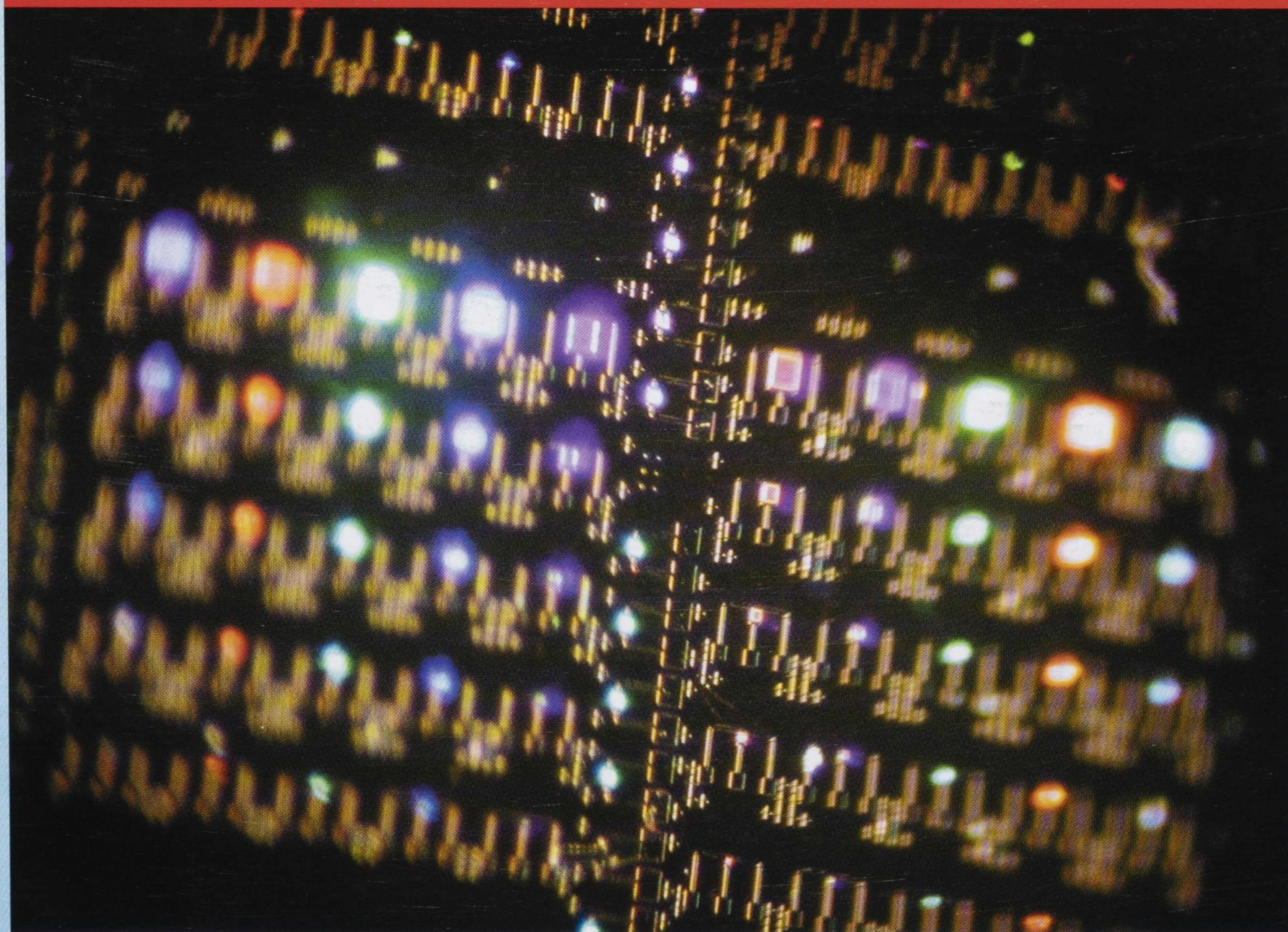


COMPOUND SEMICONDUCTOR

Three-Fives and Silicon Heterostructures

August 2004 Volume 10 Number 7



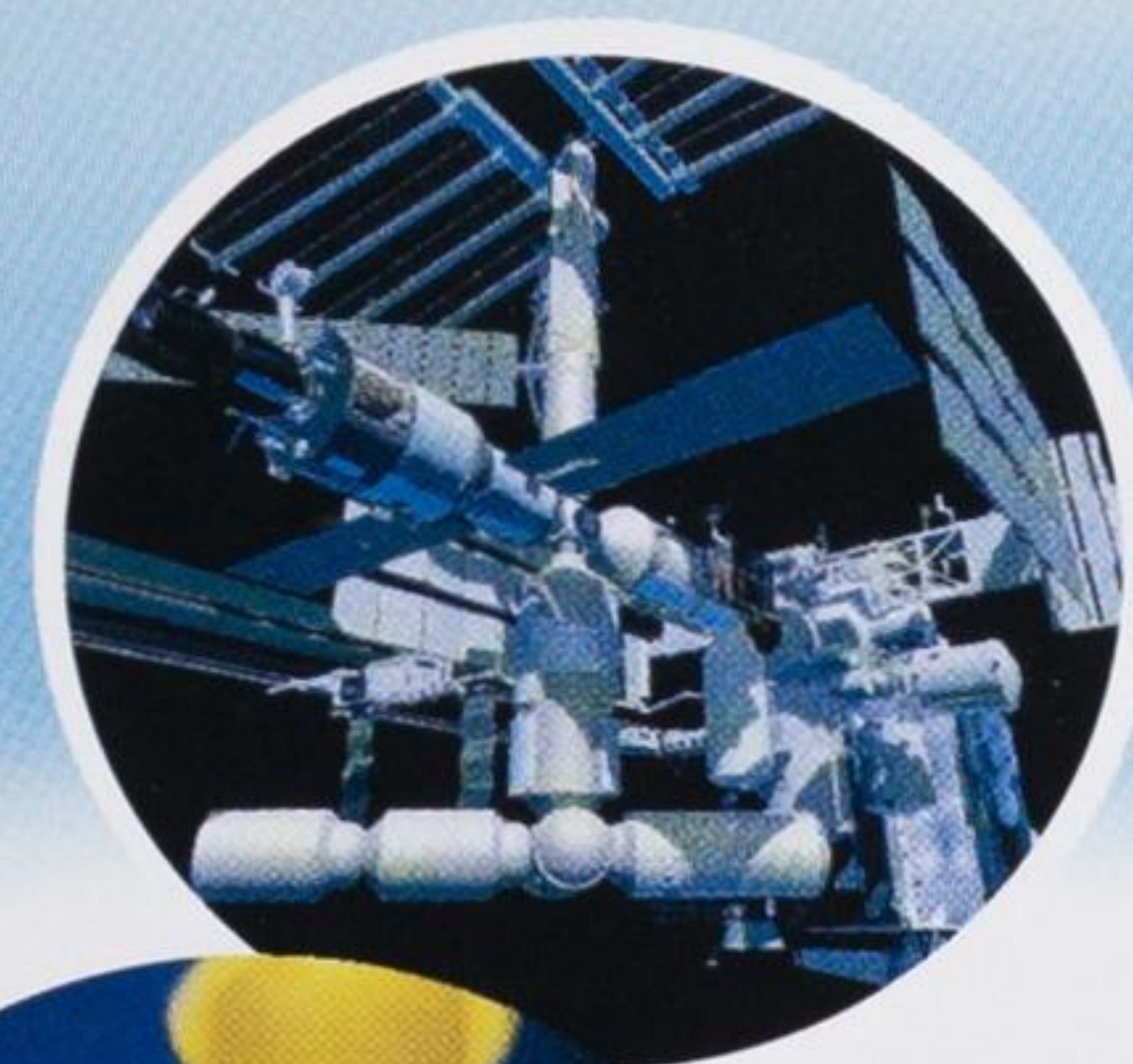
SILICON/GERMANIUM **Ge-on-insulator detectors:** **an interconnect solution?**

ALSO INSIDE

**LDMOS progress
threatens GaN**

**SiGe Semiconductor
sizes up WiMax**

**Procomp scandal
engulfs Taiwan**



Wafer sizes to:
GaAs 150mm
InP 150mm
Ge 100mm

Low EPD
Epi-Ready
High Mechanical Strength
Excellent Electrical Uniformity

VGF - The Right Choice For Compound Semiconductors

USA Corp office American Xtal Technology 4487 Technology Drive Fremont, CA 94538 U.S.A Tel: 510-226-4300 Fax: 510-683-5901 E-mail: sales@axt.com	Taiwan Conary Enterprise Co., Ltd. 9F No.28, Sec.3 Nan-King East Road Taipei, Taiwan, R.O.C Tel: +886-2-2509-1399 Fax: +886-2-2501-6279 E-mail: sale@conary.com.tw	Korea Iantek Corporation CheongMyung Towntel 607 1021-4 YeongTong-Dong PalDal-Gu SuWon-Si, KyungGi-Do, 442-813, Korea Tel: +82-31-204-4221 Fax: +82-31-204-4220 E-mail: iankim@kebi.com	Japan AXT-Japan 302 Urban Plaza Lzumi 2-26-4 Myojin-cho Hachioji, Tokyo 192-0046 Japan Tel: +81-426-56-2032 Fax: +81-426-56-6885 E-mail: yohashi@axt.co.jp	China Beijing Tongmei Xtal Technology 4 Eastern Second Street Zhangjiawan Ind. Development Zone Tongzhou District Beijing, China 101113 Tel: +86-10-6156-2241 Fax: +86-10-6156-2245 E-mail: sales@axt.com	United Kingdom & Scandinavia West Associates Ltd. 73 Lodge Close Cobham, Surrey United Kingdom, KT11 2SQ Tel: +44-1932-868-006 Fax: +44-1932-860-932 E-mail: westonweb@compuserve.com	France & Germany Geo Semiconductor Ltd. 4 Quai Gustave Ador POB 6464 CH-1212 Geneve 6 Switzerland Tel: +33-145-3162-84 Fax: +33-145-3339-43 E-mail: ralph_hananel@compuserve.com
--	--	--	---	--	---	---

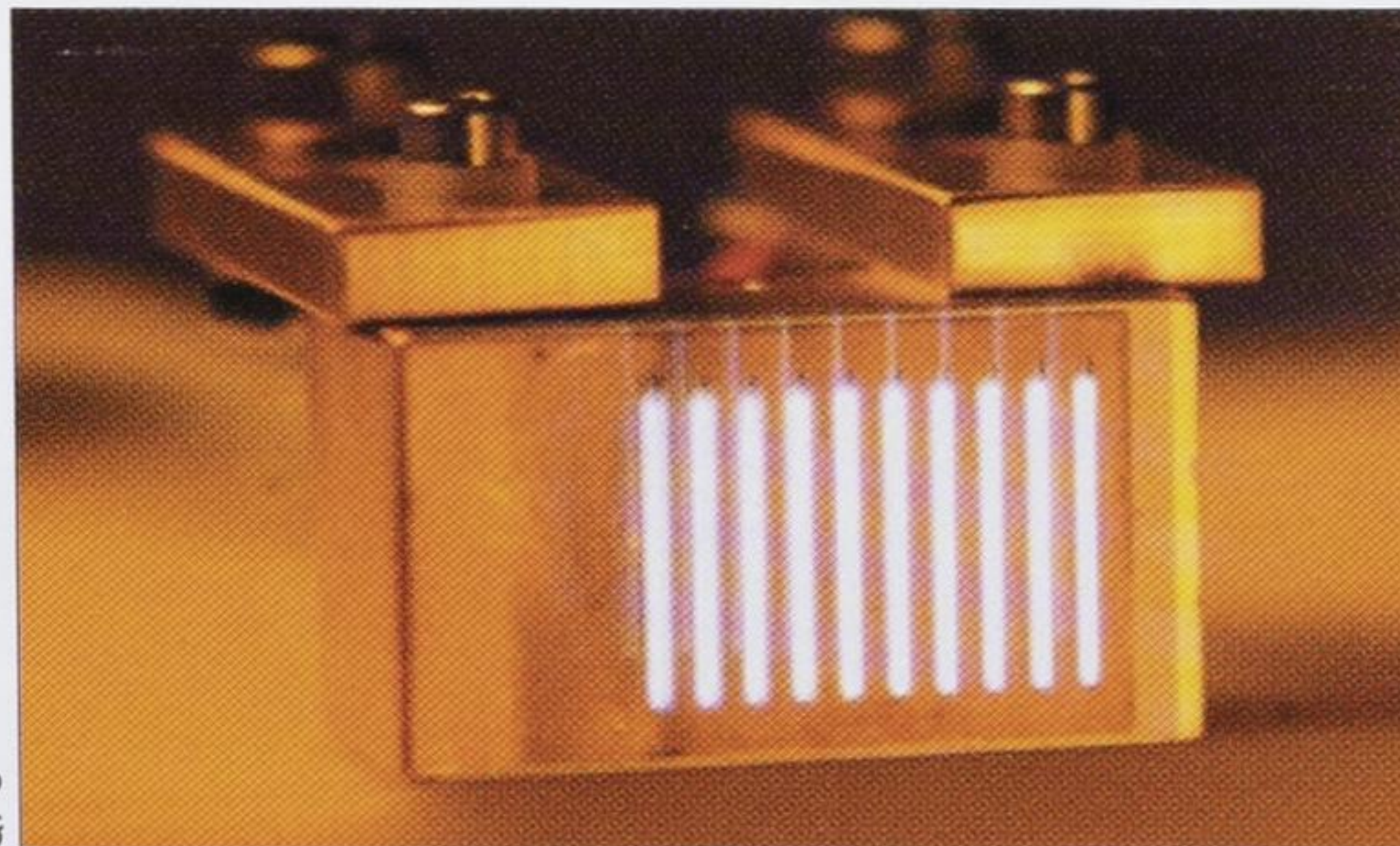
COMPOUND SEMICONDUCTOR

Three-Fives and Silicon Heterostructures

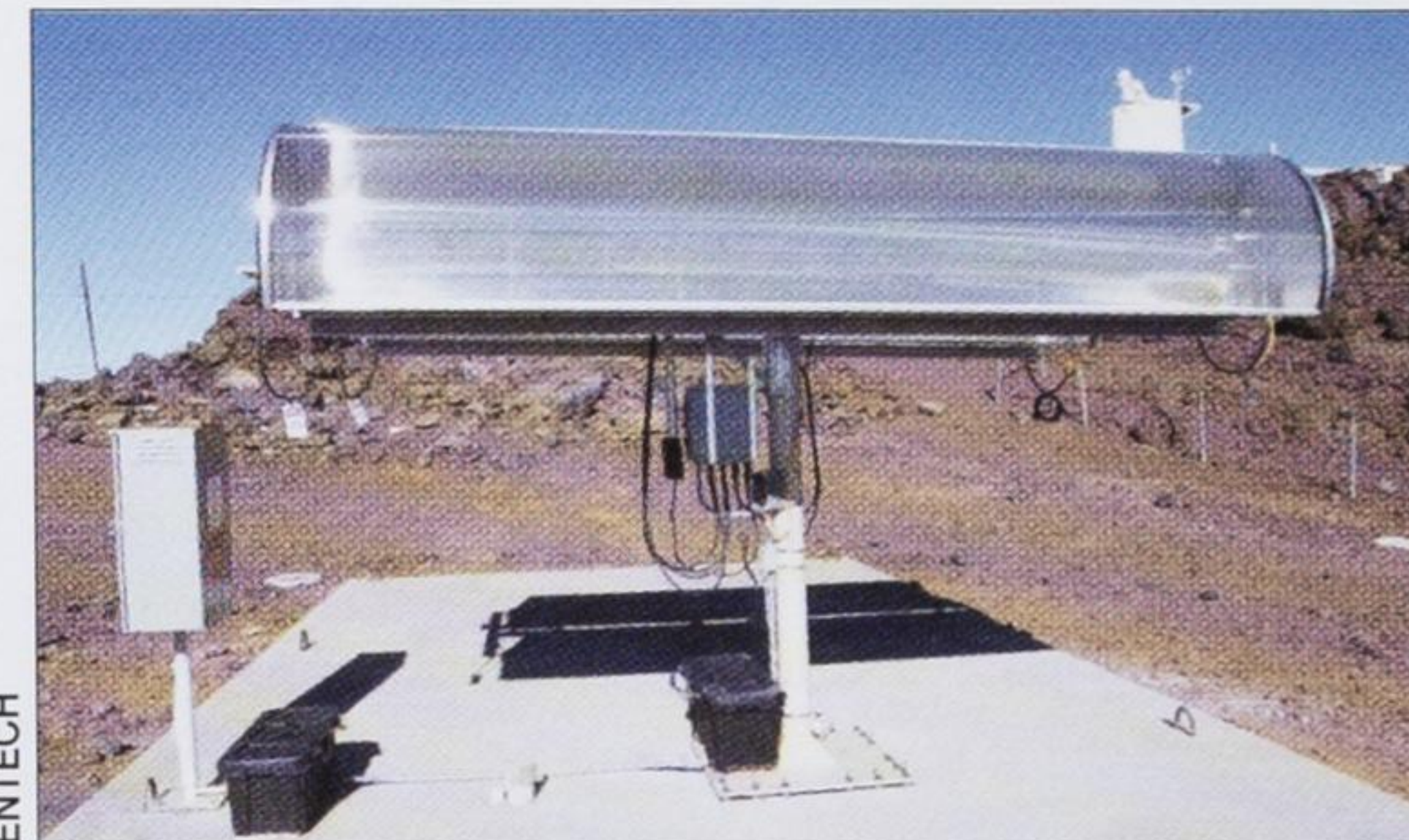
AUGUST 2004 VOLUME 10 NUMBER 7



This 22 ft high by 82 ft long casino display in China features 1.7 million LEDs **p6**



A US start-up company has made this 10 × 22 laser-diode array on a single wafer **p10**



A US team builds the first kilowatt-rated terrestrial triple-junction solar-cell array **p29**

NEWS

- 5** **Headline News** Procomp scandal engulfs Suntek... Thales and Alcatel form III–V research laboratory
- 6** **LED News** Epistar and Lumileds agree settlement... Lumileds and Aixtron tie up four-year deal
- 8** **GaAs & Wireless News** Teledyne set to acquire Celeritek's defense arm... RFMD establishes in-house packaging
- 10** **Fiber News** 40 Gbit/s link delivers error-free transmission in real-world trial... Kamelian searches for a buyer
- 13** **Opto News** Etched mirrors transform laser-diode-array output... Panasonic launches Blu-ray disc/DVD recorder
- 16** **News from Asia** Aixtron program elevates MOCVD's profile in China... Nichia imitates Intel with label guarantee
- 34** **Materials & Equipment** ATMI sells epitaxy group to International Rectifier

FEATURES

- 23** **Start-up produces blue LEDs using 'dismissed' technique**
The Fox Group has developed a hydride vapor-phase epitaxy technique that produces medium-brightness blue LEDs, based on AlGaIn/GaN structures, at a low cost, writes Tim Whitaker.
- 29** **Terrestrial triple-junction array generates kilowatt solar power**
A kilowatt-scale terrestrial solar-cell array that employs III–V-based triple-junction technology could spur the improvement of both space-based and terrestrial solar-energy systems.

COVER STORY: SILICON/GERMANIUM

- 18** **Next-generation LDMOS pushes limits of silicon base-station PAs**
Silicon LDMOS will continue to dominate the base-station power-amplifier market until an alternative technology can deliver higher performance at a lower price, writes Hamish Johnston.
- 21** **WiMax connectivity gives SiGe amplifiers the edge**
Price erosion and the emergence of new high-throughput standards are two of the big issues facing chip manufacturers in the wireless LAN market, says SiGe Semiconductor's Andrew Parolin.
- 26** **Germanium-on-insulator detectors could crack interconnect bottleneck**
Researchers at IBM say they have developed a method that enables the fast, efficient manufacture of photodetectors that are compatible with CMOS production. Michael Hatcher reports.

DEPARTMENTS

- 36** **Research Review** GaAs MBE and HVPE combination produces widely tunable IR source

ADVERTISING SECTION

- 24** **Suppliers Guide**
- 25** **Product Spotlight**
- 35** **Product Showcase**



Compound Semiconductor's circulation figures are audited by BPA International

On the cover: A research team from US chip giant IBM has developed GeOI photodetectors that could alleviate interconnect bottlenecks – see p26. Credit: IBM.

Editor Michael Hatcher
michael.hatcher@iop.org
Tel: +44 117 930 1013; Fax: +44 117 925 1942

Features editor Richard Stevenson
richard.stevenson@iop.org
Tel: +44 117 930 1192

Consulting editor Tim Whitaker
tim.whitaker@iop.org
Tel: +44 117 930 1233

Commercial manager Rebecca Griffiths
rebecca.griffiths@iop.org
Tel: +44 117 930 1032; Fax: +44 117 930 1178

Sales executive Luke Neel
luke.neel@iop.org
Tel: +44 117 930 1033; Fax: +44 117 930 1178

Publisher Sarah Chilcott
sarah.chilcott@iop.org
Tel: +44 117 930 1020

Senior production editor Teresa Ryan
Ad production Jackie Cooke/Joanne Derrick
Circulation Jackie King
Art director Andrew Giaquinto
Technical illustrator Alison Tovey
Publishing director Richard Roe

Subscriptions

Available free of charge to qualifying individuals working at compound semiconductor fabs and foundries. For further information visit compoundsemiconductor.net/subscribe. Subscriptions for individuals not meeting qualifying criteria: individual £82/\$139 US/€119; library £184/\$313 US/€267. Orders to Compound Semiconductor, WDIS, Units 12 & 13, Cranleigh Gardens Industrial Estate, Southall, Middlesex UB1 2DB, UK. Tel: +44 208 606 7518; Fax: +44 208 606 7303. General enquiries: compoundsemi@iop.org.



8476 total qualified circulation*
*May 2003 BPA audit statement

Editorial board

Mayank Bulsara AmberWave Systems (USA);
Andrew Carter Bookham Technology (UK);
Jacob Tarn Epistar/Gigacomm (Taiwan); **Ian Ferguson** Georgia Institute of Technology (USA);
Toby Strite JDS Uniphase (Poland); **Mark Wilson** Motorola (USA); **Dwight Streit** Northrop Grumman (USA); **Joseph Smart** RF Micro Devices (USA); **Colombo Bolognesi** Simon Fraser University (Canada); **Shuji Nakamura** University of California at Santa Barbara (USA)

©2004 IOP Publishing Ltd. All rights reserved.

US mailing information: *Compound Semiconductor* (ISSN 1096-598X) is published 11 times a year for \$139 by Institute of Physics Publishing, Dirac House, Temple Back, Bristol BS1 6BE, UK. Periodicals postage paid at Middlesex, NJ 08846. POSTMASTER: send address corrections to Compound Semiconductor, c/o PO Box 177, Middlesex, NJ 08846. US agent: Pronto Mailers Association Inc, 200 Wood Avenue, PO Box 177, Middlesex, NJ 08846.

Institute of Physics PUBLISHING

Editorial

Procomp troubles echo Enron, WorldCom scandals



If you thought that financial scandals at high-tech companies were a thing of the past, then think again. The mismanagement of the Taiwanese GaAs-device manufacturer Procomp Informatics has raised the spectre of the compound semiconductor industry's very own Enron-style disgrace.

Ironically, the Taiwanese authorities descended on Procomp chairwoman Sophie Yeh in the same week that US prosecutors took aim at Kenneth Lay, the former Enron CEO. Lay pleaded "not guilty" to 11 criminal charges, which include insider trading and wire fraud, while other senior Enron figures face a whole host of these and other accusations, including money laundering.

We'll have to wait and see whether the same fate awaits Yeh. While the scale of the alleged fraud at Enron and WorldCom may be of a different order of magnitude – Lay stands accused of making a personal profit of \$89 million through insider trading alone, whereas Yeh may have to fend off accusations that she wired a mere \$10 million to a personal bank account in the US shortly before seeking bankruptcy protection for Procomp – the *modus operandi* appears to have been similar. Though unproved at this stage, there are some in Taiwan's compound semiconductor community who suggest that Procomp may have invented revenues and imitated Enron by pretending to ship products to its own foreign subsidiary companies.

At a time when the III–V industry is finding its feet once more, Procomp investors appear to have been left exposed by financial mismanagement in the most scandalous fashion. The fall-out from the Enron scandal prompted a wave of similar confessions among other firms – notably telecommunications giant WorldCom – and led to the collapse of Andersen, Enron's auditor. Let's hope that the Procomp affair does not expose a similar picture in the compound semiconductor industry.

Michael Hatcher

Advertisers' Index

Aixtron	3	LED's 2004	32
AXT	IFC	Loomis Industries	4
Bandwidth Semiconductor	14	MBE – Komponenten	35
Bede Scientific Instruments	27	Nanosemiconductor	32
Compound Semiconductor Week 2004	12	Omicron NanoTechnology	15
DCA Instruments	11	Raboutet	8
Epimax	30	Riber	IBC
Groupe Arnaud	32	Rockwell Scientific	27
Henry Butcher	30	Rohm & Haas	17
IntelliEpi	15	Schwarzkopf Technologies	22
INTRINSIC Semiconductor	14	Shiva Technologies	15
k-Space Associates	30	Tecdia	7
Lake Shore Cryotronics	35	Thomas Swan Scientific Equipment	9
LayTec	35	Umicore Electro Optic Materials	28
		Veeco	OBC



AIXTRON

TECHNOLOGY

PRODUCTIVITY

SERVICE

PURE PLAY

One of your best investments won't come from a banker.

Performance stems from productivity. And with your investment in AIXTRON technology, you get a top quality CVD production system. Leading technology that fits your individual requirements. The aim of our work with you is to get the best out of the wafer: qualitatively and economically. For us, productivity is at the heart of all we do, leaving you free to concentrate on competing with the best products. Call us! And count on us. After all, the best return on your investment is at stake.

push your



PERFORMANCE

AIXTRON AG · Kackertstraße 15-17 · D-52072 Aachen, Germany · www.aixtron.com

Six Degrees of Separation

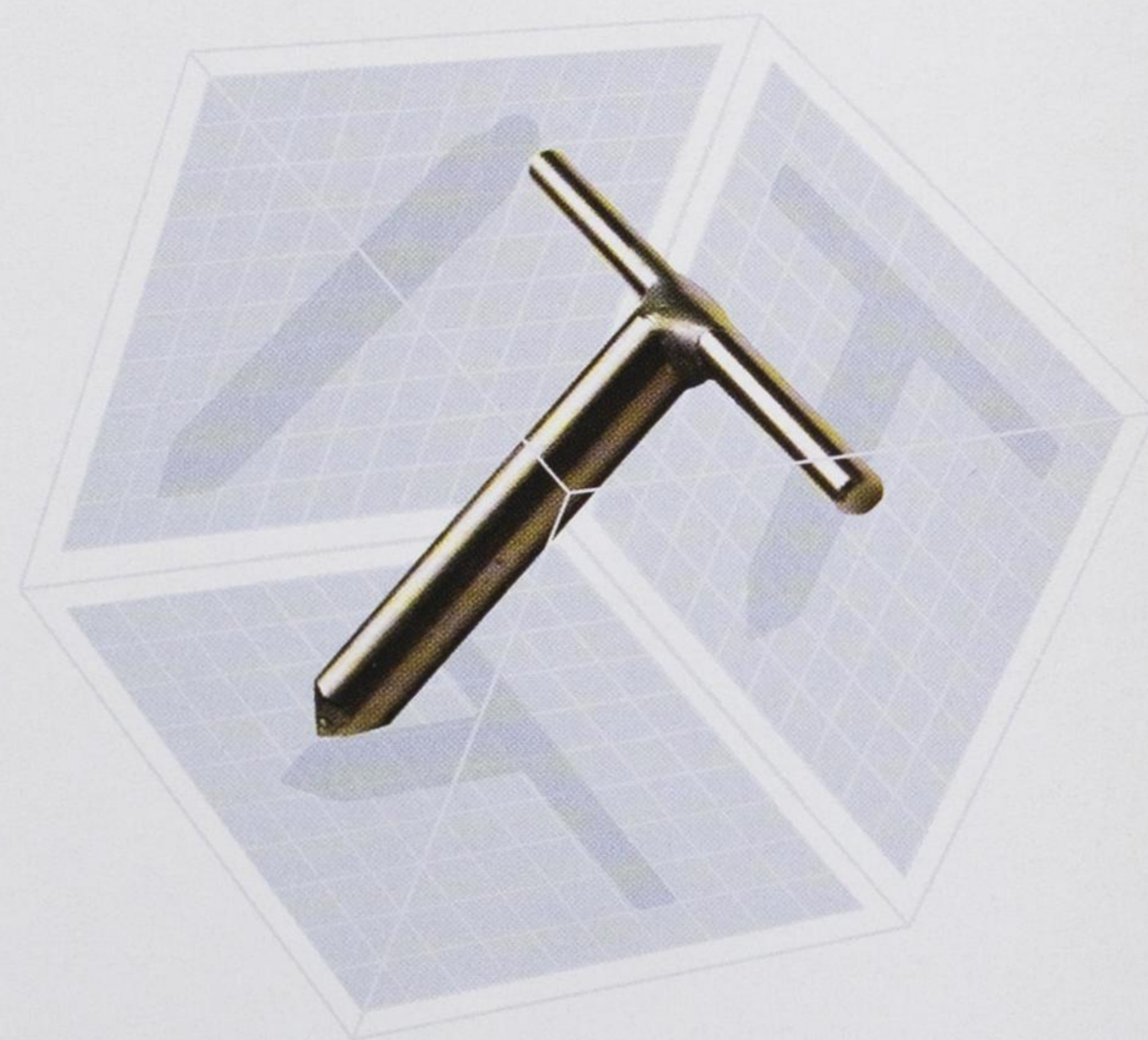
according to  **LOOMIS**

In engineering terms, a rigid object has six degrees of freedom.

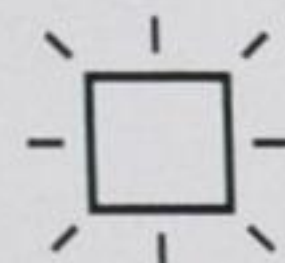
In this respect, the Loomis scribe tool is no different. What is different is the control that Loomis exercises over these six degrees to provide repeatedly optimal scribe lines and **perfect die separation**.

Loomis' patented scribe tool design and innovative manufacturing processes create scribe alignment and precision that results in perfectly controlled scribing and breaking at the crystal and molecular level.

Lines created with Loomis diamond scribe tools break without debris generation leaving edges on the separated dice with integrity and strength.



Success starts with a perfectly aligned scribe.



Natural cleaving creates clean efficient devices.



The "T-bar" construction allows for radial orientation within the patented scribe tool holder to ensure perfect alignment of the scribe tool travel in the separation channels.



The new LSD-200 large-format scribe dicing machine.

Procomp scandal engulfs Suntek

By Michael Hatcher

Sophie Yeh, founder and chairwoman of Taiwanese GaAs manufacturer Procomp Informatics, has been investigated over “missing” company assets worth NT\$6.3 billion (\$186 million). The investigation was prompted after Yeh sought bankruptcy protection for the company shortly before a bond repayment was due, despite Procomp apparently having the cash to make the payment.

The fall-out from the Procomp scandal may force its sister company Suntek Compound Semiconductor out of business. Suntek, which was founded in 2000, ran a foundry operation and had claimed to be Taiwan’s biggest manufacturer of GaAs ICs.

According to a local source in Taiwan, Suntek was due to be closed by the end of July. “Suntek does not have enough cash in hand to sustain the operation,” the source told *Compound Semiconductor*.

However, the effect on another firm that Procomp is involved with – ZnSe white LED specialist Supra Opto – does not appear to be as bad. According to a Supra employee who wished to remain anonymous, Supra would not be closed as it is independent of Procomp “both financially and technically”.

Procomp has reportedly laid off 40 staff from its MBE and MOCVD operations located in Hsinchu Science Park, with more redun-

Procomp problems

- Procomp seeks to raise \$117 million through share issue.
- June 16: Sophie Yeh blames failed share issue as bankruptcy protection is sought the day before a bond repayment is due, despite Procomp apparently having the funds to make the payment.
- June 27: Taiwan press reports Yeh detained and investigated over “missing” company assets and insider trading.
- Early July: Procomp makes widespread lay-offs.
- End of July: Suntek rumored to be close to shut-down.

dancies expected to follow. *Compound Semiconductor* has also learned that Procomp announced plans to lay off all 400 of its employees, before rehiring approximately 200. The firm is thought to have some cash available to make severance payments and to continue its activities in some business segments.

The scandal erupted when the GaAs chip manufacturer sought bankruptcy protection on the day before it was due to make a corporate bond repayment of NT\$3 billion. Procomp initially blamed its cash-flow problem on an aborted share issue that raised only half the

expected \$117 million. The bankruptcy protection move came as a surprise to investors, however, who pointed to the NT\$6.3 billion in liquid assets on Procomp’s books.

Following that, Yeh was detained amid accusations of illegally allocating investors’ money and insider trading.

In echoes of the Enron and WorldCom scandals that rocked corporate America in recent years, sources within Taiwan’s compound semiconductor community say that as much as half of Procomp’s “missing” assets may never have existed and were the result of false accounting.

“Procomp shipped out products to its branch company in the US with falsified invoices,” claimed one source. “In other words, they did not have real sales and did not ship the products at all.” Whether or not this is the case is yet to be proved and is a matter for the Taiwanese courts to decide.

The effect on the wider compound semiconductor community appears to be mixed. While there is a worry that the Procomp scandal will have a negative impact in terms of attracting venture capital, the demise of Suntek could allow rival companies, such as WIN Semiconductors, to pick up extra business. According to WIN, its business is showing a strong increase and the foundry is working near to capacity (see p16 for more details).

Thales and Alcatel form III-V research laboratory

By Tim Whitaker and Richard Stevenson

Thales and Alcatel have created a joint research laboratory in Paris, France, dedicated to III-V semiconductor technologies and targeting applications in telecommunications, defense, space and security.

The laboratory, which will be known as the Alcatel-Thales III-V Lab, will reinforce both companies’ expertise in the field of optoelectronic and microelectronic components based on III-V technologies. Thales (formerly Thomson-CSF) serves the aerospace, defense and information technology industries and Alcatel is a supplier of telecoms equipment.

Laure Reinhart, Thales’ director of technical communication, told *Compound Semiconductor* that the lab will employ about 100 scientists drawn almost exclusively from Thales and Alcatel’s current employees.

Research is already under way, and the lab will be fully established by October.

The research program includes the development of Thales products used in warfare and radar applications, such as GaN-based high-power amplifiers; optoelectronic devices including photodetectors and high-power laser diodes; as well as the development of Alcatel’s 40 Gbit/s transceivers.

Located in the heart of the French Optics Valley, the lab is located on two sites: one in Marcoussis, within Alcatel’s French research center, and the other in Palaiseau, on the campus of the École Polytechnique, where Thales’ future research center will be located. The lab’s equipment includes: MBE, gas-source MBE and MOCVD reactors for growth on substrates including GaAs, InP and SiC; and cleanrooms with processing facilities such as optical and electron-beam lithography. Modeling and sim-

ulation will also take place on the site.

In May last year, Alcatel sold its Alcatel Optonics business unit – which manufactured fiber-optic components – to the US company Avanex. However, Reinhart describes Alcatel’s stake in the joint research effort as one of “strategic importance to anticipate the market and influence technology moves”.

Thales is an established supplier of high-power laser diodes, as well as being a partner with the European Aeronautic Defence and Space company in the GaAs MMIC foundry United Monolithic Semiconductors.

A consortium called Groupement d’Interêt Economique, held equally by Thales and Alcatel, will manage the new laboratory. For fundamental research, the Alcatel-Thales III-V Lab will draw on existing partnerships, notably with the Centre National de la Recherche Scientifique.

Epistar and Lumileds agree settlement

The pending litigation between rival LED manufacturers Lumileds and Epistar relating to AlGaInP LEDs has been settled.

The allegations and counter allegations centered on US patent 5 008 718, which is owned by Lumileds. Although the exact terms of the settlement were not disclosed, the parties have agreed to dismiss all claims and counterclaims in the lawsuit that Lumileds initially filed against Epistar in August 2003.

As part of the settlement agreement, Lumileds has granted Taiwan-based Epistar a limited license to use the technology disclosed in several patents relating to absorbing-substrate AlGaInP LEDs.

The patent in question relates to the use of a transparent GaP window layer to enhance the brightness of AlGaInP LEDs. Several

years ago Lumileds had a dispute over the same patent with another Taiwanese manufacturer, United Epitaxy Company, which was resolved in October 2001.

"We are pleased that Epistar has acknowledged the value of this intellectual property," said Mike Holt, Lumileds' chief executive officer. "Lumileds holds more than 100 patents in the area of high-brightness LEDs and continues to pioneer the development of solid-state lighting technology. Holt added that Lumileds will "continue to enforce" its intellectual property rights.

Meanwhile, nitride LED and laser manufacturer Nichia has filed for a preliminary injunction order against E&E Japan – the Japanese affiliate of Epistar and Everlight.

Nichia claims that E&E Japan is infringing

Japanese patent JP 2927279 – one of Nichia's white LED patents. More specifically, it refers to the semiconductor device and phosphor combination that produces white emission.

According to Nichia's statement, the white LEDs sold by E&E Japan under the model numbers 99-215UWC/TR8 and 67-21UWC/S400-A4/TR8 infringe on this patent.

E&E Japan is the new name for Epistar Japan and Everlight Japan, a joint holding between the two Taiwanese companies. As well as white LEDs, it sells infrared LEDs, laser diodes, infrared transceiver modules, PIN photodiodes and more.

The latest infringement claim came just two weeks after Nichia said that it was involved in talks with Taiwanese LED manufacturers that might lead to a licensing agreement.

Lumileds and Aixtron tie up four-year deal

Lumileds has signed a four-year supply deal with MOCVD equipment supplier Aixtron as it looks to ramp up its epitaxial system capacity. According to Aixtron, the agreement represents the biggest deal that the Aachen-based company has ever signed.

The "significant" number of planetary reactors ordered by Lumileds will be used to make its Luxeon high-brightness LEDs.

- Lumileds has also agreed a distribution partnership with Japan-based Marubeni Corporation. Marubeni will market Lumileds' InGaN and AlGaInP chips in Japan, targeting automotive lighting, cell-phone displays, signs and pachinko gaming machines.

The company's Japanese sales network will target electronics firms making 5 mm, 4-pin, surface-mount and chip-on-board LEDs. "This is part of a larger strategy to build market share in Japan," said Norihide Yamada, general manager of Lumileds Japan.



Daktronics of Brookings, South Dakota, has completed the manufacture and installation of more than \$2 million worth of full-color LED displays for the interior of the new Las Vegas Sands Macao Casino in Macao, China. The integrated system includes 19 individual displays. Daktronics provided one large curved ProStar VideoPlus display measuring approximately 22 feet high by 82 feet long (6.7 × 25 m). The display, which overlooks a vast gaming floor, is one of the largest indoor LED displays in any casino in the world. More than 1.7 million individual red, green and blue LEDs in the display illuminate to present video images, animation and graphics.

LRC-Evident collaboration develops white quantum-dot LEDs

The Lighting Research Center (LRC) at Rensselaer Polytechnic Institute is to work with Evident Technologies in an attempt to develop and demonstrate new, efficient, white LEDs incorporating quantum-dot nanomaterials.

Material containing cadmium selenide quantum dots will be used as the down-converter in combination with GaN-based LED

chips to fabricate white LEDs.

Evident Technologies, which like the LRC is based in Troy, NY, will produce quantum-dot nanomaterials with tunable color properties. Clinton Ballinger, CEO of Evident Technologies, says that the nanomaterials will enable the production of white-light LED-based illuminating systems with better color

qualities than current white-light LEDs.

According to Nadarajah Narendran, director of research at the LRC, quantum dots offer the potential to create continuous-spectrum white light. The colors of objects illuminated by such sources appear truer than those illuminated by current white-light LEDs (i.e. the sources have a high color-rendering index).



Japanese Quality Standard In Diamond Scribing

Already the #1 scribing company in Japan,

TECDIA is aiming to be the world's best.

A track record of 28 years answers your

questions. Precision engineering and

techniques answer your requirements.

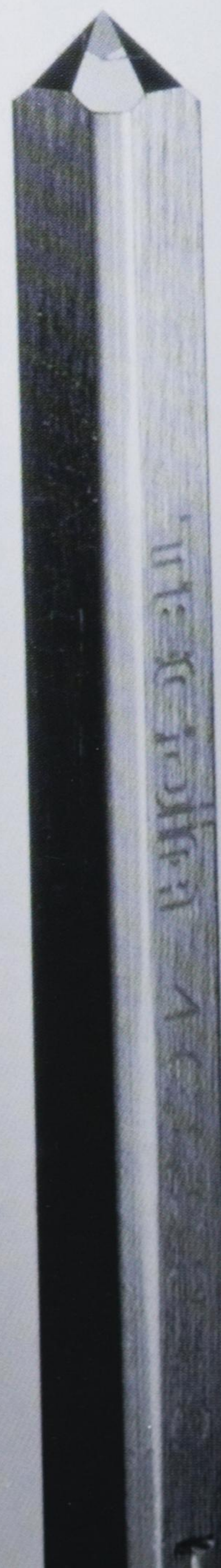
And our #1 quality cutting tools answer

your demands. In every aspect of the cutting

industry, TECDIA has the answers for you.

TECDIA
knows the answer

TECDIA CO., LTD. PO. Box 1019, Sunshine-60, Toshima-ku, Tokyo, Japan 170-6020
TEL: 81-3-3988-3500 FAX: 81-3-3988-1706 URL: <http://www.tecdia.com/japan>
E-MAIL: tecdia@tecdia.co.jp



Teledyne set to acquire Celeritek's defense arm

Teledyne Technologies, through its subsidiary Teledyne Wireless, is to acquire Celeritek's defense electronics business – based in Santa Clara, CA – for \$33 million in cash.

Celeritek manufactures GaAs-based RF and microwave components and subassemblies for electronic warfare, radar, and other military applications. On completion of the acquisition, Teledyne will relocate the business to Mountain View, CA, the home of its own defense division Teledyne Microwave.

Teledyne sells traveling-wave vacuum tubes that are used to generate high-power microwave and millimeter-wave signals. Acquiring the Celeritek business will expand Teledyne's microwave-product portfolio to include subsystems based on solid-state components as well as vacuum technology, and

guarantees a supply of GaAs components.

Teledyne Technologies expects the acquisition of Celeritek's defense electronics division, which racked up sales of \$19.7 million for the year ended March 31, to break even this year.

"This acquisition will allow us to offer a broader portfolio of microwave products and capabilities. We expect to obtain synergies through the consolidation of Celeritek's defense business with our military microwave subassembly operations in Mountain View," said Robert Mehrabian, Teledyne's CEO.

Tamer Hussein, Celeritek's CEO added: "The divestiture of our defense electronics subsystems business will allow us to focus on designing and manufacturing high-performance GaAs semiconductor components."

RFMD establishes in-house packaging

RF Micro Devices (RFMD) of Greensboro, NC, a provider of RFICs for wireless communications, has established an assembly facility at its Beijing, China, operation to provide internal module-packaging capabilities.

RFMD is aiming for the new facility to be fully operational in the December quarter and to contribute to earnings in calendar 2005. The plant will supplement existing assembly capacity, which RFMD says it sources from the world's leading assembly houses.

The company believes its assembly facility will decrease manufacturing costs, provide for guaranteed assembly capacity and enable reductions in cycle time.

In addition, RFMD thinks that housing the new assembly operations in its existing Beijing facility will significantly strengthen its position as a one-stop shop for semiconductor assembly, test and tape and reel.

RFMD expects the facility to contribute to the firm's continual gross-margin improvement plan. Other recent initiatives include converting from 4 to 6 inch GaAs wafers, improving test yields, achieving higher levels of integration and developing its relationship with Jazz Semiconductor.

"In our latest fiscal year, the structural improvements we made throughout our supply chain enabled cycle-time reductions of more than 40%, which helped us to meet incremental customer demand and improve inventory turns," said Jim Stilson, corporate vice-president of operations at RFMD.

In brief

- **Sirenza Microdevices**, a designer and supplier of high-performance RF components for communications applications, has introduced the SLM-20T low-noise amplifier (LNA) module. The module is a fully integrated, high-performance LNA offered in a standard surface-mount package. The design uses GaAs PHEMT technology and operates in the 1.7–2.2 GHz range.

- **Eudyna Devices** has introduced a family of five 28 V, low-current GaAs FET devices for use in digitally modulated base-station applications. Ideally suited for W-CDMA and multicarrier personal-communication service base-station amplifiers, these devices offer long-term reliability, ease of use with partial input and output matching, and an overall cost-effective solution, says the company.

Manufacturer
of Molybdenum
Components for MBE.

Specialized Cleaning
& Degassing available

RABOUTET S.A.

250, av. Louis-Armand - Z.I. des Grands-Prés
B.P. 31 - F 74301 CLUSES Cedex - FRANCE
Tel. : 33 (0)4 50 98 15 18 - Fax 33 (0)4 50 98 92 57
e-mail : info@raboutet.fr - http://www.raboutet.fr

Representative office in : BOSTON
Component Sources Int'l, Inc.
Steve DOODY - Tel. (508) 485 - 5999
e-mail : steved@compsources.com

Anadigics patents circuit that protects GSM PAs

RFIC manufacturer Anadigics has been granted US patent number 6 580 321 for a new active clamping circuit that protects GSM power amplifiers (PAs) from damage in extreme operating conditions. The new clamping circuit is simpler than previous designs and takes up less board real estate.

"This active clamping circuit is simple and compact yet protects PAs by reducing the gain of the amplifier when the output voltage becomes too high," said Charles Huang, executive vice-president and chief technical officer at Anadigics. "This patent provides another example of how we are continuing to develop innovative technology to further strengthen our portfolio of PA solutions."

"Our line of GSM PAs continues to grow market share by providing customers with exceptional efficiency, while ensuring that the product remains reliable, even under extreme operating conditions," he said.

PAs in mobile phones can be subjected to extreme operating conditions that can lead to

problems, including PA failure. For example, a mismatch between the impedances of the mobile-phone antenna and the PA circuit can cause the voltage standing wave ratio to increase. If in turn this causes the voltage level at the output of the PA to increase to a dangerous level, the result can be failure of the amplifier, rendering the mobile phone useless.

To prevent PA failure, active control circuits may be added to the device that can adjust its gain to keep it within safe operating limits. Most other control circuits are highly complex, expensive and take up valuable space on the IC or printed circuit board.

Anadigics' active clamping circuit for multistage PAs includes a feedback circuit that affects the gain of the amplifier. The feedback circuit connects the PA's output via a filter and a clamping transistor to the input of at least one stage of the PA. The output fed to the filter and clamping transistor can be tapped from one or more diodes belonging to a diode stack connected to the PA's output.

Skyworks Solutions nets Quanta's EDGE platform business

RF subsystem maker Skyworks Solutions, based in Woburn, MA, says that Taiwan-based Quanta Computer will use its Helios EDGE-based RF subsystem in new products to be launched in 2005. Quanta is an original development manufacturer used by many top-tier handset suppliers around the world.

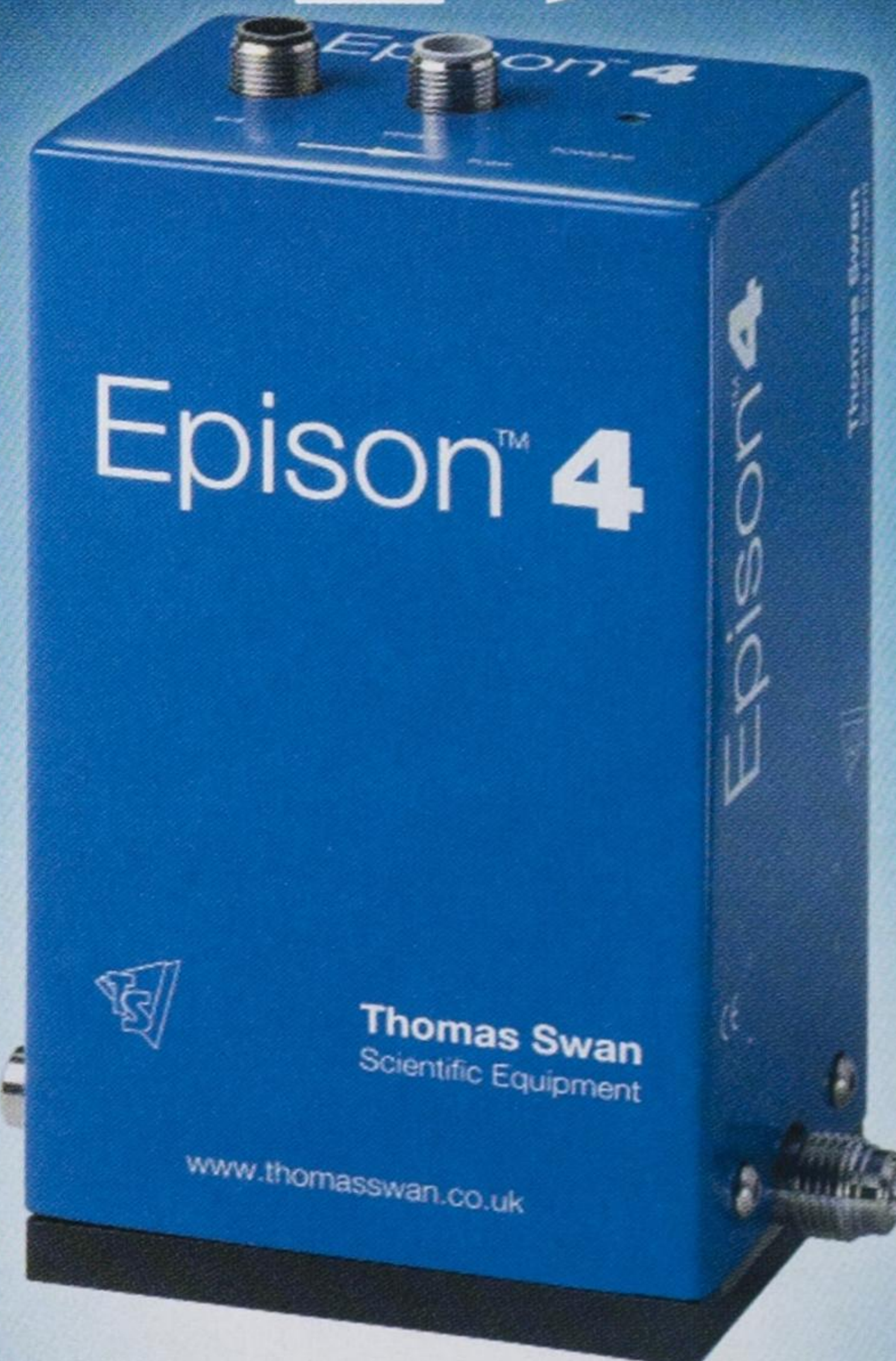
"As a high-volume supplier of field-proven GPRS power-amplifier modules and direct-conversion transceivers to Quanta over the years, Skyworks is our natural choice as we aggressively migrate to EDGE platforms," said Georges Bouloy, senior vice-president of Quanta's wireless business unit.

According to market-research firm Visant Strategies, the total number of EDGE users is expected to surpass 130 million within five years. Meanwhile, the chipset market for EDGE components in wireless handsets is expected to approach \$2 billion by 2009, with more than \$31 billion worth of GSM/GPRS/EDGE-enabled handsets sold worldwide.



Michel Mayer, Freescale Semiconductor's CEO, will be disappointed with the firm's initial public offering of 121.6 million shares on July 16. The spin-off of Motorola's chip-making unit raised only \$1.58 billion – far less cash than Freescale's earlier estimate of \$2.37 billion – with the debut-share price adjusted from \$17.50–19.50 to \$13. The disappointing price mirrored the general trend of the sector; for example, the Philadelphia Stock Exchange semiconductor index fell by more than 15% during the first two weeks of July.

new 4yo



- The Next Generation of an Industry Standard: Epison 4 OM Gas Concentration Analyser
- Improved accuracy, extended to lower concentration, better signal to noise ratio
- Optimised design – integrated ultrasonic cell and control unit
- DeviceNet and Profibus fieldbus communications for system integration

Thomas Swan
Scientific Equipment Ltd
Buckingway Business Park
Swavesey
Cambridge CB4 5FQ UK

t +44 (0)1223 519444
f +44 (0)1223 519888
e sales@thomasswan.co.uk
www.thomasswan.co.uk



Thomas Swan
Scientific Equipment

A member of the AIXTRON group of companies

40 Gbit/s link delivers error-free transmission in real-world trial

The world's first ultralong-haul (ULH) 40 Gbit/s network has been demonstrated, claims a collaboration between US companies MCI, Ciena and Mintera. The 1200 km link is four times as fast as the highest-speed ULH routes deployed today.

The trial was conducted on MCI's 1200 km optical network that runs between Sacramento, CA, and Salt Lake City, UT. This route was chosen because it contains a mixture of fiber – including dispersion-shifted fiber and singlemode fiber – illustrating MCI's claims of real-world scalability of its network.

The 40 Gbit/s system was installed in less than an hour. It then performed error-free on the same optical fibers already carrying 10 Gbit/s transmission throughout the trial.

This rapid installation demonstrates “plug and play” capability for the 40 Gbit/s system,

said the team. “No longer will customers have to wait months for a complete network build to receive bandwidth-intensive next-generation services,” is MCI's claim.

“This sets the stage for MCI customers to easily migrate to bandwidth-intensive business applications like Web services, multimedia content distribution, grid computing and storage networking,” said Jack Wimmer, MCI's vice-president of network architecture and advanced technology.

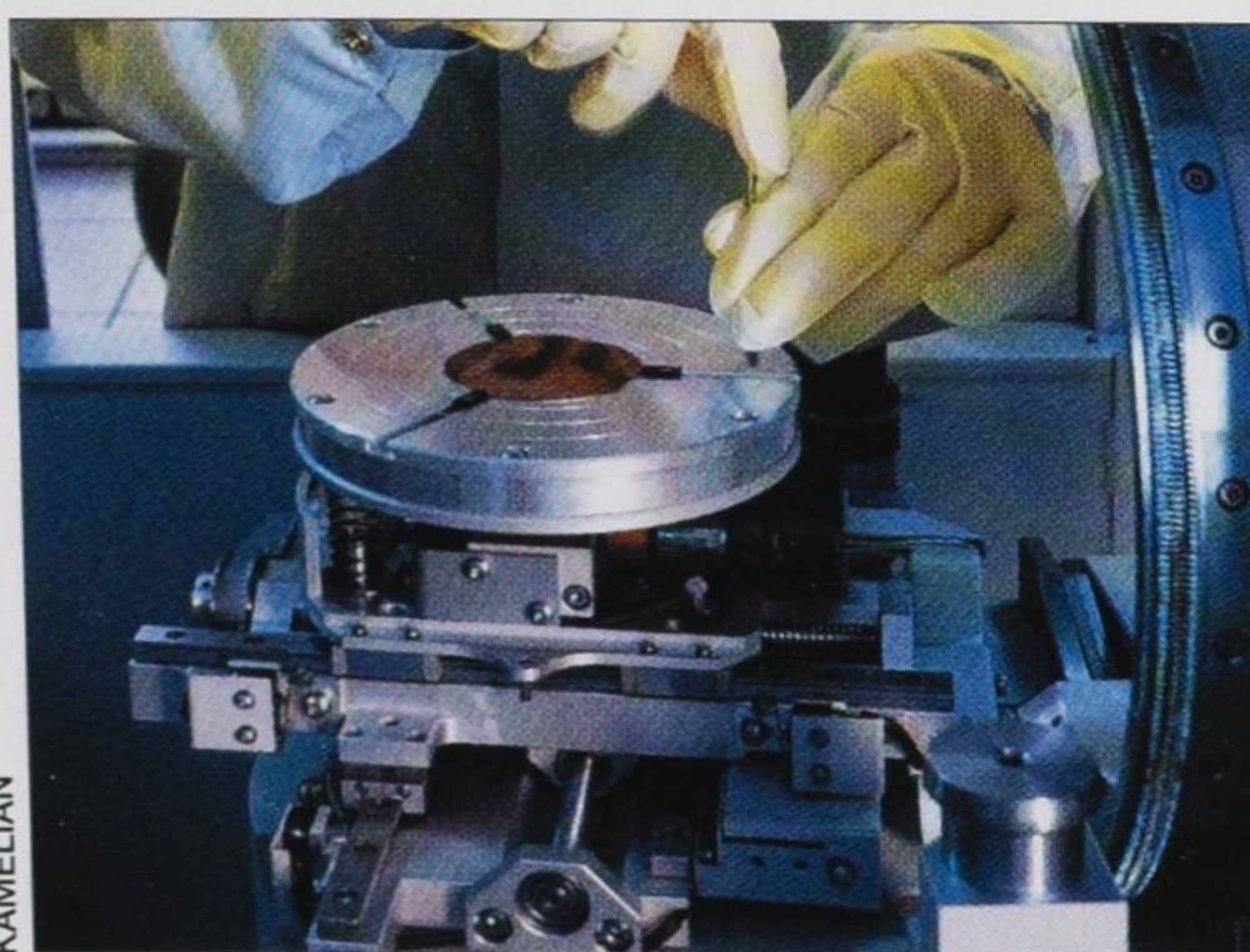
Mintera president and CEO Terry Unter commented that the 40 Gbit/s system “will allow service providers, such as MCI, to gain a significant bandwidth boost from installed infrastructure, thus delaying capital investments in equipping new dark fibers and, at the same time, permitting the deployment of new, bandwidth-intensive services”.

Kamelian searches for a buyer

Kamelian, a UK-based supplier of low-cost amplification products for optical systems, has appointed administrative receivers.

The firm will continue to trade until it finds a purchaser, according to Graham Bushby of Baker Tilley, one of the appointed receivers.

Kamelian received \$6.7 million in second-round funding and a new investor in Japanese optics specialist Hoya in April 2003, which it believed would enable it to break even by 2005. The company had also re-located from its original base in Glasgow, Scotland, to Oxford, where it had opened an InP-component manufacturing plant in 2002.



For sale: Kamelian specialized in InP-based semiconductor optical amplifiers.

Oki makes 160 Gbit/s optical transmitter

Oki Electric, based in Tokyo, Japan, claims to have developed the world's first single-channel optical transmitter and receiver able to deliver data at 160 Gbit/s over a distance of 640 km (about 400 miles).

Oki developed the transmitter, which is capable of sending the equivalent of four movies in a single second, using optical time-division multiplexing (OTDM) technology.

The OTDM module uses a free-space interconnected module structure for its delay-line

circuit, enabling four 40 Gbit/s optical modulators to work in parallel.

“This transmitter will make an impact not only in the telecommunication industry, but also in digital-movie distribution and the network computing industry,” said Harushige Sugimoto, chief technology officer at Oki.

The company plans to ship the transceiver to the worldwide market from 2005 for use as a research tool. It also aims to supply a commercial version of the 160 Gbit/s core communication system in the future; practical application is expected from 2010.

Oki demonstrated the transmitter at InterOpto '04 in Japan last month.

In brief

● Optoelectronic chip and subsystem manufacturer **Bookham Technology** plans to switch its corporate home from the UK to the US. This would mean that the firm's common stock would no longer be listed on the London Stock Exchange.

“The move represents a natural next step in the company's strategy...as a leading supplier of optical components and subsystems,” said Bookham's board.

The firm believes that the move will position it closer to end-users and help it to manage its global operations. Bookham says that it will be able to compete on an equal footing with rival suppliers – who are mostly US based – for investment and acquisitions.

The company says it will retain its technology base in the UK and will continue to invest in its UK facilities in Paignton and Caswell.

● David Clark, president and CEO of Canadian InP chip developer **MetroPhotonics**, has resigned. Citing personal reasons for the decision, Clark's departure was effective as of June 30. Clark had been president and CEO of the Ottawa-based company since April 2002.

Current chief technology officer Adrian O'Connell has been appointed acting chief operating officer and president. MetroPhotonics recently secured CDN\$7.7 million (\$5.7 million) from Technology Partnerships Canada to help develop advanced photonic ICs.

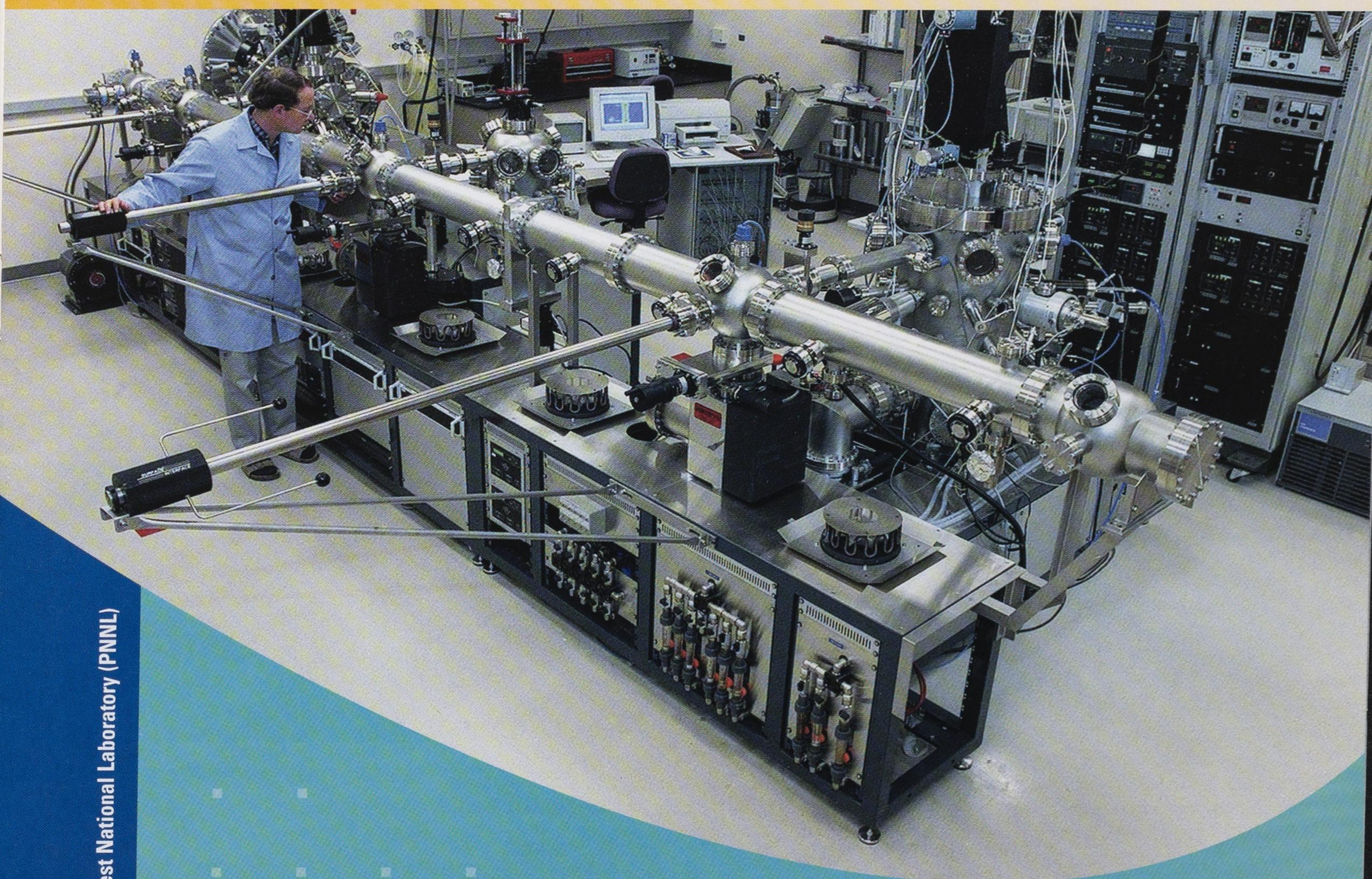
In December 2003 the firm signed a deal with Mitsubishi Corp, which now markets MetroPhotonics's products in Japan.

● **Avalon Photonics**, based in Zurich, Switzerland, has launched its Premium AVAP-850SM single longitudinal and lateral mode 850 nm VCSELs. The firm is a supplier of singlemode and multimode VCSEL chips, arrays and subassemblies for sensing and datacom applications.

The new lasers are designed mainly for sensing applications, offering: singlemode optical power of almost 2 mW; “extraordinary” spectral purity without mode hops; a stable Gaussian-beam profile without modal noise; a wide wavelength tuning range of more than 2 nm; and low electrostatic damage (ESD) sensitivity with ESD threshold voltages of up to 300 V, claims Avalon.

Spintronics Research

Proven Technology for Demanding Materials



Courtesy: Dr. Scott Chambers, Pacific Northwest National Laboratory (PNNL)

From spintronics research to GMR device production DCA thin film deposition systems are leading the way forward. Through our expertise in Molecular Beam Epitaxy, UHV sputtering, Ion Beam and Pulsed Laser Deposition we can provide technology for the most demanding thin film processes. Whether it is for custom design R&D system or a turn-key production system DCA has the right solution.

For your nearest representative
please visit our web site at: www.dca.fi
or email us at: info@dca.fi

DCA
INSTRUMENTS

COMPOUND SEMICONDUCTOR WEEK 2004

**October
24-28, 2004
Monterey,
California,
USA**



Two technical conferences One exhibition

A key event in the compound semiconductor conference calendar for 2004

The organizers of IEEE Compound Semiconductor IC Symposium (formerly IEEE GaAs IC Symposium) and CS-MAX are joining forces to bring you an event with unrivaled scope in the compound semiconductor industry.

To find out more about exhibiting or registering for Compound Semiconductor Week 2004, please visit compoundsemiconductor.net/CSWEEK-2004, or contact Harry Kuemmerle at csweek@vipmeetings.com

Gold Sponsors



Official Publication



Analyst Sponsor



Etched mirrors transform laser-diode-array output

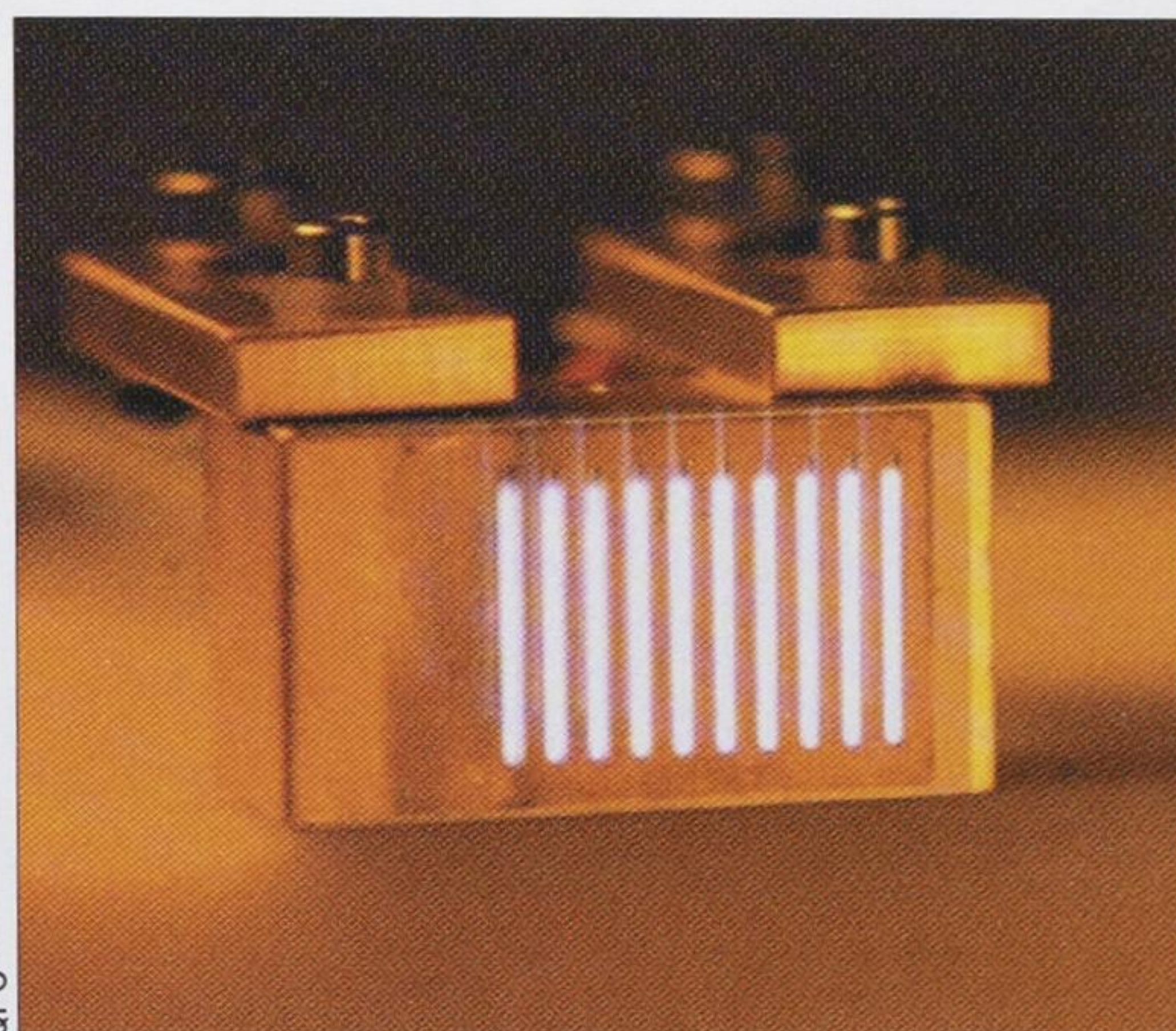
By Oliver Graydon

Compact laser-diode arrays that emit more than 1 kW and are far easier and cheaper to package than current modules could be the result of a new technology being pioneered by a US start-up. Quintessence Photonics Corporation (QPC) in California claims to have developed 2D surface-emitting-diode arrays that are made from a single piece of semiconductor.

The Los Angeles-based firm, which was founded in November 2000, has demonstrated a monolithic semiconductor chip that contains a 3×25 array of laser diodes and emits more than 100 W of continuous-wave power. The firm says that the technology is scalable to produce arrays that emit more than 1 kW.

In contrast, high-power diode arrays on the market today emit a few hundred watts and are made from a stack of discrete, edge-emitting bars (a strip of semiconductor wafer that contains up to 25 individual laser diodes), which are soldered together in series. The drawback of this approach is that the bars have to be cleaved and are difficult to connect together, package and cool. As a result, the stacks tend to be expensive and are difficult to scale up to higher powers. They are also prone to unpredictable failure at high power, often due to the catastrophic optical damage of the diodes' light-emitting facets.

QPC seems to have come up with an ingenious solution to the problem. When making its wafer of edge-emitting laser diodes it etches a series of mirrors angled at 45° next to the diodes to reflect the light from the surface of the wafer. Consequently, 2D arrays of laser diodes can be made from a single piece of semiconductor without the need for cleaving



This QPC prototype contains a monolithic 2D array of 10×22 laser diodes. Each of the 10 stripes is effectively a laser bar with the light output reflected from the surface of the semiconductor by a 45° angled mirror.

the wafer into a series of discrete bars.

One company that's certainly impressed is Pro-Lite Technology, the distributor of QPC's products in the UK and Ireland. It believes that the development could pave the way for cheaper, compact, easy-to-cool diode arrays.

"As the light is now coming out of the surface you can cool through the bottom of the wafer, which is far easier," explained Peter Blyth from Pro-Lite. "The other fantastic benefit is that because the diodes are not cleaved, their facets are never exposed to the environment. This removes the risk of problems caused by contamination or oxidation."

QPC says that it plans to demonstrate direct diode welding before the end of the year with its new devices. However, it is not clear when they will be commercially available.

APA Optics focuses its manufacturing on custom devices

APA Optics, the US-based manufacturer of GaN- and AlGaIn-based UV detectors, is to stop making standard detectors and will concentrate on making custom devices.

The action has been taken because standard GaN and AlGaIn detectors are now available much more cheaply from non-US suppliers. Up to 10 positions in APA's current workforce of 53 will be made redundant as a result.

"We will only perform MOCVD growth and processing of custom AlGaIn detectors that are not routinely available from outside resources," said Peter Nussbaum, APA's manager for GaN products. "These custom detectors will be packaged by our off-shore partners and/or suppliers," he added.

While phasing out growth and processing operations at its Blaine facility and its packaging operations in Aberdeen, South Dakota, APA is leasing space in Veeco Compound Semiconductor's process-integration facility, where it plans to make detectors in the future.

The Veeco facility is located in White Bear Lake, Minnesota, near to APA's Blaine office, and the two companies have agreed a three-year lease. APA says that the MOCVD system housed at Veeco will be sufficient for its material-growth requirements once fully operational. The reactor can grow material on six 2 inch wafers simultaneously. Operating the MOCVD machine at Veeco will allow APA access to a range of characterization tools.

APA also makes components for fiber-optic communications applications.

● Veeco Instruments launched its 15 000 sq. ft process-integration facility last year. The plant houses MBE and MOCVD compatibility for both III-IV and II-VI devices.

Panasonic launches Blu-ray disc/DVD recorder

Matsushita Electric Industrial, based in Osaka, Japan, and best known for its Panasonic-brand products, has unveiled the DMR-E700BD – a combined Blu-ray disc and DVD recorder.

The company claims that the model is the world's first DVD recorder that supports single-side, dual-layer Blu-ray discs with a maximum capacity of 50 GB.

The DMR-E700BD can record 4.5 hours of digital high-definition (HD) programming

or up to 63 hours of analog programming. It supports both DVD-RAM and DVD-R discs, so users can choose the most appropriate medium for their recording needs.

The DMR-E700BD's competition comes from Sony, NEC and Toshiba. Sony was first on the market more than a year ago with a machine that is capable of recording up to 23 GB, while Toshiba and NEC have both recently demonstrated prototypes.

"As digital-broadcasting services are expanding, the demand for recording HD video is increasing. Our new product responds to such a demand. We believe the upcoming Olympic games is one of the factors behind expanding demand," said Etsuji Shuda, director of the home audio-visual business unit of Panasonic AVC Networks Company.

The DMR-E700BD recorder was scheduled for release in Japan on July 31.

Bookham trains its sights on industrial laser market

Bookham Technology is to focus on the high-power industrial laser market with a range of GaAs-based products manufactured at its Zurich, Switzerland, facility.

The company has adapted its 980 nm telecom lasers to emit at other wavelengths, including 808 nm, which is more suitable for optically pumping high-power lasers based on certain rare-earth-doped crystals.

Bookham says that a 60 W laser bar emitting at 808 nm has now been qualified after 5000 h of testing. The company expects to release further products that emit 80 and 120 W by the end of this year.

"We have just achieved a world-record 320 W, 1 cm bar [emitting] at 920 nm on a standard microchannel cooler," said Chuck Milligan, Bookham's vice-president of industrial and defense solutions.

High-power lasers pumped by semicon-

ductor devices have been dogged in the past by problems relating to diode reliability and have not displaced the incumbent flashlamp-driven sources as quickly as expected.

However, Bookham says that the reliability of its industrial laser diodes will strongly improve system performance.

The company explains that this reliability arises partly from the gold-tin soldering method it uses to mount laser diodes. This so-called "hard" soldering allows diodes to be driven at higher powers and temperatures than other solders used in industrial applications, such as indium, says Bookham.

After data storage and telecoms, industrial lasers represent the third-biggest application sector in the market for laser diodes. The market for them is expected to grow 14% to reach \$135 million in 2004, according to a report by Strategies Unlimited published this year.

In brief

● **Spire Corporation**, based in Bedford, MA, is developing GaAs layers for miniature terahertz lasers under a \$99 000 Phase I Small Business Technology Transfer Research project. Spire's terahertz source will be a quantum cascade laser – the size of a pencil tip according to the company – containing hundreds of nanometer-thick GaAs-based layers.

The project, involving a collaboration with the University of Illinois at Urbana-Champaign, aims to use a new design to produce epitaxial structures cost-effectively through Spire's wholly owned subsidiary, Bandwidth Semiconductor. If the project is successful, it could lead to a Phase II grant of \$500 000.

● **Comlase**, which develops process technology and equipment for high-reliability optoelectronic devices, has completed a round of venture funding that provides the Swedish company with SKr12 million (\$1.6 million) in capital.

INTRINSIC
SEMICONDUCTOR

Your Partner in WBG Materials & Solutions

SiC Substrates

- Insulating
- Conducting

GaN/AlGaN Epi Services

On internal and custom substrates:
Silicon carbide, sapphire, silicon for
HEMTs, HFETs, MOSFETs, MESFETs
and other custom designed structures

INTRINSIC Semiconductor is a privately held emerging growth company focusing on materials and device technologies based on silicon carbide (SiC) and gallium nitride (GaN); clear forerunners for next-generation high power and high frequency device applications.

US & Worldwide

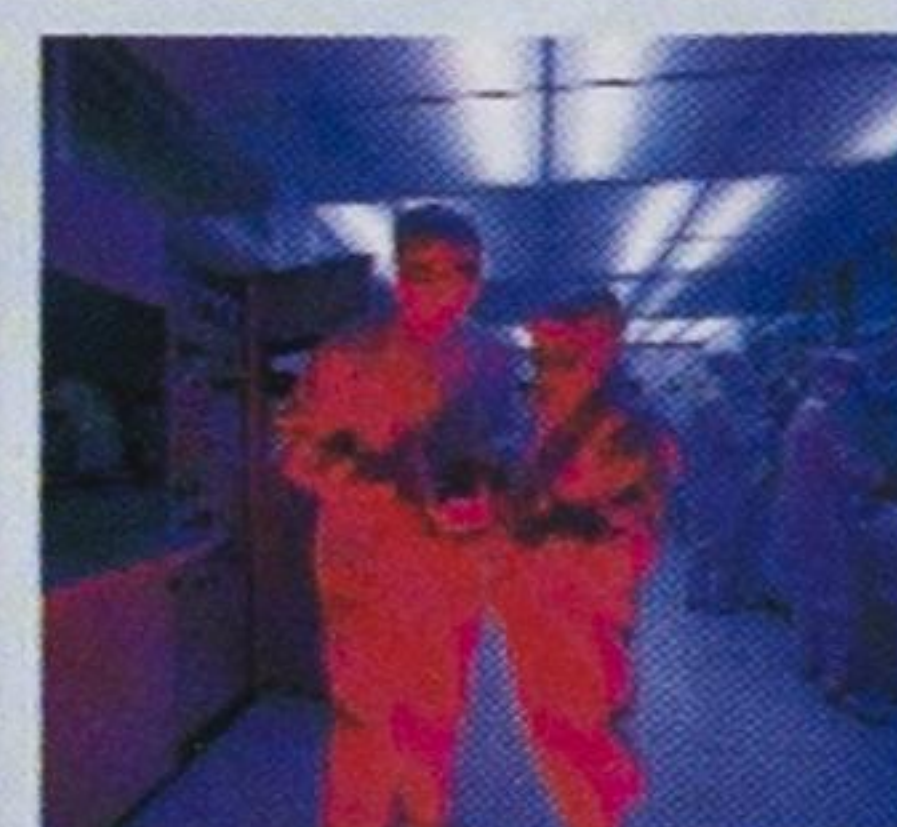
Tel: 1.703.437.4000
Fax: 1.703.437.4757
sales@intrinsicsemi.com
www.intrinsicsemi.com

Japan

New Metals and
Chemicals Corp., Ltd.
Minoru Mito
Tel: 81.6.6202.5108
Fax: 81.6.6223.0987
mmito@newmetals.co.jp



BANDWIDTH
SEMICONDUCTOR



With a cohesive and complete team of professionals, **Bandwidth Semiconductor** continues to grow in today's marketplace. We operate a complete compound semiconductor growth & device fabrication line housed in a 13,500 sq. ft. class 100/1000 cleanroom.

Epitaxial Services

MOCVD Experts – 20 Years Experience
Our extensive MOCVD experience and capacity enable us to grow a wide range of GaAs and InP epitaxial structures to our own or to customer's designs.

- GaAs and InP-based materials
- 2", 3", 4" Custom Epi-Wafer Capability
- Excellent Uniformity & Reproducibility
- Production & Development Quantities

Foundry Services

We design the process steps and conditions to meet the desired device characteristics and implement the process in our fab. Process equipment includes:

- PECVD
- Metallization
- Wet & Dry Etch
- Photolithography
- Dielectric & Optical Thin Film Deposition
- Wafer Polishing, Lapping, Dicing & Cleaving

BANDWIDTH SEMICONDUCTOR, LLC

25 Sagamore Park Rd., Hudson, NH 03051

www.bandwidthsemi.com

(603) 595-8900

Epitaxial and Foundry Inquiries: sales@bandwidthsemi.com

EOE M/F/D/V

Trace Elemental Analysis with GDMS^{*}
is more than a science. It borders on ART



^{*}Glow Discharge Mass Spectroscopy

Shiva has mastered
A-accuracy R-repeatability T-turn around

- Gained over the last 14 years, Shiva personnel have over 75,000 hours of cumulative experience to solve trace elemental problems by GDMS Technology.
- No one has as many GDMS instruments, in house, producing data for customers.
- Serves blue chip clients in USA, Japan, Europe, S. Korea, Taiwan and Singapore.
- Shiva analyses over 25,000 samples of advanced materials and 3,500 samples of SiC, high purity Graphite and LED related materials EVERY YEAR!!



ANALYTICAL SOLUTIONS
WORLDWIDE
www.shivatec.com

SHIVA TECHNOLOGIES INC.

6707 Brooklawn Pkwy, Syracuse, NY 13211
Ph: 315-431-9900 Fax: 315-431-9800
sales@shivatec.com



The Right Choice
The Intelligent Choice

Intelligent Epitaxy Technology, Inc.



- ◆ Pure-Play Epi Foundry
- ◆ Industry's First Production 7 x 4inch InP Epi Capabilities
- ◆ Real-Time In Situ Growth Sensor Technology
- ◆ Your Partner in Production and Advanced Epitaxy

We supply the following best-valued epi wafers

- GaAs-based (7 x 6inch available)
 - PHEMT
 - HBT
 - MHEMT
- InP-based
 - HBT (C-doped, Be-doped, GaAsSb)
 - HEMT
 - RTT, RTD
- Opto-electronics
 - VCSEL (Short and Long Wavelength)
 - PIN
 - Lasers (980 pump lasers, QD)
 - QWIP

1250 E. Collins Blvd. Richardson, TX 75081

Tel: 972-234-0068 • Fax: 972-234-0069 • E-mail: info@intelliepi.com • www.intelliepi.com

MBE & Analysis in a Single System

MBE meets Nanoanalytics

Semiconductor research on epitaxial films grown by MBE requires both topographic information at the atomic scale and chemical surface analysis.

We look forward to showing you our successful field solutions.



Germany: Omicron NanoTechnology GmbH

Tel: +49(0) 6128 / 987 - 0

e-mail: info@omicron.de

Web: www.omicron.de

USA: Omicron NanoTechnology USA

Tel: 952 345 5240

e-mail: info@omicronUS.com

Aixtron program elevates MOCVD's profile in China

Aixtron has received funding from the German government to establish a research and development training center in China for compound semiconductors used in optoelectronic applications.

The International Bureau of the Federal Ministry of Education and Research in Germany has approved the funding for a project involving Tsinghua University of Beijing, China, and Hong Kong University, as well as Aixtron and RWTH Aachen University of Technology, Germany.

The program will support rapid technology transfer in China and will involve training business students and engineers at small- and medium-sized companies to develop competitive new products in the field of optoelectronics using Aixtron technology.

A short course on MOCVD will be held in China covering electronic and optoelectronic devices, production issues and the use of

nanotechnology for future devices. Further hands-on lab courses will be conducted in China using state-of-the-art MOCVD equipment. These courses will include the improvement of material and device quality, yield management and other relevant topics.

At a later stage, Chinese students and engineers will carry out scientific work in Aachen on topics such as GaN-on-silicon for solid-state lighting, new laser concepts, improved LED manufacturing and high-power, high-frequency HEMTs.

Michael Heuken, vice-president of corporate research and development at Aixtron, said: "This promising project will teach young students and engineers about state-of-the-art compound semiconductor technology for optoelectronic devices.

"This know-how can be directly transferred to the local device manufacturers, so that our customers will also benefit."

Nichia imitates Intel with label guarantee

Nitride LED pioneer Nichia has followed Intel's lead by certifying lighting products that use the Japanese firm's technology.

As with the US chip giant's "Intel inside" labels on PCs, devices that use Nichia's white LED products will soon be adorned with a guarantee of what it calls "distinguished performance", by which it means features such as high brightness and high reliability.

Nichia says that it introduced the labels in response to requests from its customers.

China lends support to lighting industry

China plans to build an industrial base in Xiamen City, Fujian province, as part of a national project to develop its semiconductor-lighting sector, according to the Chinese Web-based newspaper, *People's Daily Online*.

According to the website's report, the city has been granted 15 million yuan (\$1.87 million) in state funds for base construction and aims to assist the semiconductor-lighting industry in achieving an annual output of 30 billion yuan by 2010.

Arima ramps up LED production

Arima Optoelectronics, a Taiwanese LED and laser manufacturer, is predicting an increase in production volumes this year, according to *Digitimes.com*.

Arima has expanded capacity at its Hsinchu plant – acquired in the merger with Kingmax Optoelectronics – with AlGaInP-based LEDs dominating production. Volumes are predicted to rise from the current quarterly level of 10–15 million units to 25 million, and then to 35–40 million in successive quarters.

In addition, the firm aims to ship high-luminance blue LEDs in the third quarter. It plans to install extra MOCVD capacity between August and October, leading to a monthly production of 100 million units by year-end.

Arima also hopes to raise its laser-diode production from its current 4–4.5 million units to 6 million and 7 million in consecutive quarters. It plans to introduce technology such as flip-chip-packaged LEDs and automatic optical output-power control for laser diodes.

In brief

- US-based **Emcore** has signed an agreement with BUPT (Beijing University of Posts and Telecom)-GUOAN Broadband Network Technology Company to distribute Emcore's fiber-optic cable-television and satellite-communications products in China.

The agreement combines the strengths of Emcore's Ortel division, which has expertise in hybrid fiber/coax (HFC) and fiber-to-the-premises network architectures, products and technologies, with BUPT-GUOAN's domestic sales and support staff, who have intimate knowledge of China's broadband market.

"China is the world's fastest-growing HFC market and our goal is to double our market share over the next 18 months. Already we have seen a marked increase in demand for 1550 and 1310 nm products, and we expect to continue to build momentum in Asia," said Lee Johnson, vice-president of marketing for Emcore's Ortel division.

- Taiwan-based GaAs-foundry operation **WIN Semiconductors** is seeing its orders rise. The total capacity of 6 inch GaAs wafers is forecast to reach 8700 units this year, up from 2300 last year. The company revealed that it plans to increase monthly capacity to 1000 wafers in August and to 1500 wafers in October.

Chan-Shin Wu, WIN's CEO, is reported as saying that the firm is running at full capacity, with 85 device manufacturers using the foundry. Revenues hit NT\$69 million (\$2 million) in June and a full-year revenue of NT\$900 million is now forecast.

WIN spokesperson Annie Yu said that the ramp-up in capacity was being driven by anticipated demand for WLAN and CDMA devices.

- **Epson**, based in Tokyo, Japan, has developed a VCSEL for use in optical data communications.

The new product, the S92A1A00, is said to be a highly reliable, low-power, oxide VCSEL that achieves transfer speeds of as high as 5 Gbit/s at a threshold current of 1.2 mA.

Samples of the new VCSEL will become available in September and Epson will begin accepting volume production orders in December.

the science
of materials
the power of
collaboration



© Rohm and Haas Electronic Materials, 2004

OptoGrade™ Metalorganics

We deliver performance::: EPI certified TMGa, TMIn and TMAI

We provide consistency::: Highest purity with every cylinder

We guarantee service::: Unsurpassed technical and customer service



ELECTRONIC MATERIALS
MICROELECTRONIC TECHNOLOGIES

■ Circuit Board Technologies ■ CMP Technologies ■ Microelectronic Technologies ■ Packaging and Finishing Technologies

<http://electronicmaterials.rohmhaas.com/metalorganics>

WIRELESS INFRASTRUCTURE

Next-generation LDMOS pushes limits

Silicon LDMOS will continue to dominate the base-station power-amplifier market until an alternative technology can deliver higher performance at a lower price, writes **Hamish Johnston**.

The cellular base-station power-transistor market is dominated by silicon, with about 90% of devices being LDMOS. While on paper LDMOS may not be the best technology for W-CDMA power amplifiers (PAs), generational improvements in the technology are ensuring that it will dominate in the foreseeable future. This is despite the theoretical benefits offered by wide-bandgap materials such as GaN.

A shining example of LDMOS evolution is the fifth-generation LDMOS power transistor recently unveiled by Philips Semiconductor, headquartered in the Netherlands. Based on a 0.4 μm process, Philips claims that these transistors offer 30% efficiency for 100 W W-CDMA applications and 17 dB gain for 2.5G PCS/DCS systems.

Mark Murphy, who is the program manager for RF power base stations at Philips, told *Compound Semiconductor* that the 30% efficiency rating for W-CDMA is a "world record". He also says that increasing the gain to 17 dB from the industry-standard 14–15 dB was an important achievement. Higher gain allows PA designers to reduce the number of amplifier stages by pushing more of the amplification into the final stages of the PA. This reduces the overall cost of implementation.

According to Murphy, Philips has recently moved its process to a "leading-edge CMOS fab that can go down to 0.14 μm ". He says that this has allowed the company to achieve significant improvements in the design and operation of such amplifiers. The new fab will also facilitate the launch of the next (sixth) generation of transistors, which will be based on a 0.4 or 0.35 μm process. Murphy says that 0.14 μm technology will probably be exploited in generation seven.

Philips will begin sampling generation-five products in the final quarter of 2004. "We already have prototypes in the lab, and a few weeks ago at the MTT-S [IEEE International Microwave Symposium/Exhibition in Fort Worth, Texas] we held a live demonstration of the [prototype's] 30% efficiency and 17 dB

gain." Philips is currently talking to several lead customers and is fine tuning the technology. Murphy expects that lead customers will implement the transistors by mid-2005 as they ramp up product manufacture.

Metallization change

A key feature of generation-five technology is the use of a patented four-level level aluminum/copper metallization system (figure 1). Murphy says that this gives the components a very long mean time to failure (MTTF). This is a key parameter because reliability is one of the most important features of the devices in PAs. Philips used gold metallization in its previous generations of LDMOS.

Aluminum/copper metallization allows for junction temperatures of 185 $^{\circ}\text{C}$ – instead of the standard 160 $^{\circ}\text{C}$ using gold – with the same MTTF. If the transistor is used at 160 $^{\circ}\text{C}$, it is four times as reliable as conventional LDMOS in W-CDMA operation.

Also on the temperature front, Philips has reduced the thermal resistance of its devices from 0.76 to 0.5 K/W. According to Murphy, Philips set 0.5 K/W as its thermal-resistance target for generation-five devices, and decreasing the resistance further is a key focus for the company. "There are a lot of design tricks and knowledge of the technology that we have to achieve this. This involves getting the overall design right: the thickness of the silicon and the type of heat sink used. These are all areas of current investigation."

Several of Philips's competitors have had greater success in reducing thermal resistance, with Agere Systems, US, claiming a value of 0.35 K/W in its 180 W device. However, Murphy notes that while competitors may quote better thermal-resistance values, he believes that "for a 100 W W-CDMA device at an average output power of 26 W, the fifth-generation device with a thermal resistance of 0.5 K/W combined with the record efficiency of 30% at a record gain of 17 dB gives the industry's leading proven performance".

According to a recent market survey by ABI

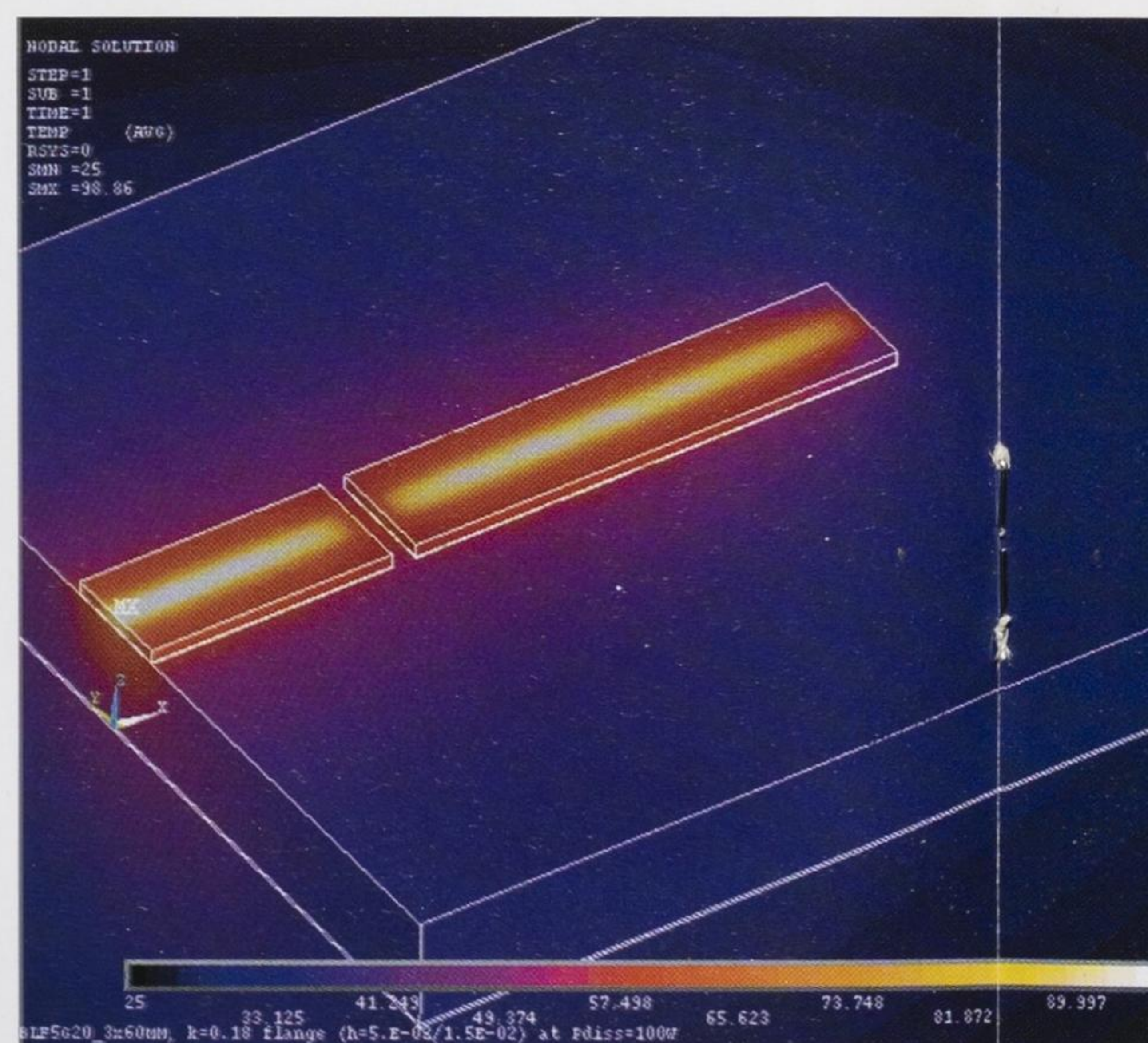


Fig. 1. (Above and below) Philips's latest LDMOS power transistor – used in W-CDMA base stations – employs aluminum/copper metallization, which allows the device to be run at much higher temperatures than previous generations of power transistor.

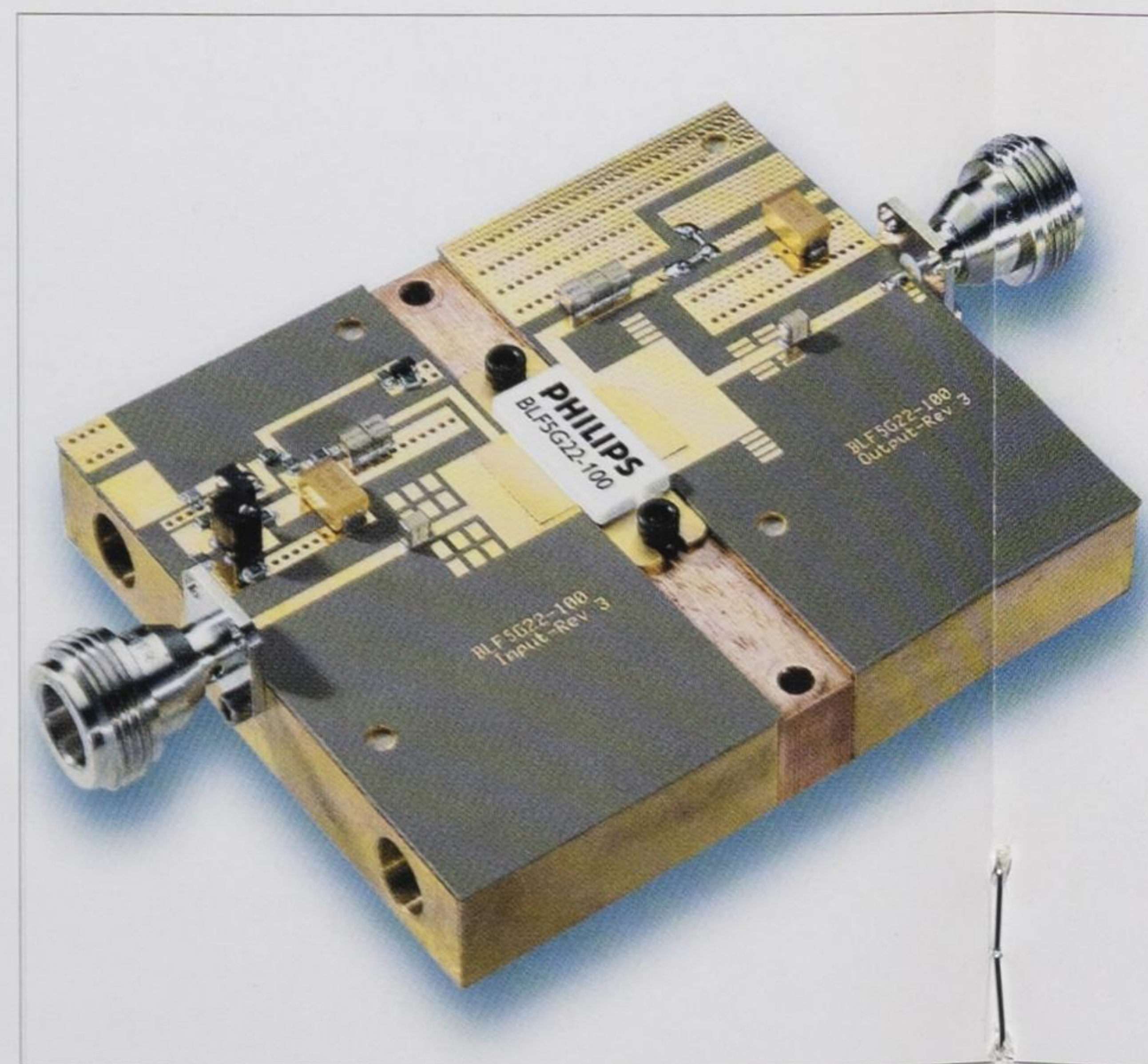
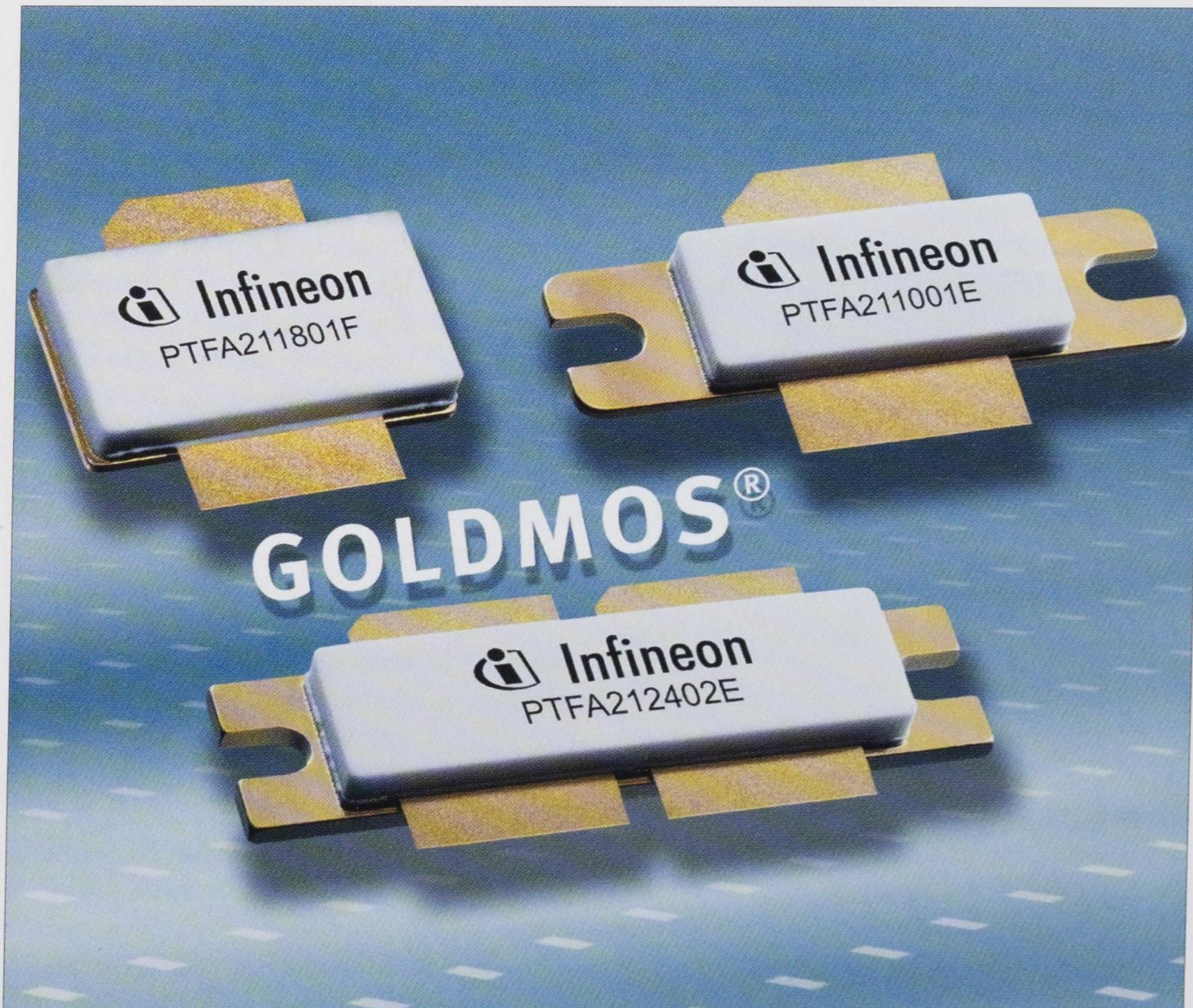


Fig. 2. It is b

Research – semiconductor-industry analysts – Philips is currently the number-two supplier of RF power transistors used in base-station PAs. Murphy believes that the company has about a 25% market share. The business was number four in the market in 2000, controlling a 10% share, so Philips's commitment to LDMOS technology appears to be paying off. The market has long been dominated by US giant Motorola (now Freescale), but relative

imits of silicon base-station PAs



“None of the GaN devices that we have seen displays a dramatic improvement over LDMOS.”

PETER KENINGTON, DIRECTOR OF ADVANCED TECHNOLOGY, ANDREW

“LDMOS is currently winning because of price,” said Kenington. He explains that the industry is under financial pressure and any technological advantages offered by an alternative to LDMOS must be sufficient to offset the added expense of the new technology. In particular, these advantages must significantly reduce the overall cost of the PA unit.

It is cheaper because it is a mature technology that is used in volume production, but as Kenington pointed out, “LDMOS is not standing still...every [new] generation of LDMOS is a small improvement on the previous one.”

The technology benefits from ongoing increases in peak and average drain voltages. For example, a device might operate at a mean voltage of 28 V but experience regular peaks of up to 40 V. W-CDMA PAs operate in a high peak-to-mean mode and future LDMOS devices will be able to accommodate the peaks by momentarily allowing a boost in drain voltage.

Steve Jones, an RF systems engineer at Agere Systems, told *Compound Semiconductor* that Agere is pushing LDMOS voltage by increasing the device’s channel length. However, he concedes that “designing for higher breakdown voltages is a compromise”. This process reduces the gain of the transistor, and operation at higher voltages can degrade the long-term stability of the device. Unfortunately these two factors are key features for PA designers.

Reliability challenge for GaN

While LDMOS producers like Philips and Agere believe that LDMOS will continue to dominate the market, they are also pursuing alternative technologies. Jones says that Agere is looking at GaAs MOSFETs while Philips has a research group in Nijmegen, the

Fig. 2. Infineon’s latest GOLDMOS power transistor offers 16.5 dB gain and 30% efficiency. It is based on an LDMOS process that employs gold metallization.

LDMOS and GaN power transistors sampling in late 2004

Device	W-CDMA average power (W)	Gain (dB)	Efficiency (%)	Voltage (V)
Nitronex GaN N40	36	>13	25	28
Philips Gen 5 LDMOS BLF5G22-100	26	17	30	28
Infineon Goldmos LDMOS PTFA211001E	22	16.5	30	28

newcomers such as Agere Systems are also making significant inroads.

Other companies producing LDMOS PAs include Germany’s Infineon and French/Italian group STMicroelectronics, which ABI says are joint third in the market. Infineon has just announced the latest in its line of GOLDMOS (LDMOS) PAs. The 100 W, 2.1 GHz devices offer 16.5 dB gain, 30% efficiency and a thermal resistance of 0.38 K/W (figure 2).

These firms must retain the loyalty of people like Peter Kenington, who is director of advanced technology at US-based PA module maker Andrew and therefore a purchaser of power transistors. “LDMOS is by far the most dominant technology at present, with about 80–90% of the infrastructure market,” he said, adding that the rest of the market is occupied by GaAs FETs, with some legacy designs using bipolar transistors.

WIRELESS INFRASTRUCTURE

Netherlands, that is focused on GaN. "Philips sees GaN as a potential technology in the future and we are tracking it closely," said Murphy. "We believe that the biggest challenge with GaN is reliability. You can look back several years to all the hype about SiC – there were even some prototypes on the market – but SiC never reached its potential."

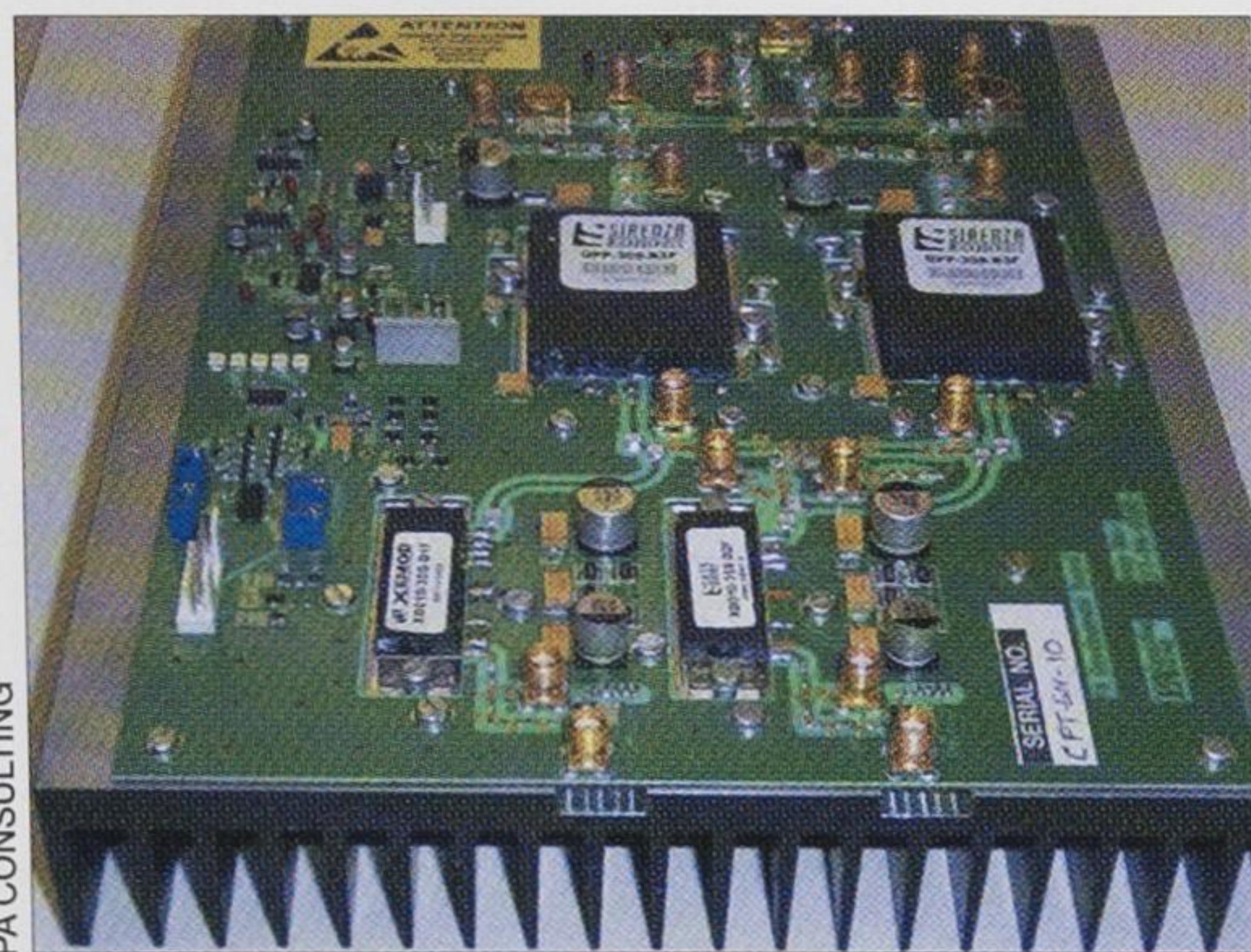
Kenington believes that GaN technology and, to a lesser extent, GaAs PHEMT present the biggest threat to LDMOS. "GaN is becoming a more mature technology but there are no commercial products available at the moment," he explained. "There are test samples and pre-production units, but what is being produced at the moment is not yet suitable for commercial base stations."

Kenington believes that current GaN prototypes could be used in the earlier stages of a PA, but not in the output stage of high-power modules. "They cannot yet compete with LDMOS in terms of absolute power level," he explained. However, Kenington points out that the power capability of each successive generation is increasing: "GaN is improving in leaps and bounds, whereas improvements in LDMOS are much more incremental."

Kenington says that Andrew has a close relationship with several companies developing GaN, and is monitoring their progress. There is currently a lot of claim and counterclaim regarding linearity – while GaN makers say that the linearity of their devices is better than LDMOS, the latter is continually improving. "None of the GaN devices that we have seen displays a dramatic improvement over LDMOS," said Kenington, who believes that LDMOS could ultimately be a better choice in certain situations. "It is going to come down to a matter of cost," he stressed.

GaN device makers, including Japan-based Eudyna Devices and US firm Nitronex, say that they will be shipping commercial products by early 2005 (*Compound Semiconductor* July p27). "In some cases I think this is a reasonable time frame," said Kenington. He adds that in other cases this might be a little optimistic. "However, I believe that they will all get there. From a purely technological perspective we could see GaN in commercial systems by the end of 2005 and these could be in the field by the middle of 2006."

Nitronex is sampling two GaN devices at 10 and 20 W that offer a gain of 11.5 dB and 30% efficiency. The company plans to sample a 36 W device later this year (see "LDMOS and GaN power transistors sampling in late 2004" p19).



A power amplifier developed by PA Consulting for a 3G microcell base station.

"Philips sees GaN as a potential technology in the future and we are tracking it closely."

MARK MURPHY, PROGRAM MANAGER FOR RF POWER BASE STATIONS, PHILIPS SEMICONDUCTOR

Availability alone will not induce PA makers like Andrew to replace LDMOS with a different technology. Kenington says that the benefits of GaN are not absolutely revolutionary and therefore the industry will not be prepared to pay a premium for the new technology. In fact, GaN producers may initially have to sell their transistors at a loss to make them competitive with LDMOS.

Beyond the issue of price, Kenington comments that some of the advertised benefits of GaN have yet to be proved. Theoretically, GaN should be more efficient than LDMOS. Its wide bandgap means that devices can be operated at higher voltages than LDMOS, which should make it easier to match the output of the transistors.

Tower-mounted PAs

Another key benefit of GaN is that the devices can be run at higher temperatures than LDMOS. While Kenington concedes that this would give GaN the edge in tower-mounted-amplifier configurations, he observes that "virtually nothing is tower-mounted at the moment because of reliability concerns". He explains that the cost of sending out a rigger to replace a PA at the top of a mast negates any savings gained in the reduced purchase price of the unit. "Network operators are currently reluctant to have anything active on masts and

this is only changing slowly. It will be a while before we see tower-mounted PAs and it is not on account of the device technology but rather the complexity of the PAs."

GaN's superior thermal properties could also allow PA modules to be made smaller, thus reducing cooling-related operating expenses. In addition, a single transistor could be used where two are used today. This could be an important improvement because matching one device is easier (and possibly cheaper) than matching two devices. Kenington emphasizes that the important question is whether a single device implementation is cheaper on a dollar per watt basis.

Looking further into the future, GaN and GaAs PHEMT transistors could be better suited to a new wave of PA architectures that employ efficient but nonlinear devices. Such designs have been around for many years and use clever techniques to achieve linear amplification using nonlinear component signals.

Kenington says that these systems could be used for W-CDMA – provided that a few existing problems can be solved. While LDMOS makers concede that their current PAs may not be suitable for these advanced architectures, Murphy – program manager at Philips – is confident that future generations of LDMOS could be made to fit the bill.

Simon Tonks, principal consultant in the Wireless Technology Practice of the UK's PA Consulting Group, has performed laboratory tests on the performance of LDMOS and GaAs transistors. Tonks concluded that LDMOS is best when used in a particular application with stabilized conditions and a limited power range. While this is fine for GSM, he points out that the output power of a W-CDMA base station varies according to the traffic loading in a specific cell. This means that an LDMOS PA may not always operate in its "sweet spot" and its performance would suffer. GaAs PAs offer better performance over a range of operating conditions and therefore could be more suitable for W-CDMA.

Despite its shortcomings for W-CDMA, a combination of inertia and incremental improvements will maintain LDMOS's market lead for the next few years. But in the future the cost-versus-performance advantage of this legacy technology will be eroded by a new generation of transistors. When this will occur, and the exact nature of the usurping technology, remains unclear.

Hamish Johnston is editor of Wireless Europe magazine.

WiMax connectivity gives SiGe amplifiers the edge

Price erosion and the emergence of new high-throughput standards are two of the big issues facing chip manufacturers in the wireless LAN market, says SiGe Semiconductor's **Andrew Parolin**.

Compound Semiconductor: What products does SiGe Semiconductor supply to the wireless LAN [WLAN] space?

Andrew Parolin: We sell power amplifiers [PAs], switches and front-end modules. Our customers can create their own designs using our PAs and switches on the board. We've also gone one step further and have designed complete front-end RF modules – everything from the uplink of the radio to the antenna – on a single device. Broadcom, which is the market leader, has taken our 2521A PA and that's a big win for us. Broadcom already uses our 2520 and 2529 PAs in its reference designs, and the company has now moved to our higher-integration module.

CS: The WLAN market boomed in 2003, how does it look this year?

AP: We estimate our total global available market to be around 65–70 million units in 2004, although there are some rumors that this may dip a little. For the 802.11g protocol, which is probably the dominant standard, we are the market leader. We have about a 48–50% share in 802.11g. The 802.11b market is dwindling and becoming commoditized, so we are focusing our efforts on 802.11g.

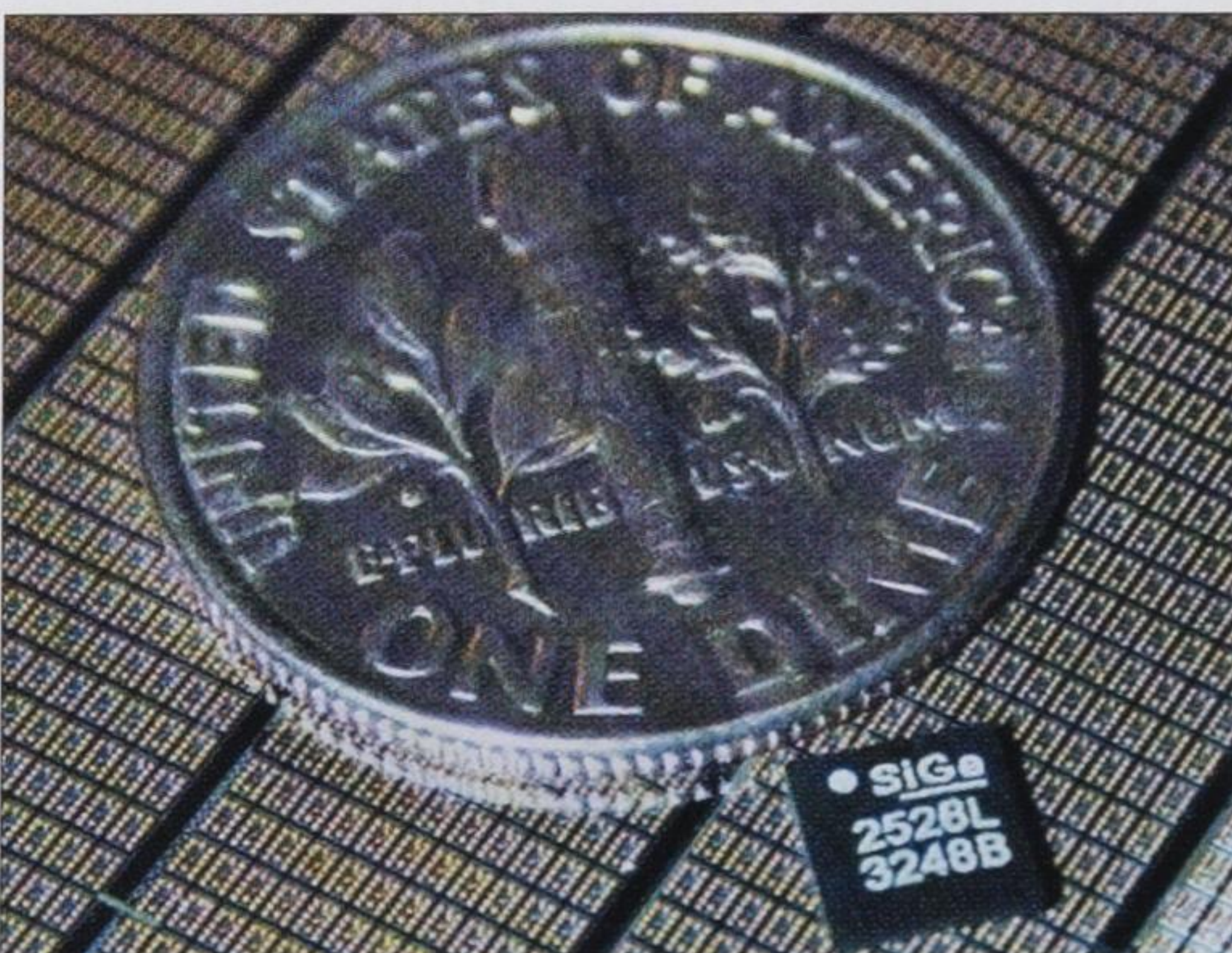
CS: How do you explain the relative success of SiGe Semiconductor PAs in WLAN compared with handsets?

AP: There has never really been a SiGe versus GaAs debate in WLAN. The integration advantage for SiGe has been a tremendous seller. Most of the GaAs guys require external transistors and regulators to provide a 2.8 V reference voltage and to turn the PA on and off. We've actually integrated that into the SiGe die, which saves about 20 cents on the bill of materials (BOM).

We've also been able to integrate the biasing with a robust power detector. I can get much more on the die and that reduces the BOM considerably [compared with GaAs].



Andrew Parolin is SiGe Semiconductor's director of wireless amplifiers.



SiGe Semiconductor's latest device to target WLAN applications, the 2528L, is said to increase data throughput by 5–6 Mbit/s and increase the connectivity range by 20–30 m.

SiGe has always met industry ruggedness requirements, it just comes down to performance and cost.

CS: Anadigics has said that the 802.11a/g dual-band protocol is more suited to GaAs than SiGe. What's your response?

AP: I disagree. I think there's a place for SiGe in the dual-band application. We have SiGe 5 GHz PAs available and we have combined the benefits of SiGe with those of GaAs for

the 5 GHz band. Therefore we can provide a cost-effective dual-band solution that the GaAs guys still cannot.

Our dual-band solution is completely digitally controlled, so for the 5 and 2.4 GHz bands you can connect our PA directly to a CMOS baseband with no interface or glue logic. The GaAs guys are still going to have that integration problem so they will need some transistors and a reference voltage, and that's all extra cost. We've already seen substantial price erosion in 802.11b and we now see it happening in 802.11g. It's going to happen in dual-band as well, and we'll be able to follow that curve down [better than GaAs].

The big figures of merit for WLAN are error vector magnitude [EVM] and output power. Our PAs combine high integration with a low EVM versus output power. The PA that we've just launched [2528L] has less than 3% EVM at a 23 dBm output. That's important. It allows our customers to provide 20 dBm at the antenna, and for regulatory reasons this is where everyone wants to be. Getting above that figure is not really required: you would have to get into some sophisticated power control and no-one really wants to do that. Independent tests showed a throughput improvement of 5–6 Mbit/s and 20–30 m extra range.

CS: How do these figures compare with the best GaAs solutions?

AP: They are competitive. There is one GaAs PA that is [marginally] better, but the problem is that there is no integration, so you have to add another 40 cents to the overall cost to get the same level of functionality. So while with GaAs there might be a little bit more there in performance, you have to pay a price. That performance margin cannot be used, so at some point there will be diminishing returns. The 40 cent price advantage is huge: now the BOM for a whole card is approaching five to six dollars, so it's 5–10% of that cost in the consumer market.

The world's largest supplier of

MBE & MOCVD Replacement Parts



- Purchase the highest quality replacement MBE and MOCVD parts without an OEM mark-up
- Schwarzkopf Technologies Corporation (STC) is the US affiliate of Plansee, the world largest refractory metals company
- STC, together with Plansee, is the leading supplier of Ta, W and Mo refractory metal replacement parts and materials for use in MBE and MOCVD

SCHWARZKOPF TECHNOLOGIES Corporation

115 Constitution Blvd • Franklin, MA 02038

Phone: 508-553-3800 ext 222 • Fax: 508-553-3823

Toll Free: 800-STC-MOLY (800-782-6659) ext 222

www.stcmetals.com

E-mail: stc.sales@stc-ma.com

SCHWARZKOPF
A PLANSEE Affiliated Company

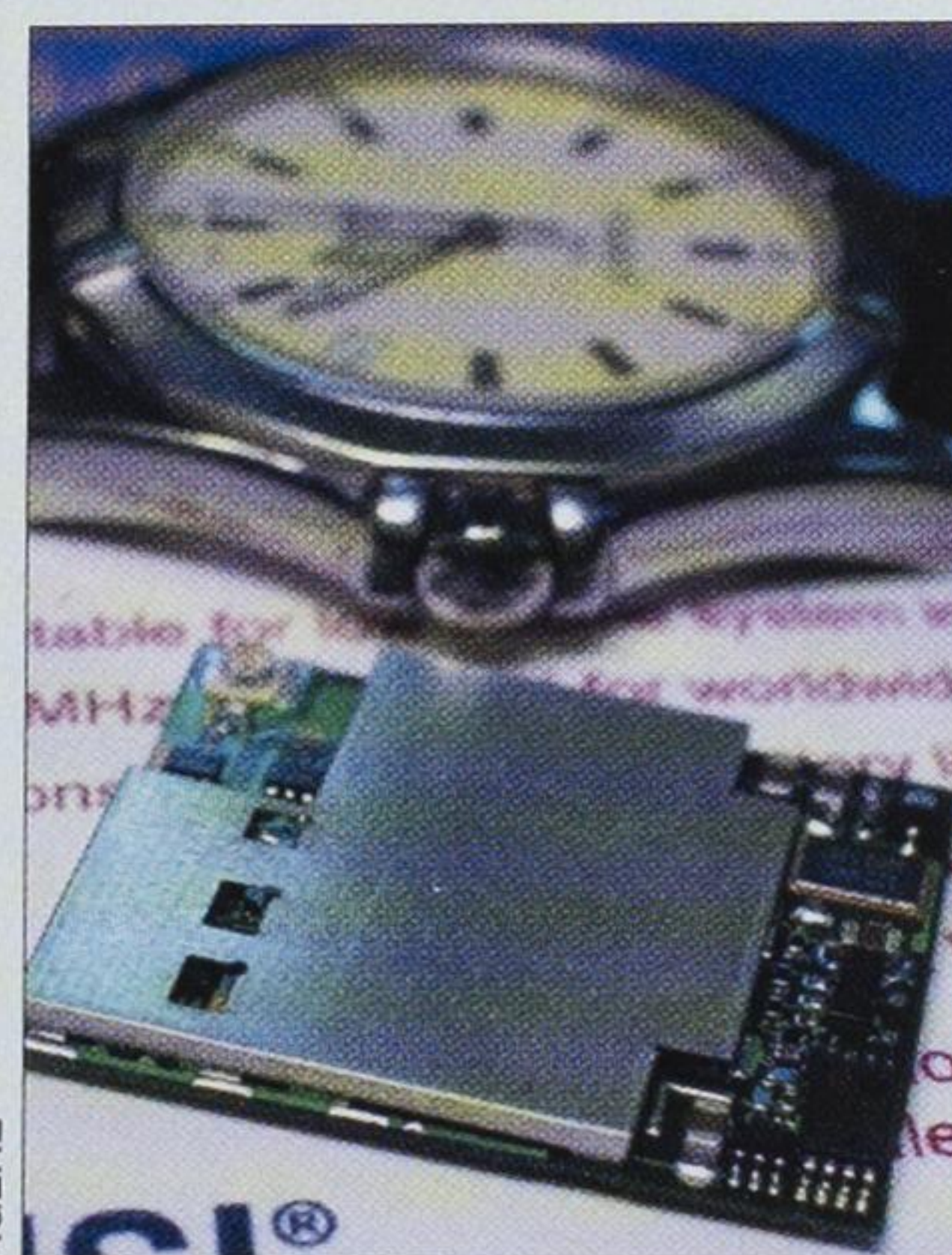
COVER STORY WIRELESS LAN

compoundsemiconductor.net

WiMax and emerging WLAN protocols

Three main versions of the 802.11 protocol exist: 802.11a, 802.11b and 802.11g. The "b" and "g" standards share the 2.4 GHz frequency band with microwave ovens and Bluetooth, while the "a" standard operates at 5 GHz.

Following the emergence of the higher-throughput "WiMax" standard, denoted 802.16 by the IEEE, volume commercial deployment is expected in 2006 and one market research firm (Parks Associates) is predicting 7 million WiMax users by 2009. The ramp-up should be helped in no small way by Intel's commitment to Wi-Max. Intel wants to see



AGERE

notebook PCs begin to incorporate WiMax connectivity during 2006.

In the meantime the IEEE 802.11n task group has been sorting through a pile of proposals for next-generation WLAN. The

802.11n standard will support transmission rates of between 100 and 200 Mbit/s, over double the current 802.11g throughput.

The WLAN community has divided into two separate camps. One camp – led by chipset maker Atheros – advocates a 40 MHz-bandwidth protocol, and numbers Intel, Matsushita and Philips among its supporters. The second camp, which supports a 20 MHz bandwidth solution, is led by Airgo Networks and includes Broadcom, Conexant, Motorola, ST Microelectronics and Texas Instruments.

CS: Has the 2528L been a success?

AP: It shares the same package as our previous 2525 device, so all of our customers can fit this higher-power device in the same socket. With three or four component changes you have the high-power design, and you don't have to change the layout or the board. Our customers love this because they can have a high-power/low-power design without having different boards.

To date we have design wins with four different customers. We gave out some early samples and people went crazy over it – it all goes back to higher performance and integration for lower BOM.

Revenue from this new PA will cannibalize some of our older designs, including the 2529 and the 2525. In the first four months or so it will probably take away about 20–30% of revenue from those existing products. By mid-2005 we would expect the old designs to be out completely, and we expect most of our existing customers to switch over.

CS: What opportunities are there for SiGe in the emergence of WiMax connectivity [IEEE 802.16]?

AP: WiMax was set up with two primary applications in mind. One is point-to-point back-haul for Wi-Fi: so if you have an access point on a lamp post and you want to connect to the main hub, then you would use 802.16. The sec-

ond is point-to-multipoint, where you have one big transmitter to provide broadband services to homes. So it's very much like the local multipoint distribution services we had six or seven years ago, but now it's standardized and pushing forward. Those are two big markets.

Having said that, there is a new activity that is also going to support mobile applications and give WiMax support on laptops (see box). For this, you need both back-haul and point-to-multipoint links.

There are lots of synergies with 802.11g and a, but for the higher throughput the noise control has to be better. WiMax mainly operates in the 2.5–3.5 GHz spectrum, with support in the 5.8 GHz band as well. The frequencies are similar and the output power is a little higher, but essentially WiMax is very similar to Wi-Fi. Some people are using our existing PAs because of that overlap.

CS: What trends are you seeing in WLAN?

AP: An emerging theme in Wi-Fi is the new 802.11n protocol. The IEEE's intention is to reach 100 Mbit/s throughput through the 2.4–5 GHz spectrum. Right now the [theoretical] 54 Mbit/s throughput is actually more like 25 Mbit/s pure data. The "n" workgroup is trying to reach an actual 100 Mbit/s throughput to enable entertainment, video and Internet through the same pipe. That's the next big thing and we're working on it.

Start-up produces blue LEDs using 'dismissed' technique

The Fox Group has developed a hydride vapor-phase epitaxy technique that produces medium-brightness blue LEDs, based on AlGaIn/GaN structures, at a low cost, writes **Tim Whitaker**.

Despite it being largely dismissed as a viable technique for the growth of GaN-based LEDs, The Fox Group – a start-up LED manufacturer headquartered in Ripon, CA – has developed a production method for manufacturing such devices by hydride vapor-phase epitaxy (HVPE).

Using technology originally developed by Technologies and Devices International (TDI), The Fox Group has established a manufacturing facility in Montreal, Canada, and shipped its first order of 460 nm "FoxBlue" LEDs in mid-May of this year. The mid-brightness devices have remarkable color consistency and are extremely low-cost, thanks to the use of the HVPE growth technique.

The devices are AlGaIn/GaN structures that do not contain indium or quantum wells. As such, they are not high-brightness devices; typical intensities are around 1000 mcd for narrow-beam-angle LEDs or up to 3 mW for dies. "We are not competing with the big players such as Nichia, Toyoda Gosei, Cree, Osram and Lumileds, or anyone else making high-brightness InGaIn LEDs," said Barney O'Meara, the company's vice-president.

Even so, the technology used by The Fox Group has three very strong advantages: the HVPE process is intrinsically low-cost; it is protected by a strong patent portfolio; and the LEDs have extremely good color consistency.

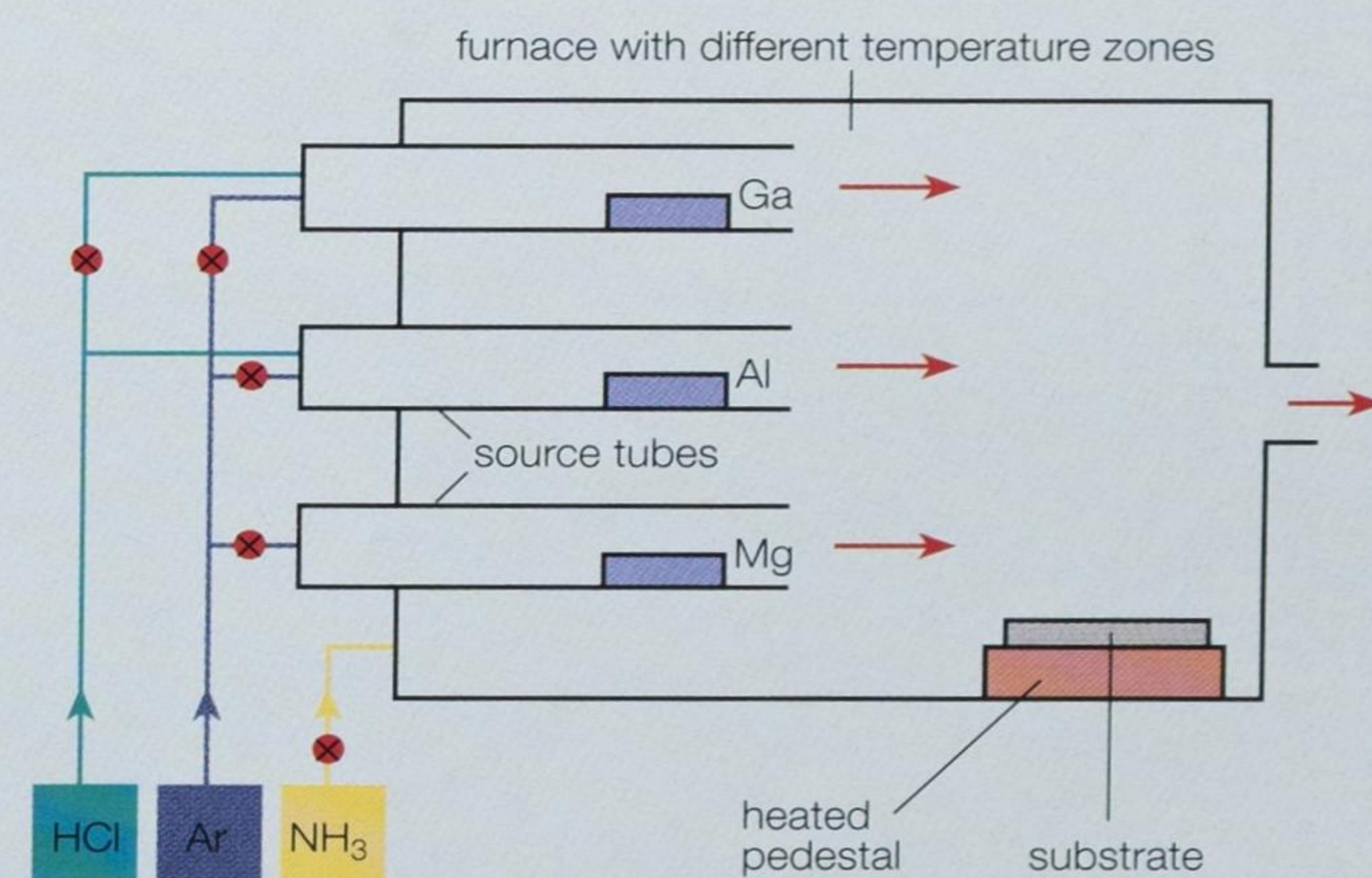
Color consistency

"The dominant wavelength is typically 460 ± 1 nm across each wafer, from wafer to wafer and from week to week," said O'Meara, who credits the incorporation of indium into InGaIn/AlGaInN structures for the much larger variations in brightness and wavelength exhibited by these devices. "Even for such applications as Christmas tree or holiday lights, color consistency is a significant issue; for sign and message board manufacturers the problem is much worse."

The HVPE technology that is used to grow LEDs was developed by TDI, a wide-bandgap

Basic principles of the HVPE technique

The figure shows the basic set-up used to grow GaN by hydride vapor-phase epitaxy (HVPE). Pure metal gallium in a boat is heated to 800–900 °C in a stream of hydrogen chloride (HCl), forming gallium chloride (GaCl). With argon as the carrier gas, GaCl is transferred to a substrate heated to a temperature of 1000–1100 °C, where it reacts with ammonia to form GaN on the surface. Aluminum is incorporated in a similar way. To grow p-type layers, metals such as magnesium and zinc are heated in a stream of argon, with the optimum temperature being 615 °C for magnesium. Silane is



used to provide silicon as the donor for n-type material. Many of the key details for HVPE growth are contained in US patent no. 6 472 300 entitled "Method for growing p-n homojunction-based structures utilizing HVPE

techniques". Typical device structures, which are grown without the low-temperature buffer layers commonly used in MOCVD, consist of a GaN p-n homojunction sandwiched between wider-bandgap AlGaIn layers.

materials specialist company based in Silver Springs, MD. The Fox Group has an exclusive license for certain TDI patents relating to light-emitting devices, and the firm has advanced the technology from the research stage to a fully automated, reproducible manufacturing process.

The company is confident of its intellectual property position. "Besides the entirely different crystal growth process, Fox Group's LED structure is different and, we believe, non-infringing," said O'Meara. "We have one or more patents pending in this regard, and we do not use a buffer layer."

So what has prevented other companies from growing GaN LEDs by HVPE? Jacques Pankove and colleagues at RCA Labs grew n-type GaN by HVPE more than 30 years ago, but used a metal junction for the p-side of their

device. Successfully growing p-type material was one of the key factors in developing a viable growth technology, while the other was the ability to use aluminum in a quartz-tube reactor. The Fox Group is currently using industry-standard 2 inch sapphire wafers, although other substrates can also be used.

Compared with MOCVD, which is used by all other manufacturers of blue GaN-based LEDs, HVPE is estimated to reduce the consumption of ammonia by at least an order of magnitude. Also, HVPE uses pure metals as starting materials rather than metal-organic precursors, which are around 10 times as expensive per gram of metal. The fast growth rate of HVPE (up to 1 $\mu\text{m}/\text{minute}$) and the relative simplicity of the HVPE-grown device structure also help to further reduce the overall cost of the process.

SUPPLIERS GUIDE

SUBSTRATES AND EPIWAFERS

If you would like to advertise in future issues, contact Luke Neel (tel: +44 117 930 1033, fax: +44 117 920 0809, e-mail: luke.neel@iop.org).

Selected suppliers of substrates and epiwafers
to the compound semiconductor industry

Substrates and Epiwafers Suppliers Guide

Company name	Web address	Telephone number	Contact	GaAs substrates	InP substrates	GaP substrates	Germanium substrates	Sapphire substrates	Silicon carbide substrates	Nitride substrates (GaN, AlN)	II-VI substrates (ZnO, CdS, CdTe, ZnTe)	Oxide substrates (ZnO, perovskites)	Antimonide and InAs substrates	Recycled wafers	Substrate preparation and polishing	Abrasives and chemicals	LED epiwafers (AlGaAs, AlGaInP, GaP, etc.)	Nitride LED epiwafers	Epiwafers for fiber-optic components	VCSELs epiwafers	HBT, HEMT and MESFET epiwafers (GaAs, InP)	GaN or SiC epiwafers for electronic devices	SiGe and Si epiwafers	Epiwafers for phosphide-based devices	Epiwafers for antimonide-based devices
Bandwidth Semiconductor LLC	bandwidthsemi.com	+1 603 689 1226	Richard E Rogers																						
Cradley Crystals	cradley-crystals.com	+7 831 278 0846	Dr Pavel Soustov																						
CrySTec	crystec.de	+49 30 6566 090	Knut Peters																						
Dow Corning	dowcorning.com	+1 989 496 4442	Fred Buether																						
Engis Corporation	engis.com	+1 847 808 9400	Ken Werner																						
EpiNova	epinova.de	+49 761 5569 7160	Sigrid Walker																						
Honeywell Electronic Materials	electronicmaterials.com	+1 408 962 2055	Lance Chapman																						
IntelliEpi	intelliepi.com	+1 972 234 0068	Sophia Wang																						
Intrinsic Semiconductor	intrinsicsemi.com	+1 703 437 4000	Katya Tsvetkov																						
Kyma Technologies	kymatech.com	+1 919 789 8880	Edward Pupa																						
Monocrystal PLC	monocrystal.com	+7 865 295 6529	Gennady Eremin																						
Nikko Materials Co Ltd	nikkomaterials.com	+1 480 732 9857	Gary Covert																						
NL Nanosemiconductor GmbH	nanosemiconductor.com	+49 231 9742 7000	Jan Kegelberg																						
Osemi Inc	osemi.com	+1 507 285 4490	David Braddock																						
Picogiga USA Inc	picogiga.com	+1 925 285 9029	Nelson von Ebbe																						
QinetiQ	qinetiq.com	+44 1684 543 732	Tim Phillips																						
Rubicon Technology Inc	rubicon-es2.com	+1 847 295 7000	Michael Matthews																						
Sensor Electronic Technology Inc	s-et.com	+1 803 647 9757	Remis Gaska																						
SiCrystal	sicrystal.de	+49 9131 73 49 84	Thomas Kippes																						
III/V-Reclaim	35reclaim.de	+49 8631 394 777	Jorg Schwar																						

SUBSTRATES AND EPIWAFERS

Improved polishing

Engis Corporation

Engis is pioneering the use of diamond-based CMP-D slurry to replace or augment costly traditional CMP polishing. Combined with the Hyprez line of flat lapping/polishing machines, a complete system is provided to bring innovative, cost-effective solutions to the most demanding applications. Benefits include substantially reduced processing times; elevated throughput with consistent, repeatable performance; reduced operating costs related to cleaning and disposal issues; and development of customized and proprietary processes for each customer. Pilot wafer processing services offered.



Contact: Engis Corporation
Tel: +1 847 808 9400
Fax: +1 847 808 9430
E-mail: info@engis.com
Web: www.engismicrotech.com

Precision ceramic machining

Insaco Inc

Insaco's specialty custom machining of sapphire and ceramic wafers allows us to respond to customer needs for nesting of wafers in larger carriers. Insaco's capability to machine and jig-grind precise features to extreme tolerances in ceramic materials allows developmental engineers to handle small process wafers on a large wafer line. Engineers are available to discuss design concepts and material choices in an unbiased way, since Insaco purchases materials from numerous resources. A FREE capabilities CD and "Interactive Designer's Guide" showing the material



properties of many ceramic materials is available through our website.

Contact: Insaco Inc
Tel: +1 215 536 3500
Fax: +1 215 536 7750
Web: www.insaco.com

SiC and GaN materials

INTRINSIC Semiconductor

INTRINSIC Semiconductor is a privately held emerging growth company developing materials and device technologies based on SiC and GaN; clear forerunners for next-generation high-power and high-frequency device applications. INTRINSIC currently offers 2-inch and 3-inch insulating and conductive SiC wafers as well as custom AlGaIn/GaN HEMT epiwafers on internally manufactured SiC or customer-supplied substrates. Intense development efforts are underway for SiC substrate and GaN epiwafer 4-inch production. For sales, product information and to request a quotation, see our contact details below.

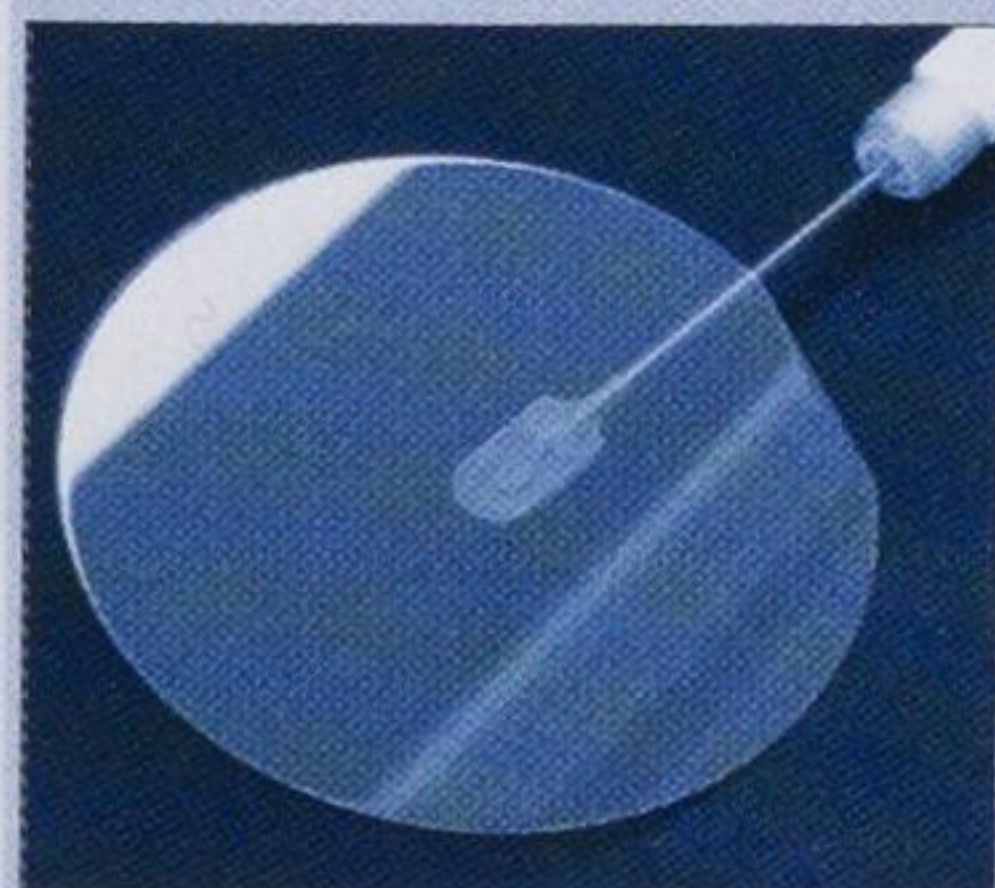


Contact: INTRINSIC Semiconductor
Tel: +1 703 437 4000
E-mail: sales@intrinsicsemi.com
Web: www.intrinsicsemi.com

Sapphire substrates

Monocrystal PLC

Monocrystal supplies high-quality 2, 3 and 4 inch C-plane epi-ready sapphire substrates for GaN deposition and A, M, R-plane epi-ready sapphire substrates for semiconductor applications. High purity, low dislocation density and precise processing make Monocrystal sapphire substrates an ideal choice for high-tech applications in the LED and semiconductor industry. We manufacture sapphire substrates according to SEMI standards as well as per customer specification. Monocrystal is ISO certified.

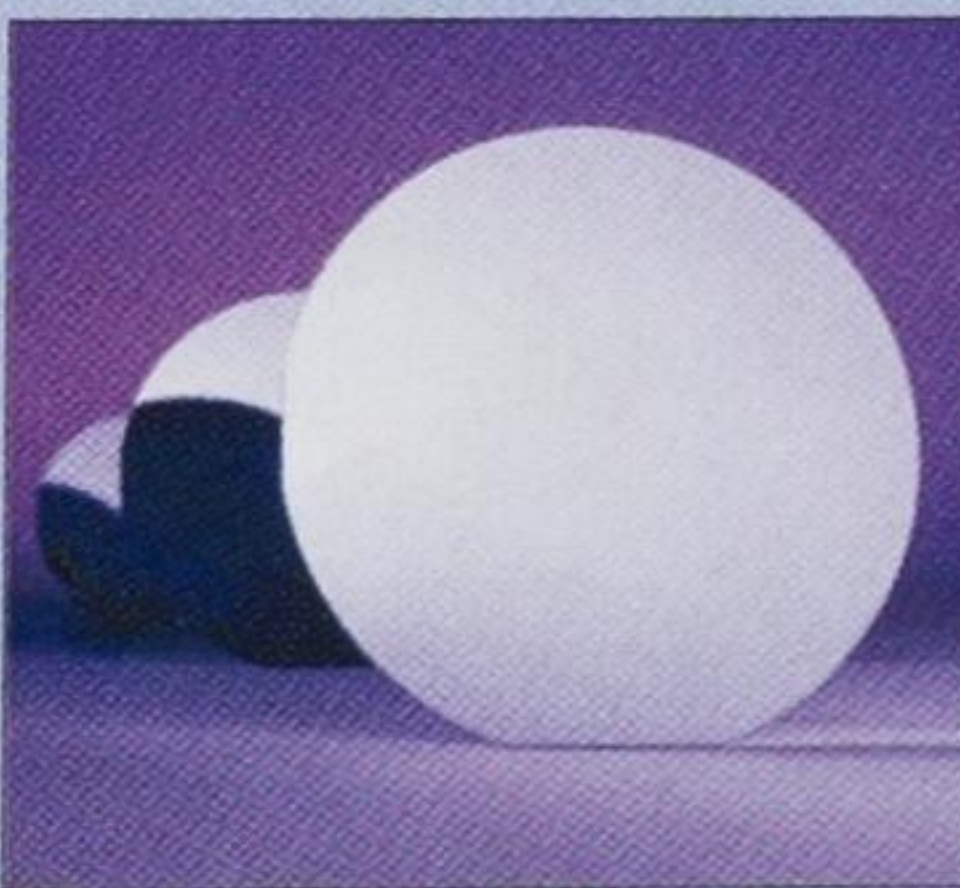


Contact: Monocrystal PLC, 4/1 Kulakov prospect, 355035, Stavropol, Russia
Tel: +7 8652 956529
Fax: +7 8652 956528
E-mail: sales@monocrystal.com
Web: www.monocrystal.com

Epi and bare wafers

Nikko Materials

Nikko Materials is a leading supplier of compound semiconductor materials, known worldwide through its ACROTEC brand. We have a wide product line that includes bare wafers and epitaxial services. Please call us if you need MOVPE and MBE grown **epitaxial wafers** for optical and electronic device applications, **InP** single crystal substrates (2", 3" and 4" diameter), **CdTe**, **CdZnTe** single crystal substrates (1 x 1 cm to 6 x 6 cm), **ZnTe** single crystal substrates, and 6N and 7N high purity source metals such as **In**, **Cd** and **Te**.



Contact: Nikko Materials
Tel: +1 480 505 2441 (US); +81 3 5573 6592 (Japan); +44 20 7929 3823 (UK)
E-mail: sales@nikkomaterials.com
Web: www.nikkomaterials.com

Picogiga 4 inch GaN

Picogiga

GaN Epiwafers on Si, SiC and multilayer Smart Cut™ Substrates for high-power HEMT devices, Picogiga, a Soitec subsidiary, continues to invest in ramping for high-volume production GaN Epiwafers on 4 inch Si, pursuing its strategy to supply high-performance epitaxial layers required for new generations of radio-frequency (RF) devices. Combining the performance benefits of GaN with the cost advantages of large-area silicon wafers and leading-edge MBE technology will ensure broad commercial availability of performance GaN-based Epiwafers. This is a progressive step in the Picogiga III-Vs material roadmap for high-power, high-speed applications.

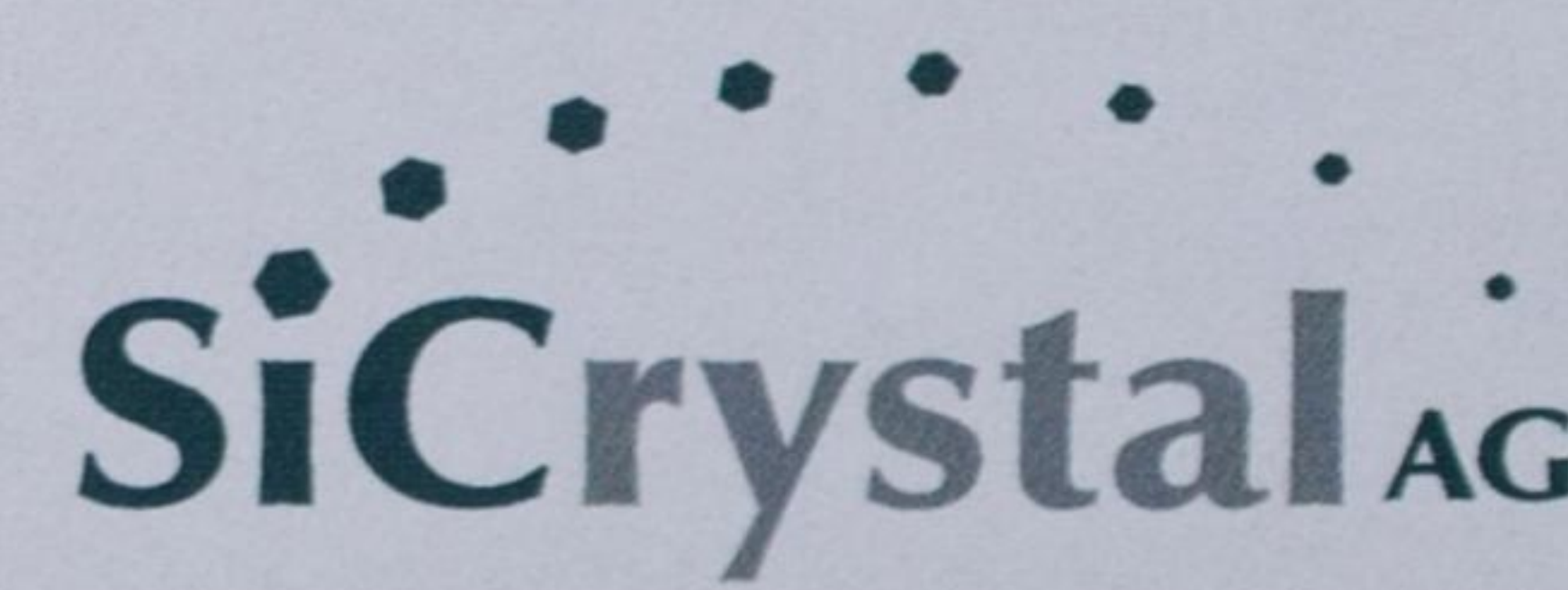


Contact: N von Ebbe
Tel: +1 925 285 9029
Fax: +1 707 667 7272
E-mail: nvonebbe@aol.com
Web: www.soitec.com/en/picogiga.htm

SPONSOR COMPANIES



Compound Semiconductor Solutions



Germanium-on-insulator detectors could crack interconnect bottleneck

Researchers at IBM say they have developed a method that enables the fast, efficient manufacture of photodetectors that are compatible with CMOS production. **Michael Hatcher** reports.

Optical interconnects have long been heralded as a possible way of solving communication bottlenecks at the chip level, but one of the key problems holding back the technology has been finding a method of making optical devices that is compatible with conventional chip manufacture.

Now, researchers at IBM appear to have developed a technique that could solve the problem at the detector end of the link. Led by Steve Koester, the team is based at the IBM T J Watson Research Center in Yorktown Heights, NY. It has made germanium-based PIN photodetectors using a method that it claims is compatible with CMOS technology.

Koester and colleagues made the breakthrough by depositing germanium films on ultrathin silicon-on-insulator (SOI) substrates. Germanium-based detectors have been developed previously for optical telecommunications, but only at wavelengths of 1.3 and 1.55 μm , which are principally used in relatively long-range links.

"It is a little-appreciated fact that germanium is an extremely efficient absorber at 850 nm, about 50 times better than silicon and with an absorption depth of only a few hundred nanometers," Koester told *Compound Semiconductor*. This is also the emission wavelength of GaAs-VCSEL sources, generally used in short-range datacom applications.

"We had the idea of making an extremely fast photodetector using germanium," Koester continued. "The catch is that silicon is also a weak absorber at this wavelength. So we adapted the germanium-on-insulator [GeOI] devices that had been made previously."

According to IBM, using current silicon photodetectors in optical interconnects makes about as much sense as trying to use transistor technology from the 1960s in today's

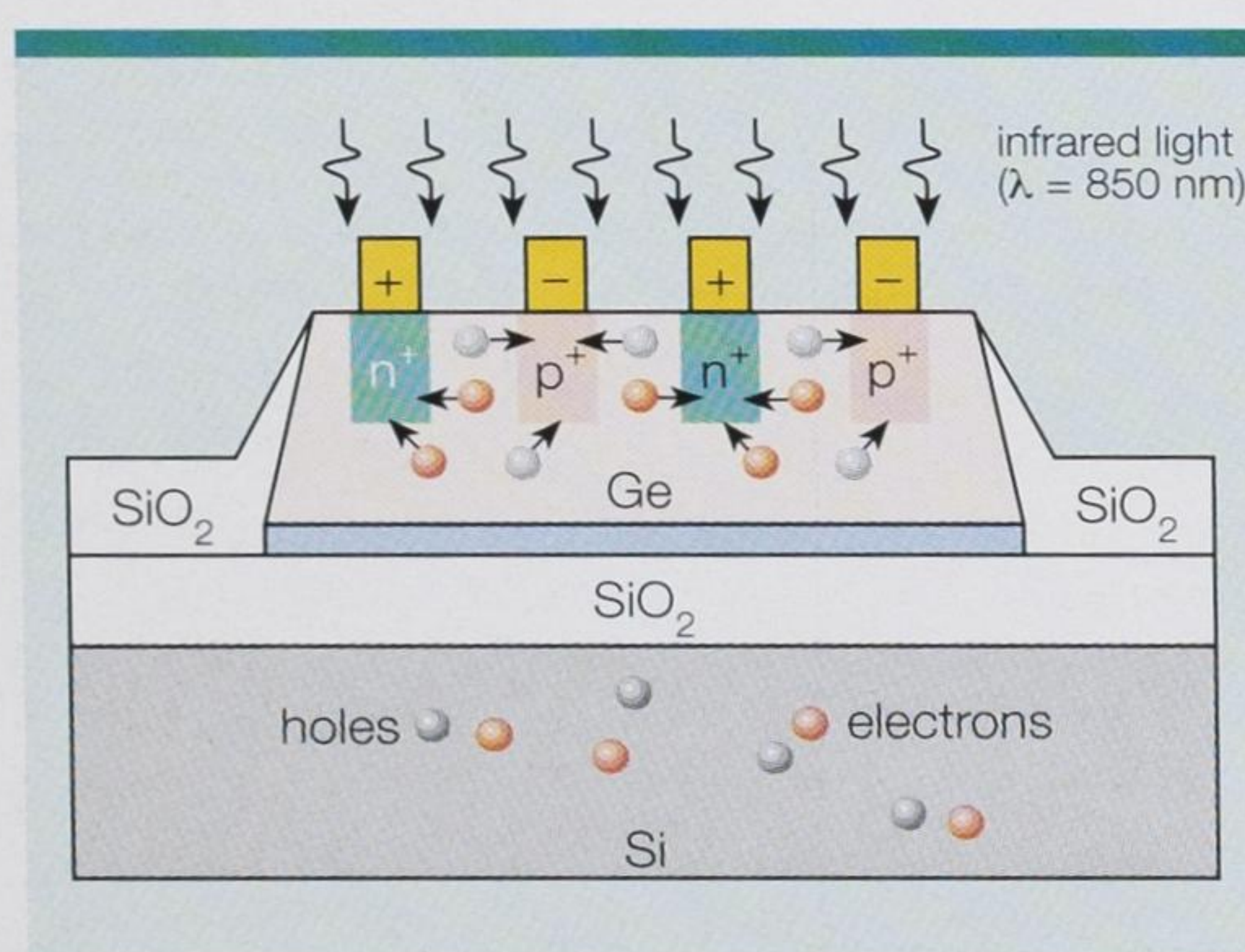


Fig. 1. A schematic cross-section of the IBM photodetector. An ultrathin silicon buffer layer is grown on top of an SOI substrate before the photodetector layer, comprising 400 nm-thick germanium, is deposited.

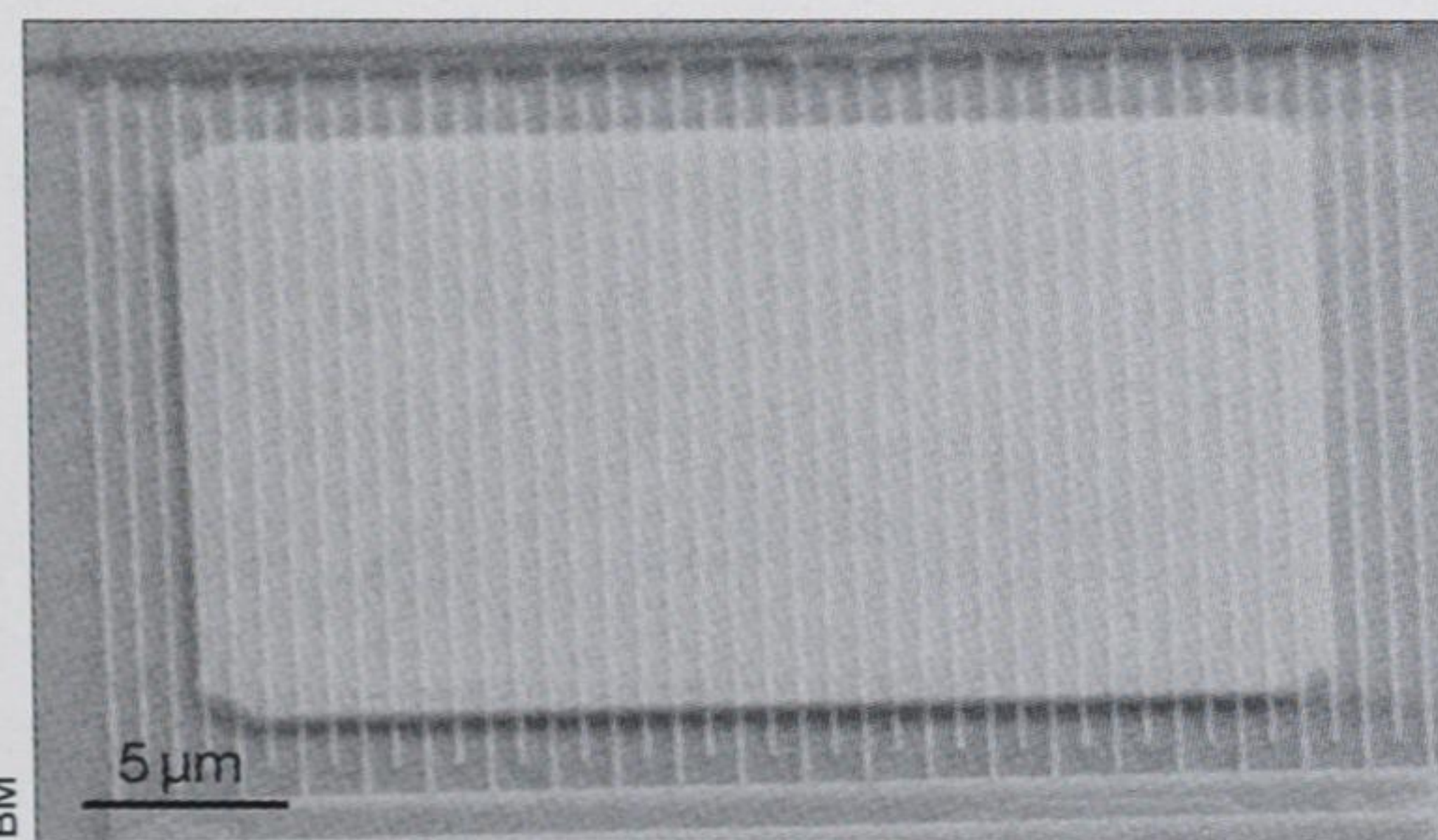


Fig. 2. This micrograph of the GeOI detector shows an active area about 30 μm wide, sandwiched between two interdigitated electrodes on top of a silicon dioxide base.

microprocessors – i.e. no sense at all.

Silicon detectors have been pushed to reasonable speeds (approaching 10 GHz) using concepts such as IBM's lateral trench detectors, where deep trenches of alternating p and n contacts are fabricated in the devices, and the electric field is perpendicular to the direction of the light hitting the detector. However, the high capacitance of the deep

trenches ultimately limits the speed at which these detectors can operate. One of the key advantages of the GeOI detectors, says Koester, is their inherent scalability.

Resonant-cavity structures offer high efficiency coupled with a speed similar to that of the GeOI detectors. As Koester points out, however, these structures are very difficult to fabricate: "[These devices] feature alternating Bragg reflecting mirrors that are hard to integrate, and they only collect a lot of light at the resonant frequency." And although InGaAs is a very good detector in the near-infrared, the III-V material will always be difficult to integrate with silicon-chip architecture.

CMOS compatibility

Perhaps the most promising aspect of IBM's GeOI detectors is that they can be manufactured in a way that is said to be compatible with CMOS technology, which allows them to be readily incorporated into many standard chips. Koester's group uses ultrahigh vacuum chemical-vapor deposition – a technique pioneered at IBM – to make the GeOI photodetectors. "IBM uses this technique in production already. For example, IBM's SiGe HBTs are made using this method," said Koester. "Although I would say that you could [make them using] any epitaxial technique."

The IBM team takes a silicon substrate and fabricates an SOI layer on it beneath a layer of germanium (figure 1). The substrate is isolated, allowing the efficient collection of charge carriers generated in the germanium layer. Germanium has a high absorption coefficient, so this detector layer can be made ultrathin and, consequently, the device can operate at a high speed. "We've combined the idea of germanium-on-silicon with putting it on an insulator," Koester said.

PHOTODIODES

PHOTODIODES

The starting material is produced by growing germanium on an SOI base that has an initial thickness of 15 nm. This is followed by a 30 nm silicon buffer layer and a 50 nm-thick germanium seed layer, which is deposited at 350 °C. In the final growth stage a 400 nm germanium layer is grown at 600 °C.

The structure then undergoes cyclic annealing at 780–900 °C to reduce defect densities. In this step the buried oxide limits silicon diffusion into the germanium layer – a process that can reduce detector efficiency by increasing the bandgap if it is left unchecked.

According to Koester, a key aspect of the device's fabrication is maintaining a good interface between the germanium and silicon layers. Owing to the lattice mismatch, germanium tends to ball up and tries to grow three-dimensionally, while it is also sensitive to interface contamination.

The resulting PIN diodes, which range in size from 10 to 100 μm (figures 2 and 3), feature an efficiency of around 52% at 895 nm – a figure that drops to 38% at 850 nm. "Our devices have a little bit of a cavity, as the buried-oxide layer acts like a reflector. Our



Fig. 3. An optical micrograph of an array of GeOI photodetectors. The active areas appear colored when held at an angle to the illuminating light because the interdigitated fingers of the devices are of a similar size to visible wavelengths. The detectors at the top of the photograph are 100 μm wide, while those at the bottom measure just 10 μm .

detector wasn't precisely tuned for 850 nm operation, but if we could tune it to a resonance maybe we could cut the absorbing layer in half," Koester explained. "Then we could decrease the finger spacing by half as well, and this would give us higher speeds."

With a bandwidth of 29 GHz, the GeOI detectors already exhibit a speed that is fast

enough to support optical links operating at more than 50 Gbps. The devices have n- and p-type implanted contacts and interdigitated titanium/aluminum electrodes. The oxide-isolated mesas are patterned using optical lithography, while all other levels are patterned using an electron-beam tool. An electrode spacing of either 0.4 or 0.6 μm is generally used.

For the semiconductor industry to even consider incorporating such devices in chip architecture, it is crucial for the technology to be readily scalable to higher performance levels. Koester says that this is possible with the GeOI detectors. "You can always make a photodetector faster by making the absorbing layer thinner, until you're limited by basic transport phenomena," he said. "But then it may be inefficient and absorb hardly any light. The trick is to combine speed and efficiency."

● IBM's progress with GeOI photodetectors comes less than a year after IBM and Agilent embarked on a separate three-year project that is focusing on the development of optical interconnects for board chip-level communication (see *Compound Semiconductor* October 2003 p16). ●

bede
X-ray metrology

Production-proven
X-ray metrology
tools for compound
semiconductors

- perfection
- thickness
- roughness
- grading
- composition

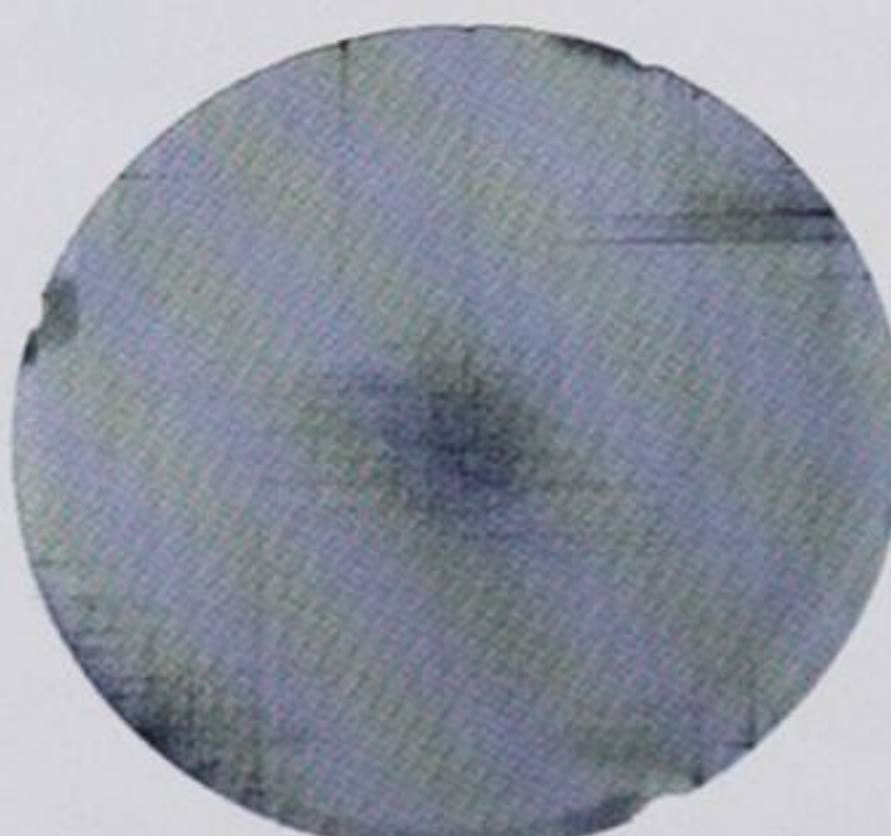
www.bede.com



BedeMetrix™-F



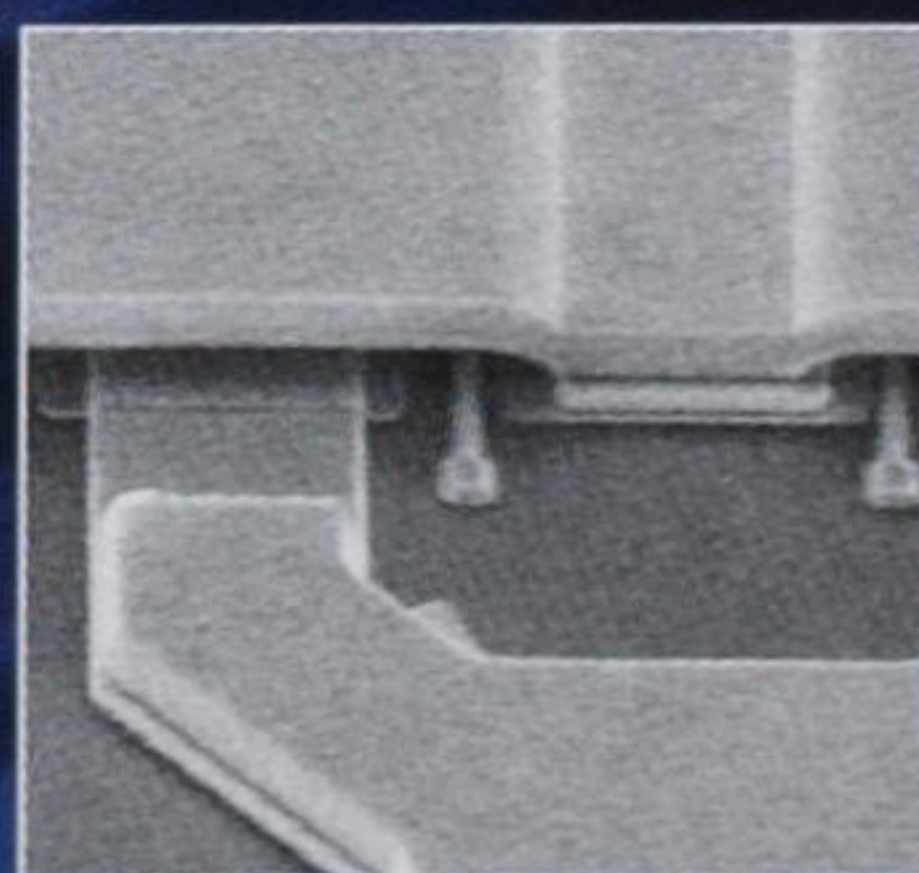
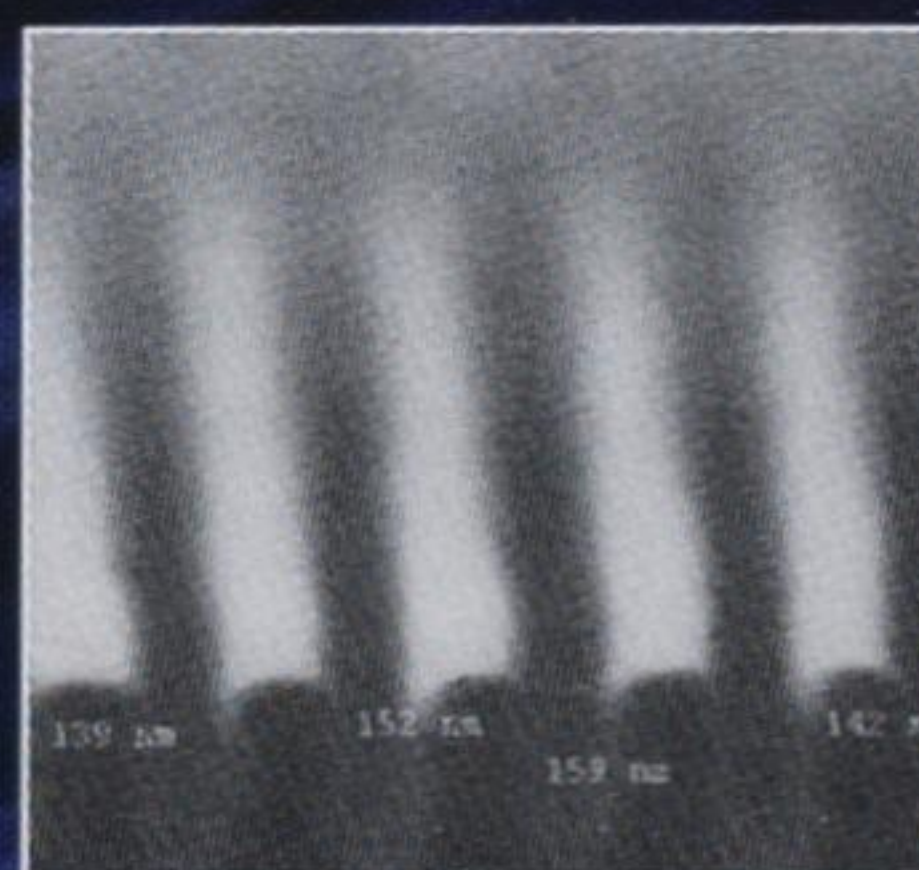
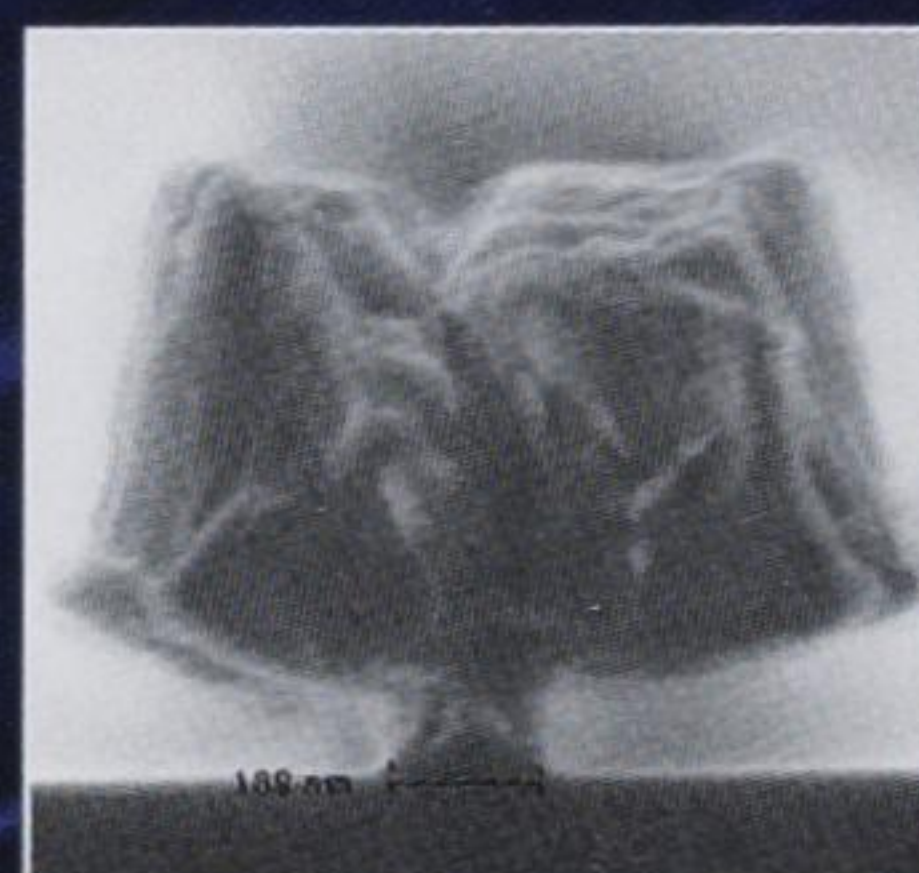
BedeMetrix™-L



BedeScan™

UK	USA	Asia
T +44 (0)191 332 4700	T +1 (303)790 8647	T +86 (0)21 64594811
E info@bede.co.uk	E sales@bede.com	E infoasia@bede-asia.com

Electron Beam Lithography Services



JEOL JBX 6000FS/E,
with machine capability
down to 20nm and
demonstrated processes
in the 100nm regime.

- Direct write onto Si, GaAs, InP and SiC technology
- Nano device structures
- FET device structures
- Over 40 years of experience
- Custom fabrication
- ISO9001 certified

**ROCKWELL
SCIENTIFIC**

Delivering the Winning Technical Edge

www.rockwellscientific.com

For additional information contact Gina Uhlman at
(805) 373-4483 or ruhlman@rwsc.com

RSC1071

Germanium powers Mars exploration

Do you see your opportunity?

Umicore's germanium substrates were used on both NASA Mars Exploration Rovers - Spirit and Opportunity - as part of the solar cells and panels provided by Spectrolab.

In less than 10 years, germanium has been able to dominate space solar power over silicon solar cell technology. In recent years, exciting new properties of this fascinating semiconductor material have been discovered in the area of opto- and microelectronics. Umicore also produces ultra-flat and thin silicon, bonded thick-film silicon-on-insulator substrates for the microelectronics,

optoelectronic, and MEMS/MOEMS/MST Industries.

Umicore Electro-Optic Materials

Watertorenstraat 33, B - 2250 Olen, Belgium, Tel: + 32 14 24 57 02, Fax: + 32 14 24 58 00, substrates@umicore.com, <http://substrates.umicore.com>

Umicore Semiconductor Processing

12 Channel St., Suite # 702, Boston, MA 02210, USA, Tel: (1 - 617) 960 5911, Fax: (1 - 617) 345 9271

Terrestrial triple-junction array generates kilowatt solar power

A kilowatt-scale terrestrial solar-cell array that employs III-V-based triple-junction technology could spur the improvement of both space-based and terrestrial solar-energy systems.

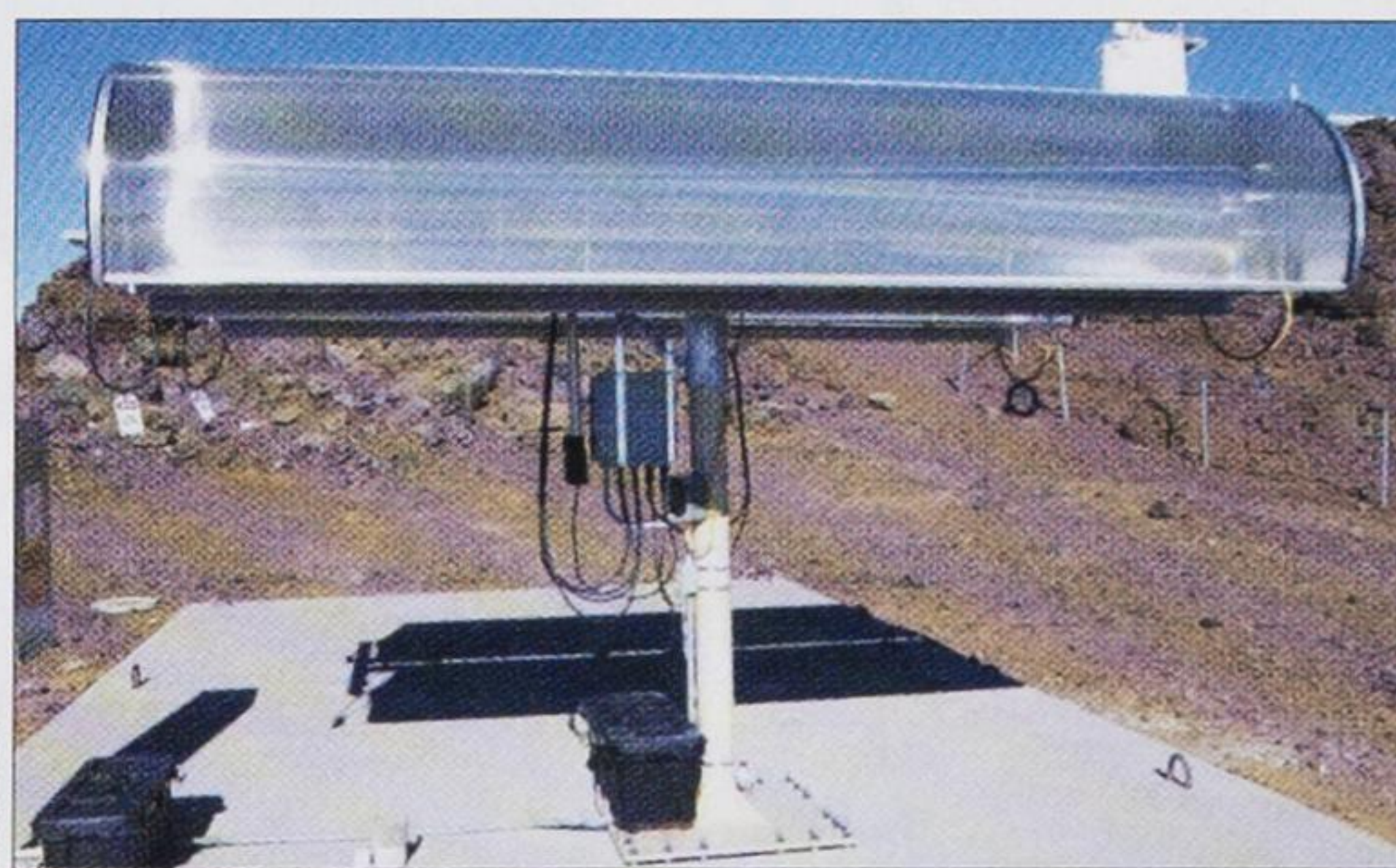
At the summit of Mount Haleakala, on the island of Maui in Hawaii, engineers have deployed and tested what is believed to be the first ever 1 kW terrestrial triple-junction solar array.

Developed by a team comprising the NASA Glenn Research Center, Boeing and Texas-based Entech, the concentrator array outputs more than 200 W m^{-2} at 600 V. This achievement promises to improve solar-power generation using high-voltage arrays in terrestrial and space applications.

"This could enable direct drive of certain types of ion thrusters, and lower conversion losses to high-voltage microwave transmitters," claimed the US team in a paper presented to the Solar Power From Space conference held in Granada, Spain, last month. In the longer term the successful deployment could even represent one of the first steps toward a space-based energy source that is capable of beaming power down to Earth via a laser.

It also demonstrates that future terrestrial concentrator arrays based on triple-junction (GaInP/GaAs/Ge) cells could achieve unprecedented performance at an affordable price.

The solar concentrator array used 240 Spectrolab GaAs P/N solar cells. Two separate modules were employed, each of which had an aperture area of 3 m^2 .



The solar concentrator module is stationed close to the summit of Mount Haleakala.

At an altitude of 3000 m, the Hawaii location was nearest the team could get to having a space-like solar spectrum without executing an actual launch. More short-wavelength radiation can reach cells at the mountain-top site than at sea-level.

According to the team, the peak power output of one of the concentrator modules reached 670 W – almost twice the capability of a standard module based on silicon solar cells. The typical energy output of the array each day was quoted as 16 kWh.

"The results of this experiment lay the foundations for future terrestrial concentrator arrays," claimed the team. "Using color-mixing lenses and triple-junction cells [could] achieve unprecedented performance and even-

tual cost-effectiveness in mass production."

If the module were deployed in space, the 200 W m^{-2} conversion figure would immediately increase by more than 50%. Improvements in array design that have already been identified – such as improved optics – ought to further increase power output. "For future systems with wider cells, edge bus-bars and interconnect tabs, power output will be at least 20% greater, not including anticipated cell-efficiency improvements," said the team.

Entech president Mark O'Neill has set out a long-term plan to reduce the power-to-weight ratio of solar systems used in space applications. His target is to reach 1 kW kg^{-1} specific power in 20 years, which he says will require an advance in multijunction-cell efficiency to 45–50%. A 40% reduction in cell mass would also be needed, something that O'Neill suggests could be achieved either by reducing the thickness of the germanium substrates used currently in triple-junction cells, or by employing a silicon substrate.

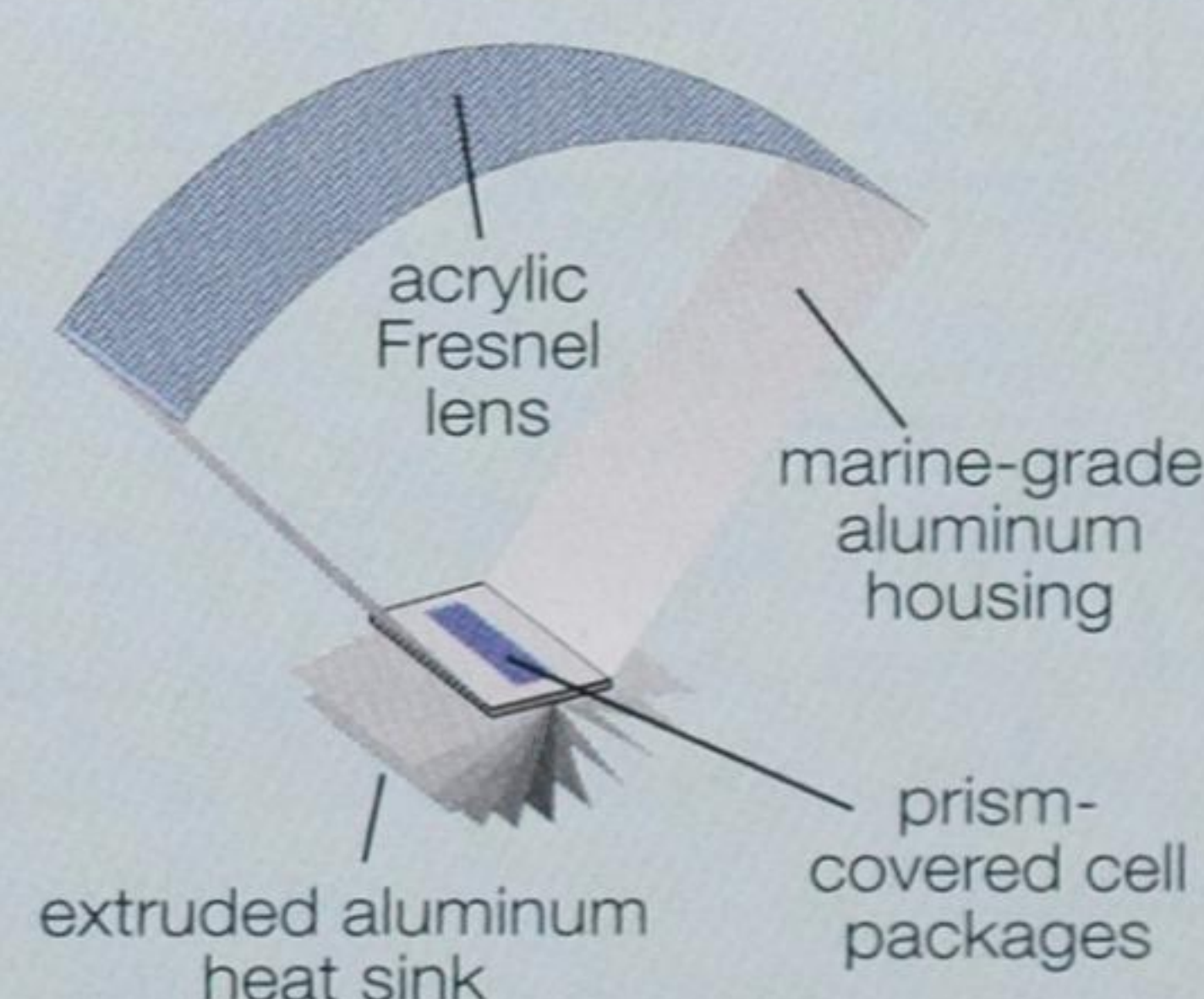
The work could become the first phase of an end-to-end power-beaming demonstration, which would incorporate either a microwave or a laser beam to direct the generated energy. The plan is to install a NASA-designed power converter at the Hawaiian site as soon as funds become available.

Concentrator array optics

A key aspect of the concentrator array is the optical system used to focus sunlight onto the cells. The two concentrator modules use a $0.84 \times 3.6 \text{ m}$ color-mixing acrylic Fresnel lens to focus light at 26× concentration. In collaboration with Sandia National Laboratories, the US Department of Energy and the National Renewable Energy Laboratory, Entech has

developed a lens that is smooth on the outside and prismatic on the inside. Compared with conventional concentrator optics that use reflective surfaces or flat Fresnel lenses, Entech's solution is said to improve the tolerance of shape errors by more than two orders of magnitude.

This is crucial in designing reliable concentrators that are to be used for long-term operation.



The cells are maintained at around 25°C above ambient

temperature by a finned aluminum heat sink that provides four times as much conductive heat-transfer area than the aperture of the lens. According to Entech, the heat-transfer area:heat collection area ratio is the most important parameter in determining cell-operating temperature.

In the Hawaii tests, the Fresnel lens helped to eradicate losses due to prismatic dispersion.

AUCTION

www.henrybutcher.com

By Order of The Joint Administrative Receivers,
G.Bushby and M.Smart of Baker Tilly
Re: Kamelian Limited (In Administrative Receivership)

LIVE AND WEBCAST AUCTION SALE

On: Tuesday 14th September 2004 at 10:30am
At: Kamelian Ltd, Oxford Industrial Park, Mead Road,
Yarnton, Oxford, OX5 1QU, UK

ENTIRE CONTENTS OF OPTO-ELECTRONIC COMPONENT MANUFACTURING FACILITY

(Majority of Equipment Year 2001)

WAFER FABRICATION EQUIPMENT: Aixtron 2400 'G3/2600G3' MOCVD Reactor, STS Multiplex CVD System, STS ICP and RIE Etchers, Leybold 'LA600' Evaporator with 'IC5' Deposition Controller (Qty 2), Leybold 'L560' Evaporator, Emitech 'K550X' Sputterer, Matrix 'E105' Asher, Suss MicroTech 'Gamma 60' Spin Coater

WAFER METROLOGY EQUIPMENT: Hitachi 'S4300' Scanning Electron Microscope, Phillips 'Xpert Pro MRD' Xray Diffractometer, Phillips 'PLM 100' Mapper, Veeco 'Dektak 8', Orbis 'SE500' Ellipsometer, Perkin Elmer 'Lambda 900' Spectrophotometer

PACKAGING & ASSEMBLY EQUIPMENT: Karl Suss 'MA6' Mask Aligner, Karl Suss 'FC150' Flip Chip Bonder, Cammax 'EDB 80', 'DB600' Wire Bonders, GSI Lumonics 'JK703' Yag Laser with 4 Way Time Share, Naples Coombes Laser Welding Alignment Rigs, Pyramid 'HPS9000' Seam Sealer, K&S '4524' Wire Bonders, Edwards 'Spectron 5000' Fine Leak Tester, Fusion Splicers and Cleavers, General Assembly Equipment

TEST AND INSPECTION EQUIPMENT: Optical Spectrum and network analyzers, Oscilloscopes, Tunable Lasers, Lightwave Meters, Multimeters, Data Acquisition Units, Power Supplies Burn In and Bar Testers, Leica Microscopes

ALSO - Class 100/1000/1000 Sectional Clean room, Clean room and Office Furniture, Office and Video Conferencing Equipment

All Assets subject to presale

On View: Monday 13th September 9:00am - 5:00pm

To Request a Catalogue: Tel 020 7098 3700, Fax 020 7098 3795,
Email sales@henrybutcher.com

For further details and webcast registration please visit
www.henrybutcher.com



Tel: + 44 (0) 20 7405 8411
Fax: + 44 (0) 20 7405 9772
Email: sales@henrybutcher.com

BandiT Goes Where Pyrometers Can't!



Band-Edge Temperature Monitor

- Optically-based, real-time wafer temperature sensor utilizing band-edge absorption for GaAs, Si, InP, ZnSe, ZnTe, SiC.
- Ideal for MBE, sputtering, evaporation, or any process where accurate substrate temperature measurement is critical.
- Provides measurements from room temperature through growth temperature with 0.1 degree resolution.
- Features a single USB connection, and utilizes powerful software that can be run from a laptop.

kSA BandiT™

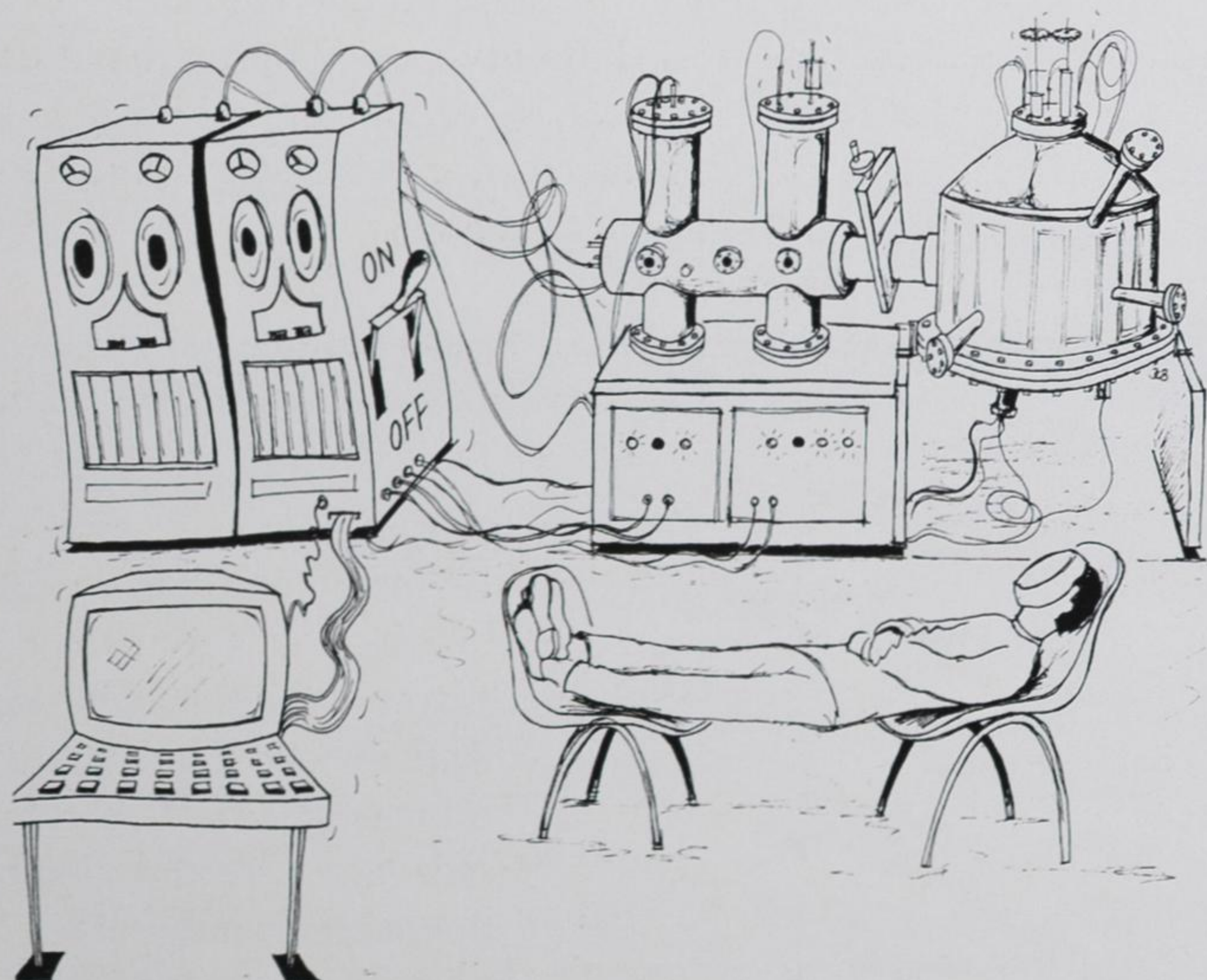
k-Space Associates, Inc.



tel 734.668.4644 fax 734.668.4663 info@k-space.com • www.k-space.com

E p i M a x C
p i M a x C o
i M a x C o n
M a x C o n t
a x C o n t r
x C o n t r o
C o n t r o l

EpiMax... Control Solutions for Deposition processes



For peace of mind: contact sales@epimax.com

Looking for reproducibility and control
in your wafer growth process?

EpiCAD™

For research, development & production
A revolution in epitaxial growth software
gives consistent precision in your wafers

Structure Oriented Control™
defines recipes in terms of:

- growth rate
- composition
- doping levels
- thickness

Precision data logging includes
consumption records and calibration
auto-correction

Recipe editing during growth

Flexible: fully configurable by the user

See us at MBE 2004

Quantum dots and GaN dominate talks in Hawaii

GaN-based materials and quantum dots were two of the major talking points at ICMOVPE-XII, which was held in Maui, Hawaii. **Richard Stevenson** describes some conference highlights.

The resort of Lahaina, on Maui island, Hawaii, provided a magnificent setting for the 12th International Conference on MOVPE, held on 30 May – 4 June. GaN-based materials and devices were the main subjects of discussion, and the opening talk, given by George Craford, chief technology officer of Lumileds Lighting, considered the role of MOVPE in solid-state lighting.

Current MOVPE technology was demonstrated by dazzling the audience with a GaN-based LED torch, while Craford underlined the global impact of semiconductor light sources by highlighting the installation of LEDs in traffic signals in Cambodia.

Craford is optimistic about the technology and, although he believes that improvements must be made to both substrates and growth processes, he predicts that the high efficiencies offered by LEDs will fuel the increase of worldwide production levels to 50 billion GaN-based LEDs per year by 2010. This assumes a 10% penetration into traditional markets and GaN-based LED lifetimes of 10 years. Overall it would correspond to an annual production of 25 million 2 inch wafers, or 1000 reactors yielding 68 wafers each day.

UV-LED developments

Later in the week John Edmond, director of optoelectronic technology at US-based Cree, described developments in deep-UV-LED sources. Edmond explained that solid-state sources emitting in the 270–340 nm region will enable technological advances such as fluorescence-based biological-agent detection; non-line-of-sight communications; water purification; and industrial processing, including ink drying and epoxy curing. In addition, Edmond described the benefits of optimizing device geometries to improve light extraction, reporting output powers of 1 mW at 20 mA and a peak wavelength of 340 nm.

An alternative method to improve light extraction – by introducing a corrugated interfacial substrate – was demonstrated by

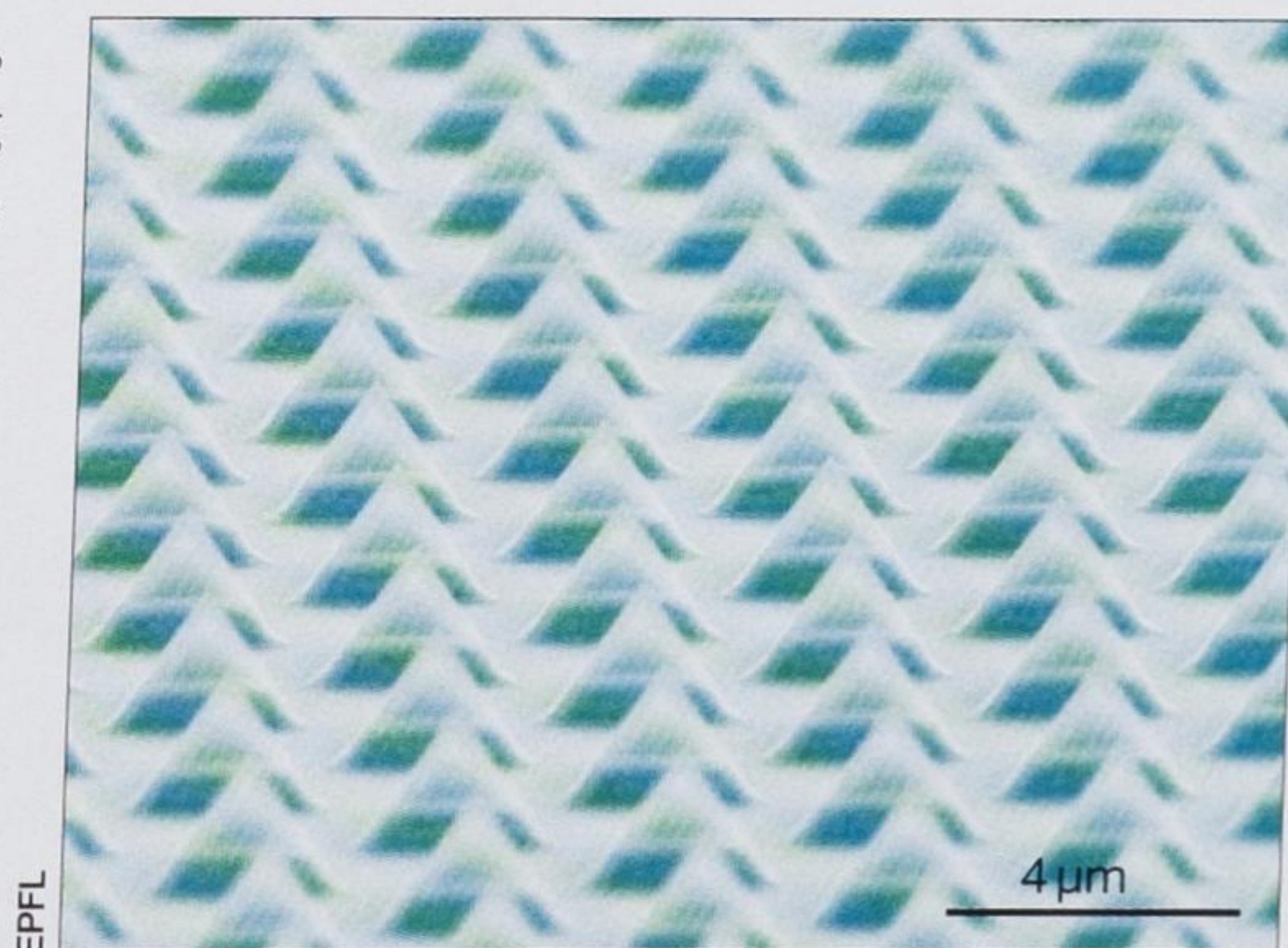


Fig. 1. This SEM image of pyramidal quantum dots was produced by the EPFL in Switzerland. This regular array is created by patterning the GaAs substrate by electron-beam lithography prior to growth.

Samsung Advanced Institute of Technology, Korea. Improvements of more than 60% in extraction power, compared with conventional UV LEDs, were achieved using standard photolithography and reactive-ion etching.

High prices and the limited availability of GaN substrates have led to the fabrication of the majority of GaN-based devices on sapphire and SiC substrates (*Compound Semiconductor* July p20). Silicon substrates are attractive alternatives in terms of cost and scale, although they have inherent drawbacks. In particular, GaN epilayers can exhibit bowing and cracking due to the large thermal coefficient mismatch between silicon and GaN.

An alternative growth scheme was put forward by Matthew Charles from the University of Cambridge, UK. He suggested incorporating AlN interlayers, AlGaIn graded layers, AlN/GaN superlattices and SiN into substrates to reduce tensile strain and dislocation density, thus allowing the growth of 2.3 μm-thick uncracked films of GaN on silicon.

Growing AlGaIn/GaN HEMTs on silicon substrates was the subject of a talk given by Shiping Guo from Emcore Corporation, Somerset, NJ. Using Emcore's proprietary buffer technology, researchers fabricated a

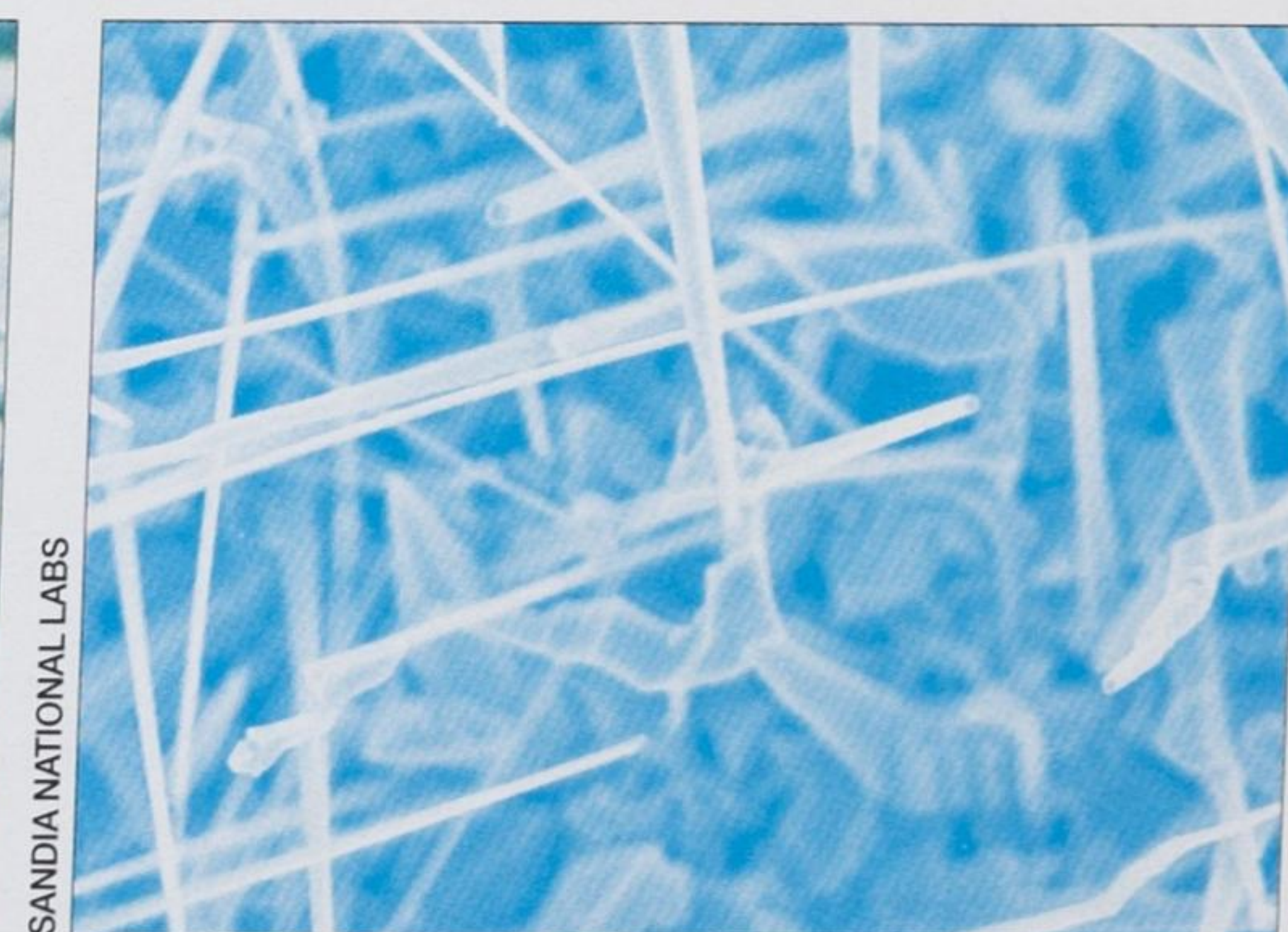


Fig. 2. A micrograph of GaN nanowires, produced by Sandia National Labs. The diameter at the tips of the wires is typically 20–100 nm, and the length of the wires can be as much as several tens of microns.

crack-free 2 μm-thick buffer layer on which they grew the HEMT structure.

Quantum dot (QD) structures and devices were another major talking point in Maui. Most groups grow QDs by strain-induced self-ordering using the Stranski–Krastanov (SK) growth mode, but a few researchers presented work involving prior growth patterning of substrates, leading to the formation of pyramidal structures with a dot defined at the very apex of the pyramid.

Improving QD lasers

Pelucchi Emanuele, from the École Polytechnique Fédérale de Lausanne (EPFL), Switzerland, explained that although SK growth can produce very good interfaces, site control of the dots is difficult to achieve and there is a wide distribution in their peak emission wavelengths. Emanuele believes that ordered arrays of dots with reproducible and controlled excitonic states can provide opportunities for studying fundamental physics (for example, exploring entangled and correlated excitonic and photonic states) and deliver improved performances in QD lasers.

The EPFL group has patterned [111]B GaAs substrates with hexagonal arrays of tetrahedral



European Sole Agent of
FURUKAWA

- Arsenic 7N5 MBE slugs
- Arsenic 6N, 7N, 7N5 chunks

**Your MBE materials
one stop shop**

- Arsenic 7N5
- Gallium 7N
- Indium 7N
- Aluminium 6N5
- Red Phosphorous 7N
- Magnesium 6N
- Manganese 5N8
- Antimony 7N
- Beryllium 5N
- Silicon Dopant
- PBN Crucibles

**Your Wafers
one stop shop**

- Indium Antimonide
- Indium Arsenide
- Indium Phosphide
- Gallium Antimonide
- Gallium Arsenide
- Gallium Phosphide
- Silicon Carbide
- Silicon
- Sapphire

New

TMGa, TM In, DE Zn, Ce, Dy, Er, Gd, HfO₂,
Ho, La, Lu, Nd, Pr, Sm, Sc, Ta, Tb, Tm, Yb, Y

WWW.ARNAUDELECTRONICS.COM

Tel : 0033-1-44 73 10 70 Fax : 0033-1-44 73 10 53
Arnaud.Electronics@A-Arnaud.fr



MBE foundry for advanced Quantum Dot and Quantum Well wafers

Quantum Dot

Grow with us!

Pseudomorphic GaAs Wafers (up to 1.3x μ m)

- ▶ Quantum Dot Edge Emitting Laser (EEL) or VCSEL structure
- ▶ Quantum Dot structures for SOAs and gain chips
- ▶ Quantum Well EEL or VCSEL structure (up to 1.1x μ m)

Metamorphic GaAs Wafers (up to 1.5x μ m)

- ▶ GaAs Quantum Dot Edge Emitting Laser (EEL), SOAs, gain chip or VCSEL structure

Wafers for: pHEMTs, mHEMTs, HBTs, QW and QD photodetectors, LEDs, GaAs Quantum Dot structures for photo/electro luminescence (0.8 μ m - 1.5x μ m) and resonant tunneling studies and other epi-products.

Call us at +49 (231) 9742-7000 or visit us online
www.nanosemiconductor.com

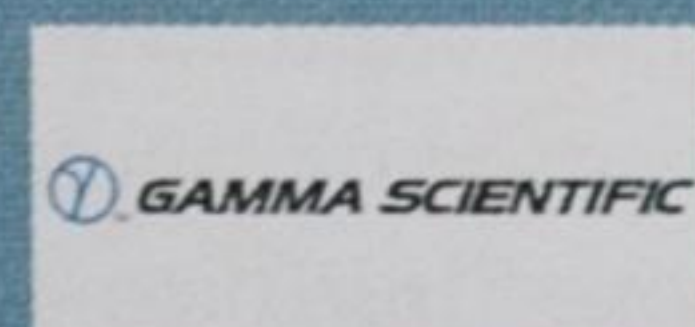
October 20-22, 2004
Sheraton San Diego Hotel & Marina
San Diego, California



LEDs 2004

Light Emitting Diodes 2004

Sponsored by:



This 5th annual conference will bring together over 400 leading developers and executives from high-brightness LED (HB LED) manufacturers, component and equipment suppliers, lighting designers and major end-users to discuss the latest opportunities and advancements in LED technology and solid state lighting.

For more information please visit
www.interechusa.com/leds.html
or call +207.781.9618

recesses with a pitch ranging from 300 nm to 5 μm using electron-beam lithography. Subsequent growth of GaAs/AlGaAs followed by InGaAs enables the formation of pyramidal structures with quantum wires along the edges and a dot at the top of each structure emitting at around 800 nm (figure 1). The size uniformity of the dots is sufficient for the intrinsic broadening of light emission from a single dot to outweigh any contribution from fluctuations in the size of the dots. The EPFL group believes that this will enable the fabrication of QD lasers with all dots participating in the lasing process, giving a performance that could potentially surpass that of state-of-the-art quantum well lasers.

Tung-Po Hsieh, from the National Central University in Taiwan, reported strong photoluminescent (PL) emission at 1.55 μm from InAs QDs on GaAs substrates. He believes that this is the longest wavelength emission reported for InAs-on-GaAs dots grown by MOVPE. This result was achieved by inserting an $\text{In}_{0.25}\text{Ga}_{0.75}\text{As}$ strain-reducing layer between the cap and the InAs QDs.

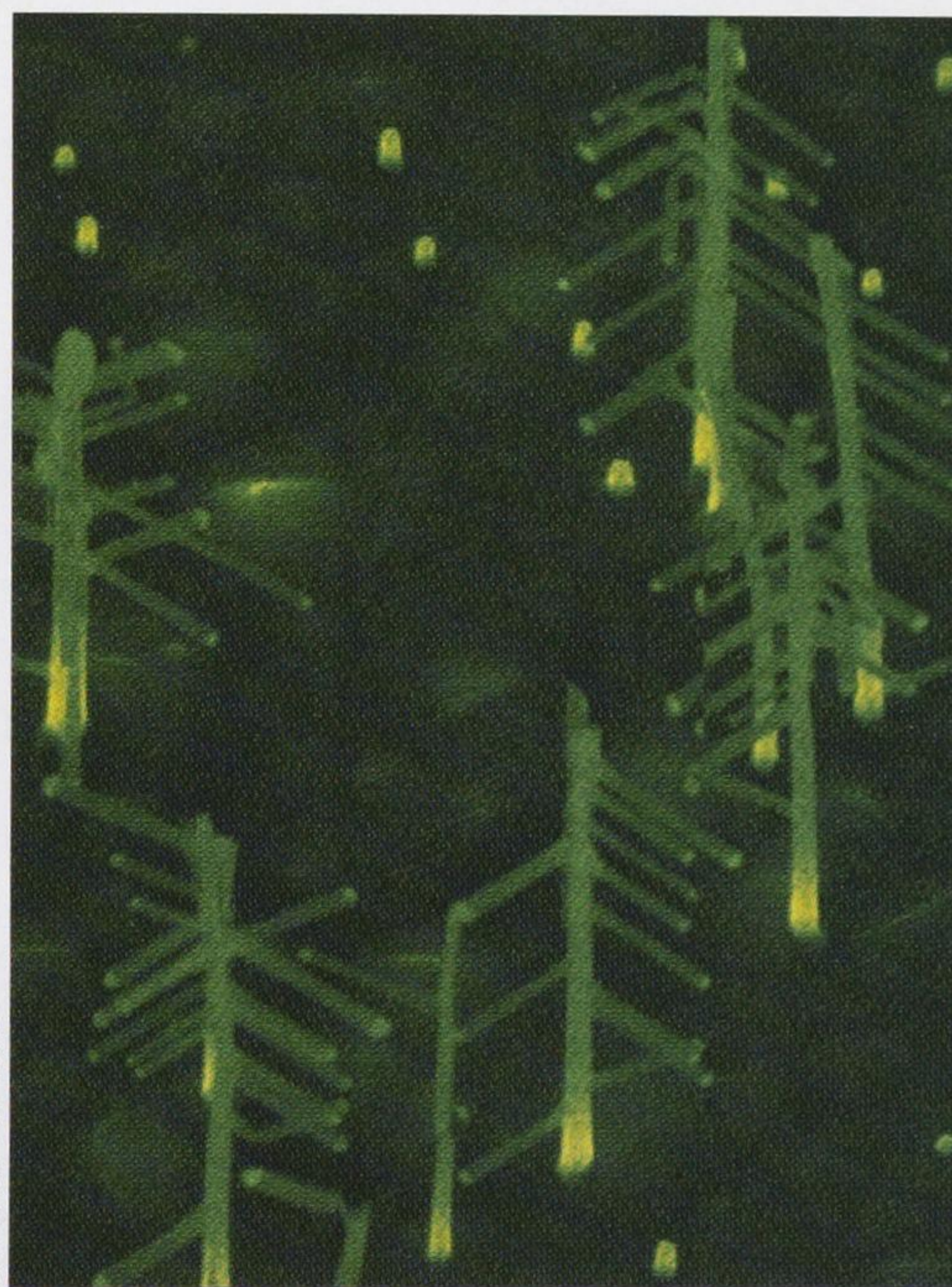
Jin Hong Lee from the Electronics and Telecommunications Research Institute of Korea reported on the tuning of emission from self-assembled InAs QDs, this time on InP substrates. Increasing the interrupt time after deposition of the InAs QD layer red-shifted emission from 1.48 to 1.66 μm and increased PL intensity. Blue-shifting emission from 1.48 to 1.38 μm was achieved by introducing a thin InAlGaAs layer on top of the InAs QDs.

The Korean team also fabricated ridge waveguide lasers using InP substrates, an InAlGaAs matrix and seven stacks of InAs QDs. This resulted in room-temperature lasing at 1.5 μm , which Lee believes is a first for this type of structure, although InAs quantum dash structures have also been shown to lase at this wavelength.

Solar-cell-production issues

Frank Dimroth, from Fraunhofer ISE, Germany, highlighted the perils of scaling up the production of next-generation solar cells from single to multiwafer reactors. He spoke about problems such as unintentional doping that can occur during the transfer of growth of solar cells containing InGaAsN from a single-wafer to an 8 $\times$ 4 inch multiwafer platform. InGaAsN, which can be lattice-matched to GaAs, has been identified as a suitable material for next-generation solar cells containing up to six active junctions.

InGaAsN's suitability was assessed by first



UNIVERSITY OF LUND

Fig. 3. This array of approximately 1 μm high nanotrees has been synthesized at the University of Lund in a process that uses gold catalysts and MOVPE growth.

producing single-junction cells on an AIX200 single-wafer reactor. These cells were considered to be of suitable quality to incorporate into multijunction cells, but transfer to an 8 $\times$ 4 inch platform was problematic.

For example, triethylgallium (TEGa) – the source used for single-wafer growth – caused black deposits on the inside of the reactor lid. Dimroth believes that these deposits alter the incorporation of indium in InGaAsN, preventing run-to-run control of the composition of the quaternary material. Substituting trimethylgallium (TMGa) for TEGa introduced a new set of problems: solar cells grown with TMGa had high background-doping levels, and external quantum efficiencies in the region of interest (800–1200 nm) of less than half of those produced from a single wafer reactor. Dimroth admits that further work is required on the multiwafer reactor either to reduce background doping or to solve the problems associated with TEGa growth.

A method to fabricate 1.55 μm VCSELs by fusing a strain-compensated InAlGaAs MQW region grown on an InP substrate, and AlGaAs mirrors on GaAs substrates was reported by Rudra Alok from the EPFL. Wafer-bonding produced 7 μm -aperture devices that operate in CW mode at room temperature with output powers of 3 mW and associated side-mode suppression ratios of 30–35 dB.

Emission at a wavelength of 9 μm from a

quantum cascade laser (QCL) was the subject of a talk by Andrey Krysa from the III–V growth facility at the University of Sheffield, UK. Krysa explained that, historically, MBE technology has dominated the growth of QCLs, but recently his group has produced InP/InGaAs/InAlAs QCLs via MOVPE. These lasers exhibit peak powers in excess of 1 W at room temperature, which is comparable to state-of-the-art devices grown by MBE.

Exotic structures

George Wang from Sandia National Labs, US, described his work on AlGaInN nanowires. He explained that, to date, the primary growth methods used in the synthesis of GaN nanowires have been thermal evaporation and chemical-vapor deposition techniques using gallium metal or GaN powder source materials in hot-wall tube reactors. Wang believes these evaporation-based techniques suffer from a general lack of control, reproducibility and scalability, and cannot be used to produce complex heterostructures.

The Sandia group now employs an MOVPE process to synthesize GaN nanowires on 2 inch substrates coated with nickel catalysts. Various studies indicate that the nanowires are single-crystalline GaN with nickel clusters at the tips, indicating growth via the vapor–liquid–solid mechanism. The nanowires have tip diameters of 20–100 nm and lengths of up to several tens of microns (figure 2). Using MOVPE, core-shell heterostructure nanowires consisting of GaN cores and various III-nitride shell materials, including AlN, InN, AlGaIn and InGaIn, have also been produced.

The creation of more complex nanostructures, such as “nanotrees” (figure 3), was described by Werner Seifert from the University of Lund, Sweden. These structures are produced by seeding a GaP [111]B substrate with gold aerosol nanoparticles, which act as catalysts for GaP nanowire growth in the [111] direction. The nanowires act as the “trunks” of the nanotrees, with subsequent “branches” generated by seeding the trunks with additional gold nanoparticles. The process can be continued for a third time forming sub-branches or “leaves”.

To form an ordered array of nanotrees, such as those in figure 3, a regular pattern of gold particles is deposited on the substrate by using electron-beam lithography. Growth is not restricted to GaP and researchers have already produced InP-based trees on InP substrates. The team hopes that one day nanoleaves will be able to replicate plant photosynthesis. ●

ATMI sells epitaxy group to International Rectifier

Materials supplier ATMI, based in Danbury, CT, is to sell its Epi Services business – which fabricates specialty silicon and silicon germanium epitaxy – to International Rectifier (IR), an IC manufacturer that specializes in power-management technology.

IR will pay ATMI \$41 million in cash for the operations and assets of the Epi Services group, located in Mesa, AZ. The deal, which is expected to close in the September quarter, includes related intellectual property, fixed assets and inventory. About 90 employees will join IR as part of the agreement.

This represents the third epitaxial-materials-related business that ATMI has sold in the space of just over a year. In fall 2002, the company stopped production at its GaAs epiwafer

facility in Phoenix, AZ, and later sold the business to Sumika Electronic Materials. Then, in April, ATMI sold its GaN epitaxy and substrates business based in Danbury, CT, to LED manufacturer Cree (*Compound Semiconductor* May p5). IR has been a major customer of ATMI's specialty epitaxial services for several years and, clearly, it decided that it was necessary to purchase a business that ATMI had already discontinued.

"Epi Services' employees are very familiar with IR's needs and requirements," said Gene Banucci, CEO of ATMI. "[They] are going to reap the advantages of joining a world leader that is devoted to advanced power-management products that require specialty epitaxial steps."

Strategy Analytics predicts significant GaAs-market growth

Market analysts at Strategy Analytics predict a 16% average annual growth rate between 2003 and 2008, in terms of materials, for GaAs semiconducting substrates. The demand for 2 inch material will continue to dominate the industry, but that for 4 inch material is expected to grow 40% year-on-year through 2008. In 2003, 2 inch material accounted for 65% of the

market, with 3, 4 and 1 inch material having a 27, 5 and 3% share, respectively.

Japan will remain the primary production centre for GaAs substrates, led by Sumitomo Electric, Hitachi Cable and Mitsubishi Chemical, predicts Strategy Analytics. In 2003, Japan and the Asia-Pacific region accounted for 84% of the total demand for semiconducting substrates, followed by North America, 10%, and Europe, 6%.

The report was restricted to semiconducting substrates used in the optoelectronic industry and did not consider semi-insulating material for the microelectronics industry.

Contamination costs Emcore \$4m

Emcore, the semiconductor materials and devices company based in Somerset, NJ, was provided with contaminated material that it used in its new transceiver product line.

Emcore identified the contamination only after qualification testing of the finished modules, which led to an expected-revenue shortfall of \$4 million for the current quarter. It anticipates costs associated with production of the substandard product of \$1.3 million.

Emcore's CFO, Tom Werthan, told *Compound Semiconductor* that the company had not switched suppliers at this stage, but is looking for second- and third-tier sources. Emcore is yet to recover any money from its current supplier. Werthan would not reveal any details

of the contamination as *Compound Semiconductor* went to press, but said that the firm will be more forthcoming when it announces its third-quarter results on August 3.

Emcore pulled shipment of the finished products because of fears of warranty returns. To prevent a repetition of the problem, it has implemented additional quality tests in its supply chain and is modifying finished products to satisfy additional customer qualification.

"We are confident the materials issues have been resolved, and high-volume production has resumed. We currently have purchase orders for this [transceiver] product of \$10.2 million that we intend to ship over the next two quarters," said Reuben Richards, Emcore's CEO.

Nitronex to provide GaN-on-Si epiwafers

GaN-on-silicon specialist Nitronex Corporation, based in Raleigh, NC, is now selling 100 mm diameter GaN epitaxial wafers.

"We realized that it was time to exploit the technology we already had to help others build their next-generation devices, just as we are doing with our commercial RF power transistors," said Christopher Rauh, Nitronex's vice-president of sales and marketing.

GaN-based materials, which are well-suited to high-temperature, high-frequency and high-voltage applications, have been a focus of intense development efforts for electronic devices in recent years. However, at present, sapphire and SiC are the substrates of choice, and these have been used in the manufacture of commercially available products such as LEDs and laser diodes.

Applications and markets that remain to be penetrated include high-temperature and Hall sensors, switches, MEMS, high-frequency MMICs, military radar and communications applications, and RF power transistors.

"Using large-area, 100 mm, silicon substrates provides the economic benefits of large wafer scaling, as well as cheaper wafer-procurement costs compared with other substrates. These benefits are what will ultimately allow for widespread GaN-based device commercialization," said Edwin Piner, Nitronex's director of materials engineering.

In brief

- **Anadigics** – a supplier of wireless and broadband solutions – has selected **Emcore Corporation** to be its primary supplier of all RF materials.
- **Praxair** has been awarded a contract by Taiwan-based LED manufacturer Epistar Corporation to supply bulk specialty gas-delivery systems of ultrahigh-purity ammonia for its next expansion.
- **Veeco Instruments** says that Raytheon has placed an order for one of its GEN20 molecular beam epitaxy (MBE) systems.
- **Riber** has delivered and installed two more Compact 21 MBE systems to prominent research institutes in Asia.
- **Correction:** Kyma Technologies' CEO, who was quoted in *Compound Semiconductor* July p20, is Ed Pupa, not Ed Pugh.

Soitec and ASM reduce strained-SOI defects

France-based Soitec and ASM International in the Netherlands say that they have made a major breakthrough in their joint development of strained silicon-on-insulator (sSOI) technology.

Company officials say that the year-long collaborative effort has resulted in sSOI substrates that have a high-quality, "wafer-level" strain, without the elevated number of crystal defects that have traditionally plagued the material.

Soitec says that the quality of the strained layer is unprecedented, with defect levels of between one-hundredth and one-thousandth that of the industry standard, and is close to that of standard SOI and bulk silicon.

Key to this effort, according to Soitec, was introducing a wafer-level strain, which will extend the technology advantages beyond the "local strain" already used in some advanced chips today.

Chipmakers will now have access to sSOI substrates that promise to break through today's looming barriers of power dissipation – an increasingly critical roadblock to higher-performing

chips. And, since wafer-level strain is now no longer dependent on IC design, sSOI substrates will enable a wider range of high-speed, low-power IC applications, including those with high-performance logic cores.

"By creating the industry's first high-quality, wafer-level sSOI technology, we have reached a milestone in accelerating the industry availability of sSOI silicon wafers and, ultimately, the future-generation chips that these substrates will enable," said André Auberton-Hervé, Soitec's president and CEO.

He continued: "In addition to being the first company to offer 300 mm sSOI wafers to the industry, Soitec's roadmap calls for the first ramp of industrial-level quantities of these wafers."

The development program used Soitec's Smart Cut technology. Soitec has been sampling 200 mm sSOI for more than a year and is currently upgrading its 300 mm sSOI production line – which is the first of its kind in the world – for sampling and pilot manufacturing.

Equipment suppliers Aixtron and Genus strike merger deal

MOCVD equipment manufacturer Aixtron, and Genus – a supplier of atomic-layer-deposition technology to the semiconductor and hard-disk-drive industries – are planning to merge. This move will create one of the world's leading suppliers of advanced deposition equipment.

Aixtron intends to acquire all outstanding Genus shares in a stock-for-stock transaction worth about \$143 million. Genus shareholders will receive 0.51 American Depositary Receipts (ADRs) of Aixtron per Genus share, and

on completion of the transaction ADRs will be quoted on NASDAQ. Each Genus share is valued at \$3.61 on this basis.

On closure of the deal, Aixtron shareholders will hold 74% of the merged firm and Genus shareholders will hold 26%.

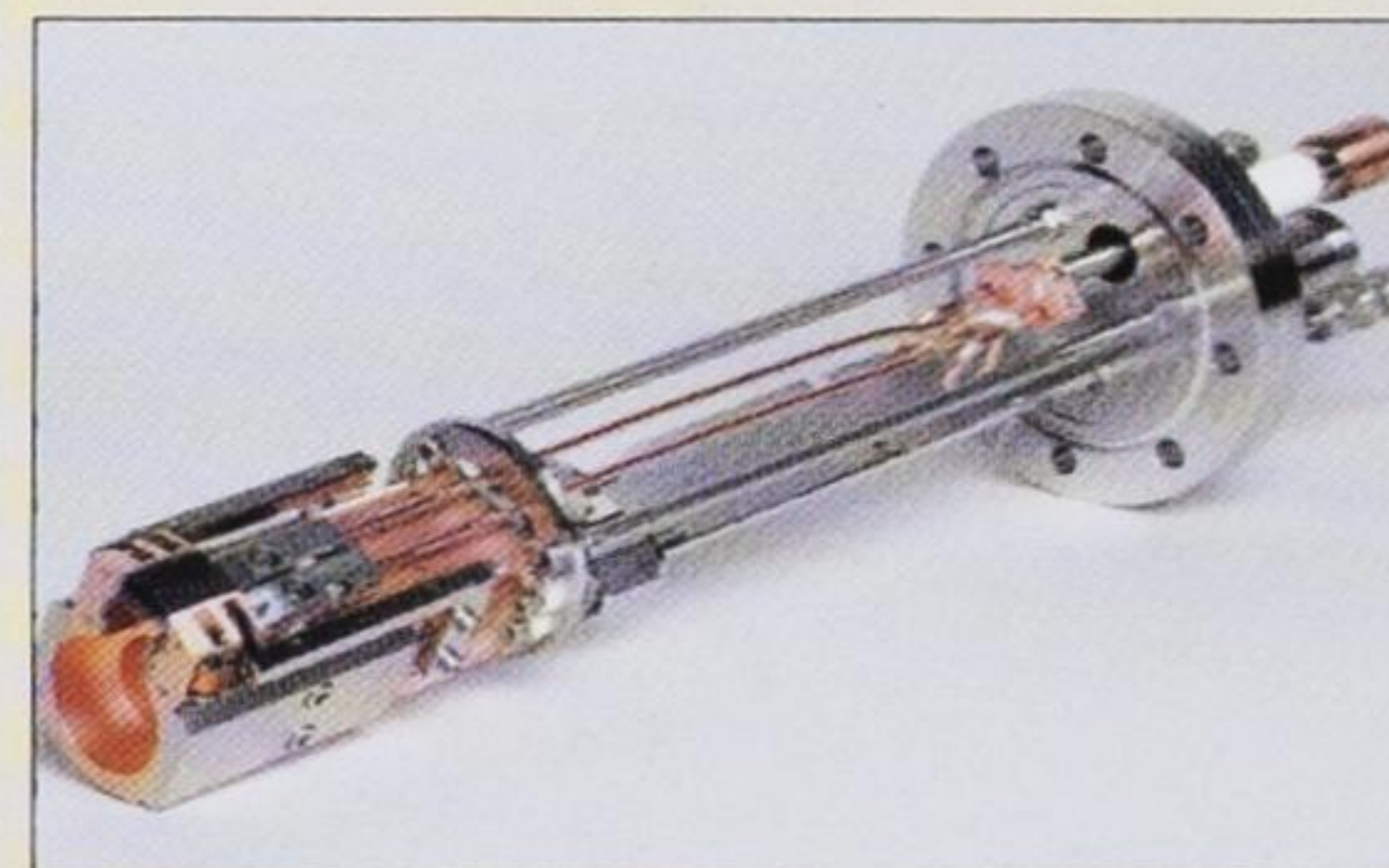
Paul Hyland will remain president and CEO of Aixtron, while William Elder, president and CEO of Genus, will join Aixtron's management board. The transaction, which will form a company with more than 550 employees, is expected to close by year-end.

To advertise your product in this section, contact Luke Neel on tel: +44 117 930 1033, or e-mail: luke.neel@iop.org.

Compact UHV e-beam evaporator

MBE Komponenten

The Electron Beam Evaporator (EBVV) allows the introduction of a true e-beam evaporation technique into a standard epitaxial growth or UHV deposition system. The EBVV's extremely compact design fits into a 4.5 inch flange (60 mm ID) effusion cell port. Despite its small footprint, the new EBVV has a 3 kW power supply and a 270° e-beam deflection design that includes an x- and y-dynamic beam-deflection system. The EBVV is suitable for low vapour pressure materials and high k-material depositions such as silicon, boron, carbon, Al₂O₃, Pr₂O₃ and other oxides and dielectrics.



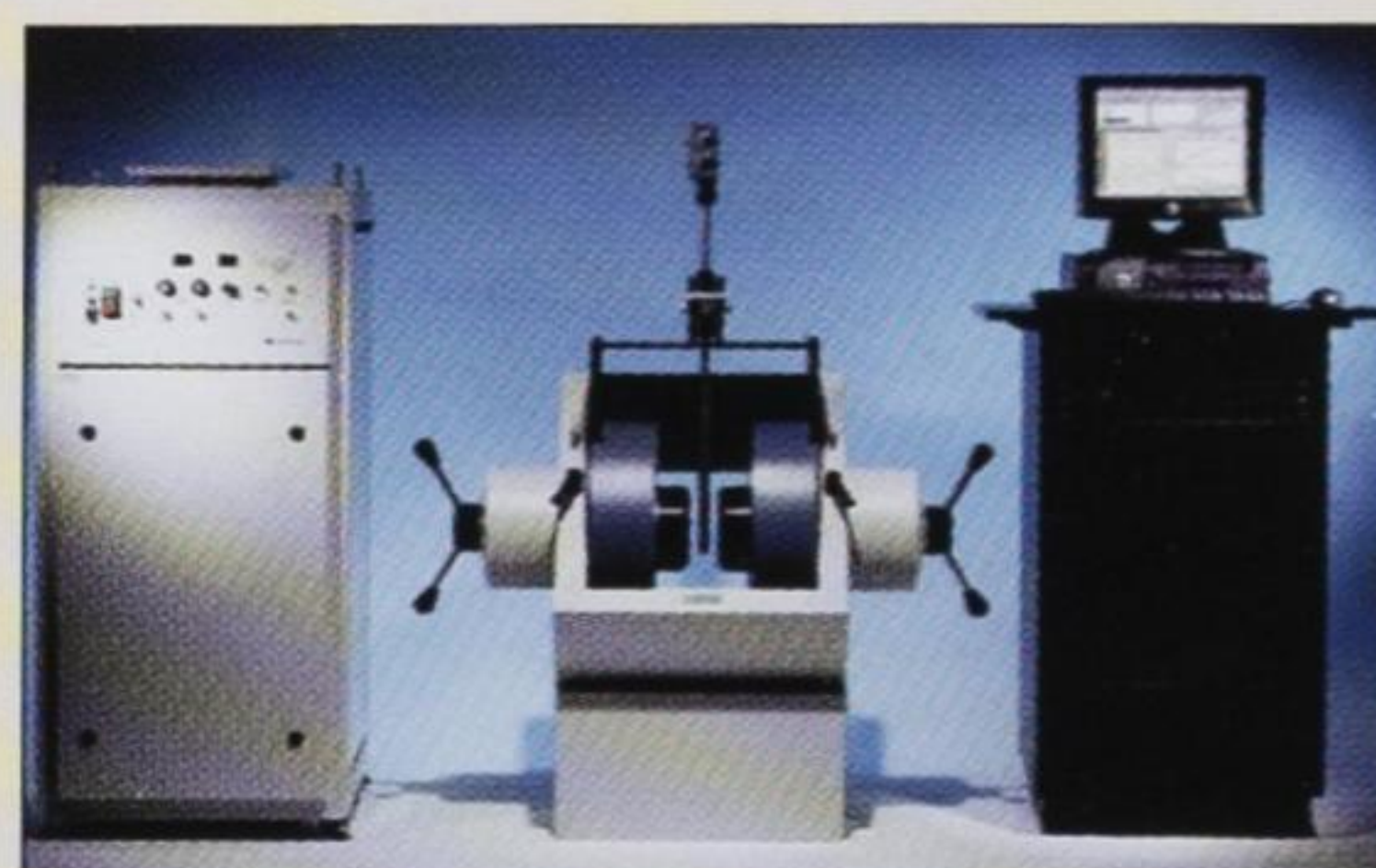
Contact: Dr Eberl
MBE-Komponenten GmbH
Web: www.mbe-components.com
In the US
United Mineral & Chemical Corp.
Tel: 1 800 777 0505
E-mail: inquiry@umccorp.com
Web: www.umccorp.com

Magneto-transport measurements

Lake Shore Cryotronics, Inc

Hall effect measurements on dilute magnetic semiconductors and compound semiconductors. Resistance ranges from 10 $\mu\Omega$ to 100 G Ω , fields to 9 T, and temperatures from 2 K to 800 K. **Quantitative Mobility Spectrum Analysis** software resolves individual carrier mobilities and densities for multi-carrier devices and compound semiconductors.

Anomalous Hall Effect measurements for spintronics and an **AC current** option measures resistance down to 10 $\mu\Omega$, and increases resolution to 10 ppm at 2 m Ω .



Contact: Lake Shore Cryotronics
Tel: +1 614 891 2244
E-mail: sales@lakeshore.com
Web: www.lakeshore.com

EpiRAS TT offers versatile monitoring

LayTec GmbH

EpiRAS TT is the most versatile *in situ* monitoring tool on the market, capable of measuring growth rate, composition, true wafer temperature, surface and interface stoichiometry, surface roughness and doping concentration. The tool is based on three optical techniques: reflectance anisotropy spectroscopy (RAS), normalized reflectance spectroscopy and emissivity corrected pyrometry. The combination of these three methods makes it a unique tool for the R&D of new GaAs- and InP-based opto-electronic devices such as quantum dot lasers, VCSEL applications and 1.3 μm lasers, among others. EpiRAS TT sensors are ideally suited for use in all types of AIXTRON MOCVD reactors and various types of MBE systems. EpiRAS

TT consists of a pre-aligned optical head, a 19 inch electronic rack and a control computer.

Contact: LayTec GmbH,
Helmholtzstr. 13-14,
D-10587 Berlin, Germany
Tel: +49 30 3980 0800
Fax: +49 30 3180 8237
E-mail: info@laytec.de
Web: www.laytec.de



GaAs MBE and HVPE combination produces widely tunable IR source

by Yvonne Carts-Powell
in San Francisco

A GaAs device can provide widely tunable coherent light in the mid-infrared, according to a group from Stanford University and Thales Research & Technology. The group reported its findings at the Conference on Lasers and Electro-Optics, held in San Francisco in May. Konstantin Vodopyanov and colleagues made an efficient GaAs optical parametric oscillator (OPO), overcoming a fabrication problem that has impeded the development of quasi-phasematched GaAs devices in the past. The group created the material, in which the sign of the nonlinear optical coefficient is periodically flipped (figure 1), using a combination of MBE and hydride vapor-phase epitaxy (HVPE).

The mid-infrared is an attractive region for spectroscopy because so many molecules have strong vibrational absorption bands there. Remote spectroscopic identification of gases could be used for applications in industry (monitoring process gases), the environment (smokestack-emission testing), medicine (breath tests), or in defense (sensing chemical and biological weapons).

GaAs transparency

GaAs is an ideal material for nonlinear optics because it has a wide transparency, from 0.9 to 17 μm , and a higher nonlinearity than other common materials like lithium niobate. A GaAs OPO could aid a number of spectroscopic applications that need a coherent light source.

"All of the existing mid-infrared tunable sources have one drawback or another," said Brian Orr, director of the Centre for Lasers & Applications at Macquarie University in Sydney, Australia. "What is needed is a reliable, low-cost, relatively compact, versatile tunable coherent light source operating narrowband throughout the mid-infrared wavelength region."

Creating a GaAs OPO is complicated because GaAs is not birefringent. The nonlinear device requires intense light waves with a constant phase relationship (phasematching) to interact in order to create light efficiently at a new wavelength.

Another method, called quasi-phasematching, can be used for non-birefringent materials, but requires that the pump light travels through many periodic domains of a controlled size, in which the nonlinear coefficient is first positive, and then negative. Some materials, like lithium niobate and KTP (KTiOPO_4), can be "periodically poled" by manipulating the electric field in the material as it is being made. However, periodic poling does not work for GaAs.

Instead, the Stanford researchers are developing epitaxial methods for growing orientation-patterned (OP) GaAs. They grow OP GaAs by first creating a template in which the orientations are set using MBE, and then adding thick layers of GaAs using HVPE (figure 2).

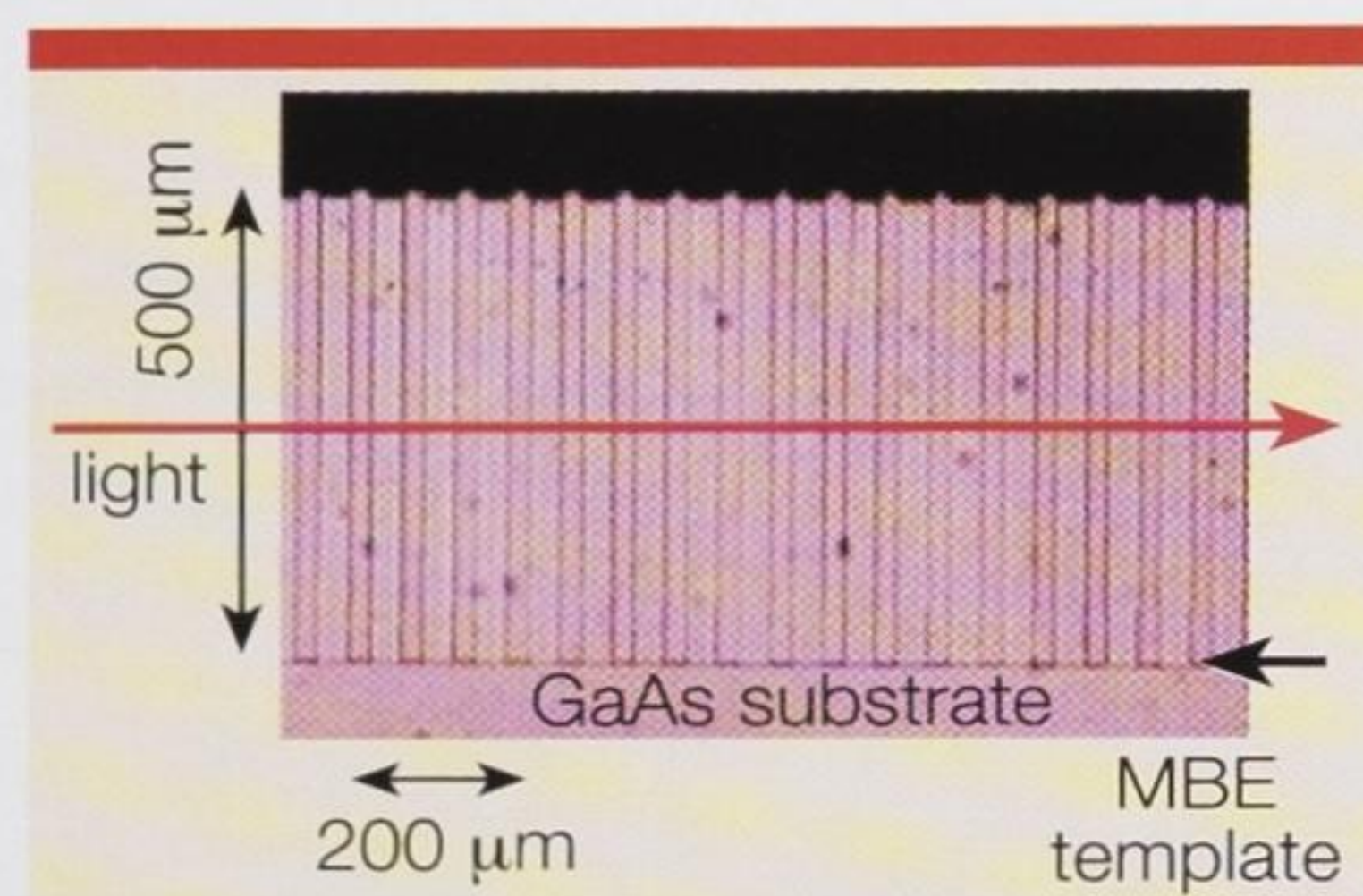


Fig. 1. A cross-section of the orientation-patterned GaAs sample used to make the OPO, which has a 61.2 μm grating period. The stains show the different orientation domains.

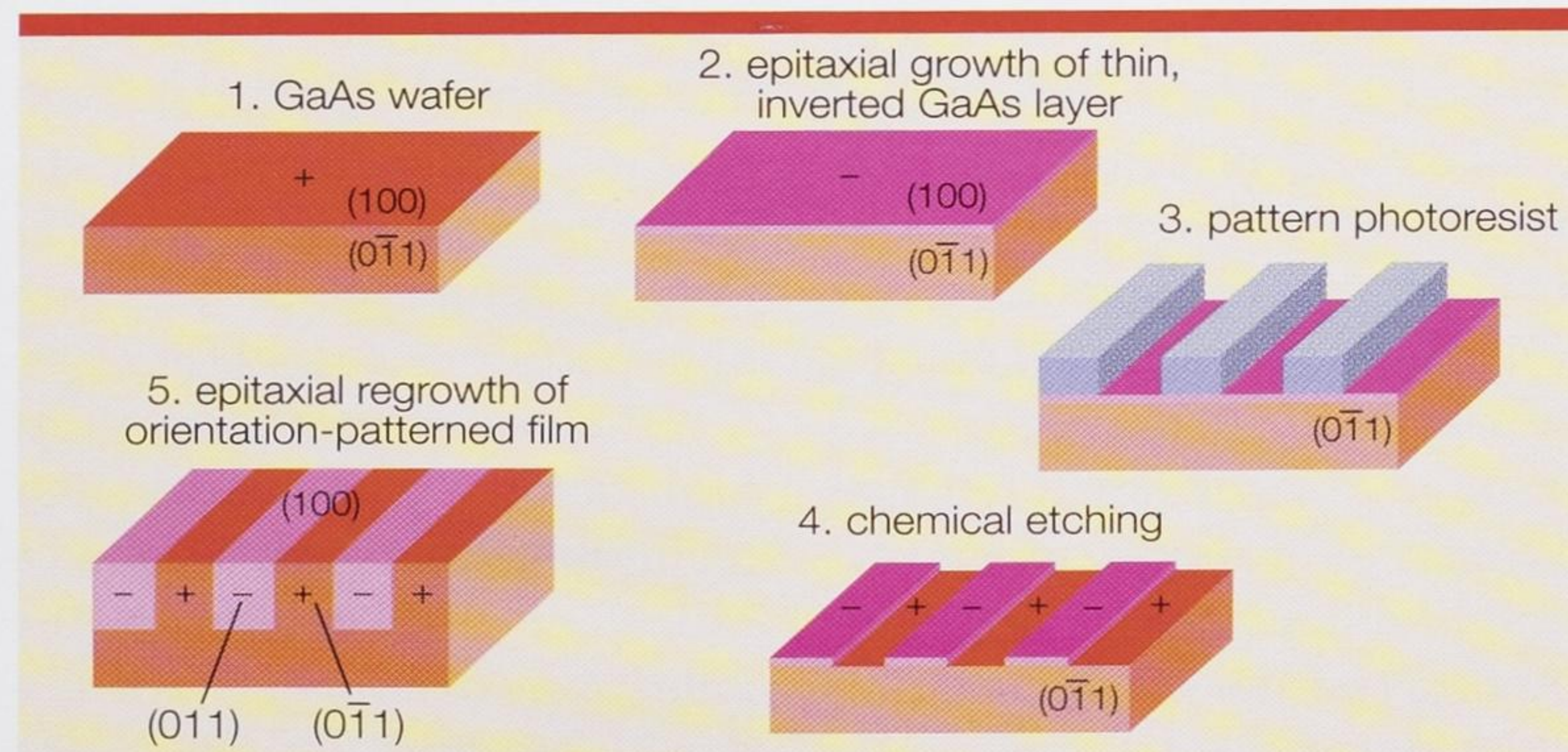


Fig. 2. The crystal used in the GaAs optical parametric oscillator is grown in a series of photolithographic and epitaxial steps.

Templates were made by first depositing a non-polar layer of germanium on the substrate. Then a layer of GaAs, with the crystal orientation inverted compared with that of the substrate, is grown on top of the germanium. A grating pattern is made using photolithography and etching, resulting in surface stripes with alternating orientations. A GaAs layer about 4 μm thick is grown using MBE, at which point the template is complete.

Three-step growth

The much thicker layer of GaAs above the template is grown by the Thales researchers in three steps, each stage producing a 150 μm thick layer. The Stanford team is also working with researchers at the US Air Force Research Lab (Hanscom AFB), who are using faster-growing low-pressure HVPE. So far, the high-pressure method has allowed thicker growth, but each interruption in the growth leads to a greater number of defects. Quality is still an issue for these crystals, although they have been adequate for the successful manufacture of an OPO.

The OPO provides 2–10 μm tunability and has a slope efficiency of 54%. The orientation-patterned GaAs was 0.5 mm thick, 5 mm wide and 11.5 mm long. The quasi-phasematching period was 61.2 μm , and the beam propagated in the (011) crystal orientation.

Vodopyanov reported that the room-temperature OPO device produced efficient mid-infrared radiation when pumped by a lithium niobate OPO producing 1.8–2 μs pulses. "Their progress so far is most impressive," commented Borr.

The group is developing the device even further. "We want to demonstrate OPO tunability across the whole 2–17 μm range," said Vodopyanov.

Yvonne Carts-Powell is a freelance science journalist based in Belmont, MA.

Next month in Compound Semiconductor: more on mid-infrared laser sources

EQUIPMENT

Global Phosphorus Solutions

■ **Innovative Reactors**

In 1982, Riber develops the industry's first phosphorus-dedicated MBE research system.

■ **Patented Phosphorus Sources**

In 1992, Riber introduces the zero-burst valved phosphorus cracker cell design that is now used by all major component manufacturers.

■ **Full-Service Process Technology Center (PTC)**

In 2002, Riber inaugurates the industry's first InP Process Technology Center to accompany you from start up through full production of phosphorus-containing compound semiconductor materials.

If you want to visit the Indium Phosphide PTC and find out more about our global phosphorus solutions for growth, characterization and maintenance, please contact us today at:

RIBER

133, bd National

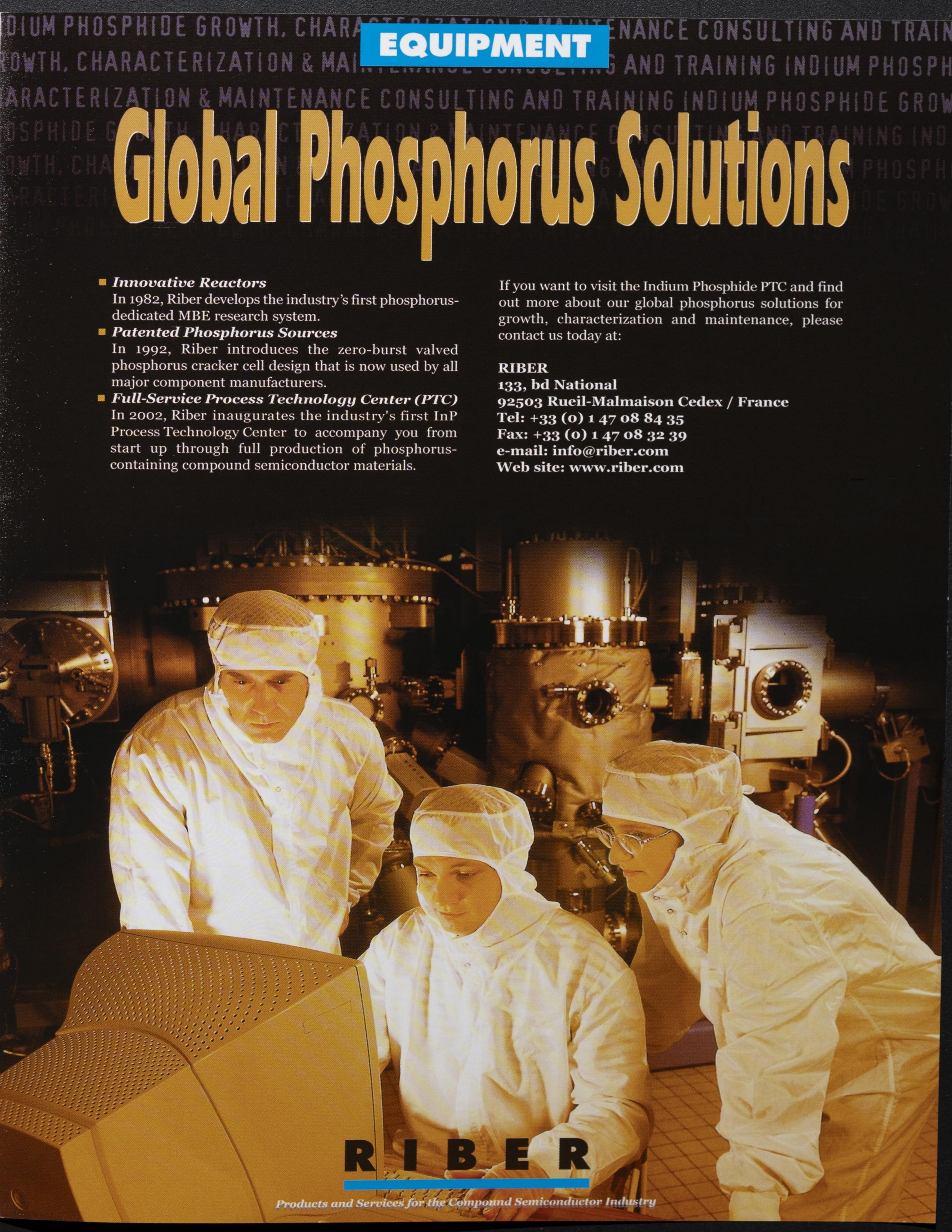
92503 Rueil-Malmaison Cedex / France

Tel: +33 (0) 1 47 08 84 35

Fax: +33 (0) 1 47 08 32 39

e-mail: info@riber.com

Web site: www.riber.com



RIBER

Products and Services for the Compound Semiconductor Industry

**For high-volume epitaxial production,
there's only one choice: Veeco.**



Veeco's high-volume GaNzilla™ MOCVD system.

**Veeco MOCVD and MBE: highest throughput,
lowest cost of ownership, superior quality.**

For high-volume production of compound semiconductors from GaN LEDs to RF integrated circuits, Veeco provides the world's leading epitaxial equipment and process solutions. Higher throughput, performance and quality give you a clear advantage. Coupled with our worldwide customer service, and complementary deposition, etch and metrology solutions, these tools make Veeco your ideal production partner. To learn more, visit www.veeco.com or call **1.888.24.VEECO** today.

**Compound Semiconductor
Solutions:**

MBE, MOCVD, PVD, IBD, IBE
AFM and Optical Metrology
Process Integration Center

Solutions for a nanoscale world.

