $750,000 in SBIR Phase-II funding in February 2005, that June Nanosolar raised $20m in Series B funding (bringing the total to $37m). The round was led by MDV-Mohr Davidow Ventures and included Mitsui (Japan's largest distribution company) and Onpoint Technologies (the US Army's venture fund), as well as previous investors including Benchmark Capital and Stanford University.

"Thin-film printing overcomes the complexity, high cost, and yield and scalability limitations associated with vacuum-based processes," claims Eberspacher. "This allows us to produce cells very inexpensively and assemble them into panels that are comparable in efficiency to that of high-volume silicon-based PV panels." Dumanski adds that, "Given the square meter economics of solar, high-throughput high-yield processes have to be used to succeed in this industry. With Nanosolar's printing process, the fully loaded cell cost — including materials, consumables, energy, labor, facility, and capital — is less than the depreciation expense alone that vacuum thin-film companies have to pay for the equipment that produces their cells."

This June, Nanosolar raised Series C equity funding of more than $75m (bringing the total to over $100m). New investors included SAC Capital and GLG Partners; Swiss Re; Grazia Equity (the original backer of Conergy AG, the largest PV system integrator); Christian Reitberger (the original backer of Q-Cells, the largest independent silicon PV maker); Capricorn Management (the investment arm of Jeff Skoll, a supporter of clean energy causes); the investment arms of SAP founders Klaus Tschira (via FirstVentury) and Dietmar Hopp; and PV power plant system integrator Beck.

The funds are going towards building "the world's largest thin-film solar factory", sited in the San Francisco Bay area and due to open in 2007. The targeted annual capacity is 200m cells, or 430MW (compared to 500MW for a large coal-burning power plant), almost triple the USA's current total 153MW PV-making capacity. Nanosolar is also to build a 1m panel/yr assembly plant in Berlin, Germany (one of the world's biggest solar markets), making it also one of the world's largest solar-panel manufacturers.

(Left) Flexible CIGS solar panels. (Right) A foldable portable power pack. Credit: Global Solar Energy.

Nanosolar's new plant alone would move the US to second, ahead of Europe and behind Japan. "This is a very important step for us to address the energy crisis we face in this country," says Rhone Resch, president of the Solar Energy Industries Association in Washington DC. "We cannot drill our way out or mine our way out, but we can manufacture our way out."

"A factory of this capacity would cost more than $1bn to build if one used conventional solar technology...we can achieve this scale with a tenth of the capital and as a start-up company," says Dumanski. "There are three miles of solar cells on a single roll of polymer film," said Roscheisen. "We're going to have the economies of scale of the print business."

Initially, Nanosolar will embed its cells into relatively standard solar panels and sell them to utilities for solar farms, followed by plastic sheets for the rooftops of 'big box' retailers. In August, Nanosolar signed a long-term supply agreement with Conergy Group of Hamburg, Germany (the largest solar company in Europe, which intends to expand its North American market share). The aim is to develop large-scale PV systems with "tightly interconnected panel and equipment design innovations". Conergy's expertise in the integration of components will provide "custom-tailored and cost-efficient solar solutions", it claims. "Delivering the next level of innovation in solar electricity requires product design work that takes a systems-wide perspective," adds Roscheisen.

Future prospects

Regardless of whether vacuum sputtering or roll printing manufacturing methods prevail, both technologies have attracted large amounts of venture capital investment. Hopefully, unlike previous, more expensive and perhaps more speculative technologies like InP-based optoelectronic integrated circuits for example, start-ups won't burn through their investors' cash interests before achieving high-volume revenues. But even if they do, it seems established solar cell makers like Shell are committing to a long-term interest in CIGS. ■

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Austria
Tel: +43 7712 5311 0
Fax: +43 7712 5311 4600
www.EVGroup.com

Oxford Instruments Plasma Technology
North End, Yatton,
Bristol,
Avon BS49 4AP
UK
Tel: +44 1934 837 000
Fax: +44 1934 837 001
www.oxford-instruments.co.uk

SAMCO International Inc
532 Weddell Drive,
Sunnyvale,
CA,
USA
Tel: +1 408 734 0459
Fax: +1 408 734 0961
www.samcointl.com

Surface Technology Systems plc
Imperial Park,
Newport,
Wales NP10 8UJ,
UK
Tel: +44 (0)1633 652400
Fax: +44 (0)1633 652405
www.stsystems.com

Leading manufacturer of plasma etch and deposition equipment, including DRIE, ICP, RIE & PECVD technologies used in the fabrication and packaging of semiconductor devices.

Tegal Corp
2201 S McDowell Boulevard,
Petaluma,
CA 94954,
USA
Tel: +1 707 763 5600
www.tegal.com

Unaxis Wafer Processing
10050 16th Street North, Suite 100,
St. Petersburg, FL 33716,
USA
Tel: +1 727 577 4999
Fax: +1 727 577 7035
www.waferprocessing.unaxis.com

Veeco Instruments Inc
100 Sunnyside Blvd.,
Woodbury, NY 11797,
USA
Tel: +1 516 677 0200
Fax: +1 516 714 1231
www.veeco.com

9 Gas and liquid handling equipment

Air Products and Chemicals Inc
7201 Hamilton Blvd.,
Allentown,
PA 18195,
USA
Tel: +1 610 481 4911
www.airproducts.com/compound

CS CLEAN SYSTEMS AG
Fraunhoferstrasse 4,
Ismaning, 85737,
Germany
Tel: +49 89 96 24 00 0
Fax: +49 89 96 24 00 122
www.cscleansystems.com

IEM Technologies Ltd
Fothergill House, Colley Lane,
Bridgwater,
Somerset TA6 5JJ,
UK
Tel: +44 (0)1278 420555
Fax: +44 (0)1278 420666
www.iemtec.com

SAES Pure Gas Inc
4175 Santa Fe Road,
San Luis Obispo,
CA 93401,
USA
Tel: +1 805 541 9299
Fax: +1 805 541-9399
www.saesgetters.com

10 Process monitoring and control

k-Space Associates Inc
3626 W. Liberty Rd.,
Ann Arbor, MI 48103,
USA
Tel: +1 734 668 4644
Fax: +1 734 668 4663
www.k-space.com

LayTec GmbH
Helmholtzstr. 13-14,
Berlin, 10587
Germany
Tel: +49 30 39 800 80 0
Fax: +49 30 3180 8237
www.laytec.de

11 Inspection equipment

Bruker AXS GmbH
Oestliche Rheinbrueckenstrasse 49,
Karlsruhe, 76187,
Germany
Tel: +49 (0)721 595 2888
Fax: +49 (0)721 595 4587
www.bruker-axs.de

KLA-Tencor
160 Rio Robles, Suite 103D,
San Jose, CA 94538-7306,
USA
Tel: +1 408 875-3000
Fax: +1 510 456-2498
www.kla-tencor.com

12 Characterization equipment

Accent Optical Technologies
1320 SE Armour Drive Suite B-2,
Bend, OR 97702,
USA
Tel: +1 541 322 2500
Fax: +1 541 318 1966
www.accentopto.com

J.A. Woollam Co., Inc.
645 M Street Suite 102,
Lincoln, NE 68508
USA
Tel: +1 402 477 7501
Fax: +1 402 477 8214
www.jawoollam.com

Lake Shore Cryotronics Inc
575 McCorkle Boulevard,
Westerville, OH 43082,
USA
Tel: +1 614 891 2244
Fax: +1 614 818 1600
www.lakeshore.com

Shiva Technologies Inc
6707 Brooklawn Parkway,
Syracuse, NY 13211,
USA
Tel: +1 315 431 9900
Fax: +1 315 431 9800
www.shivatec.com

13 Chip test equipment

Keithley Instruments Inc
28775 Aurora Road,
Cleveland, OH 44139,
USA
Tel: +1 440.248.0400
Fax 001 440.248.6168
www.keithley.com

SUSS MicroTec Test Systems
228 Suss Drive,
Waterbury Center, VT 05677,
USA
Tel: +1 800 685 7877
Fax: +1 802 244 7853
www.suss.com

14 Assembly/packaging materials

ePAK International Inc
4926 Spicewood Springs Road,
Austin, TX 78759,
USA
Tel: +1 512 231 8083
Fax: +1 512 231 8183
www.epak.com

Gel-Pak
31398 Huntwood Avenue,
Hayward, CA 94544,
USA
Tel: +1 510 576 2220
Fax: +1 510 576 2282
www.gelpak.com

15 Assembly/packaging equipment

Ismeca Europe Semiconductor SA
Helvetie 283,
La Chaux-de-Fonds, 2301,
Switzerland
Tel: +41 329257111
Fax: +41 329257115
www.ismeca.com

J P Sercel Associates Inc
17 D Clinton Drive,
Hollis, NH 03049,
USA
Tel: +1 603 595 7048
Fax: +1 603 598-3835
www.jpsalaser.com

Palomar Technologies Inc
2728 Loker Avenue West,
Carlsbad,
CA 92010,
USA
Tel: +1 760 931 3600
Fax: +1 760 931 5191
www.PalomarTechnologies.com

16 Assembly/packaging foundry

Quik-Pak
10987 Via Frontera,
San Diego,
CA 92127,
USA
Tel: +1 858 674 4676
Fax: +1 8586 74 4681
www.quikicpak.com

17 Chip foundry

Compound Semiconductor Technologies Ltd
Block 7, Kelvin Campus,
West of Scotland,
Glasgow, Scotland G20 0TH
UK
Tel: +44 141 579 3000
Fax: +44 141 579 3040
www.compoundsemi.co.uk

United Monolithic Semiconductors
Route departementale 128,
BP46, Orsay, 91401,
France
Tel: +33 1 69 33 04 72
Fax: +33 169 33 02 92
www.ums-gaas.com

18 Facility equipment

MEI, LLC
3474 18th Avenue SE,
Albany, OR 97322-7014, USA
Tel: +1 541 917 3626
Fax: +1 541 917 3623
www.marlerenterprises.net

19 Facility consumables

W.L. Gore & Associates
401 Airport Rd,
Elkton, MD 21921-4236,
USA
Tel: +1 410 392 4440
Fax: +1 410 506 8749
www.gore.com

20 Computer hardware & software

Ansoft Corp
4 Station Square, Suite 200,
Pittsburgh, PA 15219,
USA
Tel: +1 412 261 3200
Fax: +1 412 471 9427
www.ansoft.com

21 Services

M+W Zander Holding AG
Lotterbergstrasse 30,
Stuttgart, Germany
Tel: +49 711 8804 1141
Fax: +49 711 8804 1950
www.mw-zander.com

22 Resources

SEMI Global Headquarters
3081 Zanker Road,
San Jose, CA 95134, USA
Tel: +1 408 943 6900
Fax: +1 408 428 9600
www.semi.org

event calendar

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N.B. For full listings, click www.semiconductor-today.com/event_calendar.htm

12–15 November 2006
Compound Semiconductor Week 2006 (including CSIC Symposium, Key Conference, and Reliability of Compound Semiconductors Workshop)
San Antonio, TX, USA
E-mail: harry.k@vipmeetings.com
www.csics.org/

16 November 2006
MM-Wave Products and Technologies
London, UK
E-mail: amani@theiet.org
www.iee.org/events/mmwave.cfm

27–29 November 2006
2006 LED Leadership Summit
Hotel del Coronado, San Diego, CA, USA
Deadline for registration: 30 October 2006
E-mail: imcdonald@macmeetings.com
www.ledleadershipsummit.com

27 November–1 December 2006
2006 MRS Fall Meeting
Boston, MA, USA
E-mail: info@mrs.org
www.mrs.org

5–7 December 2006
ILOPE-2006 (11th China International Lasers, Optoelectronics, Photonics and Display Exhibition) and China International Optoelectronics Industry Exposition
Beijing, China
E-mail: heyu@ciec.com.cn
www.coema.org.cn/E_ilope2006.html

6–8 December 2006
Semicon Japan 2006
Chiba, Japan
E-mail: jeventinfo@semi.org
www.semi.org

11–13 December 2006
International Electron Devices Meeting
San Francisco, CA, USA
E-mail:iedm@his.com
www.his.com/~iedm

18–20 December 2006
India–Japan Workshop (IJW-2006) on Zinc Oxide Materials and Devices
University of Delhi — South Campus, New Delhi, India
E-mail:shishodiapk@yahoo.com
www.ijw2006.com

20–25 January 2007
Photonics West
San Jose, CA, USA
E-mail:spie@spie.org
www.spie.org/app/conferences/index.cfm

31 January – 2 February 2007
Getting SSL to Market: 2007 DOE Solid-State Lighting Workshop
Phoenix, AZ, USA
www.netl.doe.gov

31 January – 2 February 2007
Semicon Korea 2007
Seoul, Korea
E-mail: sko@semi.org
www.semi.org

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12–14 February
Strategies in Light
San Jose, CA, USA
E-mail: rsteele@strategies-u.com
http://sil07.events.pennnet.com/fl/index.cfm

26–28 March 2007
LED Packaging 2007
Shanghai, People's Republic of China
E-mail: pkinzer@intertechusa.com
www.intertechusa.com/conferences

25–29 March 2007
OFC/NFOEC 2007 (Optical Fiber Communication Conference and Exposition and the National Fiber Optic Engineers Conference)
Anaheim, CA, USA
E-mail: registration@osa.org
www.ofcnfoec.org

2–5 April 2007
Microscopy of Semiconducting Materials: 15th International Conference
Cambridge, UK
E-mail: clare@rms.org.uk
www.rms.org.uk/event_semi-conducting.shtml

9–13 April 2007
MRS Spring Meeting
San Francisco, CA, USA
E-mail: info@mrs.org
www.mrs.org

12–17 April 2007
Physics of Light-Matter Coupling in Nano-Structures: 7th International Conference (PLMCN7)
Havana, Cuba
E-mail: plmcn7@sheffield.ac.uk
www.shef.ac.uk/physics/plmcn7

15–20 April 2007
LDSD 2007 (Sixth international Conference on Low Dimensional Structures and Devices)
Archipelago of San Andrés, Colombia
E-mail: Jasmine.Technology@ntlworld.com
www.fis.cinvestav.mx/ldsd2007

14–17 May 2007
CS MANTECH (2007 International Conference on Compound Semiconductor Manufacturing Technology)
Hilton Austin, TX, USA
E-mail: csmantech@csmantech.org
www.gaasmantech.org

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