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C O M P O U N D S & A D V A N C E D S I L I C O N

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under control**

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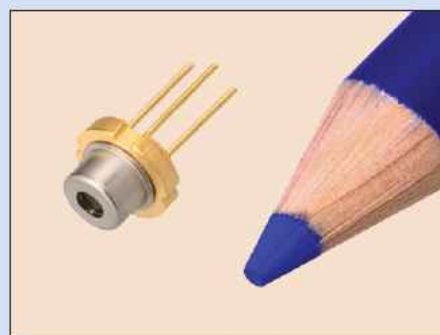
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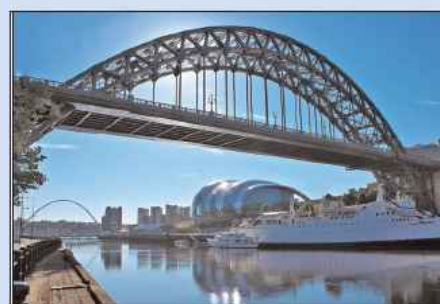
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p13 Crystal growth/wafer processing site of China Crystal Technologies, which was opened in October.



p21 Sharp's 406nm blue-violet laser, which has now entered production.



p36 The Sage center's shell-like roof, venue for ECSCRM 2006, reflecting both past and future technologies (Tyne Bridge and Gateshead Millennium Bridge).



Cover: Osram Opto Semiconductors' new OSTAR Projection LED chips (which have beam profiles tailored to injecting light into the optical engines of projection systems such as RPTV) feature in the project 'Compact LED Light Sources', which has won the Science Award from Germany's Stifterverband. **p24**

Market trends

This issue sees reports of a sixth consecutive quarter of revenue growth by major GaAs RFIC makers (RFMD's 40% being typical; see pages 6-7), driven by cell-phone sales approaching 1bn annually, and the rise in GaAs content per phone due to the trend to multi-band operation. In particular, increasing integration of functions in modules is raising product value; in November, RFMD shipped its 50 millionth Polaris Total Radio solution, which has grown nine consecutive quarters to 30% of RFMD's total revenues. RFMD is now also sampling a GPS solution for cell phones (p11).

Even greater growth and profit margins are shown by fabless GaAs RFIC suppliers such as Hittite (63%) due to their lower cost structure. This is encouraging some of the smaller GaAs RFIC makers like Mimix Broadband and, most recently, WJ Communications to go fabless, boosting foundries such as GCS and Taiwan's WIN Semiconductor and Advanced Wireless Semiconductor Co (which are expanding capacity greatly; p8).

The RFIC market is also reflected by AXT's GaAs wafer sales up 30% on Q2/2006 (in sharp contrast to InP sales down 45%), as well as the opening of another GaAs substrate plant in China in the form of CCT (p12-13).

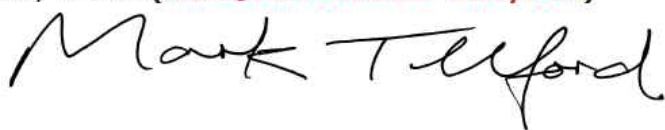
This mood was tempered at the CS Week event in San Antonio, Texas in early November by substrate and epiwafer suppliers reporting a slowdown in demand (see next issue for a full report). However, this is put down to an inventory correction among users that should ease by Q2/2007.

Meanwhile, MOCVD system maker Aixtron has raised its 2006 revenue guidance from €150m to €160m (with 81% of compound semiconductor-related revenues in Q1-Q3 coming from Asia, mainly LED makers; p15).

Although LED markets are booming, applications are constrained by substrate-limited cost-performance. This is causing interest in developments like BluGlass scaling its GaN-on-glass deposition from 2" to 4" substrates (p20) and Shimei's prototyping of blue GaN-on-Si LEDs (p24). The latter aims to develop full-colour (red-green-blue) light sources integrated on a common substrate, which is suited to the sort of display applications that Osram Opto is targeting with its OSTAR Projection LEDs. Likewise, Principia is making progress with RGB sources for rear-projection TV, but using a mix of III-V and II-VI epilayers (provided by Bandwidth Semiconductor), all on GaAs substrates, and VCSEL lasers rather than LEDs (p19). Meanwhile, Luminus is sampling a 1500lm LED chip-set for projection TV (p22).

But a big constraint remains the low yield of Nichia and Sony's GaN-based blue lasers, which has caused shortages of its Playstation 3 (launched in November, but not in Europe until next spring) and the indefinite postponement in July of its Blu-Ray Disc player's launch: bad news for people waiting expectantly hoping for Blu-Ray Disc players for Christmas to fill their TV screens. One bit of good news, however, is the advent of a third commercial supply for both Blu-Ray Disc and HD-DVD players: in November Sharp started to ship samples of its blue-violet laser, with a start-up capacity of 150,000 units per month and a cost of \$85 each (p21). Given the amount some people are prepared to pay for Playstation 3, maybe the market could bear a higher price, even for notoriously costly blue lasers!

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Regular issues contain:

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

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 **Thomas Swan**

 **EPIGRESS**

WiMAX to comprise 90% of new BWA subscribers in 2012

WiMAX is on track to compete for mainstream wireless markets, according to Research and Markets in its report 'WiMAX and Broadband Wireless (Sub-11GHz) Worldwide Market Analysis and Trends 2006-2012 — 4th Edition'.

"Nothing points out the immediate course into mass-market development more than the planned introduction of multimode WiMAX mobile plus cellular semiconductors and devices," said senior analyst and co-author Adlane Fellah.

Research and Markets says that service providers are examining fixed/mobile convergence to reverse the decline in average revenue per unit, and that WiMAX is becoming the obvious choice to extend service offerings.

The fixed/portable broadband wireless access (BWA) market (sub-11GHz) grew 18% from \$562m in 2004 to \$637m in 2005 (or \$755m including \$117m in point-to-point backhaul applications). In 2006, the WiMAX-certified equipment market will reach \$140m, 17% of the entire BWA industry. Furthermore, Research and Markets predicts 87m BWA subscribers by end-2012, 67m of which will be WiMAX subscribers. WiMAX will represent 90% of subscribers added in 2012, of

whom 75% will be using 802.16-2005 technology.

Outdoor WiMAX customer-premises equipment (CPE) will be phased out in 2008, with indoor CPEs representing the bulk of shipments. The cost of indoor CPE will fall to \$75 by 2008, boosting the proliferation of WiMAX.

Various countries do not allow TDD (time division duplexing) in the 3.5GHz band, leaving no choice but to deploy 802.16-2004 FDD (frequency division duplexing) equipment.

Key emerging countries Brazil, Russia, India and China (BRIC) will represent one third of the accumulated total number of BWA/WiMAX subscribers by 2012.

"While in most of Europe the 2.5-2.69GHz band is exclusively reserved for UMTS mobile services, the situation is evolving towards a technology-agnostic approach by regulators", said Fellah.

In 2006, the WiMAX-certified equipment market will reach \$140m, 17% of the entire broadband wireless access industry.

In China and India, the lack of spectrum allocated for WiMAX is of concern, and may impact WiMAX adoption if it is not resolved by 2008.

"The major criticism against mass-market acceptance of WiMAX has been the lack of spectrum," adds senior analyst and co-author Robert Syputa.

"Multimode does more than just open up spectrum: starting in 2008, WiMAX that combines seamlessly with cellular will open market access to hundreds of millions of existing wireless users. For operators positioned to leverage WiMAX, this is an economically viable and more immediate path to 4G than 3G-LTE for incumbent service providers who have access to mobile BWA spectrum."

Also, the essential intellectual property rights (patents) for WiMAX technology being held by different and non-dominant companies will provide WiMAX the opportunity to emerge as being a lower-cost technology.

The WiMAX equipment market is forecasted to reach \$6bn annually in 2012, and will have generated accumulated revenues of \$15bn by then, it is reckoned.

www.researchandmarkets.com

Global handset shipments reach 259m units in Q3/2006

Following year-on-year growth of 25% in Q1/2006 and 23% in Q2, handset shipments were 259m units in Q3, says Strategy Analytics in its report 'Vendor Share: Global Handset Market Update: Q3 2006'.

In Q3/2006, all the top six brands saw their average selling prices fall.

Sony Ericsson was the fastest-growing tier-1 brand and the most profitable, and it leapt to second position in 3G. Nokia passed a 40% share of the GSM market for the first time in almost two years. Motorola hung on to second position in CDMA.

Of second-tier players, Sanyo and Kyocera outperformed the market, adds Strategy Analytics.

For full-year 2006, Strategy Analytics still forecasts a total of 1bn handset shipments, up 22% on 2005's 817m.

www.strategyanalytics.net

WiMAX to grow fast despite challenges

Telecom providers have introduced data-usage broadband wireless access (BWA) technologies to tap into the wireless trend, accelerate wide market diffusion, and to provide consumers with an alternative or complementary value proposition. However, a lack of standardization and interoperability issues have not augured well in adoption rates for most proprietary BWA technologies. For example, Wi-Fi proved not to be a successful business model. Although much attention and interest in the past year has been given to WiMAX (an evolution of BWA), regulatory uncertainty and spectrum availability have continued to hamper WiMAX's growth.

But, in the report 'WiMAX: 2006 State of the Market', market research firm In-Stat says that, as service providers can now buy WiMAX Forum-certified equipment, WiMAX technology has finally moved out of the trial phase and into actual deployments, and is entering a rapid growth phase. Worldwide subscribers are forecast to reach 222,000 in 2006 and to grow to 19.7m by the end of 2010. Most subscribers are in the Asia/Pacific region. With the exception of those in South Korea, almost all are using a fixed service (the 802.16d standard for fixed WiMAX, rather than 802.16e for mobile WiMAX).

"While WiMAX faces many challenges, the biggest challenge still comes from competing technologies and services," says In-Stat analyst Daryl Schoolar. "WiMAX will have difficulty competing in areas that already have established broadband services. WiMAX will need to provide a demonstratively superior service to win customers from the incumbent provider," says Schoolar. With Sprint being the exception,

Schoolar does not believe most 3G carriers will deploy WiMAX in the near term. "Much of WiMAX's early success will come from under-developed regions of the globe."

In its report 'Cellular vs. Wireless Broadband in Asia/Pacific', In-Stat says that telecom providers have made significant efforts to compete with wireless 3G services with various BWA technologies in the Asia/Pacific market. However, for at least another five years, BWA in the form of WiMAX is unlikely to pose a big threat to 3G, as it will take longer to mature.

However, against a burgeoning mobile subscriber base in the

In-Stat expects sales in [fixed WiMAX] 802.16e equipment to quickly overtake those in [mobile WiMAX] 802.16d equipment.

Asia/Pacific region (859.4m; over 130m for 3G, including CDMA1X), robust growth in data-usage BWA technologies has entered the wireless

space. Though still largely lagging behind 3G adoption, WiMAX is now gathering momentum and is expected to reach 14m subscribers by 2011, says In-Stat.

● In mid-2006 the WiMAX market was waiting for certification of equipment based on the 802.16e standard for mobile WiMAX (rather than 802.16d for fixed WiMAX). However, equipment certified for 802.16e will start coming onto the market in 2007 (with larger carrier deployments expected), giving WiMAX added momentum. Indeed, In-Stat expects sales in 802.16e equipment to quickly overtake those in 802.16d equipment.

www.in-stat.com

IN BRIEF

RFMD 7th largest in RF and baseband application-specifics

In its report 'Market Share: Application-Specific Semiconductors for Mobile and Cordless Phones, Worldwide, 2005' Gartner lists RF Micro Devices Inc of Greensboro, NC, USA as the seventh largest supplier of subscriber RF and baseband application-specific devices, based on revenue (up two places on its previous ranking a year ago).

Also, RFMD stayed number one in power amplifier modules (with a market share more than twice its next largest competitor), as well as number two in RF application-specific devices worldwide.

The findings "validate our ongoing market share gains and continued growth in excess of the rate of growth of our end markets," said Eric Creviston, who is corporate VP of the Cellular Products Group.

"We continue to gain market share in GSM/EDGE cellular transceivers, and we anticipate sequential revenue growth in transceivers in the current quarter, as well as year-on-year revenue growth in transceivers in calendar 2007," he adds. "We have quickly become the world's leading supplier of transmit modules, and we expect transmit modules will continue to represent a growing percentage of our industry-leading PA product portfolio," he claims.

"Finally, RFMD is the world's leading supplier of wireless local area network (WLAN) power amplifiers for handsets, and we expect this high-growth segment of the wireless market will contribute increasingly to revenue as WLAN adoption in handsets grows more than six-fold by 2010," he adds.

www.gartner.com

Cell phones drive sixth quarter of growth by GaAs RFIC makers

For third-quarter 2006, many of the leading GaAs RFIC makers have reported a sixth consecutive quarter of growth in revenues.

RFMD on target for \$1bn in 2006

RF Micro Devices Inc of Greensboro, NC, USA has reported its sixth consecutive quarterly rise in revenue, up 3.6% sequentially and 39.5% year-on-year to a record \$246.9m.

Excluding a \$33.9m impairment charge related to selling its depreciated investment in Si/SiGe foundry Jazz Semiconductor (a joint venture with Skyworks Solutions acquired in late September by Acquiror Technology — see Issue 4, page 6), operating income more than doubled year-on-year, from \$5.5m to \$13m. This reflects RFMD's strength at leading handset makers, market share gains in RFICs, and record demand for its cellular transceivers and transmit modules, the firm says.

"The cellular market remains strong, and RFMD continues to benefit from strategic R&D and manu-

facturing investments made to capture growth," says president and CEO Bob Bruggeworth. "Polaris Total Radio solution product revenue continues to set records

[rising for the ninth consecutive quarter, up 13% sequentially to 30% of total revenue], and we are very well represented in future-generation handsets with leading OEMs," he adds.

Gross margin rose from 33.4% the previous quarter to 34.9%, exceeding guidance provided in July. "This is a direct result of investments RFMD has made to lower its manufacturing costs, including in-sourced assembly in our Beijing facility, in-sourced GaAs pHEMT production [at its Greensboro fab] and ongoing yield improvement initiatives," adds Dean Priddy, chief financial officer and VP of finance and administration.

In mid-November RFMD said that it has shipped its 50 millionth Polaris RF solution

For the December quarter, RFMD expects continued cellular product market share gains, driven by sales of GSM/GPRS and GSM/EDGE cellular transceivers, power amplifier modules and transmit modules. RFMD expects revenue to grow 7–13% sequentially and 27–35% year-on-year to \$264–280m (on course to reach its target of \$1bn revenue for the fiscal year). It also expects profitability to improve.

● At its second annual Analysts' Day event in New York in mid-November, RFMD said that it has shipped its 50 millionth Polaris RF solution.

RFMD said it anticipates that new product cycles in each of its three business units — Cellular, Wireless Connectivity and Infrastructure — will contribute to revenue and earnings growth in 2007, with recently introduced products targeting new growth markets in GPS, WLAN, WiMAX, and complementary analog and RF high-power base-stations contributing significantly.

www.rfmd.com

RFMD's third-quarter 2006 results by product sector

● Cellular sector:

"RFMD is enjoying increased dollar content in cellular handsets as we deliver more functionality and value," says CEO Bob Bruggeworth. "We expect this trend to strengthen as the industry consolidates and as leading customers increase their reliance on those suppliers capable of delivering increased levels of value and integration," he adds. "We continue to extend our market leadership in cellular transmit modules [which represented more than 50% of total power amplifier revenue in Q3/2006]," claims Bruggeworth.

Also, RFMD says it continues to progress toward production readi-

ness of its next-generation Polaris 3 solution, as additional transceiver design wins have been secured in future cellular handsets.

RFMD expects sales for Polaris (used in high-end, feature-rich cell phones) to continue to grow sequentially in the December quarter, based on current design activity, as new customers and new platforms are added, and to achieve year-on-year growth in 2007.

● **Wireless Connectivity sector:** RFMD also experienced strong design momentum for WLAN front-end modules and power amplifiers at the world's top-five handset makers and across multiple non-

handset applications, including access points, mobile computing and consumer electronics. Also, the SiW3500 Bluetooth radio processor was qualified on the reference designs of two Asia-based baseband manufacturers. In addition, RFMD released its software-based RF8110 GPS solution, for which it expects production shipments in first-half 2007.

● Infrastructure sector:

RFMD sampled 60W, 90W and 120W GaN WCDMA high-power amplifiers (HPAs) to leading base-station customers. RFMD also sampled 6–12W GaN power ICs for WiMAX, Public Mobile Radio and other wideband applications.

TriQuint handset revenues grow 57%, driving increased profits

For TriQuint Semiconductor Inc of Hillsboro, OR, USA, Q3/2006 was its sixth consecutive quarter of revenue growth, up 37% year-on-year to \$103.3m. Handset revenue grew 57% and CDMA transmit modules ramped from nearly zero revenue in Q2/2006 to over \$2m.

"We set new revenue records in Q3 for both our transmit modules and our power amplifier modules as TriQuint continues to gain share with major handset manufacturers," said president and CEO Ralph Quinsey.

"Orders for 3G products were up 168% in Q3 over Q2. The broadband and base-station products generated higher-than-expected revenues in the quarter, offset by lower revenues from our foundry products."

Operating income rose from \$0.35m a year ago and \$3.9m last quarter to \$7.2m (the best since Q1/2001). For the first nine months of 2006 it was \$12.35m, compared to a loss of \$13.1m last year. Net income was \$8.1m for Q3, up from \$2.6m a year ago. Excluding equity compensation expense, gross margin rose from 31.4% a year ago to 32.5%, mainly due to capacity utilization improvements.

Bookings in Q3 were over \$100m: stronger for military products but weaker for broadband and base-station products compared to Q2. Nevertheless, for Q4 TriQuint expects revenues to rise to \$108-112m.

www.triquint.com

Skyworks operating profits rise, excluding baseband shutdown

In Q3/2006, Skyworks Solutions Inc of Woburn, MA, USA reported revenue of \$198.2m (within its guidance of \$197-200m).

Revenue in its core analog and RF business was \$194m, up 4% sequentially and 18% year-on-year. Shipments of WCDMA power amplifiers more than doubled sequentially. Shipments of Helios transceivers were over 5m, up from 2m last quarter and 100,000 a year ago.

On a pro forma basis, operating income was \$11.6m, up 15%

sequentially and 31% year-on-year, while net income was \$10.4m.

However, including \$3.9m of equity-based compensation expense plus \$90m of asset impairments, severance and shut-down costs related to October's exit of the baseband product sector (see last issue, page 7) gives an operating loss of \$83.2m. Including a \$12m non-cash charge, net loss was \$96.4m. Nevertheless, cash reserves rose by \$17m to \$171.2m.

"Post-restructuring, we plan to deliver above-market growth driven by our portfolio of differentiated linear products, leadership front-end modules and highly integrated Helios radios," says David J. Aldrich, president and CEO. "We intend to demonstrate our financial leverage through gross margin expansion, increased asset turns and significant cash flow generation."

Next quarter, Skyworks aims to raise gross margin to 38.5% and double pro forma operating income.

www.skyworksinc.com

Anadigics makes pro forma profit on sales up 53.2% year-on-year

For Q3/2006, Anadigics Inc of Warren, NJ, USA reported its sixth consecutive quarter of sales, up 53.2% on a year ago and 11.5% on last quarter to \$44.8m.

Net loss was cut from \$6.8m a year ago and \$2.8m last quarter to \$1.3m. Pro forma net income, excluding non-cash stock compensation expense, was \$0.9m, compared to a loss of \$6.2m a year ago. Cash reserves rose from \$128.9m to \$130.5m.

"Our strong product portfolio in both the wireless and broadband growth markets, including 3G mobile phones, Wi-Fi, and tuner ICs and our tier 1 relationships continue to drive revenue growth and momentum in operating leverage," said president and CEO Dr Bami Bastani.

Sales for Q4/2006 are expected to rise sequentially for a seventh consecutive quarter by 4-7% and by 40-44% year-on-year.

www.anadigics.com

IN BRIEF

RFMD ramps Polaris 2 for EDGE handset...

One of RF Micro Devices' existing Polaris customers has started production of a new high-volume EDGE handset enabled by RFMD's Polaris 2 Radio Module for EDGE solution.

"It enables full quad-band EDGE in cellular handsets and is instrumental in helping mobile device makers meet the size, cost and performance requirements of next-generation EDGE-enabled handsets," says Eric Creviston, corporate VP, Cellular Product Group.

...shipping to China's Amoi for GSM/GPRS/EDGE handsets

RFMD has started volume production shipments of its Polaris 2 Radio Module for EDGE for several GSM/GPRS/EDGE handset models across the portfolio of China's Amoi Electronics Company Ltd. These include devices running Windows Mobile software that target the growing market for smartphones.

"These designs were won as a result of our ongoing collaboration with a leading top-tier baseband manufacturer," said Eric Creviston, Corporate VP, Cellular Products Group.

● Bob Bruggeworth, president and CEO, rang The NASDAQ Stock Market Closing Bell on 17 November. RFMD began trading on NASDAQ in 1997. This July it was named to The NASDAQ Global Select Market, the premier listing tier within The NASDAQ Stock Market for companies that satisfy the highest financial and liquidity qualifications.

www.rfmd.com

GaAs foundries benefit from growth in fabless RFIC firms

Although GaAs RFIC makers are showing sustained revenue growth (39.5% for RFMD, 37% for Skyworks, 53.2% for Anadigics year-on-year — page 6–7), fabless GaAs RFIC makers are showing greater growth and larger profit margins, thanks to their lower cost structure. This is encouraging some of the smaller GaAs RFIC makers to go fabless, and boosting the foundry sector.

Hittite grows revenue 63.5% and doubles profit year-on-year

In its 'GaAs Device Vendor Market Share 2005' report, Strategy Analytics says that Hittite Microwave Corp of Chelmsford, MA, USA, a fabless maker of RF, microwave and millimeter-wave GaAs, SiGe and silicon-based ICs and modules, rose into the top-10 in 2005 (see August issue, page 9).

In Q3/2006 Hittite's revenues were \$34.6m (up 7% on Q2 and 63.5% on a year ago). Non-US sales rose from 57% in Q2 to 60%.

Gross margin rose further, from 69.5% a year ago to 73.5%. Net income was \$11.6m (exceeding the forecast \$10.2–10.6m, and up 32.2% sequentially and 113.6% on a year ago). Cash reserves rose from \$90m to \$105.7m.

"Favorable market conditions and product mix allowed us to deliver strong results," said chairman and CEO Stephen Daly. "Our engineering team remains focused on developing innovative new products for our diverse customer base," he adds. "During the quarter we launched 20 new products, including a novel family of integrated receiver ICs which operate between 7 and 16GHz. These products will support a wide range of applications, including the large back-haul radio link market."

For Q4/2006 Hittite expects revenue of \$34–35m and net income of \$10.4–10.8m.

Mimix sheds GaAs fab to USTI

In April, Mimix Broadband Inc of Houston, TX, USA, which supplies microwave and millimeter-wave GaAs ICs, went fabless when it sold the former Celeritek Inc GaAs MES-FET, pHEMT and HBT fab in Santa Clara, CA (acquired in June 2005 for \$8.5m) to Universal Semiconductor Technology Inc, a thin-film silicon and ceramic circuit component and substrate foundry.

"USTI's financial resources, experience and expertise position them to be a successful partner and supplier for the long term," said CEO Rick Montgomery. "USTI will have the opportunity to manufacture GaAs semiconductors, using proven and industry-leading processes, and the foundry will serve as a platform to develop new, cutting-edge processes," said USTI chairman Bao Hua Zheng.

Mimix's products cover wireless infrastructure, satellite communications, and defense applications, including recently launched 0.15µm-gate-length pHEMT MMICs for point-to-point radio, LMDS, and VSAT.

WJ grows 57%, but going fabless after GCS ramp to cut losses

In March WJ Communications Inc of San Jose, CA, USA, which makes RFICs for wireless infrastructure, agreed for pure-play III-V wafer foundry Global Communication Semiconductors Inc of Torrance, CA to act as a second source of GaAs and InGaP HBT wafers. Initial production wafer runs began in July.

Then, at the beginning of November, announced president and CEO Bruce Diamond, "As a result of our successful qualification and production ramp, we have solidified a restructuring plan, resulting in the planned closure of our wafer manufacturing facility during the first quarter of 2007", making GCS the

sole source. WJ plans to produce extra wafer inventory to be used as a buffer in the event of delayed qualifications from customers or ramp-up issues with GCS.

WJ's 4" GaAs fab in Milpitas, CA comes from its June 2004 acquisition of EiC Corp's wireless infrastructure business, but it had 'substantial excess capacity'. WJ expects restructuring costs of \$1.5m in Q4 to be substantially offset by a gain on the sale of equipment in first-half 2007, adding to future cost savings of \$1–1.25m per quarter (\$4–5m annually).

For Q3/2006 WJ reported revenue of \$12.7m (up 2% on Q2 and 57% on a year ago) and its highest gross margin in two years (55.7%). Net loss was cut from \$3.4m a year ago and \$1.5m in Q2 to \$1.2m (which included \$743,000 of stock compensation expenses). So profitability is feasible after WJ closes its fab.

"Our business continues to benefit from the growth in the 3G wireless infrastructure, strong distribution channels and consistent demand from our OEM business," Diamond said in August. After launching 13 new products in first-half 2006 (exceeding its goal of 10), in early November WJ launched three RF power amplifiers in the new AP60x family (which uses the industry's first 28V InGaP HBTs process technology), targeting 3G base-stations.

GaAs foundries expand

Expecting continued growth in demand for handsets over the next five years, in June Taiwanese GaAs foundry T said it aimed to triple capacity from 1100 to 3000 4" wafers per week by end-2007.

Rival WIN Semiconductors Corp of Tao Yuan, Taiwan is also expanding, from 2400 to 4000 wafers per month by end-2006, then to 7000 in 2007.

Wu-Jing Ho, VP-Technical Market-

Kopin revenues fall in transition to higher-margin products

Pending the completion of an independent review of past stock option grant practices (see panel below), for Q3/2006 HBT wafer supplier Kopin Corp of Taunton, MA, USA has reported preliminary revenue of \$15.6m. This is slightly higher than early October's revised guidance of \$14–15m, but still down on its previous guidance of \$19–20.5m and down 17% from \$18.9m in Q2 and 39% from \$25.4m a year ago.

This is due mainly to CyberDisplay revenue of just \$5.6m (down from \$6.8m in Q2 and \$14.6m a year ago, impacted by the need for further testing of the display module for the US Army's Thermal Weapon Sight II program).

III-V revenue of \$10.0m was slightly lower than expected (down from \$10.8m a year ago and \$12.1m in Q2), largely due to a customer's short-term inventory correction.

For the first nine months of 2006, Kopin's total revenues were \$53.3m (down 19% year-on-year); CyberDisplays \$18.3m (down 49%); III-Vs \$34.9m (up 20%).

Kopin's cash reserves are down from \$119.8m at year-end 2005 to \$108.7m at the end of Q3/2006.

"This year has marked a period of transition for Kopin as we introduce

new, higher-margin products, expand our global manufacturing capacity and broaden the reach of our technology to new end markets," says president and CEO John C.C. Fan. "Shorter product life cycles are fueling an ever-increasing level of design activity in both our III-V and CyberDisplay businesses. Our technology enhancements, product innovations and manufacturing capacity expansion are all steps designed to help Kopin achieve long-term growth."

"Discussions with our customers indicate that 2007 will be an exceptionally strong year for the handset market, not just in terms of the number of units sold but also the content per phone," Fan says. "We also expect momentum in our HBT business will be driven by growth in WiFi and WiMAX networking equipment."

"Trends in the wireless sector continue to be favorable, and we

have been working hard to increase capacity," Fan continues. "KTC, our OEM HBT manufacturing facility in Taiwan, is now qualified for production of certain products for our largest customer. The ramp of KTC and the addition of three new large HBT production machines at our wafer fabrication facility in Massachusetts will allow us to increase our III-V capacity by 50% in the next 12 months."

"Through a combination of technology improvements, new product introductions and capacity expansion, Kopin is positioning itself for growth in what we expect to be a strong year ahead," concludes Fan. "We continue to execute on various elements of our long-term strategy by transitioning into higher-margin and higher-growth applications — particularly in the military and mobile video markets."

For Q4/2006, Kopin expects revenue to recover to \$17.5–19.0m.

www.kopin.com

Momentum in our HBT business will be driven by growth in WiFi and WiMAX networking equipment

2007 will be an exceptionally strong year for the handset market, not just in terms of the number of units sold but also the content per phone

Kopin appeals to NASDAQ while reviewing stock option practices

During Q3/2006, Kopin repurchased about 550,000 shares of its common stock, bringing the total to \$13.7m of the \$15m authorized at the inception of the stock buyback program.

However, on 1 November the program was suspended until after a review of its past stock option practices by a special committee appointed by the board (assisted by independent legal counsel and

accounting experts). This follows a derivative lawsuit (related to certain stock option grants issued during 1996–2001) that was filed in Massachusetts against certain Kopin directors and officers. The company has been named as a nominal defendant.

Because Kopin did not file its quarterly report on Form 10-Q by the 10 November deadline, on 15 November it received a

NASDAQ Staff Determination letter indicating that it is not in compliance with NASDAQ Marketplace Rule 4310(c)(14).

Kopin's common stock is subject to delisting from The NASDAQ Global Market. Accordingly, on 21 November Kopin requested a hearing before the NASDAQ Qualifications Panel to review the determination and to request continued listing.

IN BRIEF

RFMD elects CEO of eSilicon to board

RF Micro Devices Inc of Greensboro, NC, USA has elected Jack Harding, the co-founder, chairman, president and CEO of eSilicon Corp, to its board of directors. This expands RFMD's board to nine members (of which seven are independent directors).

Harding brings "years of extensive industry experience in custom chip design and manufacturing," says RFMD's chairman Al Paladino. "RFMD's growth and rapid expansion underscore the increased importance of custom chip design and manufacturing in mobile communications," adds Harding.

Venture-capital-backed company eSilicon designs and manufactures custom chips, has attained annual revenues approaching \$100m, and has 105 staff. It was ranked third in 2005's Inc. 500 List as one of the fastest growing private companies in the USA.

Harding was previously president and CEO of publicly traded electronic automation software supplier Cadence Design Systems Inc, which acquired his former company, Cooper & Chyan Technology Inc. Harding has also held senior management positions at Zycad Corp, and has worked at TXL and IBM Corp.

www.rfmd.com

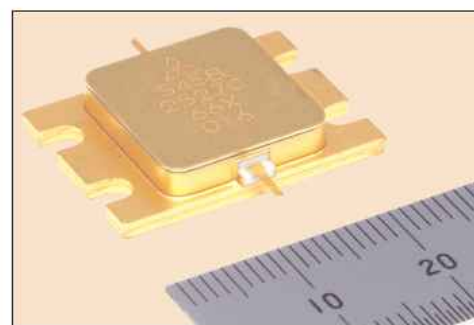


eSilicon Corp's co-founder, chairman, president and CEO Jack Harding, elected to RFMD's board of directors.

Mitsubishi launches GaAs FETs for WiMAX base transceiver stations

Mitsubishi Electric has until now produced high-power devices for pre-WiMAX base transceiver stations of proprietary systems for the American and European markets. With IEEE establishing a global standard system specification, Mitsubishi Electric Corp of Tokyo, Japan has developed three internally impedance matched 12V high-output-power GaAs FETs for 2.5 and 3.5GHz band WiMAX base transceiver stations, and will begin shipping samples in late December, with a capacity of 5000 units/month.

Models MGFS45B2325C and MGFS45B2527C (for the 2.3–2.5 and 2.5–2.7GHz bands, respectively) offer 30W of output power, and a linear power gain of 12dB. Model MGFC47B3436C (for the 3.4–3.6GHz band) offers 50W and 10dB. By developing an internally impedance matched circuit that reduces distortion and using a FET chip optimized for each frequency



The MGFS45B2527C for 2.5–2.7GHz WiMAX base transceiver stations.

band, the adjacent channel leakage power (ACP) has been reduced by five-sixths to –45dBc at a low quiescent current of 0.9A (the "best performance in the industry", claims Mitsubishi), reducing energy consumption by six-sevenths compared to its previous models with equivalent output power (pre-WiMAX base transceiver MGFC45A3339).

Mitsubishi plans to develop 5GHz band devices by December 2007.

www.mitsubishichips.com

Microsemi's PA for WLAN & WiMAX

Microsemi Corp of Irvine, CA, USA is sampling its next-generation LX5530 4.5–6.0GHz power amplifier, a three-stage InGaP HBT-based MMIC, for existing 802.11a/n WLAN and emerging high-band 802.16d/e WiMAX applications.

Target applications include access point WLAN hardware, extended-range routers/bridges, video distribution/entertainment systems, and mesh networks. The LX5530 is suited to use in 802.11a and 802.16 wireless PBX, point-to-point/point-to-multipoint access and infrastructure amplifier driver stages.

"It delivers best-of-class performance in a space-saving package that includes an integrated power detection function to save board space and reduce system costs," says Paul Bibeau Sr, general manager of Microsemi's Integrated Products Group.



The InGaP HBT-based LX5530 PA for WLAN and WiMAX applications.

The LX5530 operates from a 3–5V single-polarity power supply and features active bias and on-chip RF decoupling. At 4V supply, power gain is up to 33dB and linear output power is 20dBm. At 5V, it delivers up to 23dBm. Error vector magnitude (EVM) is a low 3% across the entire 4.9–6.0GHz frequency range.

www.microsemi.com

GaAs Bluetooth PA extends range and battery life for EDR

According to Strategy Analytics, the Bluetooth device market is growing at a compound annual rate of 24% in 2006, to 420m units shipped (mainly for low-data-rate, short-range applications). But at November's Electronica 2006 in Munich, Germany, TriQuint Semiconductor of Hillsboro, OR, USA launched its first GaAs power amplifier for the silicon-dominated 2.4–2.5GHz Bluetooth market, designed for enhanced data rate (EDR) v2.0 Class 1 operation (2 and 3Mbps) over long range (up to 100m), which is "ideal for handsets and use in non-handset devices, which make up approximately 45% of the projected market," says product marketing manager Berry Leonard. Longer-range Class 1 designs are increasingly being targeted by manufacturers of Bluetooth-enabled products, he adds.



TQP770001 InGaP HBT power amp.

The TQP770001 enables the high linearity required for these modulation modes and data rates, while offering high power added efficiency of 50% (at 21.5dBm output) and low power consumption, giving longer mobile device battery life compared to silicon, claims TriQuint.

InGaP HBT process technology also allows higher integration and smaller device size (in a 2x2mm

QFN package) compared to silicon, simplifying circuit board design and lowering the external parts count.

The TQP770001 is a two-stage design with an integrated bias controller, which allows accurate device gain temperature compensation, power control (variable gain), as well as low current standby power control. All functionality is internal to the package. Under EDR operation, its low AM-AM and AM-PM distortion guarantee high modulation accuracy. The TQP770001 can operate under a variety of Bluetooth modulation types, including FSK, 8DPSK, and Pi/4-DQPSK formats. Upgrading to Class 1 from existing lower-specification Class 2/3 Bluetooth designs can be as simple as adding the TQP770001, a single-pole double-throw switch and a bandpass filter.

www.triquint.com

RFMD launches its first scalable GPS solution and collaborates on CMOS Bluetooth IC for baseband design

RFMD is sampling the RF8110 scalable GPS solution, a software/host-based GPS solution that combines an RFIC and software to deliver GPS technology to next-generation mobile phones and personal multimedia and navigation devices.

The RF8110 is the first in RFMD's line of scalable GPS solutions. It allows handset makers to use their internally developed GPS functions, such as navigation and mapping, to accommodate multiple navigation architectures. "The RF8110's adaptable software-based architecture allows customers to easily add features, upgrade or customize their product," says Dave Lyon, vice president of Wireless Connectivity.

RFMD expects production shipments of the RF8110 to start in March 2007.

● Also, RFMD is collaborating with MediaTek Inc, a supplier of consumer and communications IC solutions, to create Bluetooth-enabled EDGE and GPRS mobile phone reference designs with RFMD's SiW3500, a highly integrated system-on-chip Bluetooth solution that combines a direct conversion radio modem with an ARM7TDMI processor core, Bluetooth baseband logic and complete protocol software in ROM. All active RF components are integrated into the CMOS-based IC, making it a complete low-cost solution with a very small footprint, says RFMD.

"Our collaboration proves Bluetooth technology is increasingly a mainstream application across most categories of mobile phones," Lyon adds.

www.rfmd.com



At a ceremony in Xiamen, director of China Assembly Operations, Pat Pare, accepted RFMD's second consecutive annual 'Best Supplier Award' from Lenovo Mobile, China's biggest local handset brand and its fourth largest overall. RFMD is its primary PA supplier and is pursuing opportunities to supply complementary RF technologies, including Polaris Total Radio RF solutions, GPS and Bluetooth components.

AXT's GaAs revenues grow 30%

Substrate maker AXT has reported Q3/2006 sales of \$12.5m, up 21% on Q2 and 104% on a year ago.

Asia-Pacific revenues climbed from 52% to 60%, while Europe fell from 22% to 16% and North America fell from 26% to 24%. AXT is headquartered in Fremont, CA, USA but has manufacturing plants plus five raw materials joint ventures in China.

GaAs sales were \$10.6m, up 30% on Q2, driven by rising demand for 4" and 6" semi-insulating substrates, mainly for HBT and pHEMT devices in wireless handsets. "We have several significant customer qualifications going on for both semi-insulating and semiconducting substrates with tier 1 companies," says CEO Phil Yin. "The invitations by these customers to re-qualify our substrates indicate that our industry is recognizing the improvements that we have made [over the past 18 months]." AXT has shipped wafers to these customers for qualification and hopes to move into volume production with them in early 2007.

Germanium sales were \$387,000, up 129%. "While our revenue in this area is comparatively small, it has experienced significant growth over the past several quarters. AXT

now has shipped qualification samples to customers all over the world and is in volume production with two customers in Asia," says Yin.

"The greater efficiencies of triple-junction concentrator solar cells, coupled with the shortage of polysilicon, are causing Ge substrates to become the material of choice for photovoltaic applications."

However, raw materials revenue was \$1.3m, down slightly on \$1.4m the prior quarter, and InP substrate revenue was \$340,000, down 45% from Q2's \$613,000.

Operating expenses have risen from \$3.4m a year ago then \$4.4m in Q2 to \$4.5m, but this was due mainly to a \$1.4m impairment charge to write down US property (which has been decommissioned and prepared for sale). Operating loss has been cut from \$2.2m a year ago and \$1.7m in Q2 to \$1m, mainly due to a rise in gross margin (from 26.6% to 27.7%).

A tax benefit of \$862,000 boosted net income to \$639,000, in contrast to a net loss of \$876,000 in Q2 and \$2.1m a year ago (excluding the discontinued optoelectronics division).

"There are several areas that can yield considerable growth," says Yin.

"Our core business can grow through capacity expansion in areas such as 6" and 4" semi-insulating substrates, where the industry is severely constrained, as well as through continued development of our customer base. Second, we believe that our raw materials business is increasingly becoming a key strategic differentiator, and thus we expect to increase our raw materials sales efforts and explore new investment opportunities. Finally, as device requirements become more demanding based on product innovations and applications, we will continue to explore businesses complementary to our core product line that we believe will allow us to serve the increasing demand for compound semiconductor substrates." AXT expects Q4 sales of \$12.9–13.6m.

● After tax changes in China, AXT's raw materials JVs will no longer receive a value-added tax refund for Ga or As exports, including shipments to AXT's China subsidiary that are treated as exports. But the JVs sell only part of their Ga in exports, and none currently export As, so consolidated financial results will not be materially affected, says AXT.

www.axt.com

Founder Young to retire as CTO, but remains on board

Twenty years after founding AXT, Dr Morris S Young, chief technology officer since 2005, has decided to retire at the end of this year at the age of 61. However, he will continue to serve on the board of directors. Young was CEO from 1989 to 2004 and chairman from 1998 to 2004.

"Young is a visionary technologist, a pioneer of the gallium arsenide industry and the person most responsible for the early growth and success of AXT," says chairman Jesse Chen.

Young pioneered vertical gradient freeze technology as the founda-



tion of AXT's business. VGF has been used for the production of

lower-defect substrates, and has become the technology of choice for the GaAs industry, AXT claims. "The growth and core foundation of the company is the direct result of his hard work and technical abilities," adds CEO Phil Yin.

"We are pleased that Dr Young will continue to consult with AXT on matters as needed," adds Chen. "I believe the company has a very bright future," says Young. "With its core technology, strategic investments in joint ventures, and new management team, I believe AXT is positioned for continued strong growth."

China wafer making coalesces

China Crystal Technologies Corp, which is based in Beijing Economic & Technological Development Area (BDA), held an official opening of its high-volume GaAs substrate production line in October.

CCT was formed with invested capital of over \$20m by the merger of volume GaAs VGF crystal grower American-West Semiconductor Materials Co with the volume wafer processing (and LEC crystal growing) part of Compound Crystal Technology Co Ltd, which was founded in 2001 by the Institute of Semiconductors of the Chinese Academy of Sciences and four companies (including China Energy Conservation Investment Corp). American-West Semiconductor Materials Co was founded in March 2005 by private investors from China, Hong Kong and the US. Its two-storey Phase I production facility, completed in April, has



Chairman Zhang Jie at CCT's opening.

6000m² of manufacturing space, but can add a further floor for future production expansion needs. Most wafer processing is done in another facility, originally belonging to Compound Crystal Technology.

CCT claims fully integrated operation, making it "the first Chinese company with the scale and capability to offer competitive compound semiconductor crystal products".



Crystal growth/wafer processing site.

With both LEC and (mainly) VGF growth capabilities, CCT's monthly capacity is about 50,000 2" and 3" and 5000 4" and 6" GaAs substrates. The firm is working on an expansion roadmap so it can at least double its current production capacity by 2008, aiming to become "one of the major GaAs substrate producers worldwide". Materials such as Ge and InP are also on the roadmap.

www.awsmco.com

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IN BRIEF

Matheson boosts arsine capacity

Matheson Tri-Gas Inc of Parsippany, NJ, USA has announced a significant capacity expansion and production enhancement for its hydride plant in New Johnsonville, TN (the firm's flagship facility).

The two-phase plan, begun in 2005, has already added over 30% more production capacity for high-purity arsine. The final phase, for implementation in January, incorporates an extra purification step for arsine production that will enable continued advancement of critical impurity reduction for the III-V market.

"With the increased demand for hydrides, such as arsine, in the compound semiconductor market, and the apparent apathy of some of the traditional suppliers to continue to deliver these hydrides, Matheson Tri-Gas is proud to step up and commit capital," says Bill Kroll, chairman and CEO. "We want to be a bigger part of the success of compound semiconductors well into the future. We believe our commitment of financial and human capital demonstrates that we 'walk the talk'," adds Kroll.

www.mathesontrigas.com

GPT purifier for EpiLEDs

Johnson Matthey Gas Purification Technology (GPT) group of West Chester, PA, USA has supplied a GPT-20 hydrogen purifier, capable of flowing 15Nm³/hr, to EpiLED for its new fab in the Tainan Science-Based Industrial Park.

EpiLED is a joint venture formed in August by Taiwanese DRAM maker ProMOS Technologies and chip processing equipment maker Hermes-Epitex to manufacture blue LED chips. Pilot production is due to start in Q1/2007.

www.pureguard.net

Valved As effusion source for MBE

Oxford Instruments' ECellAs valved arsenic effusion source (cracker cell) for the MBE growth of As-containing III-V materials has a large crucible capacity, fast and precise flux control, and easy, modular handling for maintenance and crucible refill, suiting both production and high-throughput development systems, as well as research, via 1l, 3l and 8.5l versions.

An independent heater design prevents valve clogging (a frequent problem in valved cracker cells). The reservoir can be individually demounted from the cracker unit, minimizing system down-time and removing the need for complete cell replacement or factory service. A heated secondary filling port allows As recharge without needing to empty the crucible first.

"Excellent control over MBE growth processes has been demonstrated, with rapid, linear valve response, highly controllable As₄ to As₂ transition and fast, repeatable As flux modulation," says Tony Cornish, business manager for MBE and Ion Beam products.



ECellAs valved arsenic effusion source

The reservoir heater design allows mounting of the cell in any orientation. A motorized valve and growth software interface allows complete automated control.

Valved effusion sources offer benefits over the thermal control of conventional open sources for MBE: a needle valve provides optimized control over the growth process with precise, fast flux modulations and complete flux shut-off, allowing the source to be left continuously at operating temperature without depleting charge material. Whether using the 1l or 8.5l versions, As flux responsiveness remains constant.

www.oxford-instruments.com

Riber's sales up 27% for Q1-Q3/2006

MBE reactor maker Riber had sales of €11.8m in the first nine months of 2006 (up 27% on a year ago). This was boosted by the sale of three multi-6" production machines (two more than a year ago), four research machines and €3.2m in accessories and components.

Q3 sales were €4.5m. This compares with €7.3m in first-half 2006, which included two multi-6" production systems (one MBE6000 and one MBE7000) and one research machine (a Compact21).

Order backlog at the end of September was €11.2m (down 10% on €12.5m a year ago and down 17%

on €13.5m at the end of June). This includes seven research machines and two production machines.

Riber has lowered its guidance for full-year 2006 sales slightly from €19-22m to €19-21m. This compares with sales of €17.7m in 2005 and €13.5m in 2004.

● In Q3/2006 Riber moved to a new site in Bezons, not far from its original site in Rueil-Malmaison, France. The new custom-configured facilities allow more efficient flow between departments, an improved manufacturing process, and will accommodate a capacity increase.

www.riber.com

Aixtron raises 2006 revenue guidance

Deposition system maker Aixtron has reported revenues for the first nine months of 2006 of €108.6m (up 14% year-on-year).

This included €54m (49%) for compound semiconductors (down from 57% the prior year). Of this, 81% came from Asia (up from 72%), driven by LED makers.

Silicon comprised 31% of sales (up from 24% the prior year, due partly to acquiring ALD system maker Genus in March 2005).

Q3 revenues were €40.9m, up 15% on Q2 and 41% on a year ago.

Gross profit for the first nine months of 2006 was €41.5m (up 38% year-on-year). This included €16.2m in Q3. Gross margin was 38% (up from 31%), which is nearing Aixtron's targeted 40%. Net loss after tax was cut from €11.7m in the first nine months of 2005 to just €2.4m.

Equipment orders for the first nine months of 2006 were up 76% year-on-year: €101.9m for compound semiconductors (up by as much as

89%) and €31.6m for silicon (up 44%). This included €52.3m in Q3 (up 6% sequentially), the highest quarterly order intake for five years.

The results show "another quarter of improving profit, increased cash, growing order intake, reduced costs, better margins and stable market conditions...a reflection of a more consistent and focused internal performance across the Aixtron group," said president and CEO Paul Hyland. "Over the next three months...we expect to continue to make good progress with our own internal operational performance, and to make further progress towards extending both our technology and our market reach."

Since August, Aixtron has raised its full-year 2006 guidance for revenue from €150m to €160m, and for net income after tax from breakeven to €3m, mainly due to Asian LED makers. The 2007 performance should be much stronger, given the large number of orders.

www.aixtron.com

Veeco planning for successor to Braun as chief executive officer

The board of directors of Veeco Instruments Inc of Woodbury, NY, USA, which makes MOCVD and MBE reactors, have formed a succession planning committee to oversee the transition of Edward H. Braun, age 67, from his current role of chairman and CEO to that of chairman in 2007. Independent director Roger D. McDaniel will lead the committee in its search for a new CEO.

"Veeco, at \$440m in revenue, possesses multi-market, technology leadership in high-brightness-LED, data storage, semiconductor and scientific research applications,"

claims Braun. "The separation of CEO and chairman positions will help Veeco achieve its potential growth to be a \$1bn company." Rising demand for high-specification LED chips required for lighting applications, and next-generation reactors needed to make them, will be behind much of that increase, reckons Veeco.

www.veeco.com



**Veeco's chairman
Edward H. Braun.**

IN BRIEF

Epitech orders 12x4" reactors for AlGaInP HB-LEDs

Augmenting its earlier Aixtron reactors, for mass producing red, orange and yellow AlGaInP high-brightness LED epiwafers, Epitech Technology Corp of south Taiwan's Tainan Science-based Industrial Park has ordered three Aixtron AIX 2600G3 MOCVD epitaxial reactors, but this time in 12x4" multiwafer configuration.

This follows Epitech's acquisition in July of a Thomas Swan CRIUS 30x2" wafer MOCVD reactor for mass producing GaN LED epiwafers.

"Adding to the existing tools, of which most are currently being upgraded to the latest configuration, we now transition to the latest generation of MOCVD processes for optoelectronics," says president Semi Wang. The Planetary Reactor is the "foundation for our planned strategic expansion of volume production to meet growing customer demand," he adds.

Founded in May 2000, Epitech is an epiwafer and chip manufacturing foundry for the complete spectrum of ultrahigh-brightness LEDs, from AlGaInP red, orange and yellow-green to InGaIn blue, green and UV HB-LEDs, including power LEDs for white lighting applications. Shareholders include UMC of Hsinchu, Taiwan's second-largest silicon foundry. In late September, Epitech, as well as Highlink Technology, agreed to merge with LED maker Epistar (already the world's biggest manufacturer of AlGaInP-based red, yellow and orange LEDs), creating a Taiwanese LED chip maker able to compete with the global top five (Nichia, Cree, Philips Lumileds, Osram Opto Semiconductors, and Toyoda Gosei).

www.aixtron.com

Operating profit a quarter early

For fiscal 2006 (to end-September) process equipment maker Aviza Technology Inc of Scotts Valley, CA, USA reported net sales of \$160.9m, down 6% year-on-year. However, net loss was cut from \$16m to \$14.7m.

Also, for its fiscal Q4, revenues were \$52m (up 19% on the prior quarter and 60% on a year ago). This was partly due to conversion of the Celsior next-generation single-wafer ALD system from 'new' to 'proven' technology.

In contrast to the prior quarter's operating loss of \$2.6m, Aviza also achieved an operating profit (a quarter earlier than forecast) of \$752,000, despite stock-based compensation expense of \$383,000. Net loss was cut from \$4m to \$779,000 and gross margin rose from 24.6% to 33.1%. However, cash reserves have shrunk from \$17.9m to \$10.7m, mainly due to repayments under Aviza's revolving line of credit and its decision to increase inventory in response to customer forecasts.

In Q4 Aviza received multiple-system orders from Inotera Memories Inc for Celsior (following production release of a system at its Fab 1 earlier in 2006) and for RVP-300plus thermal processing systems for its Fab 2 expansion. Aviza also shipped RVP-300plus systems in a follow-on order from one of Singapore's leading 300mm foundries.

For fiscal Q1/2007 Aviza expects sales of \$55–60m as well as an operating profit, based on anticipated customer acceptances of certain etch modules and conversion of a new etch module from 'new' to 'proven' technology.

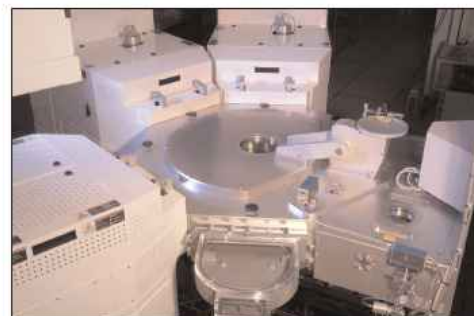
For full-year fiscal 2007 (to end-September), Aviza expects sales of \$220–240m, based on anticipated continued strength in the DRAM market and its anticipated product mix.

www.avizatechnology.com

BOC and Aviza to collaborate on ALD

BOC Edwards of Wilmington, MA, USA and Aviza Technology Inc of Scotts Valley, CA, USA have entered into a joint development agreement to develop atomic layer deposition technology. The collaboration will use BOC Edwards' expertise in chemical precursor formulation and Aviza's ALD hardware technology to optimize deposition processes for high-k materials and metals and evaluate BOC Edwards' new line of Flex-ALD precursors before their full commercial release. Flex-ALD refers to ALD precursor formulations designed to address cost, stability and process issues with known ALD precursors, together with an associated delivery system.

The precursors enable deposition of very pure thin films and extend the range of ALD-compatible compounds to include heavier elements not previously available, claims BOC Edwards. They can reduce the cost and improve the efficiency of ALD processes by increasing precursor utilization compared to traditional ALD precursors and methods. This provides stable and consistent delivery without decomposition or condensation, and



Aviza's Celsior ALD system.

increases growth rates for higher throughput, it is claimed.

"Strategic partnerships with established technology leaders in the semiconductor supply chain is an integral part of Aviza's advanced application activities," says Helmuth Treichel, VP, Advanced Applications. "This partnership with BOC Edwards will support our advanced ALD film development efforts to offer a diverse set of films for multiple IC applications."

Aviza offers both the Celsior single-wafer ALD system and the Verano 5500 batch ALD system (for up to 100 wafers) for DRAM, flash and logic device applications.

www.bocedwards.com

www.avizatechnology.com

STS' senior management changes

Plasma etch and deposition tool maker Surface Technology Systems plc (STS) of Newport, Wales, UK has announced a series of board and senior management changes.

Dr Robin Johnson has been appointed as board member and chief operating officer (COO). Johnson joined STS in July as interim COO to lead the manufacturing improvement process, with responsibility for all manufacturing operations at STS.

Company secretary Richard Rees has been promoted to deputy chief

financial officer. Rees joined STS in August 2005 as group financial controller.

Andrew Tucker, currently vice president of sales at ST Systems (USA) Inc, has been promoted to general manager of the US subsidiary. Tucker joined STS' US Sales team in 2000.

Customer support director Andrew Chambers will resign at the end of 2006 and leave STS in January to return to a career in technology development.

www.stsystems.com

Tegal's sales fall, but boosted by legal win and Japan distributor

For its fiscal second-quarter 2007 (to end-September) plasma etch and deposition system maker Tegal Corp of San Jose, CA, USA had sales of \$5.1m, down 22% sequentially and 20% year-on-year. Net loss is \$3.3m, up from \$1.8m the prior quarter and \$2.7m a year ago. Cash reserves shrank from \$12.6m to \$10.5m. However, gross margins rose from 38% to 47%. Shipments included several 900 and 980 series etch tools to the USA, Europe and, especially, Japan.

"Our gross margins exceeded our targeted goal of 40% as a result of both product mix and lower overhead rates associated with lower manufacturing costs," says president and CEO Thomas R. Mika.

"Excluding major litigation and lease termination expenses, we came much closer to being cash positive during the quarter," adds Mika. The Sputtered Films Inc subsidiary has settled its trade secrets case against Sergey Mishin, Advanced Modular Sputtering (AMS),

Agilent Technologies Inc, Avago Technologies US Inc, Avago Technologies Wireless (USA) Manufacturing Inc and other defendants. The terms involve a payment to Tegal of \$13m, the transfer of PVD-related assets from AMS to SFI and the dissolution of AMS in March. "The payment will more than double our cash on hand, significantly strengthening the company's balance sheet at exactly the right time," says Mika. "We are in the final stages of new product development with the compact etch platform and our Nano Layer Deposition (NLD) product, and we expect to be into beta sites with both tools within the next few months."

● Mika has been appointed to Tegal's board and elected chairman. He was previously on the board from 1992 until his appointment as executive VP and CFO in 2002. Ralph Martin and Brad Mattson, who was chairman, resigned from the board. Duane Wadsworth is now lead independent director.

● In October, Tegal signed an exclusive distributor agreement, initially for three years, for Noah Corp to take on sales and field service support in Japan. "It is a good time to enhance our sales coverage to better meet the strong opportunities in the Japanese market... where we have a long history of direct operations," said Mika. "Retention of our own field service engineers by Noah guarantees a high level of support and continuity to our existing customer base. This agreement is consistent with the strategy of enhancing our distribution throughout Asia," he adds. Noah's president and CEO, Hiroshi Tabira, adds that "Tegal's etch and PVD tools are well suited to the needs of Japanese device manufacturers, especially those which are focused on consumer electronics, cell phones and other wireless products."

"The signing on of Noah Corp in Japan both improves our sales coverage and lowers our cost to access this important market," says Mika.

www.tegal.com

Finland's VTT orders flip-chip die bonder from Laurier

Contract research organization VTT Technical Research Centre of Finland has ordered an M9 ultra-high precision flip-chip die bonder (including an optional ultrasonic bond head) from Laurier Inc of Londonderry, NH, USA, via its European distributor Datacon Technology of Radfeld, Austria (both part of packaging tool supplier BE Semiconductor Industries of The Netherlands). The highly flexible, small-footprint, semi-automatic bonder will be used for development projects in optoelectronic, RF and MEMS applications.

In its most basic configuration, the M9 performs cold compression, thermo-compression, adhesive cure and solder reflow, without the



Laurier Inc's M9 flip-chip die bonder.

need for hardware changes. It can be used to bond photonic devices, RF devices and MEMS devices on various substrates, such as low-temperature co-fired ceramics and polymer as well as silicon substrates.

Placement accuracy goes down to $\pm 0.5\mu\text{m}$, with automatic alignment, while providing bonding forces up to 50kg (M9A) or 200kg (M9G). Upper and lower heads and chucks are heatable up to 500°C, with ramping and cool-down feasible. Features include closed-loop feedback temperature and force maintenance routines.

www.vtt.fi
www.laurieinc.com

Sofradir building MBE fab for IR detector mass production

Sofradir of Veurey-Voroize, near Grenoble, France, has received permission to construct a new €9m (\$11.5m) factory that will allow it to increase its production area from 5500m² to 9000m² and to mass produce third-generation infrared detectors made from mercury cadmium telluride (HgCdTe, or MCT), starting in late 2007.

Sofradir will upgrade from 2" to 4" MCT wafers, at the same time becoming the first manufacturer in Europe to produce IR detectors using MBE and the only one worldwide to do so on an industrial scale, it claims. Part of the new facility will be devoted to enhancing customer support by providing demonstration rooms and additional testing facilities. "The new factory will give us more cost-efficient production that runs a secure, environmentally friendly process," says Yves-Henri Bourgeois, VP Facilities and Quality.

The decision to invest in the new plant follows five years of consecu-

tive growth, increased customer demand, and the industrialization of a new technological process, says Sofradir. The company, which was founded in 1986, claims it is ranked number two for deliveries of second- and third-generation MCT IR detectors worldwide (with 20–25% of the MCT second-generation detector market). Sofradir's scanning and staring array products cover the 1–16μm infrared spectrum using MCT, quantum well infrared photodetector (QWIP) or microbolometer technology platforms.

The products are used by defense and security equipment manufacturers in thermal imagers, missile seekers, satellites, and other surveillance, targeting and homing infrared equipment. Customers include the US Army, Thales, Sagem, Selex, Alcatel Alenia Space and the European Space Agency. More than 60% of Sofradir's products are exported. Its long- and mid-wave IR detectors have been

deployed in battlefield equipment, such as the Storm Shadow/SCALP EG IR missile seeker, Damocles targeting and NAVFLIR navigation pods, Sophie hand-held goggles, IRIS cameras and SADA II.

Together with its subsidiary Ulis (which specializes in uncooled IR detectors), the company generated revenues of \$90m in 2005. Sofradir and Ulis currently employ 350 staff. The company aims to maintain its current annual hiring rate of 20–30 staff for the next three years.

The investment comes as the market is looking for larger-format IR detectors, more complex features (such as bi-color, dual-band or laser imaging), and products that are more competitively priced, says Sofradir. "The new factory will bolster our product lines, satisfy customer demand through increased capacity, and better position us for longer-term growth," says CEO Philippe Bensussan.

www.sofradir.com

MCT FPAs for airborne hyperspectral imaging

At the end of October, Sofradir signed a €1m (\$1.26m) contract with a worldwide supplier of electro-optic space and defense systems to provide space-qualified, large-format, 30μm pixel pitch shortwave infrared detectors (SWIR) for hyperspectral application in airborne platforms.

The MCT focal plane array (FPA) to be supplied, Saturn SWIR, is one of the largest monolithic formats on the market (1000x256) and Sofradir is the only manufacturer to have a space-qualified FPA of this size available, off-the-shelf, the company claims. Saturn will play a key role in the initial testing phase of the customer's hyper-

spectral system on aircraft. The contract offers the potential for further collaboration on projects for space applications in the future, claims Sofradir.

Hyperspectral imagery is used to detect chemical and biological weapons, make bomb damage assessment of underground structures and penetrate foliage to detect troops and vehicles. Instruments provide images of an observed scene with a high number of spectral channels (typically more than 100) and with a high spectral resolution (typically 10–15nm) in the considered waveband.

Sofradir sees continuing growth of hyperspectral vision in satellites,

where various technologies are being tried.

The Saturn operates in the 0.8–3μm waveband window and has an operating temperature up to 200K.

The device is already being used in a number of space projects, including the European Space Agency's Airborne Prism Experiment (Apex) mission.



A Saturn IR detector mounted on a cryostat.

Photo: www.artechnique.fr

Bandwidth tripling epiwafer capacity for III-Vs and II-VIs

Epiwafer and device foundry Bandwidth Semiconductor LLC, a subsidiary of Spire Corp based in Bedford, MA, USA, has bought multiple TurboDisc E450 As/P MOCVD systems from Veeco Instruments, for installation in Q1/2007. The E450 is Veeco's largest-capacity reactor, and claims to offer the highest throughput in the industry.

The expansion will triple capacity, and is "critical as we scale up our existing MOCVD and related processing facilities to satisfy our customer requirements for VCSELs, LEDs and concentrator solar cells," says general manager Ed Gagnon.

In September, Bandwidth signed a five-year agreement to become the exclusive supplier of III-V and II-VI wafers to Principia Lightworks Inc of Woodland Hills, CA, USA, enabling it to enter high-volume production of its patented electron-beam-pumped vertical cavity surface emitting laser (eVCSEL). Principia's eVCSELs are used as a light source for projection display applications, including rear-projection television (RPTV). Bandwidth expects to start full production of

the wafers for Principia in mid-2007.

Although Bandwidth is committing capital resources to complete the scale-up, it anticipates that an up-front payment already made by Principia for non-recurring engineering and facility access costs, together with monthly payments to be made over the five years for facility availability, will be sufficient to meet the capital requirements, with no net outlay of capital by Bandwidth needed. Bandwidth expects the first three years of the agreement to yield revenues of over \$16m (including wafer production revenue and non-recurring engineering and facility access payments).

"We chose Bandwidth because of their broad range of MOCVD and compound semiconductor device experience," said Don Klein, Principia's executive VP of business development. "Once in production,



Veeco's TurboDisc E450 MOCVD system.

Principia will offer the projection display market the first truly high-powered, low-cost, red, green, and blue laser light source. The agreement with Bandwidth will allow us to meet the high volume demand from RPTV manufacturers."

Gagnon added: "We have invested heavily in bringing Bandwidth to this level of expertise needed to satisfy Principia's requirements. Our scale-up will meet Principia's production demands, as well as allow us to continue to satisfy our growing customer base."

www.spirecorp.com/spire-bandwidth-semiconductor

Principia's RGB eVCSELs for rear-projection TVs

In collaboration with Moscow's P.N. Lebedev Physical Institute and the Institute of Radiotechnics and Electronics of the Russian Academy of Sciences, Principia LightWorks has developed red, green and blue electron-beam-pumped vertical cavity surface emitting lasers (eVCSELs), which can be driven by the scanning electron beam of a cathode ray tube (CRT) to form an RGB light source in rear-projection TV.

The eVCSEL's gain layers contain multi-quantum wells. Principia uses III-V GaInP/AlInGaP MQWs

for red light emission, but II-VI materials ZnCdSe/ZnSSe for green and ZnSe/ZnSMgSe for blue, all lattice matched on GaAs wafers.

October's 15th International Symposium 'Advanced Display Technologies-2006' at the P.N. Lebedev Physical Institute saw the presentation of red (635nm) GaInP/AlInGaP MQWs showing that mini laser CRTs can have efficiencies as high as 10%, making them prospective monochromatic light sources for displays.

For high-quality growth of II-VI MQWs, high internal stresses are the main problem. But this has been solved by using a GaAs substrate of appropriate crystal orientation.

The latest peak output powers at 35kV are 8W (red), 4W (green) and 4W (blue). "We expect that that the power will double in green and blue once Bandwidth begins growing these structures, because of the high uniformity in the deposition of layers using the Veeco system," says Principia's president Michael Tiberi.

www.principia-lightworks.com

TDI samples 4-inch AlN-based semi-insulating substrates

Technologies and Devices International Inc (TDI) of Silver Spring, MD, USA has made available sample quantities of 100mm (4") diameter AlN-based semi-insulating substrates. TDI introduced the first 2" AlN-on-SiC substrates three years ago followed by 3" substrates last year, and announced fabrication of the first prototype 4" AlN-based semi-insulating substrate this June.

Proprietary stress control technology and crystal growth equipment developed by TDI allows the deposition of crack-free single-crystal AlN film 10–20µm thick. This is sufficient for reliable insulation and low current leakage to the electrically conductive 100mm (4") SiC substrate.

So, as well as having good lattice and thermal match to GaN-based devices, says president and CEO



2", 3", and 4" AlN-on-SiC wafers. Thick AlN layers are deposited on electrically conducting SiC by HVPE.

Vladimir Dmitriev, AlN-on-SiC substrates combine the high thermal conductivity of SiC and the high intrinsic electrical resistivity of AlN for ultra-high-power AlGaIn/GaN devices (including HEMTs and high-frequency power amplifiers for

next-generation wireless communications). Future applications also include optoelectronic devices, e.g. high-power lasers, operating in the ultraviolet region of the spectrum.

Test samples have been shipped to customers. "Results have been positive and very encouraging," says Dmitriev. "Large-area AlN-based substrates offer important technical and economical benefits. This can lead to dramatic cost reductions for GaN high-electron-mobility transistors and power amplifiers, particularly for base-station applications," he adds. "New product breakthrough will allow our customers to use existing 4" manufacturing lines [standard for GaAs RFICs], reduce production cost, and speed up commercialization of GaN devices."

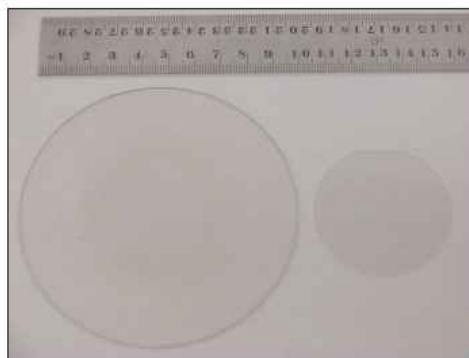
www.tdii.com

BluGlass scales up GaN deposition to 4-inch substrates

BluGlass Ltd of Sydney, Australia says that it has demonstrated its gallium nitride production technology on 4" substrates — double the diameter (four times the deposition area) of the current 2" industry standard, it says — well ahead of expected timelines.

BluGlass was spun off from the III-nitride department of Macquarie University in New South Wales in June 2005, and this September it raised \$7.7m in an initial public offering. In October it signed an 18 month joint development agreement to work with France's Saint-Gobain Recherche on developing specifically engineered substrates.

"BluGlass has already identified considerable savings at the wafer level through our process by demonstrating GaN growth at lower temperatures [of 500–700°C, rather than over 950°C for current



A 4" BluGlass GaN wafer (left) and a standard 2" sapphire wafer (right).

commercial MOCVD techniques], on cheaper substrates, such as glass," says chief executive officer David Jordan. BluGlass now aims to develop commercial manufacturing equipment in 2007. "The next step in the development of BluGlass' technology will be to move towards 6", 8" and eventually even larger wafers which will, in combination

with other BluGlass technological advances, dramatically lower the production cost of GaN," he adds.

One application for a cheaper source of GaN is high-efficiency LED lighting. "Now that we are proving our technology on the four-inch system and beyond, we are very confident of being able to open up the market for GaN in general lighting, which has a current global market value of more than \$100bn," Jordan reckons.

"There are many other markets for GaN devices including backlighting for computers and TVs, automotive lighting and successors to DVD and CD. Widespread adoption is currently limited by cost, and this is something that our technology aims to help overcome," says Jordan.

"Every price reduction along the way will unveil new applications for GaN."

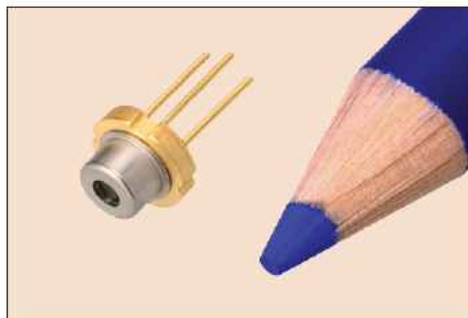
www.bluglass.com.au

Sharp starts blue laser production

In November Tokyo-based Sharp Corp began shipping samples of blue-violet laser diodes (emitting at a wavelength of 406nm) from its LED and laser fab in Mihara, Hiroshima, becoming only the third volume manufacturer so far.

Previously, volume supply has been limited to MOCVD-grown blue-violet laser diodes from Japan's Nichia Corp (estimated at several hundred thousands units per month) and Sony Corp, under a cross-licensing deal with Nichia. However, Sony is currently devoting capacity to Sony Computer Entertainment Inc's new Playstation 3 (launched in the USA in mid-November), planning to ship 1m units into both Japan and the USA by end-2006, before launching the PS3 in Europe next spring. This has contributed to the ongoing shortage of lasers required for the next-generation DVD player formats HD-DVD and Blu-Ray Disc (the format used for PS3), with Sony having postponed its Blu-ray Disc player's July US launch indefinitely.

In contrast, the Advanced Optoelectronic Devices group of Sharp Corp's subsidiary Sharp Laboratories of Europe (SLE) of Oxford Science Park, UK in January 2004 fabricated the first InGaN blue-violet laser diode grown by MBE (which Sharp uses to produce half of all infrared and red CD/DVD lasers sold). Grown on sapphire templates, the devices operated in pulsed mode at 405nm (for Blu-ray), with a threshold voltage of 33V and a high room-temperature current density of 30kAcm^{-2} . In June 2005 it demonstrated the first MBE-grown blue-violet laser to operate in the necessary continuous wave (CW) mode at room temperature (for several minutes without degradation, with a threshold current density of 5.7kAcm^{-2} and an oper-



Sharp's blue-violet laser.

ating voltage of 8.6V). At this May's 6th International Symposium on Blue Laser and Light Emitting Diodes (ISBLLED 2006) in Montpellier, France, SLE's Valerie Bousquet reported a laser grown on free-standing substrates (produced by Japan's Sumitomo and France's Lumilog) with a CW lifetime extended to 3 hours (still much shorter than that of MOCVD-grown lasers in first-generation HD-DVD and Blu-ray Disc players). At a drive current of 450mA and a threshold voltage of 6.5V, CW output was 14mW.

Now, Sharp says its new production 406nm GH04020A2GE blue-violet laser (which has a small diameter of 5.6mm for easy implementation in Blu-Ray Disc and HD-DVD players) has a maximum CW optical output of 20mW for read-only applications. When set to 10mW, it ensures what Sharp claims is the industry's smallest power consumption and longest lifetime simultaneously (168mW and over 10,000 hours, respectively).

The first samples cost 10,000 yen (\$85). Sharp has a start-up capacity of 150,000 units a month, but says it is ready to expand capacity depending on demand.

● Sharp says it is also developing a high-power, pulsed-wave blue laser that will output 130–210mW.

www.sle.sharp.co.uk

IN BRIEF

BinOptics funded to speed blue laser development

After raising \$8.1m then \$10m in first- and second-round funding from Draper Fisher Jurvetson, Cayuga Venture Fund, FA Technology Ventures, and ArrowPath Venture Partners, BinOptics Corp of Cornell Business and Technology Park, Ithaca, USA has raised a further \$6m in a series C round, led by STIC International, the Palo Alto, USA-based arm of South Korea's STIC Investments.

Founded by chairman Alex Behfar and Darius Forghani in 2000, BinOptics now has 33 staff. At its 10,000ft² fab it makes laser chips using lithography and chemically assisted ion-beam etching (CAIBE) to etch (rather than cleave) facets. Due to its flexibility and high yield, this allows monolithic integration of multiple functions on a single chip as well as low cost, it claims. Products include edge-emitting lasers with optional integrated monitoring detectors and what it says is the first horizontal-cavity surface-emitting laser (HCSEL), a high-power laser operating at the 1310 and 1550nm communication wavelengths.

The funding will support scale-up of its InP telecom and datacom lasers (for speeds up to 10Gbps) and accelerate development of etched-facet blue lasers for optical storage, for roll out in 2007. BinOptics is focusing first on lower-powered lasers for reading discs, then a higher-power model for reading and writing.

"South Korea is a very important market for us," says Behfar, who was CTO until resuming the role of CEO in February. BinOptics is already working with some companies in Asia.

BinOptics is also developing blue lasers for other applications, including displays.

www.binoptics.com

IN BRIEF

Cree's new senior VP of Worldwide Sales

LED chip maker Cree Inc of Durham, NC, USA has appointed Robert Pollock as senior VP of worldwide sales. He will "build our sales team to support our current customers and drive Cree's growth into the emerging markets for more energy-efficient lighting and power", says chairman, president and CEO Chuck Swoboda, to whom Pollock will report. "One of Cree's priorities is to expand our global sales, marketing and distribution capabilities," he adds.

Pollock has almost 30 years experience of sales and sales management, starting at Hewlett Packard with its LED and RF/microwave product groups, via sales positions with Qusion Technologies and Anadigics, to VP of sales at Philips Lumileds.

www.cree.com

Arrow targets Cree's high-power LEDs

Cree has signed a global distribution agreement for its high-power packaged LED products (including the Xlamp 7090 XR-E, the first 160lm white power LED) to be sold and supported by Arrow Electronics Inc of Melville, NY, USA. Arrow is one of the world's largest distributor supply chains (with over 130,000 customers).

"Arrow Electronics represents the first global lighting distribution agreement Cree has awarded and a milestone in our strategy to grow global sales, marketing and distribution capabilities," said Cree's senior VP sales Bob Pollock. "Cree is aligning itself with one of the top electronic components distributors in the world and its large base of customers to drive the LED lighting revolution."

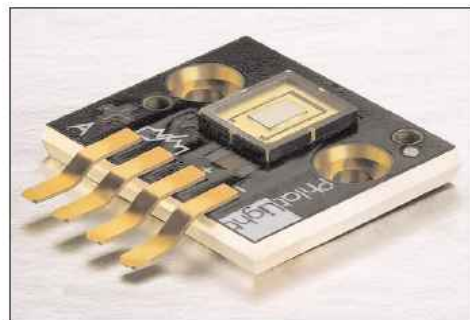
www.arrow.com

Luminus sampling 1500lm LED chipset

LED maker Luminus Devices Inc of Woburn, MA, USA, which was spun off from Massachusetts Institute of Technology in 2002, is sampling its PhlatLight (Photonic Lattice Light Source) PT120 chipset to microdisplay projection TV makers, offering brighter backlighting.

PhlatLight is a three-color system that includes red, green and blue large-area LEDs, each separately packaged using a proprietary Phlat-Pak package (designed exclusively for PhlatLight chips) that provides 'excellent thermal management at very high operating power, a simple electrical interface and efficient optical coupling to the microdisplay'. The LEDs can sustain fast pulsing and combine to produce extremely high power. The PT120 provides more than 1500lm of white light under normal operating conditions, the first single-chip solid-state light source powerful enough to illuminate large-screen high-definition rear-projection TVs (RPTV) up to 62 inches, Luminus claims.

Though suitable for microdisplays smaller than 0.7 inches, the PT120 chipset was specifically optimized



The PhlatLight chipset for RPTV.

for use with the Texas Instruments' xHD5 1080p digital light processor (DLP) chipset. Its size and shape allow users to maximize the amount of light that can be collected and projected onto the screen.

Because they are solid-state light sources, in a DLP HDTV system PhlatLight LEDs can cycle at 2.9kHz, which is 48 times faster than traditional TV frame rates (using fluorescent sources), providing superior motion quality, claims VP of products Christian Hoepfner. Also, with significantly longer lifetimes than arc lamps (exceeding 60,000 hours), PhlatLight chipsets will never need to be replaced, he adds.

www.luminus.com

BridgeLux launches side-view LED chips for thinner mobile displays

BridgeLux Inc of Sunnyvale, CA, USA (founded as eLite Optoelectronics Inc in 2003) has launched its BSV Series side-view LED chip product line, based on its structure for elongated geometry under its first US patent (number 6,869,812, the subject of a patent infringement lawsuit with Cree — see last issue, page 29).

The rectangular chips, available in 10mil x 18mil and 10mil x 23 mil sizes, enable thinner displays for cell phones, PDAs, digital cameras, MP3 players and notebook PCs.

Combined with commercially available phosphors, the blue chips yield 1500mcd typical luminous intensity for a packaged white LED, enabling a variety of backlight applications.

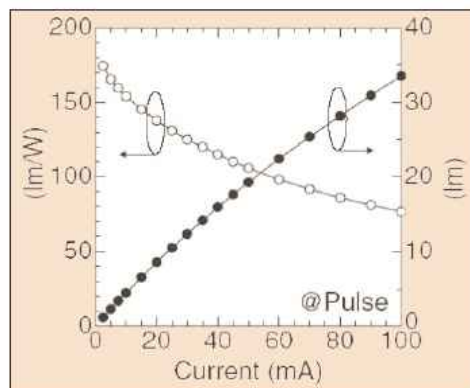
"As we extend our high-power illumination LED technology to smaller-size LED chips used in mobile applications," says CEO Dr Robert C. Walker, "the BSV series will enable our customers to greatly expand their offerings in the backlight market".

www.bridgelux.com

White LEDs hit 138lm/W at 20mA; over 90lm/W at 350mA

After Cree's June report of a white LED chip delivering 131lm/W at 20mA with a correlated color temperature of 6027K, Japan's Nichia Corp has reported a high-luminous-efficiency white LED with a small-area ($240\mu\text{m} \times 420\mu\text{m}$) chip, operating at a forward-bias voltage of 3.11V and current of 20mA, with a record luminous efficacy of 138lm/W (a luminous flux of 8.6lm). The quantum efficiency is 63.3%, the wall-plug efficiency is 41.7%, and the correlated color temperature is 5450K.

A high-power white LED with a larger 1mm x 1mm chip operating at 3.29V and 350mA had a slightly lower color temperature (5200K) but delivers a luminous flux of 106lm (a luminous efficacy of 91.7lm/W, greater than the 90lm/W



Luminous efficiency (left) and flux (right) for a Nichia white LED with a small-area $240\mu\text{m} \times 420\mu\text{m}$ chip.

of a tri-phosphor fluorescent lamp). The wall-plug efficiency is 27.7%, greater than the 25% of a fluorescent lamp in the visible region. Also, at 2A the luminous flux is 402lm (equivalent to the total flux

of a 30W incandescent lamp).

In both LEDs, the InGaN/GaN chip, grown by MOCVD on a patterned sapphire substrate, emits blue light (with a wavelength of 450nm) that excites a yellow YAG phosphor, yielding white light. For a p-type electrode, the LEDs use an indium tin oxide (ITO) contact with a higher transmittance (95%) than the 40% of a conventional translucent Ni/Al contact.

* Presented in 'Recent Progress of High Efficiency White LEDs' at the International Workshop on Nitride Semiconductors (IWN 2006) in Kyoto, Japan, 22-27 October. See Narukawa et al 'Ultra-High Efficiency White Light Emitting Diodes' 2006 Jpn J. Appl. Phys. **45** (41), L1084.

<http://jjap.ipap.jp/link?JJAP/45/L1084>



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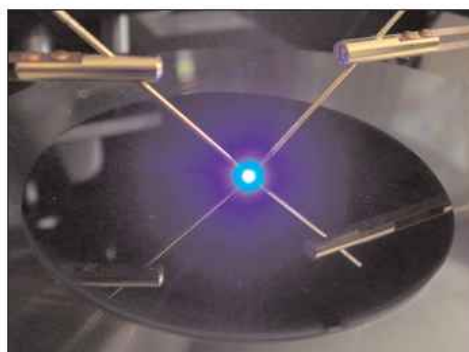
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Shimei to produce GaN-on-Si blue and then green LEDs

Japan's Shimei Semiconductor of Kyoto Research Park has developed prototype 0.3mm x 0.3mm blue LEDs on silicon substrates. The maximum output power (emitting at 450nm wavelength) is 10mW (on a par with existing products) and luminous intensity is 1.5-2.0cd when driven at 20mA.

Shimei was founded in May 2005 by chief technology officer Hirofumi Yamamoto with \$5.5m from Shin-Etsu Chemical Co Ltd and venture-capital companies in Japan. Shimei says it is developing technology that focuses on not only boosting LED emission power but on cutting cost, through the use of silicon substrates (which are much cheaper than sapphire substrates).

Shimei says it applies proprietary calculation theory to simulate MOCVD configuration and surface and vapor phase reactions, helping to cut development time and cost, and claims that this enables epitaxial growth of high-quality III-nitride compounds on any substrate.



Blue light emission from Shimei's GaN-on-silicon LEDs.

Since silicon absorbs more light than sapphire, Shimei forms a reflective structure in the buffer layers between the substrate and the active emitting layer, improving the efficiency of light emission through the top surface. Also, because silicon is electrically conductive (unlike the insulator sapphire), the n-type electrode is made with a direct contact to the bottom of the chip rather than indirectly via the top.

Shimei expects to improve performance through prototyping. It is

readying production lines for a monthly capacity of 3m units and aims to ship samples in April 2007, in either bare chip or wafer form.

Shimei is also looking at the untapped potential for III-nitride LEDs with longer wavelengths, including green and even red, the company's Isao Kohda told *Semiconductor Today*. This would enable them to produce all three primary colors (for full-color LEDs), unlike III-V compounds for existing red and infrared LEDs (which also contain toxic arsenic and phosphorus). Shimei has also started blue laser development, added Kohda.

Also, apart from lowering LED cost, simplifying structure, and extending lifetime, compared to sapphire substrates "it is easy to make large-area LEDs", says Yamamoto. "Using silicon wafers could enable the integration of optical devices with CMOS circuits drivers and other circuits on the same substrate," he adds.

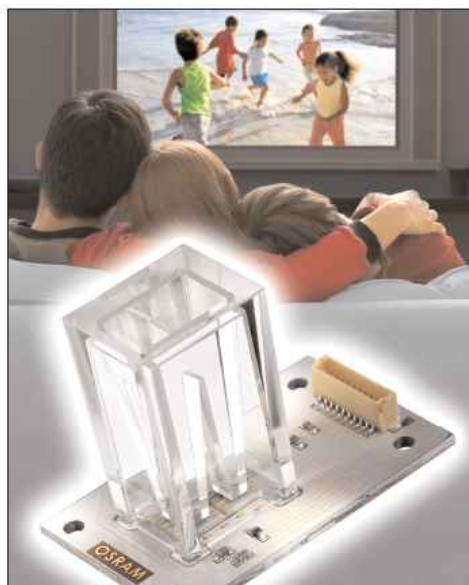
www.shimeisemicon.com

Award for 'Compact LED Light Sources' project

At October's annual Fraunhofer conference, the Science Award from the Stifterverband (a German foundation for the promotion of science) was presented to the 'Compact LED Light Sources' project, which was initiated by Osram Opto Semiconductors, partnered by the Fraunhofer-IOP (Institute for Optics and Precision Engineering), Carl Zeiss Jena and Siemens VDO Automotive.

The project's aim, promoted by the German Federal Ministry for Research and Development, was to identify new applications for LEDs and produce marketable products.

Osram Opto developed a new generation of LED chips with tailor-made beam profiles that no longer emit



An OSTAR LED for rear-projection TV.

light on all sides but just at the surface, suiting injecting light into the optical engines of projection systems. Project partners contributed expertise in beam positioning, special optics, and implementing novel system solutions.

As they are pure surface emitters, the new compact, high-power red, green, blue and white light sources from the OSTAR LED series meet requirements for use in high-performance projection systems such as high-brightness rear-protection TVs, claims Osram. OSTAR Projection has also already been used in mini projection systems and head-up displays.

www.stifterverband.de

LED lighting sources for direct connection to AC power supply

At November's Electronica event in Munich, Germany, South Korean LED lighting maker Seoul Semiconductor Co Ltd said it has invested \$40m in the mass production of its new Acriche LED lighting source, which can be connected directly to 110V or 220V AC power outlets using a simple circuit, eliminating the need for a DC converter. Initially available in 4W and 8W two- and four-LED-board modules with standard connectors as well as a two-LED board without connectors, other options will follow.

As conventional LED products can only work with DC power, it has previously been impossible to use them with AC light bulb outlets without using a converter. AC operation makes the use of LEDs more cost effective, says sales director Du Yeal Kim. Also, "LED applications are no longer limited to cell phones, computers or cars, but can expand to general lighting applications as well," adds Lee Jung-Hoon (who has been CEO since 1992).

Acriche requires 75% less electricity than an incandescent lamp and 40% less than a general fluorescent lamp, says Seoul Semiconductor. For example, if all the lights in Korea were replaced by 2010, savings would reach 60bn kWh (equivalent to a nuclear power plant's output), saving 6 million tons of CO₂ emissions per year, the company claims. The devices can last up to 30,000 hours, compared with typically 1000 hours for incandescent lamps, 3000 hours for halogen lamps, and 8000 hours for fluorescent lamps.

The product's relatively fast pace of development was enabled by chip-making subsidiary Seoul Optodevice Co Ltd, which devised a chip packaging process that works with DC. The company holds more than 100 patents on the chip technology.

Seoul Semiconductor is planning to sell Acriche to its key customers first, and then to expand its supply to general lighting companies early in 2007. Power consumption (800lm benchmark) is 21W (the same as for a Power LED).

Seoul Semiconductor is also planning to improve the devices' efficacy from its current level of 40lm/w (compared to 50lm/W for a Power LED) to 80lm/w by the end of 2007, and to 120lm/w by Q4/2008.

According to market research company Strategies Unlimited, Seoul Semiconductor, which was founded in 1987, is already the number-one Korean LED supplier and is one of the top 10 in the world for high-brightness LEDs. Annual sales are currently \$155m and staffing is almost 900.

Targeting sales of Acriche chips and modules of KRW20bn (\$20m) in 2007, KRW100bn (\$100m) in 2008 and KRW300bn (\$300m) by the end of 2009, the company aims to reach the top 3 overall by 2010. After 16% annual growth to KRW147.3bn in 2005, total company sales in



Lighting products containing Acriche LED sources for direct connection to AC power supplies.

Q1-Q3/2006 were KRW129bn, up 22% year-on-year. For 2010, Seoul Semiconductor's target is KRW1.3tn (\$1.3bn). The company reckons that the total global LED market will grow annually by 25% to reach \$20bn by 2010.

● Earlier in November, Seoul Semiconductor was named by Forbes magazine to its annual list of Asia's Top 200 Best most dynamic publicly traded firms with sales of under a \$1bn.

www.seoulsemicon.com



Acriche 4W and 8W two- and four-LED-board modules, together with a two-LED board without connectors.

Auto industry's first LED for resistor drive applications

Philips Lumileds of San Jose, CA, USA has launched new SnapLED 150 LEDs, designed, qualified, tested and binned for use in automotive dual-drive-current applications, such as rear combination lamps (RCLs), which provide both stop light and tail light functions.

The visual difference between a tail lamp and stop lamp is a direct result of the current applied to the LED. Philips Lumileds says that technology advances in the LED die and package for SnapLED 150 deliver stability at very low currents, as low as 5mA, and improved lifetime at all drive currents, resolving the technical issues that made resistor drive difficult. Eliminating the pulse-width modulation (PWM) circuit removes the cost and complexity of the PWM solution and eliminates the 'flicker' that is sometimes noticeable in rear combination lamps.



The SnapLED 150 for automotive dual-drive-current applications such as rear combination lamps.

"We have never accepted that the technology hurdles preventing resistor drive circuits for RCL applications could not be solved," said Jason Posselt, automotive marketing manager. "The new SnapLED 150 products enable resistor drive circuits and fundamentally improve the engineering process and lower costs for rear combination lamps.

Coupled with SnapLED's unique clinch technology that enables dimensional design, SnapLED 150 will lead where lower system costs, high performance and design flexibility are critical."

Continued technology innovation and improvements as well as a dual-current complex binning structure developed for the SnapLED 150 program will further stimulate LED implementation in the automotive rear combination lamp market, says Philips Lumileds.

The automotive industry manufactures about 4 million vehicles per year that use Philips Lumileds' SnapLED in such rear combination lamps. This number is expected to grow substantially as system costs decrease and LEDs are implemented in more cars and trucks, reckons Philips Lumileds.

www.philipslumileds.com

Smallest 0.5W PLCC-4 HB-LEDs for exterior auto lighting

At November's Electronica event in Munich, Germany, Avago Technologies of San Jose, CA, USA launched the industry's first 0.5W red-orange and amber high-brightness LEDs in an automotive-industry-standard PLCC-4 surface-mount (SMT) package.

The latest addition to Avago's family of 0.5W Envisium Mid-Power LEDs (which contain Philips Lumileds die), the ASMC-QxB2-Txxx series of SMT LEDs features the industry's smallest package size. They are optimized for long operating life under severe environmental conditions, making them suitable for automotive exterior lighting applications, says Avago.

ASMC-QHB2-TCDOE (red-orange) and ASMC-QAB2-TACOE (amber) Envisium LEDs have typical lumi-



Avago's 0.5W ASMC-QxB2 series red-orange and amber LEDs in automotive-industry-standard PLCC-4 surface-mount packages.

nous fluxes of 6.6lm and 9.3lm, respectively, at 150mA drive current. Other features include high typical optical efficiencies of 35lm/W (red-orange) and 20lm/W (amber).

The target automotive applications include rear combination

lamps (RCLs), center high-mounted stop lights (CHSML), tail lights, brake lights, side mirror turn-signal repeaters, and marker lamps for trucks and trailers.

Avago Technologies claims that the ASMC-QxB2 series' high brightness output per LED and small package footprint (3.2mm x 2.8mm x 1.9mm) allow greater flexibility in designing the size, shape and appearance of lighting assemblies.

The series provides two advantages for automotive production: they can be easily soldered using conventional SMT techniques to minimize production costs, and the package is qualified to a Joint Electron Device Engineering Council (JEDEC) moisture sensitive level (MSL) rating of 2A.

www.avagotech.com/led

Osram's LED headlamps for automotive forward lighting

With the launch of its new OSTAR Headlamp and the upcoming launch of OSTAR Headlamp Hot Spot, LED-maker Osram Opto Semiconductors of Regensburg, Germany is targeting vehicle forward lighting applications based on both reflector and projector systems.

The new high-power light sources are each equipped with five large, tightly packed ThinGaN chips, which together generate the high brightness and luminance required to match both halogen and high intensity discharge (HID) performance.

For a typical forward current of 700mA, the OSTAR Headlamp achieves 250lm and the Headlamp Hot Spot up to 350lm. So, four LEDs are sufficient to generate as much light as a halogen lamp. A larger number would be needed to produce the same level as a xenon lamp.

"The LEDs provide concentrated light from a small emitting area, and are therefore ideal for use in vehicle headlights," Ellen Sizemore, director, LED/IR marketing said. Robust,



Osram's five-LED OSTAR Headlamp.

vibration-proof and moisture-resistant, the lamps generate white light in the ECE and SAE standard color range with a high color temperature of 5600K, closer to natural daylight than other headlight sources, Osram Opto claims. Because the human eye is better at perceiving objects in daylight white light than in other light colors, whiter light can help increase visibility at the edges of the illuminated zone, improving reaction time and safety.

Systems designed with OSTAR Headlamps are suited to applications such as high and low beam

headlights, fog lights, daytime running lights and Adaptive Front lighting Systems (AFS), the company says. Direct access to the LED chips maximizes optical coupling efficiency. Available without primary optics, OSTAR Headlamp meets the requirements of reflector-based systems. The light from these surface emitters can be injected in customer-specific optics. For projector-based systems, OSTAR Headlamp Hotspot will include a primary optic to focus the light.

The OSTAR Headlamp's packaging simplifies LED forward lighting integration, claims Osram Opto. Precise mounting of the LED chips minimizes tolerance stack up and the low thermal resistance ceramic carrier maximizes brightness and lifetime at under-hood temperatures. The integral connector and mounting holes enable solder-free installation into the vehicle headlamp package. The lamps also meet the automotive AEC-Q101 standard.

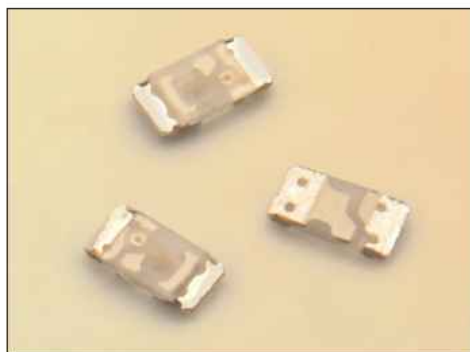
www.osram-os.com

Surface-mount LEDs in smallest industry-standard packages for backlighting enable thinner handsets

Avago Technologies of San Jose, CA, USA has introduced the industry's thinnest surface mount (SMT) LEDs in the smallest industry-standard (0603) footprint available.

The 1.6mm x 0.8mm x 0.25mm InGaN-based HSMx-CL25 series ChipLED lamps have typical luminous intensities of 11.2–45mcd for the HSMR-CL25 (blue, with a dominant wavelength of 473nm) and 28.5–112.5mcd for the HSMW-CL25 (phosphor white), respectively, at 5mA drive current. All packages use diffused optics.

Avago says that the ultra-thin LEDs are suited to backlighting



Avago's SMT-packaged HSMx-CL25 series ChipLED lamps.

keypads and status indicators in even smaller and thinner mobile handsets, as well as for office

automation devices and consumer electronics such as handheld games. The new top-emitting LED packages represent a lower-cost alternative to electroluminescent backlighting, says Avago, eliminating the need for high voltages and difficulties with high-frequency electrical noise. Their wide viewing angle is also suitable for direct backlighting or use with light pipes.

The LEDs are supplied in 8mm tape on 178mm (7-inch) diameter reels for compatibility with automated manufacturing.

www.avagotech.com/led

Bookham's falling Nortel sales offset by Cisco revenue up 47%

For its fiscal Q1/2007 (to end-September), InP-based optical component, module and subsystem maker Bookham Inc of San Jose, CA, USA has reported revenue of \$56.4m, down 10% on last year but a second consecutive quarter of 3% growth.

From \$24.1m in the March quarter, revenue from leading client Nortel fell 23% in the June quarter then 21% in the September quarter to \$14.6m, while non-Nortel revenue has risen from \$29.3m by 25% then 15% to \$41.8m, including revenue from optical network equipment maker Cisco Systems up 47% to 13% of total revenue. Non-telecom revenue (including the industrial laser business) rose 14% to \$11.6m.

"The continued growth in our non-Nortel revenue and the positive impact of our cost reduction plans resulted in better-than-forecast first-quarter gross margin [17%, down from 23% a year ago but up from 9% last quarter] and adjusted EBITDA [-\$7.7m, cut from -\$13.4m last quarter]," said CEO Giorgio Anania.

Compared with just \$0.5m a year ago, net loss was \$22.9m, but this includes restructuring charges of \$2.9m and an impairment charge of \$1.9m for the Paignton, UK plant and is down from \$27m last quarter.

In September, Bookham also agreed to sell its Paignton assembly and test facility for £5m (\$9.5m), but the deal includes a two-year option to lease back part of the site from the new owner. (This follows March's \$24m deal with UK property investment company Scarborough Developments to sell and lease back its wafer fab in Caswell.) Bookham has been transferring assembly and test from Paignton to its plant in Shenzhen, China as part of ongoing cost-cutting. "With this latest transaction we will have raised approximately \$41m from the recent private placement of common stock and the sale of our Paignton facility," said Anania.

"The current cost reduction plans [started in May] are progressing as planned and are producing the significant savings we expected [\$5.5-6.5m per quarter by the March 2007 quarter]," said Anania. "We initiated our chip-on-carrier line in Shenzhen [China] last month and are on track to complete this transition by the end of the year. Also, we are moving other functions to

Shenzhen [including its laser prototype line and engineering support], which will result in additional staff reductions elsewhere," he adds.

"We now have a much stronger balance sheet, which we plan to leverage to better address our growing markets." After falling from \$66.9m to \$43.3m in the June quarter, cash reserves have risen to \$58.2m, which include net proceeds of \$28.8m from a private placement of common stock in September.

"The telecom spending environment continues to be healthy, especially in areas where Bookham has competitive product advantages. In addition, a number of our new products, especially our tunable lasers, are seeing significant new design-in activity," claims Anania. "I do not anticipate any let-up in long-term customer demand and believe that in the second quarter [to end-December] we expect to achieve revenue growth and greater savings in our overhead cost structure through our cost reduction plans."

For its fiscal Q2/2007 (to end-December) Bookham expects revenue of \$56-59m, gross margin of 16-20%, and adjusted EBITDA of -\$6m to -\$10m.

www.bookham.com

The telecom spending environment continues to be healthy, says Anania

Optium's initial public offering on NASDAQ raises \$91m

In late October Optium Corp of Chalfont, PA, USA, a supplier of optical transceivers for telecom and cable TV network systems, raised \$91m in an initial public offering on NASDAQ. Optium had expected to raise \$66.6m.

Founded in 2000, Optium raised \$65.9m in four rounds of financing from four venture firms: Battery Ventures (which owns 34.9%), KPLJ Ventures (15.7%), TL Ventures (5.4%) and TPG Ventures (7.3%).

CEO Eitan Gertel and senior VP of engineering Mark Colyar both came from JDSU's transmission subsystems division.

In September, Emcore and JDSU filed a lawsuit alleging that Optium has violated US patents 6,282,003 and 6,490,071 describing a phase modulation method at two modulation tones to provide a more stable and reliable signal despite drift ('Method and Apparatus for Optimizing SBS [Stimulated Brillouin

Scattering] Performance in an Optical Communication System Using at Least Two Phase Modulation Tones') by making and selling its Prisma II 1550nm transmitters.

Both patents were originally owned by JDS Uniphase (awarded to Uniphase Corp in 2001 and JDSU in 2002, respectively), but the patents were transferred when Emcore bought JDSU's CATV business in May 2005.

www.optium.com

JDSU optical communications business turns operating profit

JDSU of Milpitas, CA, USA has reported revenue of \$318.1m for fiscal Q1/2007 (to end-September), level on the prior quarter but up 23% on a year ago. The geographical split was: Americas 56.9%; Europe 25.6%; Asia-Pacific 17.5% (compared to 61%, 22% and 17% last quarter, representing a shift from the Americas to Europe).

Optical Communications revenue was \$138m (43% of the total), up 3.8% on the prior quarter and 37.3% on a year ago, with an operating income of \$2.2m compared to a loss of \$16.7m a year ago. Communications Test and Measurement revenue was \$116.8m (37% of the total), down 7.5% on last quarter. Advanced Optical Technologies rev-

enue was \$39.3m (12%), up 7.1% on last quarter but down 10.9% on a year ago.

Commercial Lasers business revenue was \$24.1m (8%), up 6.6% on last quarter and 25.5% on a year ago. Net loss according to generally accepted accounting principals (GAAP) was cut from \$67.0m a year ago and \$45.8m last quarter to \$17.4m. On a non-GAAP basis, net loss of \$15.4m a year ago and

[non-GAAP] positive earnings per share... marks another significant milestone on the journey to sustained profitability

\$2.1m last quarter has turned into a net income of \$6.8m.

Non-GAAP EBITDA (earnings before interest, taxes, depreciation and amortization) were \$9.6m, compared to \$5.5m last quarter and to a loss of \$4.3m a year ago. Cash reserves are \$1.2bn.

"The achievement of positive earnings per share on a non-GAAP basis for the first time in more than five years marks another significant milestone on the company's journey to sustained profitability," says CEO Kevin Kennedy.

For fiscal Q2/2007 (to end-December 2006), JDSU expects revenue to rise 4–10% to \$332–352m.

www.jdsu.com

Avanex's revenues rise 12%, but losses continue

For its fiscal Q1/2007 (to end-September), optical network component, module and subsystem supplier Avanex Corp of Fremont, CA, USA reported record net revenue of \$50.9m (including record revenues in transponders, modulators, and dispersion compensators). This exceeded August's guidance of \$48–50m, and is the third consecutive quarter of double-digit revenue growth (up 12% on the prior quarter and 23% on a year ago).

Gross profit rose from \$1.8m the prior quarter to \$4.7m, and gross margin rose from 4% to 9%. Non-GAAP loss (excluding share-based payments, amortization of intangibles, restructuring charges, and gain/loss on the disposal of property and equipment) was cut from \$14.7m a year ago and \$9.1m last quarter to \$7.2m. However, net loss, though down from \$16.9m a year ago, rose from \$9.1m last quarter to \$9.8m. Cash reserves shrank from \$29m at the end of

June to \$16.4m, partly due to problems with the company's invoicing system.

"We saw strong growth from new products we announced, including our amplifier with integrated optical monitoring capability developed for next-generation deployments that provide the network backbone for the delivery of high-bandwidth triple-play services," said chairman and CEO Jo Major. "Also during the

quarter, our supply chain initiatives started to take hold, helping reduce our overall product cost. Our operational metrics (including yield, on-time shipments and return rates) continued to recover following last year's manufacturing transition," added Major.

Avanex expects fiscal Q2/2007 revenue of \$52–55m and improved gross margin.

www.avanex.com



Avanex has appointed Marla Sanchez as chief financial officer, succeeding Cal R. Hoagland. Sanchez was corporate controller for SDL Inc, then interim CFO at a portfolio company for SDL Ventures.

Avanex has also promoted Yves Le Maitre to chief marketing officer, after joining Avanex in 2005 as general manager of the optical components division.

Previously, he was general manager of Core Data Products at Alcatel USA Inc and president and chief executive officer of MEMS component and module supplier Lightconnect Inc.

IN BRIEF

Avago's 600 millionth optical mouse sensor

Avago Technologies of San Jose, CA, USA has shipped its 600 millionth optical mouse sensor since the release of its first navigation sensor in 1999.

The company pioneered optical sensing for mouse technology and claims to provide optical and laser mouse sensors to all major LED and laser optical-mouse manufacturers.

Since the release of its first optical mouse sensor in 1999 (as Agilent Technologies, before its Semiconductor Products Group was spun off as Avago Technologies in December 2005), milestones include:

- In 2001, the first low-power optical mouse sensor for cordless optical mice and the first USB and PS/2 optical mouse reference design kit.
- In 2002, the smallest optical mouse sensor.
- In 2004, co-developing the first high-performance 27MHz USB wireless optical mouse reference design kit and the first 2.4GHz USB wireless mouse/keyboard reference design kit.
- In 2004, LaserStream illumination and tracking technology.
- In 2005, the highest-resolution laser optical mouse sensors for high-end office use, wireless and PC gaming applications; and the lowest-power LED optical mouse sensor offering 18 months of operation from alkaline AA battery cells.

"To put this milestone in perspective, we have provided manufacturers with enough optical mouse sensors to provide a PC mouse to every citizen living in the US, Japan, Malaysia, Germany and France," says Ngoh Kee Hane, VP and general manager of Avago's Navigation Products Division.

www.avagotech.com

Emcore cuts sales forecast by 12.5%

Component and subsystem maker Emcore Corp of Somerset, NJ, USA has lowered its revenue forecast for fiscal Q4/2006 (to end-September) from \$40m to \$35m for continuing operations (excluding the Electronic Materials and Device epiwafer-making division sold in August to IQE).

The shortfall is mainly from the Photovoltaics division, which did not receive export licenses covering three international satellite programs in time. Emcore has since received license approvals and is shipping against the orders in the December quarter. A fourth license is expected later in the quarter. The division should report record revenue gains in fiscal Q1/2007, says president and CEO Reuben F. Richards Jr.

Emcore is required to obtain approvals from the US Department of State to export certain satellite photovoltaic products. However, the firm says it has shipped these specific products in the past and has requested a Commodity Jurisdiction classification that would simplify their export.

Emcore expects September-quarter revenues from its video transport line for CATV and FTTX products to be flat, but Fiber Optic division revenues to be \$28m (up 7.7% on the June quarter), due to an increase in demand for its 10Gb/s product line. Fiber Optics revenues for the December quarter are expected to rise a further 3%.

www.emcore.com

Report reveals stock option grant backdating, but no fraud found

A voluntary investigation by a special committee of Emcore's board (consisting of independent directors) together with independent counsel and external accountants has reported instances since its initial public offering in 1997 when stock option grants (mainly for new hires) rose in value after being changed to reflect a lower price on a date prior to issuance. However, the committee was unable to find any willful misconduct. Senior management did not tamper with or fabricate documents, take any actions intended to defraud, seek to profit at the expense of the company or its shareholders, or receive any option grants between 3 October 2001 and 18 May 2004 — the low point of the stock price. Senior management received only 12% of the options granted; 88% went to non-senior management staff.

Rather, the grant process was marred by carelessness and inattention to applicable accounting and disclosure rules. Also, the firm failed to maintain adequate controls concerning the issuance of stock options.

Emcore's CEO and chief legal officer have voluntarily repaid benefits received for misdated grants they exercised (\$147,775 and \$97,000, respectively). The chief financial officer did not exercise any stock option grants that may have been backdated.

Emcore expects to record about \$24m in non-cash financial charges to correct accounting errors related to backdated grants, principally affecting fiscal years 2000–2003. It will file its annual report for the fiscal year to end-September as soon as it finishes determining the exact amount of the charges.

Finisar doubling fab capacity

Finisar Corp of Sunnyvale, CA, USA has made its 50 millionth VCSEL (more units for the datacom market than all other manufacturers combined, it claims). Production began in 1996 at Honeywell International's fab in Richardson, TX, mainly for 850nm short-reach Gigabit Ethernet and Fiber Channel datacom as well as position sensing (with Finisar as a main customer). Finisar acquired Honeywell International's VCSEL Optical Products business for \$75m in 2004, and created the Advanced Optical Components (AOC) division. More than 300 staff ship hundreds of thousands of products each week.

The milestone shows the growing ubiquity of fiber-optics in data networks, says CEO Jerry Rawls. Bandwidth demand for new applications — including IPTV, IP Video, video over wireless networks and HDTV — combined with global adoption of Fibre Channel and Ethernet standards have driven demand.

Finisar's VCSELs are grown using a unique process on top of an integrated monitor photodetector, enabling precise readings and low power for applications including optical mice. Because of the com-



Finisar's new wafer fab in Allen, TX.

plicated structure, fabrication is challenging, but yields have made progress, Joe Young, senior VP and general manager, Optics Group, told *Semiconductor Today*. Finisar has been shipping tens of thousands of chips per week to Logitech for optical mice in Europe, and is also targeting the growing market for VCSEL sensor applications. However, Finisar has been capacity-limited due to the strong demand for laser mouse die, as well as for 4Gb/s and 10Gb/s die, says Young.

The 50 millionth VCSEL was presented to Edward Flynn, director of HP's SAN Infrastructure, Storage-Works Division, at a ribbon-cutting ceremony in October for Finisar's new expansion from the 60,000ft²

Richardson fab into a 160,000ft² facility in the Millennium Technology Park, Allen, TX. Finisar has renovated the fab over the last few years at a cost of \$13m.

To duplicate the Richardson plant, Finisar has refurbished an additional MOCVD reactor (increasing capacity by 30–40%), installed a second wafer fab line, and implemented new automated assembly and test equipment. This will support the rollout of 10Gb/s products for local area networks, as well as the upgrade of storage area network products from 2 to 4Gb/s data rates. "We're starting to see demand shift from 2 to 4Gb/s, already in short wave, but all of a sudden now SAN extensions for disaster recovery are shifting to 4Gb/s," says Young.

Allen currently employs over 300 staff. With a second MOCVD reactor in place by mid-2007, total capacity should be doubled after migrating the Richardson operation to Allen (Finisar expects that the transition will be complete by May 2007).

In addition, Finisar is expanding its Malaysian assembly plant to build more 4 and 10Gb/s transceivers and transponders, adds Young.

www.finisar.com

10Gb/s transceivers drive 13th quarter of growth

For fiscal Q2/2007 (to end-October), Finisar reported its 13th consecutive quarter of growth and its 9th of record revenues: \$108.2m (up 1.8% on the prior quarter and 24.9% year-on-year).

Optical subsystem and component revenues were \$99.0m (up 3.1% on the prior quarter and 27.8% year-on-year) and storage-area and local-area network test and monitoring system revenues were \$9.2m (down 10% on the prior quarter and level with a year ago, although Finisar is introducing monitors targeting new high-speed SANs deploying in late 2006).

"We had very strong growth in sales of 10Gb/s optical transceivers," says chairman, president and CEO Jerry Rawls. "We expect market demand for 10Gb/s transceivers to remain strong for the foreseeable future," he adds.

Joe Young, senior VP and general manager, Optics Group, expects a strong ramp in the transceiver market of 24% per year to boost Finisar's market share from under 20% in 2004 to nearly 30% by the end of 2006. Rawls expects continued record revenues for at least the rest of the fiscal year "driven in part by the progress we are making in

qualifying a range of 10Gb/s products at a number of customers.

"The richer product mix resulting from sales of these products should positively impact our gross margins and help offset the effect of a delay in the adoption of the 8Gb/s Fibre Channel standard [see August Issue 2, p5], which was expected to provide a boost to revenues for our Network Tools business in the second half," Rawls adds.

Finisar expects profitability on revenue of \$430m for fiscal 2007, and 20% growth to \$512m in fiscal 2008.

Stress control for GaN HEMTs on 150mm Si

Belgian research institute IMEC explains how innovative stress-control techniques to control wafer bowing have enabled gallium nitride high-electron mobility transistors to be grown on 100mm and 150mm silicon wafers, offering compatibility with standard silicon processing.

The growth of AlGaIn/GaN heterostructures on silicon substrates by metal-organic chemical vapor deposition (MOCVD) is key to widespread industrial acceptance of III-nitrides high-electron mobility transistors, since it allows the cost-effective production of HEMTs in standard silicon-based production environments. However, growth on silicon is a difficult matter due to the large crystalline and thermal mismatches between the two semiconductors. The Belgian research institute IMEC in Leuven has recently demonstrated AlGaIn/GaN HEMTs grown on 150mm silicon substrates (see Figure 1) with excellent characteristics. One of the major challenges is to get the wafer bowing under control to such an extent that the HEMT production process is compatible with standard silicon processing.

The need for GaN-on-silicon substrates

Gallium nitride is probably the most important semiconductor material since silicon, offering outstanding capabilities in terms of high-power, low-noise, high-frequency and high-temperature operation, even in harsh environments (e.g. radiation). The bright blue and white GaN light-emitting diodes on the market today are only the tip of the iceberg of breakthrough commercial applications based on GaN. High-frequency, high-power GaN transistors, capable of operating at high temperatures, could revolutionize emerging wireless applications, as well as automotive electronics and renewable energy markets.

The key to fulfilling all these wonderful promises is the ability to grow high-quality GaN on large-diameter silicon wafers. However, this is extremely difficult due to the lattice mismatch and, more importantly, the huge mismatch in thermal expansion between GaN and Si. Large tensile stress is induced in the GaN film during cool-down from the growth temperature to room tem-



Figure 1: A 150mm GaN HEMT on a silicon wafer.

perature, resulting in cracking of the GaN layer. For these reasons, GaN is mainly grown on silicon carbide or sapphire substrates, both of which are very expensive. Large-scale silicon substrates are the only cost-effective solution for a real commercial breakthrough.

New results are now paving the way to growing high-quality, high-resistivity GaN layers on silicon suited for the production of HEMTs.

Tuning the stress

GaN has a higher thermal expansion coefficient than silicon, which explains the build-up of tensile stress in GaN/Si heterostructures during cool-down after growth. To circumvent this problem, an intermediate layer of AlGaIn (300–700nm thick) is grown on an AlN nucleation layer before growth of the GaN buffer (see Figure 2). This layer provides a compressive stress in the GaN layer, compensating the tensile stress and preventing cracking of the GaN layer. By changing the properties of the AlGaIn layer, the stress in the GaN layer can be tuned, covering the whole range from compressive stress, over full relaxation, to tensile stress.

In-situ passivation of AlGaIn top layer

A key problem in GaN HEMT production — whether on silicon carbide, sapphire or silicon substrates — is the tensile stress in the AlGaIn top layer imposed by the GaN buffer because of the lattice mismatch. This stress causes defects, which result in mobility degradation and lower electron density in the two-dimensional electron gas (2DEG, which makes up the transistor channel) at the AlGaIn/GaN interface. Typical sheet resistance

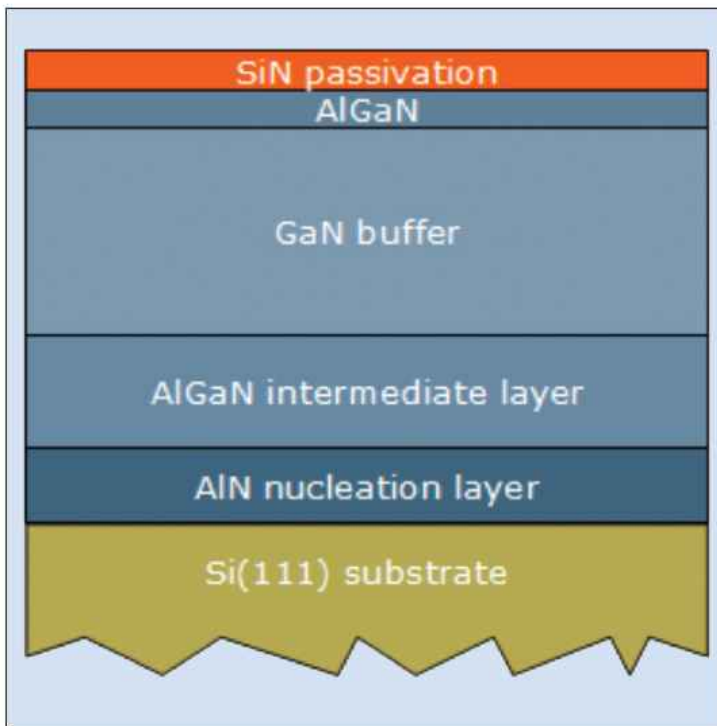


Figure 2: Schematic epitaxial structure realized with the new growth recipe for 100 and 150mm wafers.

values as large as 500 Ω /square have been reported.

Various solutions have been proposed to passivate the AlGaIn surface. These include ex-situ deposited SiO_2 , Si_xN_y , SiON , Sc_2O_3 , MgO as well as in-situ deposited insulating, p-type, n-type or low-temperature GaN cap layers. Promising results have been reported so far, but ex-situ depositions are always carried out on a surface that has been exposed to air, while GaN passivation layers may lead to lower 2DEG density and consequently higher sheet resistance.

Consequently, IMEC has worked out an in-situ passivation technique, based on an in-situ deposited Si_3N_4 layer, to stabilize the AlGaIn/GaN heterostructure. This has resulted in improved electrical properties, surface quality and structural quality of the AlGaIn/GaN heterostructures. Hence, a reduction in sheet resistivity by almost a factor two has been obtained by using this in-situ Si_3N_4 passivation technique.

GaN HEMT performance on 150mm silicon

AlGaIn/GaN heterostructures were grown on 100mm and 150mm silicon substrates using the above-mentioned technical implementations (AlN nucleation layer, AlGaIn intermediate layer, and Si_3N_4 passivation layer). Sheet resistance values in the range 250–280 Ω /square were obtained for 100mm wafers in a reproducible way. The uniformity of the sheet resistance over the wafer ranged from 2% to 4%, excluding a 5mm edge.

The uniformity as low as 1.0% was achieved for the best wafers. As mentioned above, the stress in the GaN layer could be controlled very well, resulting in overall wafer bow ranging from $-30\mu\text{m}$ to $+100\mu\text{m}$, depend-

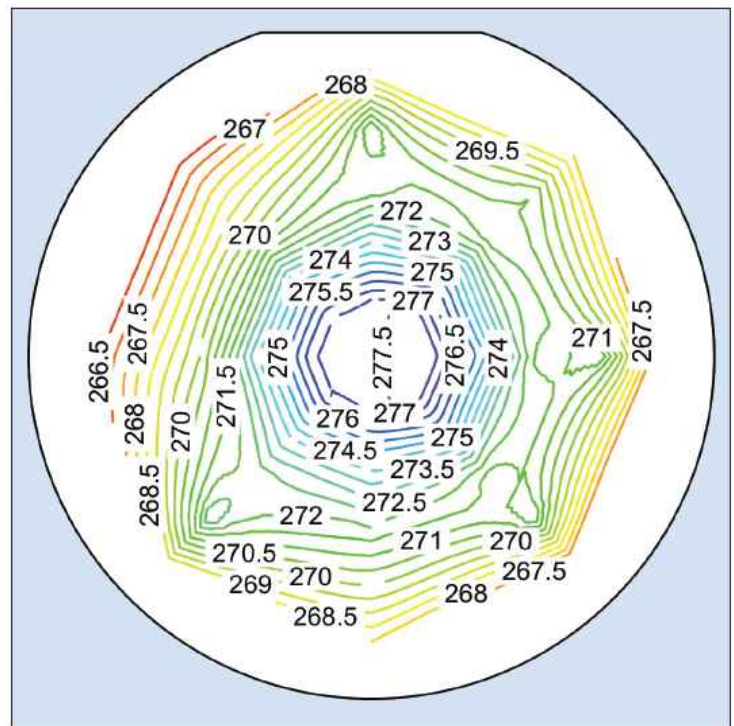


Figure 3: Contactless sheet resistivity measurement mapping on AlGaIn/GaN HEMT on 150mm Si wafer. A mean value of 272 Ω /square was obtained, with a uniformity of 1.9%. The values were extracted using a 5mm edge exclusion.

ing on the properties of the intermediate AlGaIn layer. The bow is defined as the height difference between the center and the edge of the wafer.

Some of the 100mm wafers were diced to perform Hall–Van der Pauw measurements. Electron mobilities in the range of 1500 to 1800 cm^2/Vs , and electron densities from $1.3 \times 10^{13}/\text{cm}^2$ to $1.7 \times 10^{13}/\text{cm}^2$ were recorded. As a comparison, without Si_3N_4 , the electron mobility was degraded to 1200 cm^2/Vs and the density was reduced to $1.1 \times 10^{13}/\text{cm}^2$, which, incidentally, are still very good values.

The surface morphology of the AlGaIn/GaN heterostructures was rather smooth. Atomic force microscopy

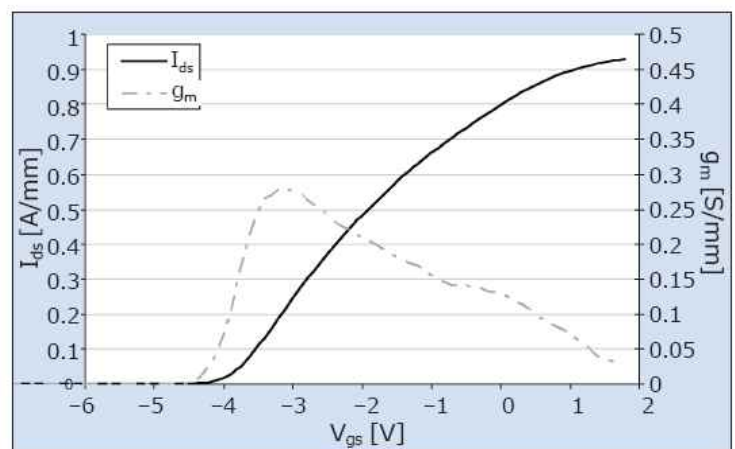


Figure 4: Transfer characteristics of an AlGaIn/GaN HEMT grown and processed on 150mm silicon wafer.



Figure 5: IMEC's GaN research is centered around two Thomas Swan close-coupled-showerhead MOCVD reactors.

measurements showed a root mean square (RMS) surface roughness as low as 0.2nm. As a comparison, AlGaIn/GaN heterostructures without an in-situ Si_3N_4 passivation layer show an RMS surface roughness of about 0.5nm. Moreover, the epilayers show very good crystalline quality, as evidenced by high-resolution x-ray diffraction, transmission electron microscopy, and Rutherford back-scattering (RBS)/channeling. A resistivity above $10^6\Omega\text{cm}$ has been measured on the GaN buffer layer. For 150mm wafers, a sheet resistance of $272\Omega/\text{square}$ with a uniformity of 1.9% has been demonstrated (Figure 3). A bow of $70\mu\text{m}$ was obtained.

The wafers were then processed using IMEC's standard HEMT process, which consists of several steps: mesa etching using an inductively coupled plasma to electrically isolate devices, fabrication of TiAl-MoAu ohmic contacts followed by rapid thermal annealing, definition of interconnects and contact pads, definition of 200nm long T-shaped gates using electron-beam lithography and finally a second passivation step using PECVD Si_3N_4 .

Upon characterization, these devices yield an excellent performance with a maximum current of over 0.9A/mm, a transconductance of over 270mS/mm and a very low on-resistance of $2.6\Omega\cdot\text{mm}$ (see Figure 4). ■

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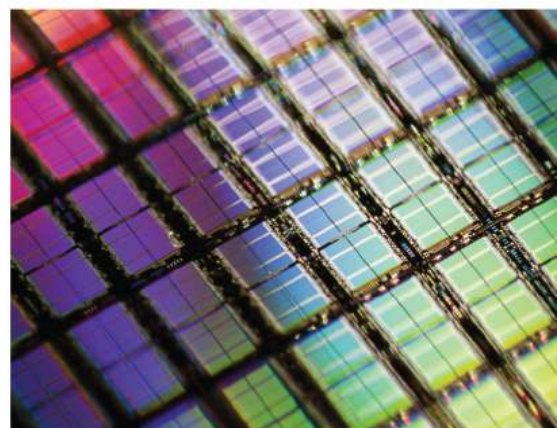


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SiC driving interest for power semiconductors

Silicon carbide has formerly been the preserve of niche industrial applications such as power generation and control, but is now attracting interest from major silicon power semiconductor manufacturers. As material quality and size rises, attention is focusing on devices and applications.

The 6th European Conference on Silicon Carbide and Related Materials (ECSCRM 2006) took place on 3–7 September at the striking, two-year-old, £70m Sage Centre in Gateshead, a former industrial powerhouse in north-east England from the industrial revolution through to the 1970s (home to companies such as Reyrolle Ltd of Hebburn, a maker of electrical protection and control equipment since 1886) but long since overshadowed by the more dominant city of Newcastle on the opposing north bank of the river Tyne.

Now Gateshead is resurgent after attracting government funding and investment back across the prize-winning, electric-powered, *Gateshead* Millennium Bridge (the world's only tilting bridge) as part of a £250m re-generation of the south bank of the Tyne.

An appropriate venue, then, for a conference on a technology, SiC, that has formerly been the preserve of niche industrial applications such as power generation and control and overshadowed by the success of silicon, but is now attracting long-overdue interest from many mainstream silicon manufacturers (including Infineon, which abandoned the former Siemens North Tyneside DRAM memory chip fab in Newcastle).

In his invited plenary presentation, Peter Friedrichs, managing director of the Siemens/Infineon joint venture SiCED Electronics Development GmbH, gave an overview of SiC power device development, from the first wafer-like base material in the early 1990s, through demonstrations of high-voltage Schottky diodes in 1993 and switching devices in the mid-1990s, the first MOS interfaces in the late 1990s, to the availability of the first commercial SiC Schottky barrier diodes in 2001 (from just two suppliers: Infineon and Cree). This was boosted in 2003 by the development of 3" SiC wafers with a macro defect density of under $<10\text{cm}^{-2}$.



No, not Sydney but Gateshead! The Sage Centre's shell-like roof, venue for ECSCRM 2006, reflecting both past and future technologies (Tyne Bridge, top; the Gateshead Millennium Bridge, background-left).

Initial SiC Schottky diodes were fast but had limits in surge mode, and many failures due to over-temperature, whereas users were familiar with silicon PIN diodes. However, Infineon's second-generation ThinQ!2G devices had additional p-doped islands (a combination of a Schottky diode and a pn diode) for improved surge current stability and an avalanche safety feature, and further p-doped regions only at the periphery to give a higher blocking voltage in 1200V Schottkys, as well as to reduce electric fields from $<2\text{kV/cm}$ to $<1.8\text{kV/cm}$. Turn-off behaviour is now as good as for a pure Schottky diode, says Friedrichs. SiCED is prototyping 1700V Schottkys, but expects to extend this to 3300V. For Schottky diodes, the killer application for is power factor correction (PFC), he adds.

An additional consideration, says Friedrichs, is that the price of silicon has doubled in the last two years, reducing the price difference between silicon and SiC devices.

Apart from the established SiC device makers SiCED, Cree, Northrop Grumman, Rohm and SemiSouth, ECSCRM 2006 was distinguished by interest in SiC from many of the major silicon-based power semiconductor manufacturers, including STMicroelectronics and Philips (represented via its collaborator Chalmers University of Technology in Sweden), Microsemi (which started up its new SiC fab this year, after acquiring Advanced Power Technology, which has SiC technology licensed from Northrop Grumman), International Rectifier, Rockwell Scientific and Fairchild in the USA, and, in

ECSCRM draws main players in power semiconductors

ECSCRM 2006 drew a healthy contingent of over 420 delegates — over 50% from Europe, but as many as 25% from the Far East and 20% from the USA.

Most European delegates came from traditional SiC powerhouse Sweden (dominated by KTH Royal Institute of Technology and Linköping University, plus contrast research organization Acreo, Chalmers University of Technology, substrate and epiwafer maker Norstel, and SiC/SiGe CVD reactor maker Epigress) as well as Germany (dominated by the University of Erlangen and Erlangen-based Siemens/Infineon SiC power device making joint venture SiCED, plus substrate maker SiCrystal and reactor maker Aixtron).

In addition to delegates from the UK (mainly the universities of Newcastle and Sheffield, plus etch system maker STS) and Poland's Institute of Electronic Materials Technology (IEMT), other large contingents came from France (research institutes UMR CNRS, INSA Lyon, Centre de Génie Électrique de Lyon and Institut National Polytechnique de Grenoble-CNRS, substrate polishing service provider NovaSiC, and materials supplier Saint-Gobain Crystals) and Italy (hot-wall CVD reactor maker LPE and epiwafer-mak-

ing subsidiary ETC of Catania, Sicily, as well as the University of Catania and Catania-based CNR-IMM, which collaborates with French/Italian silicon device maker STMicroelectronics, whose Central R&D facility is also in Catania).

Delegates from Japan came from substrate makers SiXON and Hoya, SiC MESFET maker New Japan Radio, and silicon device makers Rohm, Sumitomo Electric Industries, Mitsubishi Electric, Toshiba Corp R&D Center, Matsushita Electric Industrial, Fuji Electric and Oki Electric Industry, car makers Honda R&D, Nissan, Toyota Motor and automotive component supplier Denso, and AIST (the National Institute of Advanced Industrial Science and Technology), CRIEPI (the Central Research Institute of Electric Power Industry) and the Japan Atomic Energy Centre.

The US contingent was dominated by device and substrate maker Cree, along with substrate makers II-VI Inc and Dow Corning Compound Semiconductor, SiC device makers SemiSouth and Northrop Grumman, power silicon device maker International Rectifier, system maker GE Global Research Center, the Naval Research Laboratory and NASA Glenn/OAI.

Japan, Toshiba, Hitachi, Sumitomo Electric Industries, Mitsubishi Electric, Matsushita, and Oki Electric.

Such interest is indicative of the rapid trend among manufacturers — including the world's largest manufacturers of power electronic devices in Europe, Japan and the USA — that are now embracing SiC as an essential material for power electronics.

The applications attracting much interest include energy generation and distribution, especially in Japan (CRIEPI and the Japan Atomic Energy Centre) and the USA (General Electric), which have strong reasons — ecological, economic and political — for reducing energy wastage and consumption.

Roger Bassett of French power transmission and distribution company Areva T&D highlighted SiC's three-fold reduction in switching losses compared to silicon. Also, whereas silicon-based devices can shrink the real estate needed for voltage source converters six-fold, SiC can give a further three-fold reduction. Boosted by US defense funding of \$20m per year on SiC R&D (with Cree as a leading contractor) for applications like lighter, all-electric ships, in 2007 Cree is due to sample 10kV, 20A p-channel SiC insulated-gate bipolar transistors (IGBTs), for prototype equipment in 2010. Bassett expects this to lead to a 'significant market' for 10kV/1kA IGBTs in 2012 (e.g. for solid-state sub-stations).

Another major application is automotive electronics, especially in switching power in hybrid electric vehicles, attracting the involvement of Japanese car makers

Toyota (which already has its own in-house silicon chip manufacturing facilities), Honda and Nissan. Hence Fuji Electric Advanced Technology Co Ltd is starting SiC MOSFET production in 2007–2009 for inverters, initially for industrial motors, and then later for hybrid electric vehicles (HEVs), said Yoshiyuki Yonezawa, manager of its Semiconductor Laboratory's SiC Project. The devices can reduce inverter losses by 30%, increase drive frequency, and reduce the space needed for passive devices. Toyota, for example, is aiming to shrink the system size 10–50-fold.

A characteristic of silicon power device makers is that, according to Philippe Roussel of Yole Développement, of 82 power device fabs surveyed, 10% use 3" wafers, 33% 4", 18% 5", 35% 6", and just 4% 8", with no move to 12" wafers forecast. So, as many as 43% could use existing available SiC wafers (up to 4").

SiCED's Peter Friedrichs reckons on 6" SiC substrates being available by 2010 ("before 6" equipment vanishes from [silicon] fabs"). Adrian Powell of Cree, in the conference's 'Industrial News' session, reckoned Cree would make 6" SiC available "by 2009".

However, Thomas Kippes of wafer maker SiCrystal points out that some manufacturers (e.g. International Rectifier Corporation Italiana S.p.A. in Milan as well as many Japanese power semiconductors manufacturers) fabricate power semiconductors on 5" silicon wafers, suggesting the possibility that the next step from 4" SiC could be 5" SiC substrates. ►

Wafer scale-up: from hero to zero-micropipe

It was said that this year's ECSCRM had more of a device focus than previous events and less focus on material quality. This is a sign, perhaps of concerns now shifting to device design and processing, as some of the previous application-limiting material defects such as micropipe density have now been reduced to zero for 2" substrates and almost negligible densities on 3" substrates.

At ECSCRM 2006, Cree Inc of Raleigh, NC, USA, which makes the vast majority of all commercial SiC wafers (including those for its own SiC-based blue and white LED manufacturing, which make up 80% of its \$400m annual revenues), launched its zero-micropipe substrate technology (which was acquired in July when it bought Intrinsic Semiconductor of Dulles, VA, USA, now Cree Dulles Inc, in order to speed quality improvement).

In the 'Industrial News' session, Cree's Adrian Powell detailed how its standard n-type semiconducting 100mm 4H-SiC was achieving a lowest micropipe density of 0.31MP/cm², with a monthly median of 5MP/cm² in production. The latter should be reduced to zero next year, Powell said. Cree's 100mm high-purity semi-insulating (HPSI) SiC substrates have 'hero' micropipe densities of 2.5MP/cm². However, the micropipes are 'mostly at the edges', says Powell. The next step will be zero-micropipe 100mm wafers, says Powell, followed by 150mm substrates.

Although Cree dominates the SiC substrate market, other suppliers are scaling up, in terms of both size and quality.

II-VI Inc manufactures SiC substrates, but only for electronic applications, says Dr Andrew Souzis, manager, Programs & Business Development of the Wide Bandgap Materials Group (WBG), since "only Cree and Infineon [which uses Cree substrates] use SiC for opto applications". II-VI first demonstrated its 100mm SiC substrates in late 2005, and plans to make initial sales of engineering samples in early 2007, with volume quantities available later in the year, says Souzis.

Souzis also explained that II-VI has achieved micropipe density of zero on its 2" wafers, less than 1 on 3" wafers and from 600 per square in June 2005 to 9 per square now on 100mm wafers. But Souzis stated that, at current levels, even for 4" SiC, "micropipe density is not such a big issue any more, other than for the largest devices — dislocation density is more important". In addition, as SiC moves into full-scale manufacturing, issues such as particulates become more important. Following the purchase of an atomic force microscope last February, a new standard cleaning process with extremely low particulate levels was introduced.

II-VI performs all SiC crystal growth and fabrication at its Technology Center in Pine Brook, NJ, but is in the process of moving the manufacturing portion of its polishing capacity to its new facility in Starkville, MS, USA

(leasing space in SemiSouth's new SiC epiwafer and device fabrication plant in the Ralph E. Powe Center for Innovative Technology, adjacent to Mississippi State University's campus in the Thad Cochran Research, Technology and Economic Development Park). Initially, the polished wafers will undergo final quality control inspection back in New Jersey, shipping from Starkville once the process transfer is fully qualified.

Benefits of the Mississippi plant include cheaper energy and labor costs, as well as tax breaks for training etc, says Souzis. Proximity to MSU, which has an active SiC R&D program, is also a benefit. Plans currently call for a separate, full-scale manufacturing plant to be built elsewhere in the research park within the next 3–4 years to meet anticipated demands, adds Souzis. All manufacturing will then move from New Jersey, with R&D and new process and product development remaining there.

Thomas Straubinger of SiCrystal AG, based in Erlangen, Germany, outlined their priorities as being: 2" and 3" n-type 6H-SiC wafers for optoelectronic (i.e. LED) applications (focusing on cost); 3" n-type 4H-SiC, now in production for high-power applications (focusing on dislocations); and 3" semi-insulating wafers for high-frequency applications (focusing on improving the surface quality). He gave their typical micropipe density for 3" wafers in production as 4MP/cm² for 4H-SiC and 0.9MP/cm² for 6H-SiC. Straubinger says that substrate quality is determined mainly by the initial seed crystal, since micropipes are transferred from the seed crystal to the growing crystal. So, SiCrystal has improved the quality by developing a new generation of seed crystal for 3" 4H-SiC substrates, said Straubinger. However, the challenge is to transfer that quality improvement to larger diameters, for high-quality 4" 4H-SiC.

The most critical type of dislocations for failure in high-power devices are basal plane dislocations (BPDs). Their occurrence shows a correlation with thermo-elastic stress generated during growth. Stress can be reduced by minimizing temperature gradients and improving the crystal-wall contact in the growth chamber. For the 3" 4H-SiC wafers now in production, crystals grown with lower thermal stress contain fewer slip bands, improving from 70% to 95% free of BPDs.

Thomas Zoes, Dow Corning's global commercial manager for Compound Semiconductor Solutions in Midland, MI, USA, said that the firm "does not have zero micropipe yet", but is working on it.

Also present at ECSCRM were: Japan's SiXon Ltd, which was spun off from Kyoto University in 1998 (with initial funding from Sumitomo Electric Industries) and manufactures SiC electronic devices as well as 6H-SiC n-type, 6H-SiC semi-insulating and 4H-SiC n-type wafers; and Okmetic spin-off Norstel, which opened its SiC substrate and epitaxy manufacturing plant in Norrköping, Sweden in late August (see Issue 4, page 12).

Equipment for silicon carbide processing

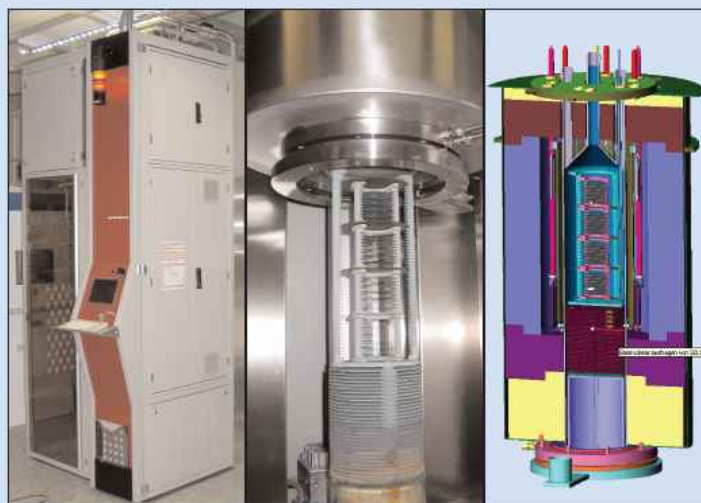
At ECSCRM, Centrotherm Thermal Solutions of Blaubeuren, Germany introduced the CHV100 (Centrotherm High-temperature Vertical vacuum furnace, with a maximum wafer size of 100mm). Developed in cooperation with Fraunhofer IISB (Institute of Integrated Systems and Device Technology) in Erlangen, it is the world's first mass-production high-temperature annealing furnace developed specifically for SiC electronic materials, it is claimed.

The system originated as the CVS HT (Centrotherm Vertical Special-application High Temperature) in 2003. The first system was built for the University of Erlangen and installed at the Fraunhofer IISB in Erlangen as a part of a joint program in 2003.

Compared to the CVS HT, the CHV100 has a faster cool-down rate, improved vacuum seals, an updated temperature controller, increased temperature of operation (from 1750°C up to 1850°C annealing temperature, ramping at up to 100°C/min).

The CHV100 is designed for Al post-implant activation annealing of SiC devices at high temperatures. Traditionally, comparatively low-volume annealing furnaces are used for SiC device manufacturing. But the system can process up to 50 2", 3" or 4" wafers per batch (intermixed in the same process run) and has a small footprint of 1.3m², reducing cost of ownership. The flexibility in wafer diameter and process capability also enables the development of individual processes as well as use for mass production, with options for robot handling and a load-lock/mini-environment, says Uwe Keim, product manager for SiC Processing Systems.

A second system was bought in June by Microsemi for its former APT fab in Bend, OR, USA, for annealing Al implants in SiC power semiconductor devices. Dr Douglas Meyer, executive scientist for Centrotherm Technologies in Danvers, MA, USA, says that the increased acceptance of SiC devices and rapidly growing market, driven by the need for exceptional



The CHV100 Centrotherm high-temperature vertical vacuum furnace for 100mm wafers.

performance from Schottky diodes and FETs at high temperatures, has motivated a recent maturation of SiC manufacturing techniques, necessitating high-productivity process tools with greatly reduced cost of ownership, small footprint and minimal particulate contamination.

Other systems have recently been sold in Europe. "We are negotiating two more sales in the US right now and there is growing interest in Japan," says Meyer. Centrotherm is beginning a product offering for annealing (sintering) of metal contacts for SiC devices, and is doing some demonstrations.

Also, Italy's LPE S.p.A. is supplementing its ACiS M8 horizontal hot-wall CVD reactor for 4H-SiC epitaxy up to 2000°C (which has a capacity of 6x2", 3x3" or 1x4" wafers) with the new high-throughput ACiS M10 reactor (with a capacity of 9x2", 5x3" or 3x4" wafers and 12x2" on request), to be available in Q2/2007. A new-generation process chamber and inductor design give improved temperature uniformity. M8 reactors can be retrofitted, says LPE.

SiC epitaxy

Powell says that Cree's 100mm 4H-SiC epi achieves thickness uniformity of <2% and doping uniformity of <7% — "epi quality is as good as 3-inch", he adds. The next development, he says, will be epi that is free of basal plane defects, and 150mm epi.

Italy's LPE S.p.A. developed SiC epi over three to four years, together with the Epitaxial Technology Center. For over a year, using a new 2500m² plant in Catania, it has been making epiwafers for commercial sale.

In addition, ESICAT Japan LLP, a partnership formed in September 2005 between Showa Denko KK and several researchers belonging to AIST (Japan's

National Institute of Advanced Industrial Science and Technology) and CRIEPI (the Central Research Institute of Electric Power Industry), aimed to start selling SiC epi services in fourth-quarter 2006, according to marketing manager Takayuki Sato.

Also, Dow Corning presented a poster on in-situ gas phase etching for defect reduction in epilayers and chlorosilane-based SiC CVD epi, and is planning to supply epi commercially, says the firm's Thomas Zoes.

No doubt, by the time of the International Conference on Silicon Carbide and Related Materials 2007, 14–19 October in Otsu, Japan, such developments will have advanced the SiC industry to even greater maturity. ■

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542 Route 303,
Orangeburg, NY 10962,
USA

Tel: +1 845 398 8242

Fax: +1 845 398 8304

www.praxair.com/electronics

8 Wafer processing equipment

EV Group

DI Erich Thallner Strasse 1,
St. Florian/Inn, 4782,
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

Henry Butcher International
Brownlow House,
50-51 High Holborn,
London WC1V 6EG, UK
Tel: +44 (0)20 7405 8411
Fax: +44 (0)20 7405 9772
www.henrybutcher.com

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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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

30 January – 2 February 2007

1st International Conference on Display LEDs (ICDL 2007)

COEX, Seoul, Korea

E-mail: smshin@tftlcd.khu.ac.kr

www.sid.org/conf/icdl2007/call.pdf

31 January – 2 February 2007

Semicon Korea 2007

Seoul, Korea

E-mail: sko@semi.org

www.semi.org

31 January – 2 February 2007

Getting SSL to Market: 2007 DOE Solid-State Lighting Workshop

Phoenix, AZ, USA

www.netl.doe.gov

7 February 2007

Nano-electronics – Materials and Technology

Institute of Physics, London, UK

E-mail: n.g.wright@ncl.ac.uk

www.iop.org/Conferences

12–14 February

Strategies in Light

San Jose, CA, USA

E-mail: rsteale@strategies-u.com

<http://sil07.events.pennnet.com/fl/index.cfm>

13 February 2007

LED2007 Conference & Showcase

Eindhoven, The Netherlands

E-mail: hellen.dankers@weare.nl

www.ledcongres.nl

19–21 March 2007

LED China 2007

Guangzhou, People's Republic of China

E-mail: LED@TrustExhibition.com

www.LEDChina-gz.com

21–23 March 2007

SEMICON China 2007

Shanghai, People's Republic of China

E-mail: mhua@semi.org

www.semi.org

25–29 March 2007

OFC/NFOEC 2007 (Optical Fiber Communication Conference and Exposition & National Fiber Optic Engineers Conference)

Anaheim, CA, USA

E-mail: registration@ofcconference.org

www.ofcnfoec.org

26–28 March 2007

LED Packaging 2007

Shanghai, People's Republic of China

E-mail: pkinzer@intertechusa.com

www.intertechusa.com/conferences

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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

**Materials Research Society (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

20-23 May 2007

**WOCSDICE 2007 (Workshop on Compound
Semiconductor Devices and Integrated
Circuits), including WOGATE (Workshop on
the GaN Advancement Technology in Europe)**

Venice, Italy

E-mail: wocsdice2007@wocsdice2007.org

www.wocsdice2007.org

29 May - 1 June 2007

LED & Solid State Lighting Expo 2007

KINTEX, Seoul, South Korea

E-mail: info@ledexpo.com

www.ledexpo.com

28-29 June 2007

**Hetero-SiC'07 Workshop (International
Workshop on 3C-SiC Hetero-Epitaxy)**

Grenoble, France

www.lmgp.inpg.fr/Hetero-SiC



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