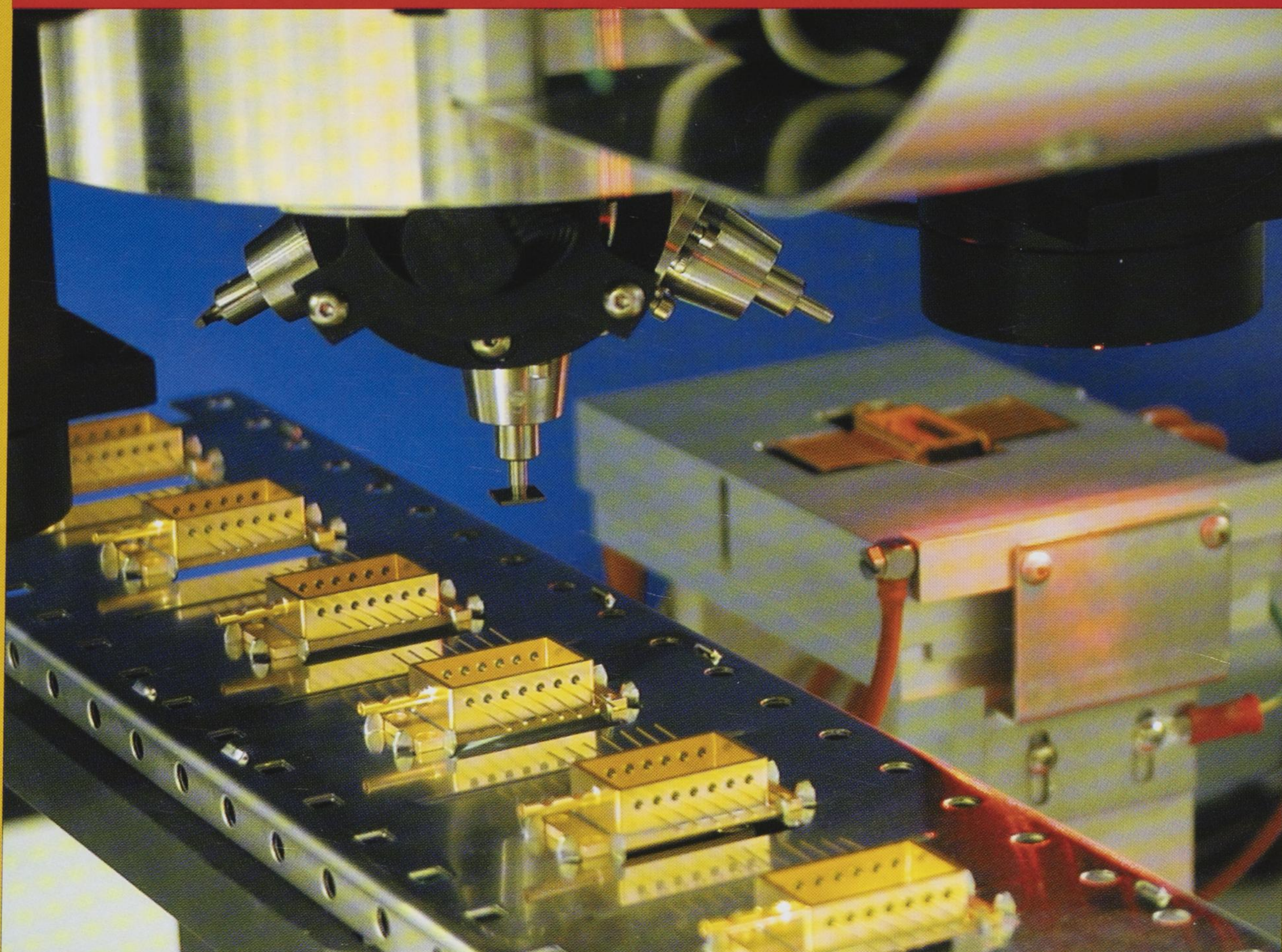


COMPOUND SEMICONDUCTOR

August 2002 Volume 8 Number 7

www.compoundsemiconductor.net



PHOTONICS MANUFACTURING **Industry workshop discusses** **five-year roadmap**

ALSO INSIDE

**VSK builds InP fab
in record time**

**Skyworks opens
for business**

**Reports from IPRM
and IC-MOVPE**

HIGH PURITY METAL ORGANICS

Aluminum

TEAL Triethylaluminum
TMAL Trimethylaluminum
DMEAAI Dimethylethylaminealane
DEMAAI Methyl-diethylaminealane

Antimony

TMSb Trimethylantimony
TESb Triethylantimony

Arsenic

TMA Trimethylarsine
TBA Tertiarybutylarsine

Carbon

CBr₄ Carbontetrabromide

Gallium

TMG Trimethylgallium
TEG Triethylgallium

Indium

TMI Trimethylindium

Magnesium

Cp₂Mg bis(cyclopentadienyl)
magnesium

Nitrogen

UDMHy 1,1-Dimethylhydrazine
TBHy Tertiarybutylhydrazine

Phosphorous

TBP Tertiarybutylphosphine

Silicon

DTBSi Ditertiarybutylsilane

Zinc

DMZ Dimethylzinc
DEZ Diethylzinc

the right ingredients for growth

Akzo Nobel and Mochem are pleased to announce their intent to merge their metalorganics businesses serving the compound semiconductor industry.

This merger offers the customers an excellent combination of benefits:

- Group III as well as Group V sources
- Akzo Nobel's manufacturing and engineering know-how and global sales and logistics reach,
- Mochem's sophisticated semiconductor know-how and Epiproof material certification.
- Together we can support the commercialization of compound semiconductors to the fullest potential

MOCHEM
metal organic chemicals

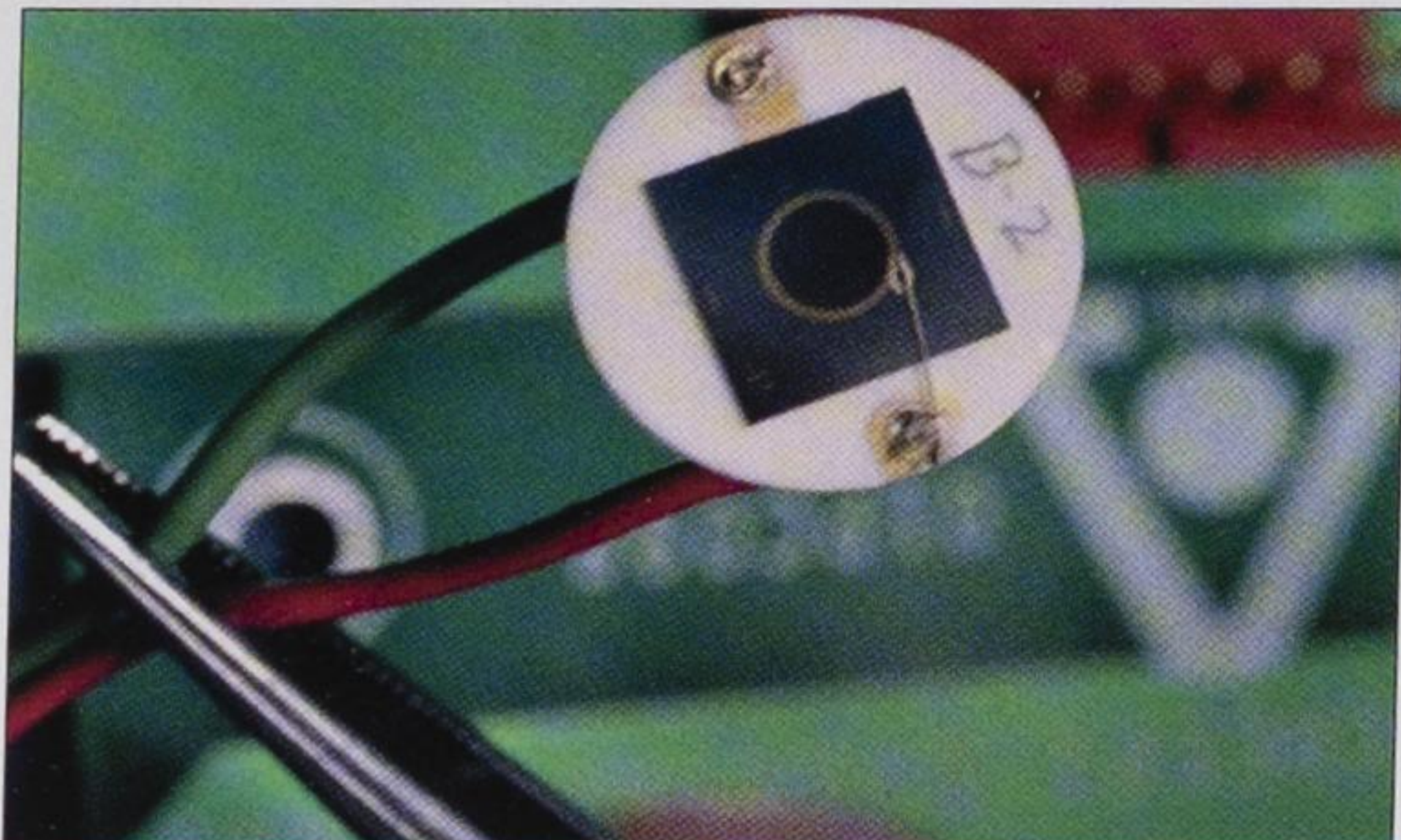

AKZO NOBEL



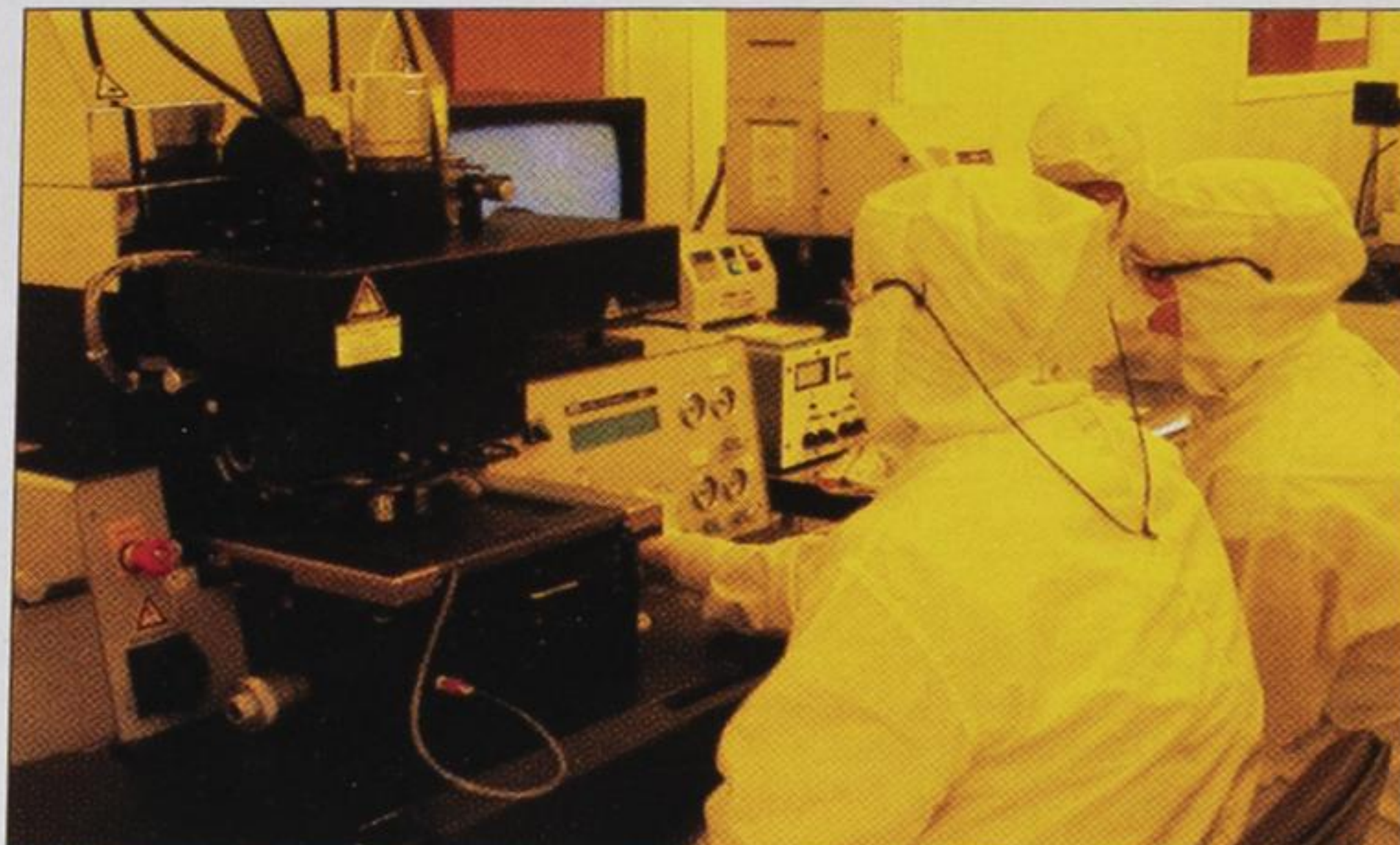
www.anhmipo.com
www.mochem.de

COMPOUND SEMICONDUCTOR

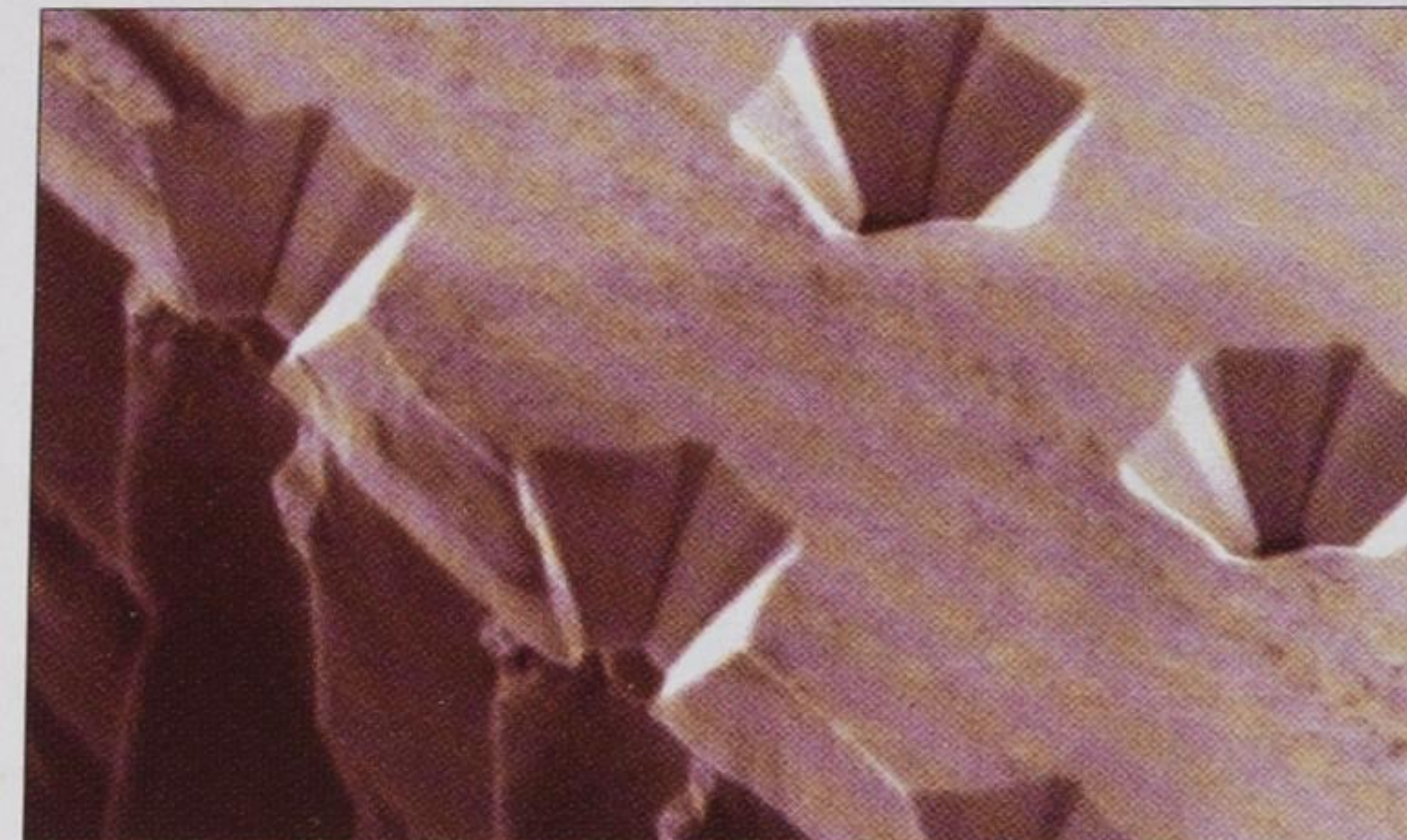
AUGUST 2002 VOLUME 8 NUMBER 7



New miniature GaAs-based neutron detectors were made using VGF-grown GaAs wafers **p8**



VSK Photonics built its InP wafer fab in less than five months, and under budget **p41**



ELO growth of GaN on Si was a hot topic at this year's IC-MOVPE conference **p49**

NEWS

- 3** **Headline News** Skyworks Solutions begins trading... TriQuint to share in IBM's SiGe business... Uniroyal delisted from Nasdaq
- 6** **GaAs News** Endwave wins military contract... Researchers reveal GaAs-based neutron detector
- 9** **LED News** Nichia and Osram settle LED dispute... US government promotes LEDs... Lumileds improves LED reliability
- 13** **Nitride News** Cree wins defense contracts... SEI advances GaN substrates... QD researchers target blue and UV lasers
- 19** **Opto News** QD devices get funding boost... Philips reveals optical disk drive
- 20** **Fiber News** Components makers cut costs... VertiLas wins funding... EpiWorks announces VCSEL program
- 23** **News from Asia** Epistar and Lumileds ease customer LED fears... Intel seeks Taiwanese partners... Union Technology opens new plant
- 25** **Materials & Equipment** Epichem installs TMG plant... Johnson Matthey makes mass production move... Emcore wins awards
- 29** **Silicon Compounds** IBM expects strained silicon by 2005... Motorola develops promising insulator... Memscap and Jazz team up for ICs

DEPARTMENTS

Index 2 **Research Review 35**
Product Showcase 53
Portfolio 54 **Advertisers' Index 56**

COVER STORY: PHOTONICS MANUFACTURING

37 Low-cost manufacturing is key to the future of photonics

The latest OIDA workshop challenged all photonics players to develop a manufacturing roadmap to guide the industry. Richard Dixon reports.

FEATURES

33 Silicon Update: The shape of things to come

The ability to assemble and solder thousands of individual chips simultaneously into a circuit may spell the beginning of the end for the pick-and-place assembly of components, writes Bob Metzger.

41 In-house production reduces costs and time to market

VSK Photonics, a start-up fiber-optic component manufacturer, took less than five months to build its InP wafer fab, and the project came in under budget, write John Lungo and Tamin Rofagha.

45 IPRM showcases advanced InP devices and novel applications

New materials, high-performance devices and next-generation technologies were all covered at the 14th IPRM conference. Colombo Bolognesi reports on a show that provided a glimpse of what the future holds for InP.

49 Optical monitoring comes of age at IC-MOVPE 2002

MOVPE may be a mature technology that is widely used in manufacturing, but nitrides and optical monitoring provoked much of the discussion at this year's IC-MOVPE, writes Jon Newey.

On the cover: the latest OIDA workshop urged the photonics manufacturing industry to develop a roadmap for the next five years.

COMPOUND SEMICONDUCTOR

Editor Tim Whitaker
tim.whitaker@iop.org
Tel. +44 117 930 1233
Fax +44 117 925 1942

News editor Richard Dixon
rdixon@compsem.com
Tel. +1 617 666 1720

Technology editor Jon Newey
jon.newey@iop.org
Tel. +44 117 930 1192

Features editor Rebecca Pool
rebecca.pool@iop.org
Tel. +44 117 930 1256

Contributing editor Robert Metzger

Managing editor Marie Meyer
marie.meyer@iop.org
Tel. +44 117 930 1034

Publisher Geraldine Pounsford
geraldine.pounsford@iop.org
Tel. +44 117 930 1022

Production editor Ruth Aspinall
Ad production Rachel Clark/Joanne Scriven
Circulation Laura Serratrice
Art director Andrew Giaquinto
Technical illustrator Alison Tovey
Publishing director Richard Roe

Advertising Joanna Hook
joanna.hook@iop.org
Tel. +44 117 930 1033
Fax +44 117 930 1178

Subscriptions

All general enquiries: compsem@iop.org. US enquiries: tel. +1 215 627 0880; non-US inquiries: tel. +44 117 930 1018. *Compound Semiconductor* is available by free subscription for qualified individuals working at compound semiconductor fabs and foundries. For a subscription order form please visit our website at www.compoundsemiconductor.net. For other subscribers the individual annual subscription price is \$95 US; £61 foreign. Library rate: \$300 US; £207 foreign. Send payment to: Compound Semiconductor, WDIS Ltd, Units 12 & 13, Cranleigh Gardens Industrial Estate, Southall, Middlesex UB1 2DB, UK.

Editorial board

Colombo Bolognesi Simon Fraser University (Canada); **Steven DenBaars** University of California at Santa Barbara (USA); **Andrew Johnson** QinetiQ (UK); **Robert Metzger** Georgia Institute of Technology (USA); **Rodney Moss** Agilent Fiber Optic Components (UK); **Shuji Nakamura** University of California at Santa Barbara (USA); **Dwight Streit** TRW (USA); **Toby Strite** JDS Uniphase (Switzerland); **Jacob Tarn** Epistar (Taiwan); **Gary Tomkins** Nortel Networks (Canada); **Andreas Waag** University of Ulm (Germany); **Gary Wicks** University of Rochester (USA); **Peter Zory** University of Florida (USA)

©2002 IOP Publishing Ltd. All rights reserved.

US mailing information: *Compound Semiconductor* (ISSN 1096-598X) is published 11 times a year for \$95 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

Organization Index

Accent Optical Technologies	27	Multilink	55
ADC	20	NEC	30, 46
Agere	55	NEL	7
Agilent	55	New Elite Technologies	24
Aixtron	26, 55	Nikon	9
Akzo Nobel	49	Nippon Sheet Glass Co.	27
Alcatel Optronics	55	NLight Photonics	20
Anadigics	7, 55	NMRC (Ireland)	22
Anaren Microwave	3	Nortel Networks	38
Argonne National Lab.	5	Northwestern University	3
Atmel	4, 29	NTT Photonic Labs	16, 45
ATMI	55	OIDA	37
AXT	55	ONR	13
Bede	55	OpNext	24
Boeing	7	Opticis	24
Bookham Technology	20, 55	ORS	49
Cascade Microtech	27	Osram Opto	50
CEA-LETI	30	Otto-Von-Guerick University	9
Celeritek	3, 55	Oxford Inst.	26
Coherent	55	Palomar Technologies	25, 38
Communicant	30	Philips	19
Conceptronic	25	Picogiga	4, 55
Conexant	3, 30	QinetiQ	51
Cree	10, 13, 55	Qusion	22
CVD Equipment	25	RF Micro Devices	55
CyOptics	20, 24	Riber	55
Digital Optics	38	Rubicon Technology	15
Eblana Photonics	22	Sanken Electric	11
Electronicast	20	SIC	24
EM4 Photonics	38	Sirenza Microdevices	55
Emcore	15, 22, 26, 27, 55	SK Display	7
Endwave	7, 55	Skyworks Solutions	55
Epichem	25	South Epitaxy Corp.	27
Epistar	23	StratEdge	4
Epiworks	21	Strategies Unlimited	37
FEI Company	4	Stratos Lightwave	55
Filtronic	55	Sumitomo Electric	13
Formosa Epitaxy	27	Surface Technology Systems	55
Fukui University of Technology	46	Suss Microtec	26
Gartner Dataquest	3	TDI	15
Genoa	20	Tegal	26, 27, 55
Gigacomm	24	Thales	19
Heinrich-Hertz-Institute	47	Trikon	55
High Power Devices	19	TriQuint	55
Hitachi	24	Tronics	4, 30
Hoya	13	Truelight	24
IAF Fraunhofer Institute	45	TSMC	3, 7
IBM	29, 35	UEC	27
Industrial Tech. Research Inst.	7	Unaxis	7
Infineon	26, 46, 47	Union Technology	24
Infinesse	4	Uniroyal Technology	55
Infomax Optical	24	United Epitaxy Co.	4, 23, 24
Innovative Processing AG	46	University of Boston	37
Intel	24	University of CA Santa Barbara	50
IntelliEPI	25	University of CA Santa Cruz	45
IQE	55	University of Illinois	35
Jazz Semiconductor	30	University of Minnesota	33
JDS Uniphase	55	University of Nanyang	29
Johnson Matthey	26	University of Nijmegen	50
Kodak	37	University of Osaka	46
Kopin	55	University of Otto-von-Gueriche	49
LayTec	49	University of Tokyo	16
Light Wave Venture	37	Veeco	55
LightLogic	24	Veritech Microwave	3, 7
Lumileds	10, 23	VertiLas	21
Luminent	10	Vitesse	55
Max Planck Inst.	30	VLSI Research	26
Memscap	30	VSK Photonics	24, 41
Microvue	27	XenICs	35
Mochem	49	Zarlink Semiconductor	21
Motorola	29	Zia Laser	20
MRSI	38		

Skyworks Solutions begins trading

By Richard Dixon

Skyworks Solutions, the company formed by the merger of Alpha Industries and Conexant's wireless business, has begun trading as an independent company. The merger creates the largest standalone RFIC supplier, with considerable strength in switches, PAs and highly integrated PA modules. Skyworks expects to generate revenues of \$150 m in the September 2002 quarter.

The new company will be headquartered in Woburn, MA, with executive offices in Newport Beach, CA. Skyworks' key product lines include front-end modules, RF subsystems, cellular systems and wireless infrastructure products. The company's goals extend to increased RF integration of modules used in all major air interfaces, including CDMA and GSM, plus complete semiconductor and software solutions for 2.5G and 3G applications.

Facility consolidations

Skyworks will take steps to capitalize on product synergy and operational efficiencies. It will close a test and assembly facility in Haverhill, MA, by the end of the year, transferring operations to the former Alpha GaAs fab in Woburn, MA, and to the Skyworks facility in Mexicali, Mexico. This facility, bought from Conexant for \$150 m, carries out the high-volume assembly of modules, lead-frame packages and ball-grid arrays, in addition to RF, digital and mixed-signal testing.

The company's Newport Beach facilities

will be consolidated into one location in Irvine, CA. Elsewhere in California, Skyworks will continue to operate the former Conexant GaAs fab in Newbury Park and the former Alpha/NDI GaAs fab in Sunnyvale.

According to Gartner Dataquest, Alpha and Conexant led the PA module market last year with a combined share of more than 30%.

By the end of the year, Skyworks will also close the facility in Frederick, MD, run by its Trans-Tech subsidiary. Trans-Tech manufactures ceramic resonators and bandpass filters and the work will be folded into the nearby Adamstown facility, which also makes RF ceramic components.

Skyworks' moves will cut its workforce by approximately 8%, from around 4200 to 3850. The company also expects to reduce its quarterly break-even sales mark to \$140 m from \$170 m at the end of 2001, excluding Mexicali assembly and test service revenues.

"We are implementing a set of cost reductions designed to provide us with a significantly lower cost structure, putting us on a path to profitability right out of the gate," said David Aldrich, president and CEO of the merged company.

Skyworks will provide RF front-end modules combining considerable expertise in GaAs PHEMT switches and HBT PA power amplifier module and design. The operation has produced 175 million PA modules to date. According to Gartner Dataquest, Alpha and Conexant led the PA module market in 2001 with a combined share of more than 30%, in addition to supplying 40% of switch requirements. The top-five handset manufacturers are all customers of Skyworks.

The company's integrated modules will be used in front-end 2.5G GSM/GPRS chipsets that feature the complete RF subsystem, baseband processor, and protocol stack and user interface software. Skyworks will also supply chipsets for basestations, which will form about 10% of its business. The company says it is unique in providing a direct conversion radio unit enabling full transmit and receive chain functionality in a single package.

"Skyworks' mission is to provide customers with increasing levels of product integration by offering the industry's broadest array of CDMA and GSM semiconductor solutions," said Aldrich.

"These initiatives focus our merged resources on those product areas with the highest growth and margin potential, while improving our capacity utilization, shortening manufacturing cycle times and eliminating duplicate operations, functions and processes," he added.

Anaren purchases 6.35% stake in Celeritek and seeks a merger

Anaren Microwave, a manufacturer of microwave signal distribution networks and components, has bought a 6.35% stake in GaAs component maker Celeritek. A total of 777,300 shares of Celeritek's common stock worth \$6.6 m were bought on the open market and Anaren is now hoping to persuade Celeritek to enter into a merger agreement.

Anaren is a customer of Celeritek, and the stock acquisition follows several merger proposals from Lawrence Sala, CEO of Anaren, to Tamer Hussein, Celeritek's CEO.

In a letter to Hussein, Sala said that Anaren is keen to combine its products with those of Celeritek to target wireless subscriber appli-

cations and build active array antennas for space, defense and commercial applications.

"[With] our passive design expertise and experience of active device performance... we strongly believe that we can develop multi-function modules integrating Celeritek's active devices with Anaren's multi-layer PTFE and ceramic technologies," wrote Sala.

"We are enthusiastic about the prospects of a merger between Celeritek and Anaren and believe that both employees and shareholders of Celeritek would benefit from... the combined entity," he added.

Celeritek plans to consider the proposal at its next board meeting in August.

Northrop buys TRW for \$7.8 bn in stock

Northrop Grumman has acquired TRW in a stock deal valued at \$7.8 bn. The deal follows Northrop's purchase of Litton Industries last year, and includes TRW's Velocium subsidiary, which designs and fabricates GaAs- and InP-based ICs for fiber-optic and wireless telecommunication applications. TRW also owns Cutting Edge Optonics, a manufacturer of high-power laser diodes.

Northrop is also involved in compound semiconductors, and has a GaAs foundry service in Linthicum, MD, although it has recently scaled back some of this activity. Late last year, Northrop sold the former Litton Airtron SiC operation to II-VI Inc and shut Airtron's GaAs substrate production facility.

TriQuint to share in IBM's SiGe activity

By Richard Dixon

TriQuint Semiconductor is to buy a portion of IBM's wireless handset chipset business, which includes SiGe-based components such as voltage-controlled oscillators (VCOs), receivers and wideband CDMA chipsets. IBM will retain its SiGe manufacturing capability and will provide the company with a SiGe foundry service.

TriQuint will design, develop, market and sell SiGe-based components to both TriQuint and IBM customers. However, TriQuint has no plans to start manufacturing SiGe-based ICs. "We will be using IBM's foundry services," confirmed Rob Christ, TriQuint's foundry marketing director. "Eventually, the back-end [packaging and testing] will be done by TriQuint and we will purchase finished SiGe wafers from IBM. We do not currently have plans to process our own silicon."

TriQuint will initially pay IBM \$22 m for the assets, with subsequent adjustments that depend on business volumes. The company expects the deal to bring in \$12–15 m over the next 12 months.

"This acquisition provides TriQuint with another key piece of the RF front-end that will further help us in developing fully integrated modules for wireless phones," said Steven Sharp, chairman, president and CEO of TriQuint. "In addition, the relationship with IBM gives us access to a leading foundry for devices based on SiGe."

"Eventually, the back-end will be done by TriQuint and we will purchase finished SiGe wafers from IBM. We do not currently have plans to process our own silicon."

IBM has recently divested itself of several interests, including its GPS business which has gone to RFMD (*Compound Semiconductor* January/February 2002 p4). Michel Mayer,

general manager of IBM Microelectronics, says that IBM will refocus its microelectronics business on high-end foundry services, ASICs and power PC-based standard products.

Sharp says TriQuint will continue to develop CDMA RF chipsets using Atmel's SiGe foundry process. "As part of our agreement with Atmel, we are developing CDMA [SiGe HBT] power amplifiers and PA modules, in addition to CDMA small-signal devices," said Sharp. "With IBM, we will be manufacturing VCOs for the GSM and CDMA markets, and receivers for the GSM market. VCOs are a critical component of the radio that we did not [previously] possess."

TriQuint has a strong footing in CDMA and TDMA handset component sales, but has recently focused attention on developing its share of the GSM handset and basestation market. This includes deals with Philips Semiconductors for the InGaP HBTs used in GSM PA modules, and its recent acquisition of Infineon's GaAs unit and GSM reference design capability (*Compound Semiconductor* June 2002 p3).

Veeco and FEI agree to merge during Q4

Signaling more consolidation in the semiconductor equipment market, Veeco Instruments and FEI Company are to merge to become the third-largest US supplier of metrology equipment. Veeco will buy FEI in exchange for around 44 million shares, and the merger is expected to close during the fourth quarter of this year. Veeco's shares closed at \$15.93 on July 18, making the deal worth around \$700 m.

The new company, known as Veeco FEI, will be based in Woodbury, NY, at Veeco's former headquarters. Veeco, with 2001 revenues of \$449 m, manufactures process equipment and metrology tools for a variety of markets. The company has acquired at least 10 technology businesses in the last five years, including Applied Epi, a leading manufacturer of MBE equipment, as well as CVC and Digital Instruments.

FEI Company, with 2001 revenues of \$376 m, manufactures dual-beam and single-column focused-ion and electron-beam products for three-dimensional metrology, device trimming and structural analysis.

Uniroyal delisted from Nasdaq and faces class-action lawsuits

By Tim Whitaker

As a result of its sinking stock price, Uniroyal Technology has been forced off the Nasdaq national market, according to a company statement on June 18. Its shares will now be traded on the Nasdaq SmallCap market.

Companies listed on the main Nasdaq exchange must maintain a share price in excess of \$1. Uniroyal's shares have traded below this level since early January 2002.

Delisting is potentially disastrous, as it makes it extremely difficult to raise new capital via traditional outlets. Uniroyal is looking for potential buyers for its coated fabrics division and also for its SiC subsidiary, Sterling Semiconductor, after the proposed deal with Umicore fell through (*Compound Semiconductor* July 2002 p3).

Uniroyal also faces several class-action lawsuits from disgruntled investors. These allege that Uniroyal's CFO and treasurer George Zulanas, and Howard Curd, chairman of the board and CEO, violated sections of the Securities Exchange Act by making

materially false and misleading statements to the market between February 8, 2000 and May 13, 2002.

Several of the complaints mention press releases that misrepresented both Uniroyal's financial stability and the value of its acquisition of Sterling Semiconductor. The complaints allege that in order to inflate Uniroyal's net worth and foster the illusion of growth, the defendants agreed to pay an inflated price for Sterling with overvalued stock serving as currency. On December 31, 2001, 18 months after Uniroyal acquired Sterling in exchange for stock with a purported value of more than \$40 m, the company recorded a write-down of Sterling goodwill of approximately \$9.8 m. Umicore had planned to pay \$13 m for Sterling until the deal collapsed.

Another complaint alleges that the defendants "failed to disclose material facts relating to Uniroyal's production facilities and ability to manufacture high-brightness (HB) LEDs," adding that Uniroyal could not actually manufacture HB-LEDs in commercial quantities.

The CVD Engineering Company

IT'S A FACT

that no other MOCVD company in the world offers you the **unique, versatile, and constantly high quality** technology you're assured of from AIXTRON, whether you're producing LED's, Lasers, Detectors, HEMTs, HBTs, OEICs...
...And we can prove it!

FACT!

No other company in the world offers you a complete MOCVD reactor line, based on a proven scaling concept, from R & D up to full-scale production (1x2" up to 95x2" wafers or equivalent 3", 4" wafers).

FACT!

AIXTRON is the only company in the III-V epitaxy field offering proven processes from mono layer thickness up to more than 200µm/h.

FACT!

AIXTRON was the first MOCVD company worldwide to receive the ISO 9001 Certification - the internationally recognized quality symbol.



WHAT BETTER GUARANTEE OF OUR

Commitment to AIXcellence

AIXTRON

European Headquarters
Aachen, Germany
AIXTRON AG
Kackertstrasse 15-17
52072 Aachen

Phone: +49 (241) 89 09 - 0
Fax: +49 (241) 89 09 - 40
E-mail: info@aixtron.com
www.aixtron.com

US Headquarters
Chicago, IL
AIXTRON Inc.
1670 Barclay Blvd.
Buffalo Grove
IL 60089

Phone: +1 (847) 215 - 7335
Fax: +1 (847) 215 - 7341
E-mail: usinfo@aixtron.com
www.aixtron.com

AIXTRON Korea
AIXTRON cshs
4F, Korea Exchange Bank B/D
358-1, Yatap-Dong
Bundang-Ku, Sungnam City
Kyoungki-Do, 468-828

Phone: +82 (31) 703 - 51 00
Fax: +82 (31) 703 - 51 10
E-mail: koreainfo@aixtron.com

AIXTRON Japan
Moritani & Co., Ltd
8th Machinery Dept.
1st Business Group
1-4-22 Yaesu, Chuo-Ku
Tokyo 103-8680

Phone: +81 (3) 32 78 - 61 31
Fax: +81 (3) 32 78 - 60 03
E-mail: m8info@moritani.co.jp

AIXTRON Taiwan
Challentech International Corp.
Pateh Road No. 1
Lane 9
Hsin-Chu, 300

Phone: +886 (3) 56 14 - 211
Fax: +886 (3) 56 11 - 194
E-mail: hoton@challentech.com.tw

Endwave wins contract for military radar system

Endwave has entered into a multi-year contract with Lockheed Martin to design the RF receiver unit that is used in the radar system in Boeing's Comanche helicopter. Endwave will design, manufacture and deliver prototype evaluation units that employ the company's GaAs LNAs.

Endwave makes RF modules, integrated transceivers, broadband antennas and outdoor units for cellular backhaul, point-to-point access and point-to-multipoint access, using MMICs that are manufactured by TRW and Velocium.

Endwave already supplies Lockheed Martin with LNAs for the radar used in the Apache attack helicopter, as part of the Longbow Radar program. For the new program, Endwave will deliver a higher level of integration into its module. The Comanche



Endwave will supply GaAs ICs for a receiver unit in the Comanche helicopter radar system.

receiver will integrate GaAs LNAs with other active components, such as frequency converters, and is intended to provide a complete replaceable subsystem assembly.

UMS adds US and German design sites

United Monolithic Semiconductors (UMS), a GaAs MMIC maker with manufacturing facilities in France and Germany, has established a new company to service its North American customer base. The new site in Andover, MA, includes sales and customer support activities, and a MMIC design center.

"The design center will expand our product

lines into new business areas," said president and CEO of UMS, Heinrich Daembkes. "The US is the largest user of GaAs MMICs, and we are confident that UMS will enhance its American presence and increase its market share."

UMS has also extended its agreements with German design company IMST, which will act as a UMS-certified design house. Based in Kamp-Lintfort, Germany, IMST will design and develop products using UMS processes for applications including remote sensors and wireless communications.

New devices from UMS, NEC and Raytheon

- **UMS** has introduced an LNA that is fabricated using the company's 0.25 μm PHEMT process. The four-stage MMIC spans the 12.5 to 17 GHz range with a gain of 34 dB and noise figure of 2.5 dB. The output power at 1 dB gain compression is +15 dBm and the current requirement at 4 V is 130 mA.

- A GaAs MMIC switch from **NEC** is intended for high-power operation without compromising

isolation and insertion loss. The UPG2009TB offers a power (0.1 dB) of +34 dBm and typical isolation and insertion loss figures of 25 and 0.4 dB, respectively, at 2.5 GHz. NEC says the switch is suited to transmit/receive switching, antenna diversity switching and power level control switching applications.

- **Raytheon RF Components Division** has unveiled several new GaAs

PHEMT MMICs including the RMTR 13390 tripler, which is designed for 13 to 39 GHz operation in the local oscillator chain of millimeter-wave radios. The three-stage amplifier employs Raytheon's 0.15 μm PHEMT process, which delivers a conversion loss of just 5 dBm. The company says that the MMICs are ideal for point-to-point and point-to-multipoint radios and LMDS systems.

Anadigics focuses on Europe and Asia

Anadigics has launched a new technical development center in Denmark to concentrate on wireless design for its European and Asian handset customers. The company's center is located in Aalborg and adds to an existing design center in the UK. Anadigics says the focus will be GSM and EDGE, in addition to W-CDMA RF design support for European and Asian wireless handsets.

The company will also use the site to support next-generation GSM wireless products, including the company's PowerPlexer GSM/DCS module, which houses an InGaP HBT power amplifier, a PHEMT switch and harmonic filters, in a package containing a CMOS IC controller.

"Our new center strategically positions Anadigics' technical resources at the epicenter of the GSM reference design world," said CEO and president, Bami Bastani. "In Denmark, our team will be working closely with reference design partners and key European and Asian handset manufacturers to deliver complex and highly integrated GSM solutions, from component levels up to handset type approval."

Sirenza patents aid GaAs IC efficiency

Sirenza Microdevices, a fabless manufacturer of GaAs ICs based in Sunnyvale, CA, has been awarded two US patents for IC development.

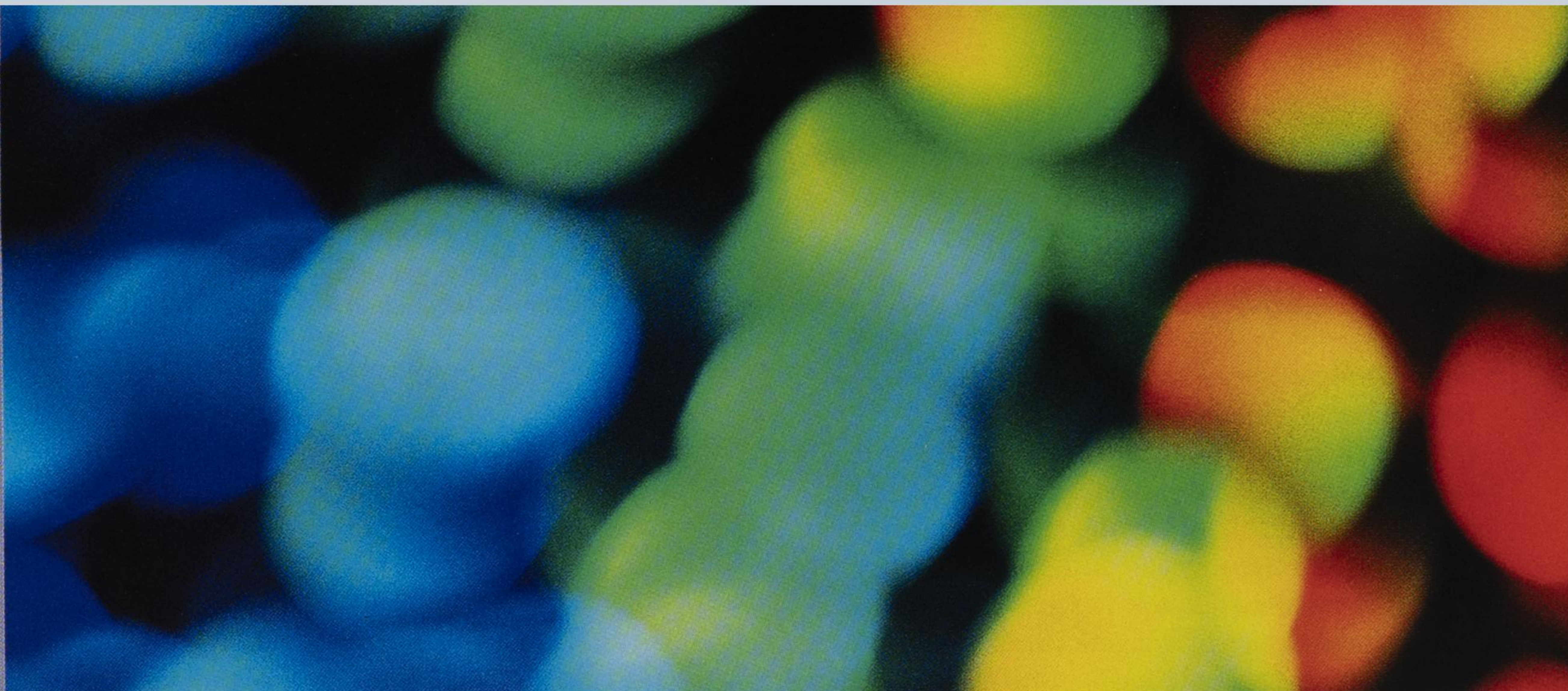
The first patent (number 6,373,346) relates to an analog method of pre-shaping data to improve the signal-to-noise ratio of VCSEL transmitters, and describes a technique being applied to Sirenza's laser-driver ICs developed for 10 Gigabit Ethernet systems. The second patent (number 6,404,281) covers an approach for improving the dynamic range of its transimpedance amplifiers (TIAs).

According to Kevin Kobayashi, Sirenza's director of advanced design, the technique is being used in the company's 10 and 40 Gbit/s TIA product development, which uses SiGe, GaAs and InP fabrication technologies.

"This approach improves the dynamic range of fiber-optic receivers, while allowing high receiver sensitivity and low DC power consumption," said Kobayashi. "Our 10 Gbit/s InGaP TIAs have demonstrated a dynamic range of 21 dB and a sensitivity of -19.6 dBm, while consuming only 250 mW of DC power."

**Exhibitors at
CS-MAX 2002
will include:**

Accent Optical
Technologies
Air Products and
Chemicals
AIXTRON
APT/Telemark
ASML Special Applications
Axic Inc
Bede Scientific Inc
BOC Edwards
Compound Semiconductor
Corning Tropel
CVD Equipment Corp
Epichem
Evans Analytical Group
Gavish
Hologenix
IPAG - Innovative
Processing AG
IQE
JIPELEC
JMAR/SAL
Nanolithography
Kopin Corporation
Leighton Electronics
Loomis Industries
Matheson Tri-Gas
Mattson Technology
Maxwell Technologies
MicroChem
MKS Instruments
Modular Process
Technology Corp
Nippon Sanso Corporation
OSEMI
Oxford Instruments
Philips Analytical
Praxair Semiconductor
Materials
Riber
SAMCO International
Semicon Equipment
Spectrolab
Spectral Corporation
Semescal
Sermo VG Semicon
Thomas Swan Scientific
Equipment
Vikon Technologies
Vikon Technology
Vikon Electro-Optical
Materials
Vikon
Williams Advanced
Materials



Plan to attend

Compound semiconductors in the heart of Silicon Valley!

McEnry Convention Center

San Jose, CA November 11–13, 2002

Dedicated to **high-volume manufacturing** of compound semiconductor devices

Technical sessions to include:

• **processing & characterization of VCSELs** • **laser diode packaging and reliability** • **fabrication of HB-LEDs** • **front-end & back-end processing of RFICs** • **arsine & phosphine handling & purification** • **high-volume III-V epi**

Comments from last year's attendees:

"It is refreshing to have a CS show, instead of always feeling lost at a Si show."

"Nicely balanced technical program, and I found the exhibit extremely useful."

"Very worthwhile, very efficient use of my time."

**COMPOUND
SEMICONDUCTOR**

www.cs-max.com

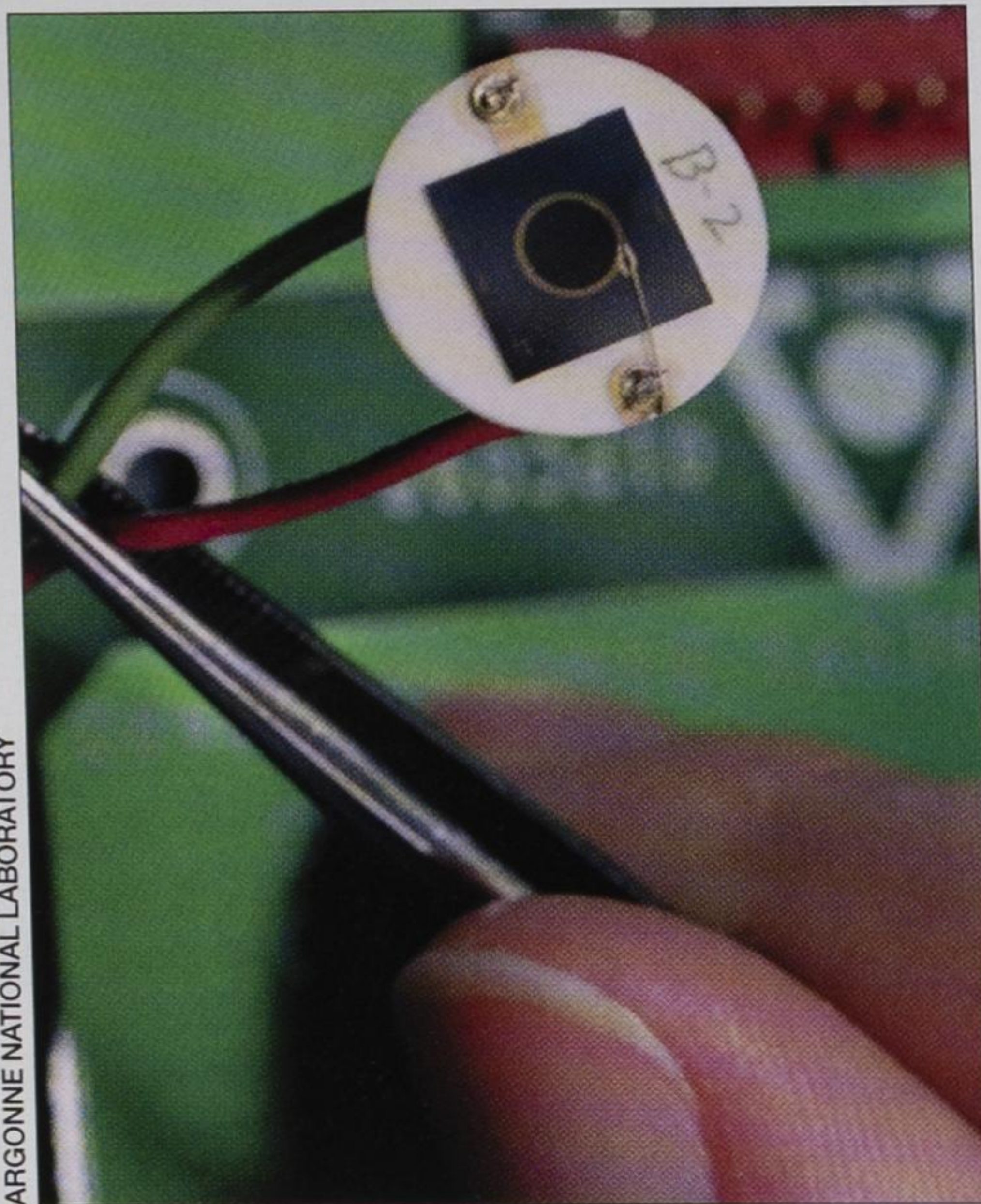


Miniature GaAs detector finds neutrons

By Jon Newey

Researchers at Argonne National Laboratory (ANL) in Illinois and Kansas State University have been busy developing a GaAs-based neutron detector. The researchers turned to GaAs in an effort to miniaturize the detectors, making them more portable for applications such as the detection of smuggled fissile material at ports and airports, and for use by international nuclear non-proliferation inspectors. Currently, two types of detector are in use, those based on a tube filled with gas that is ionized by neutrons, and those based on Si.

The new detectors developed by ANL are made using VGF-grown semi-insulating GaAs wafers. The wafers are thinned and polished to a thickness of 250 μm before being implanted with Si. The implant is activated by a rapid thermal anneal and metal contacts evaporated onto the front and backsides of the wafer. An isotopically enriched boron layer is evaporated onto the frontside Schottky



Miniature GaAs-based neutron detectors developed by ANL could enable the detection of smuggled nuclear material.

contact. A neutron striking the coating releases a cascade of charged particles (alpha particles and lithium ions for thermal neutrons striking ^{10}B), which excite free carriers in the GaAs active region. The carriers drift to the detector contacts under an applied voltage and the induced charge is detected and amplified.

Using GaAs rather than Si brings several advantages. The detectors can be made smaller, require less than 50 V operating power and operate at room temperature. Replacing Si with GaAs also improves the lifetime of the detector when used in areas which have high radiation levels.

"The working portion of the wafer is about the diameter of a collar button, but thinner," said Raymond Klann, who leads the detector development group at ANL. "It is fairly straightforward to make full-sized detector systems about the size of a deck of cards, or smaller. Something that small can be used covertly, if necessary, by weapons inspectors to monitor nuclear facilities."

Klann's team has experimented with various coatings and detector configurations to make the devices even more efficient, and to detect neutrons of different energies. The group found that detection efficiency was improved by etching cylindrical holes into the GaAs before the contacts and boron layer were deposited.

Problems with the adhesion of the boron films were also alleviated using wafers with etched holes. The optimum boron film thickness is 2.4 μm for neutron detection. The researchers found that above a critical thickness of 1 μm , the boron film began to peel away. Below 1 μm the detector efficiency is limited to 2.9%.

By using RIE, holes of different depths and diameters were tested, resulting in the ability to grow films as thick as 4 μm without any peeling. Klann expects that detection efficiency can be increased to 10% for a single wafer using holes 10 μm deep and 3 μm in diameter with a 40% coverage. The devices can also be stacked, so two etched devices facing each other with 10 μm deep holes could achieve an efficiency greater than 20%.

To date, Klann's work has been funded by the US Department of Energy through the Laboratory Directed Research and Development Program. ANL is now looking for partners to develop the prototype detectors into commercial products.

It's a game of microns...

When you need nanometer accuracy and precision... we have your solution!

Micro-Metric

As seen at SEMICON WEST 2002



- ¥ Sub-micron critical dimension measurements
- ¥ Dimensional metrology capabilities to 0.01 microns
- ¥ Automation options for streamlined manufacturing
- ¥ Unmatched price performance



800.490.3333 • 408.452.8505 • www.micro-metric.com

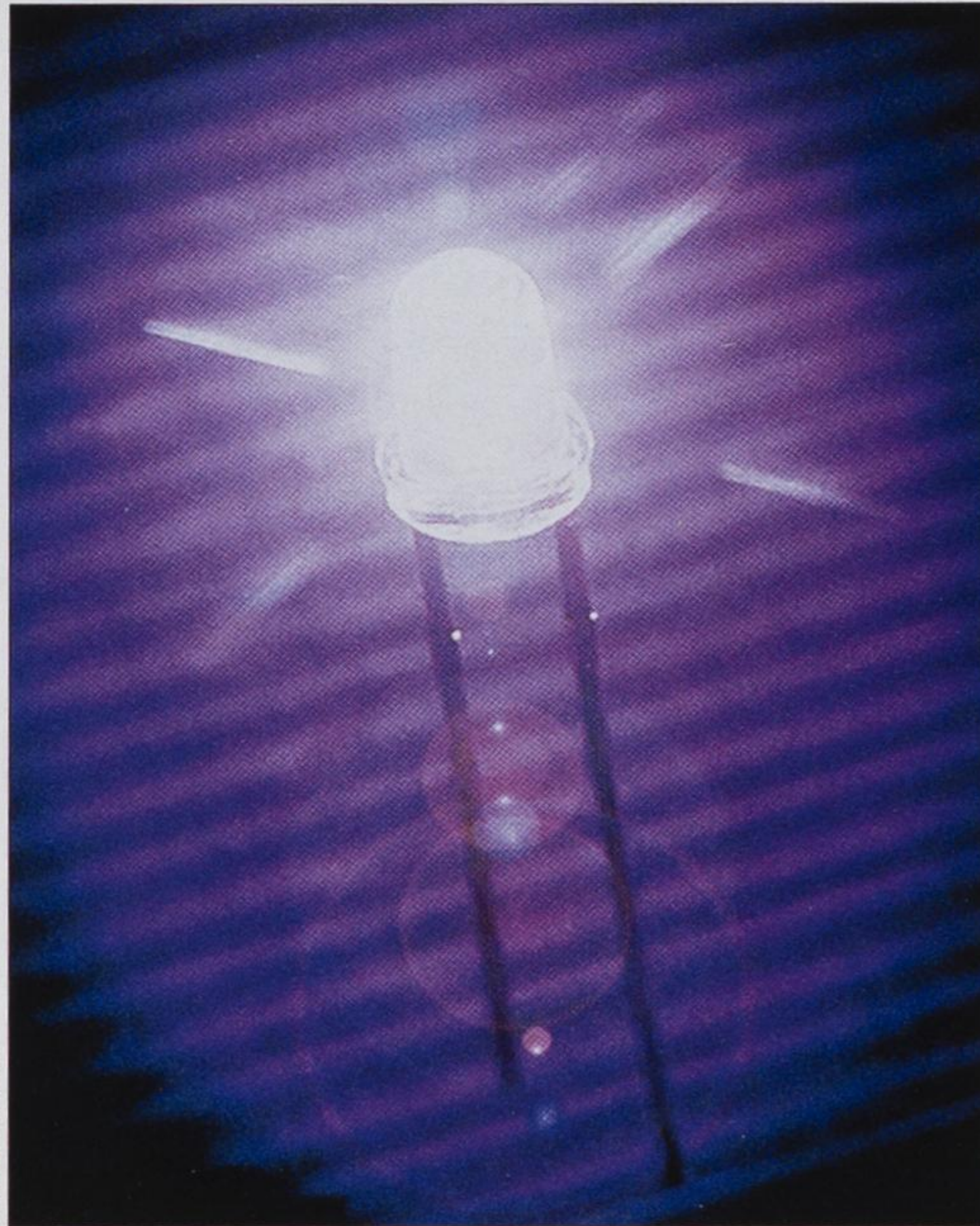
Nichia and Osram agree licensing deal to settle white LED patent dispute

Nichia and Osram Opto Semiconductors have agreed to cross-license all patents relating to their InGaN-based LEDs and associated packaging technologies. The cross-licensing agreement ends the patent disputes in Japan, Europe and the US between the two companies.

The legal dispute centered on the basic technology for manufacturing GaN/InGaN-based LEDs and laser diodes, in particular the use of phosphor converters to generate white light from blue and UV LEDs.

In December 1999 Nichia filed an injunction against Osram Opto Semiconductors in a bid to prevent the German LED manufacturer from selling its white LEDs in Japan. The complaint was dismissed in July 2001, but in September of that year Osram Opto filed two lawsuits in the US and Germany to prevent Nichia from importing and selling its white LEDs (*Compound Semiconductor* November 2001 p10).

The recent agreement resolves these disputes, which according to Rüdiger Müller,



Nichia and Osram's white LED battle is over, with both companies agreeing that they will profit from the cross-licensing deal.

CEO of Osram Opto, is good news for the white LED market. "The patent dispute had brought an air of uncertainty to the market, but we are sure that both partners will profit from this agreement," he said.

"Both companies are pioneers of the InGaN market, especially for white LEDs," added Noboru Tazaki, who is general manager of Nichia's optoelectronics products division. "However, this agreement complements our technology base and will enable us to make better products."

This latest settlement is only Nichia's second cross-licensing agreement. Earlier this year the company agreed to sell blue LED chips and license its packaging technology to Citizen Electronics in Japan (*Compound Semiconductor* January/February 2002 p11). This move allowed Citizen to package blue LED chips in high volume, and marked an end to Nichia's track record of only selling packaged devices and keeping all of its LED production technology in house.

US energy department to foster the use of LEDs

By Richard Dixon

The US secretary of energy, Spencer Abraham, recently unveiled a plan by the Department of Energy to include LEDs in its campaign to reduce energy waste. In particular, Abraham highlighted advances in white LEDs, which he called "a revolutionary technological innovation that promises to change the way we light our homes and businesses".

"Nationwide, lighting consumes at least seven quadrillion BTUs in a given year, or 7% of all energy usage," said Abraham. "On top of that, less efficient incandescent bulbs produce large amounts of heat that our climate control systems must manage, so we pay an additional energy penalty as well."

Abraham's remarks were made to the US Energy Association at the 13th Annual Energy Efficiency Forum held in Washington, DC early in June, and mark the first time the US government has endorsed LEDs for solid-state lighting. In comparison with incandescent bulbs, LEDs deliver a much longer life-cycle. Currently the most advanced white LEDs deliver around 30 lm/W compared with

"The inorganic LED is to fluorescent lamps what transistors were to vacuum tubes, or what the automobile was to the horse-and-buggy."

7 lm/W for a light bulb, and are expected to provide energy savings of 90% on these light sources by the year 2020.

"Unlike conventional lighting, which throws off substantial amounts of wasted energy in the form of heat, an LED directs its energy entirely toward providing light," explained Abraham. "The benefits are obvious: close to no wasted energy, more efficient lighting and lower electricity bills for homes and businesses."

Abraham said that the Department of Energy plans to form a partnership with industry in order to devote more resources

to next-generation solid-state lighting, as one of the US government's energy policies. Abraham's remarks refer to the Next Generation Lighting Initiative. This initiative is currently under consideration by the US Committee on Energy and Natural Resources, and encourages the US administration to provide support for an industry consortium and to research organizations that are investigating white LEDs.

Currently LEDs are not as efficient as fluorescent lamps, which deliver approximately 70 lm/W, but LEDs have a considerable advantage over this technology because mercury is not used in the processing steps. This reduces the health hazards that are associated with fluorescent lighting.

"While modern fluorescent bulbs with electronic ballasts are more efficient, they remain glass nodules filled with gas, not unlike the vacuum tubes of the last generation of electronics," said Abraham. "The inorganic LED is to fluorescent lamps what transistors were to vacuum tubes, or what the automobile was to the horse-and-buggy."

Sanken samples red and yellow LEDs on Si substrates

Sanken Electric, an LED manufacturer based in Saitama, Japan, has introduced AlGaInP-on-Si red and yellow high-brightness LEDs, which it claims offer up to 100 times the luminosity of its conventional LEDs. The devices are made by wafer-bonding AlGaInP active layers to a Si substrate. Samples will be available from October, and commercial production is expected in spring 2003.

The new LEDs employ large-area chip designs that carry up to 40 times more current than the company's standard 20 mA LEDs. The new chips measure either 0.7 or 1.0 mm per side, and are driven by currents of 400 or 800 mA. The forward voltage was not specified.

The 620 nm red LEDs exhibit a luminous flux of up to 74 lm at 800 mA, while 590 nm yellow LEDs deliver 42 lm under the same conditions (see table). The 1.0 mm devices represent a 100-fold improvement in output on the

Characteristics of Sanken's AlGaInP-on-Si LEDs

Color	Design	Chip size (mm)	Current (mA)	Luminous flux (lm)
red (620 nm)	standard	0.3 x 0.3	20	0.74
red (620 nm)	wafer-bonded	0.7 x 0.7	400	37
red (620 nm)	wafer-bonded	1.0 x 1.0	800	74
yellow (590 nm)	standard	0.3 x 0.3	20	0.42
yellow (590 nm)	wafer-bonded	0.7 x 0.7	400	21
yellow (590 nm)	wafer-bonded	1.0 x 1.0	800	42

standard die, although the final output will depend on packaging and use, says Sanken.

Sanken has been developing blue GaN emitters on Si substrates since 1995, and earlier this year described developments with low-brightness blue devices (*Compound Semiconductor* January/February 2002 p12). Although AlInGaP chips are grown on GaAs substrates, Si wafers exhibit better thermal dissipation properties than GaAs, which is important at high currents. Si is also less expensive and benefits from mature processing technology.

The wafer bonding process normally requires high temperatures to bond the quaternary with the Si substrate. Due to the large difference in thermal expansion coefficients,

this resulted in flexing and cracking of the LED wafer. Sanken also had to circumvent the difficulty of light being lost due to the absorbing nature of the Si substrate.

To address these issues, a thin metal layer was added between the epitaxial layer and the Si substrate. This lowered the bonding temperature and prevented deformation of the LED wafer during processing. Sanken says the lower bonding temperature simplifies processing and improves productivity. The metal layer also acts as a mirror, improving light extraction efficiency by up to 2.5 times.

Sanken is planning to further develop GaN-on-Si blue and white emitters using its direct wafer-bonding technology.

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

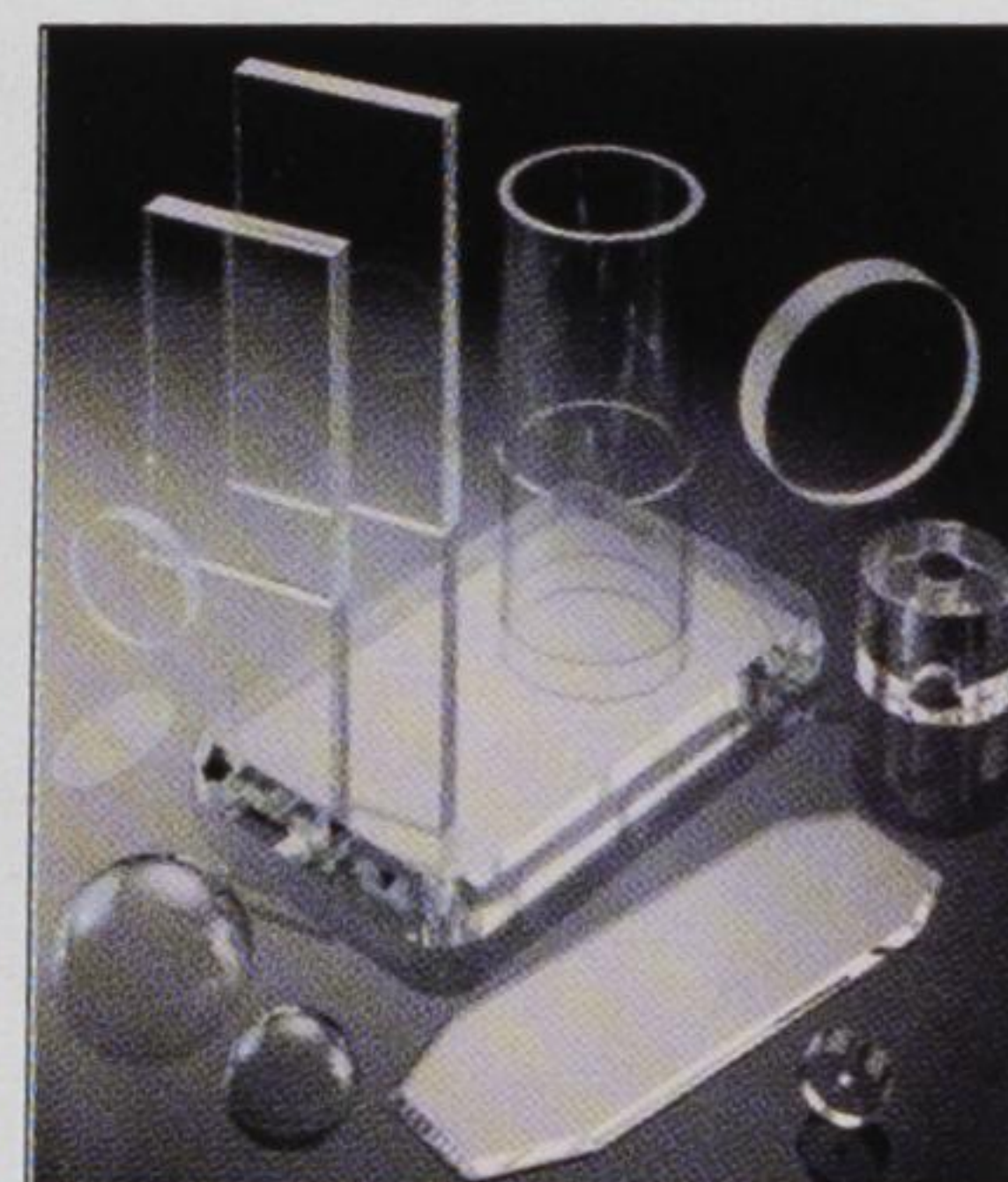
25 Sagamore Park Rd., Hudson, NH 03051

www.bandwidthsemi.com

(603) 595-8900

Epitaxial and Foundry Inquiries: sales@bandwidthsemi.com

EOE M/F/D/V



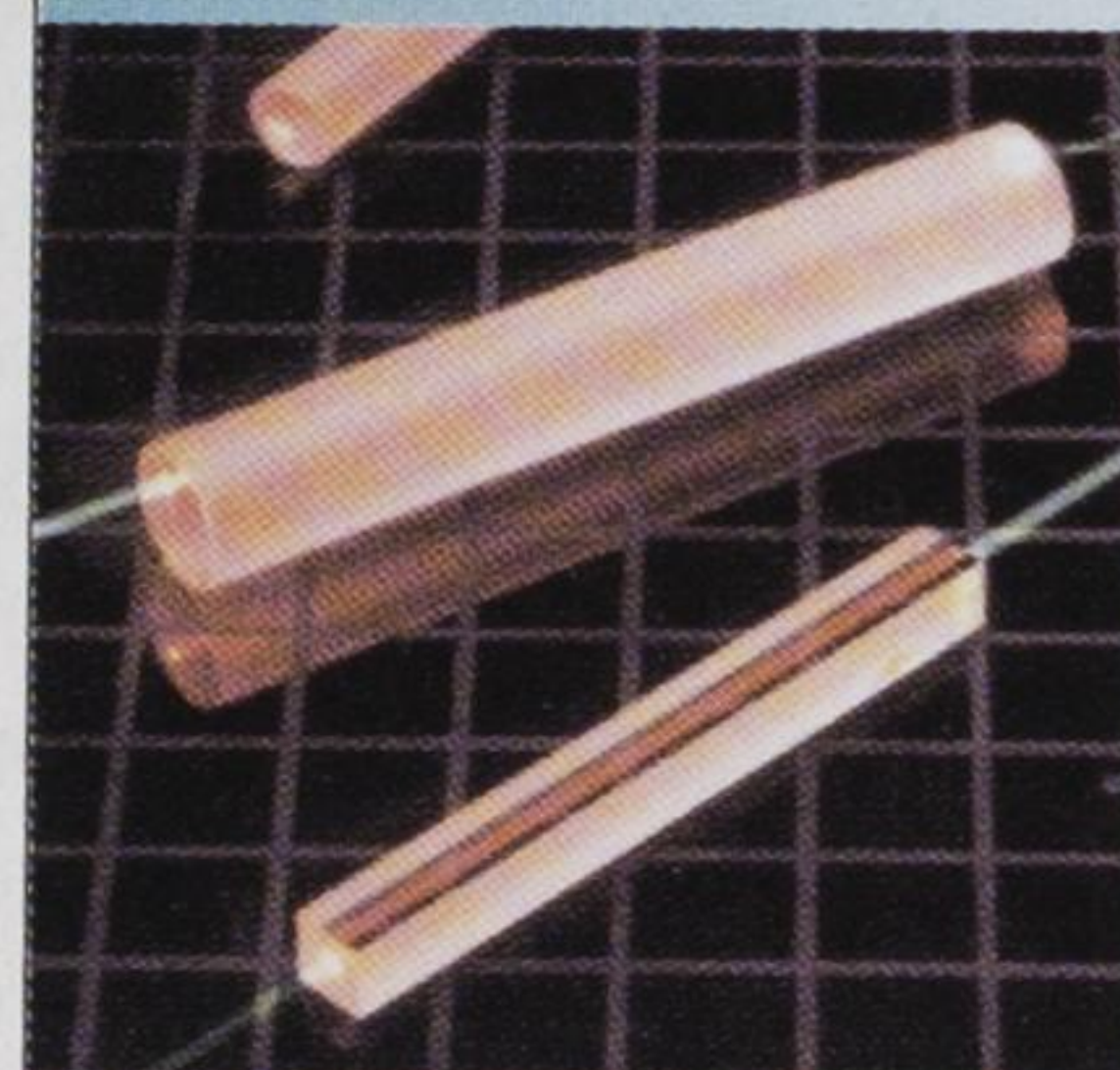
HEM SAPPHIRE FOR HIGH QUALITY OPTICS

- Windows to 13" Ø
- Domes and Lenses
- Laser Optics, 1/10, 10-5
- 0001 Optics up to 7" Ø

The sapphire solution for critical, high temperature, high damage threshold, broad spectrum applications

HEM SAPPHIRE SUBSTRATES FOR BLUE LEDs & LDs

- 2" 3" 4" Ø available
- Lowest defect density sapphire
- Low sub-surface damage
- 0001, off-axis, other orientations
- Large volume capabilities



TI:SAPPHIRE LASER RODS

- Highest FOM material available
- Absorption in the 0.4 to 7.0/cm Alpha 514 range
- Tunable from 0.66 to 1.2 microns
- Free of internal scatter
- Typical Figure of Merit 380+



CRYSTAL SYSTEMS

27 Congress Street, Salem, MA 01970
TEL: 978-745-0088 FAX: 978-744-5059
www.crystalsystems.com

Lumileds provides encouraging update on Luxeon LED reliability

Lumileds has reported that its Luxeon LEDs have maintained more than 90% of their lumen output after 9000 h. The company says that this far exceeds conventional 5 mm LEDs, which retain only 70% of their brightness after just 3000 h, and less than 40% after 9000 h.

The results are significant because the lumen depreciation studies associated with LED packaging processes (such as the use of epoxy as a light coupler) have recently shown that such devices fall well short of the predicted 50,000 to 100,000 h often quoted for LEDs (*Compound Semiconductor* January/February 2002 p45).

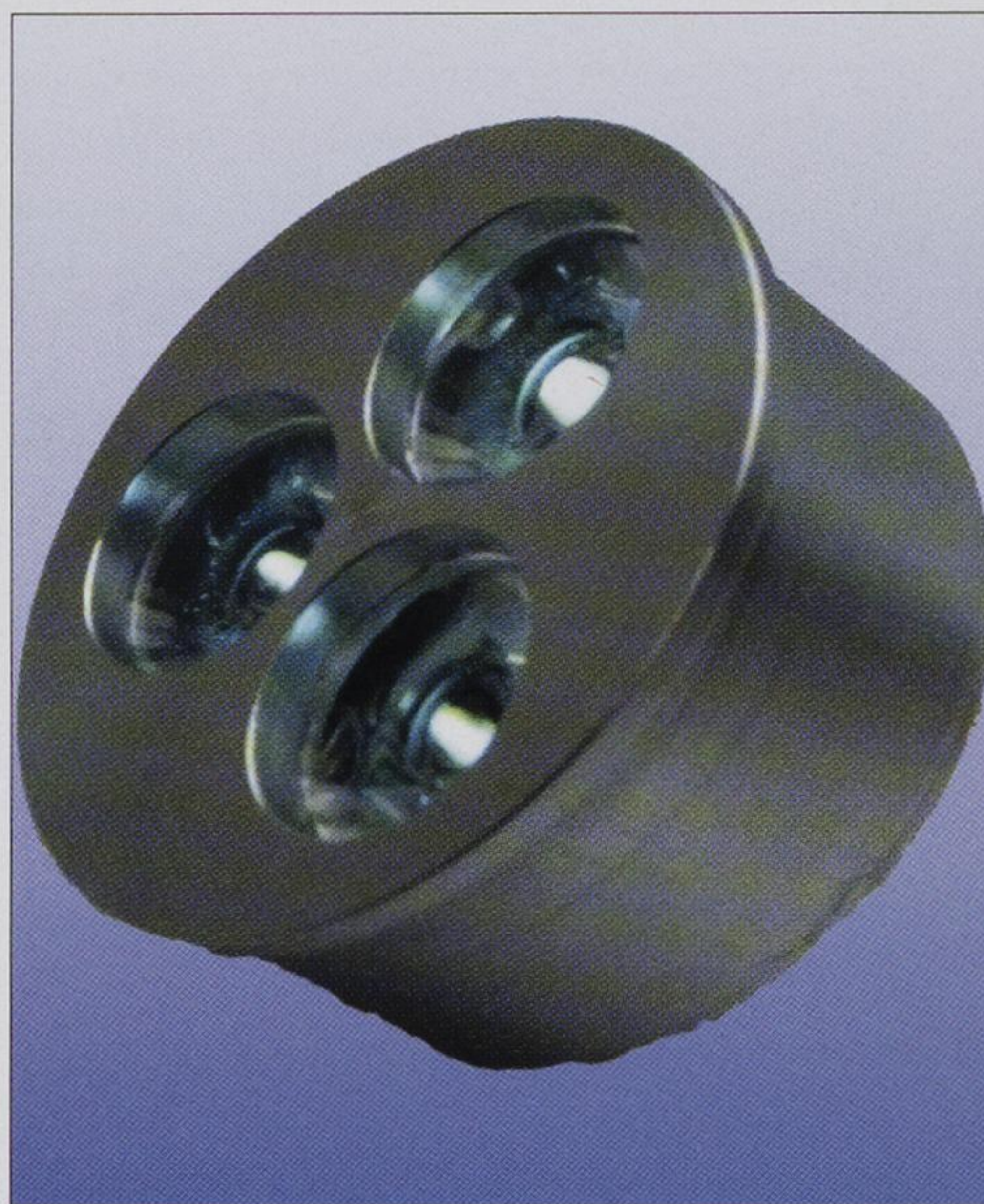
Extrapolation of the results suggests that the company's Luxeon device delivers an average lumen maintenance of 70% up to 50,000 h, under typical temperature and humidity conditions. In comparison, incandescent bulbs typically need to be replaced after just 1500 h.

The measurements were based on independent testing from the Lighting Research Center at Rensselaer Polytechnic Institute, and remove a chief concern over the use of white LEDs in general lighting and other applications, says Lumileds. The company's Luxeon LED delivers up to 120 lumens of white light in a single 5 W emitter package, which is as much as 60 times the output of competitive devices.

"Lighting manufacturers are rapidly adopting Luxeon technology for a wide range of applications, and this new lumen maintenance data adds a compelling reason for using Luxeon over other light engines," said Jason Posselt, Luxeon worldwide product manager. "No other LED product comes close to either the light output or the lumen maintenance of Luxeon lamps, and that means Luxeon is the most practical and cost-efficient alternative light source on the market today."

Cree receives QS-9000 certification

Cree has received QS-9000 registration. Based on standards developed by the International Organization of Standards, known as ISO-9000, QS-9000 applies to certain suppliers of products, services, parts and materials for major US auto manufacturers.



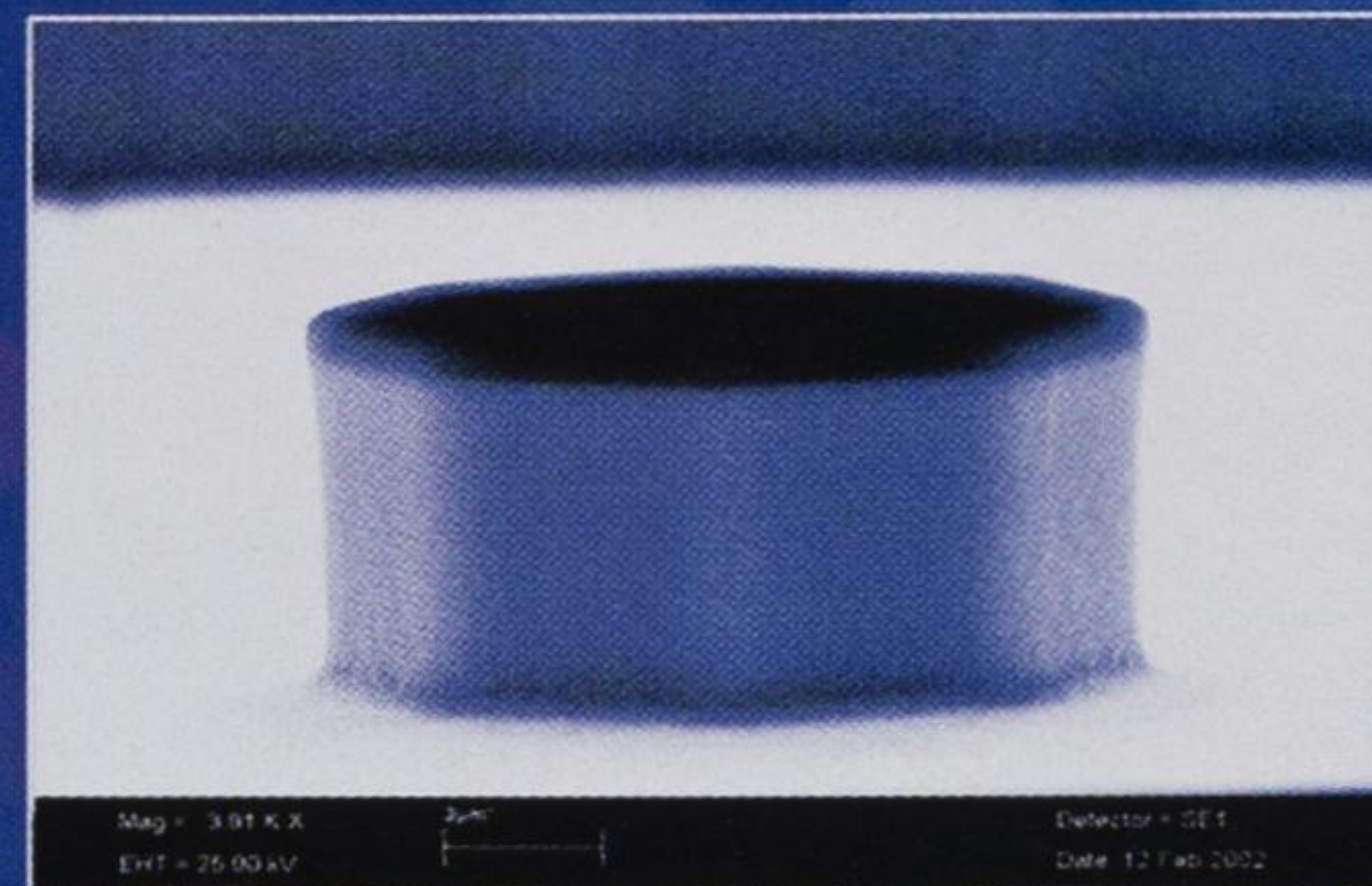
LumiDrives is entering into a partnership with Lumileds to supply standard and custom driver solutions, including this fixture with three Luxeon white LEDs.

To reduce the degradation effects of epoxy caused by the UV radiation in conventional LEDs, Luxeon lamps employ an alternate non-organic encapsulation scheme. This is based on a silica gel that is not reactive and eliminates discoloration. Lumileds also uses aluminum heatsinks to manage heat and a moisture-resistant construction to prevent oxidation and eliminate other problems that contribute to lumen depreciation.

In more news, Lumileds is partnering with LumiDrives of Knaresborough, UK, to accelerate the use of its high-power Luxeon LEDs in the lighting industry. The companies have formed the Luxeon Solutions Center, and as part of the deal LumiDrives will supply drivers with custom fittings that are designed to accommodate several LEDs.

"We are extremely pleased that Cree's quality system was assessed and met the rigorous QS-9000 standard," said Todd Tucker, executive VP of operations. "Achieving this standard reflects the expectations of the Daimler Chrysler, Ford, GM and other subscribing companies, and provides Cree with an excellent opportunity to further penetrate the automotive market with our LED products," he added.

Production-Proven Plasma Processes for Compound Semiconductors



InP-based VCSEL test structure. Smooth anisotropic sidewalls with no undercutting of layers. (Courtesy of Honeywell VCSEL Optical Products)

Plasma etch and deposition processes for a wide range of compound semiconductor materials - customized to optimize profile, yield, throughput and device performance

- Experienced in a variety of compound semiconductor materials & systems
- Well developed processes for the manufacture of via holes, lasers (including VCSELs), LEDs, lenses, waveguides, and photonic devices
- Excellent sidewall angle control
- High throughput processes for through-wafer etching.
- Accurate process control for gate etching
- Smooth etched sidewalls for complex epitaxial structures
- Robust, reliable, production-proven equipment platforms

For further details regarding STS' compound semiconductor etch or PECVD processes, please visit our website at:

www.stsystems.com



SURFACE TECHNOLOGY SYSTEMS

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



RealTemp

**He's Not the Only One
Who Can Accurately Control
High Temperatures**

**RealTemp™ from EMCORE - Standard on all EMCORE Tools*
Now You Can Master the Art of Wafer Temperature Control**

RealTemp™ enables epitaxial materials manufacturers unprecedented control of wafer surface temperatures, improved yield and less downtime. Exclusively offered by EMCORE, RealTemp™ enables users to improve the quality of highly sensitive materials and facilitates a more efficient, accurate, and cost-effective production process.

*RealTemp is not yet available for GaN MOCVD Tools.



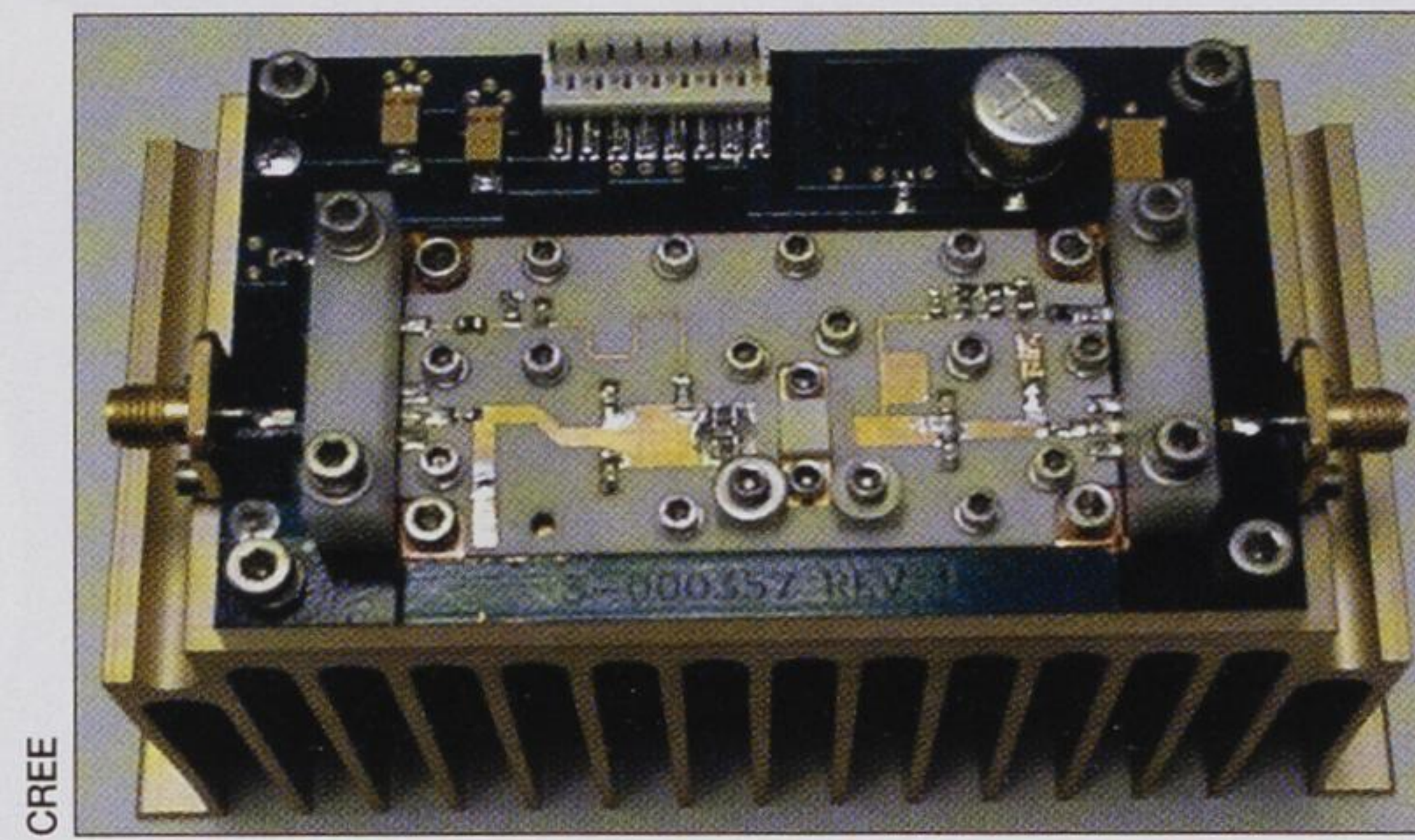
For more information, please contact sales at EMCORE - 732.271.9090

Cree defense contracts top \$40 million

Cree has won four US Department of Defense (DoD) contracts worth more than \$40 m. Two contracts totaling \$14.4 m for research into wide-bandgap devices and materials were followed by two additional contracts for SiC MMIC amplifiers worth \$26.5 m. Military applications such as radar are expected to benefit from high-power SiC and GaN-based devices, which can also operate in extreme environments.

Two of the contracts were awarded as part of DARPA's Wide Bandgap Semiconductor Technology Initiative. The first contract, from the Office of Naval Research (ONR), forms part of "Thrust I" of the DARPA program. It will provide Cree with up to \$8.8 m over a period of 18 months to develop 4 inch semi-insulating SiC substrates for the growth of SiC MESFET and GaN HEMT microwave devices. The work also includes the development of epitaxial processes on large-diameter wafers, and studies that will correlate material advances with device performance.

The second contract, for \$5.6 m, is part of "Thrust II" of the DARPA program and will also run for 18 months. Cree will target low-defect-density n-type 4H-SiC substrates with



DoD grants will enable Cree to develop high-power, high-frequency amplifiers.

a diameter of 4 inches, which will help to reduce the cost of fabricating high-current, high-voltage power devices. Cree will also develop thick epitaxial layers with improved uniformity for the fabrication of devices with blocking voltages in excess of 10 kV, as well as pursuing reliable high-voltage SiC *pin* rectifiers and MOSFETs. ONR has the option to extend these contracts by six months, with additional funding of \$2.9 m for the Thrust I contract and \$1.8 m for the Thrust II contract.

The second pair of awards are from ONR and the US Air Force Research Laboratories. The three-year grants provide \$26.5 m to de-

velop SiC MMIC high-power amplifiers for military radar. Funding is jointly administered by the US Navy, the Missile Defense Agency and DoD's Title III program. The work will build on Cree's existing SiC MMIC program, and is designed to improve the manufacturability of SiC materials, both for substrates and epitaxy. To date, Cree has commercialized several SiC MESFETs, including a 48 V, 10 W device for wireless infrastructure applications.

Specifically, the company will direct its efforts towards enhancing the yield and reducing the costs of fabricating SiC MMICs on 3 inch diameter SiC wafers. In addition, Cree will develop automated wafer-handling systems for larger wafers and will also implement statistical process control.

"These awards represent the largest government contracts in the company's history, and underline the importance of SiC for high-power microwave devices," said Chuck Swoboda, Cree's president and CEO. "We anticipate that all of these [SiC] products will use the same 3 inch semi-insulating substrate platform and automated 3 inch fabrication facility, leveraging the volume of both military and commercial applications."

SEI edges closer to commercial GaN substrate production

Sumitomo Electric Industries (SEI) has developed single-crystal GaN substrates with a low dislocation density, and hopes to mass-produce substrates for the growth of blue laser diodes for the so-called "Blu-ray Disc" optical video recording technology.

The new substrates have regions measuring 500 μm in diameter that have dislocation densities in the 10^4 to $10^5/\text{cm}^2$ range. This is 10^5 times less than the dislocation densities typically achieved in conventional GaN epitaxial layers on sapphire substrates.

SEI developed the world's first 2 inch GaN wafer two years ago, using a unique GaN substrate fabrication process called dislocation elimination by epitaxial growth with inverse-pyramidal pits (DEEP). By forming inverse-

pyramidal pits on the surface of the crystal, this technique reduces both the area of regions that contain dislocations, as well as the density of the dislocations. Despite these reductions, SEI's wafers still contained too many dislocations to be useful in device fabrication. But the researchers have now enhanced the technique and can control the regions where dislocations form, as well as extend the areas of these low-dislocation regions.

The substrates also feature higher conductivity and offer better cleavage than sapphire substrates. SEI plans to commence mass production of the substrates once laser-device manufacturers have evaluated the new GaN material, and initially hopes to fabricate 300 substrates per month by April 2003.

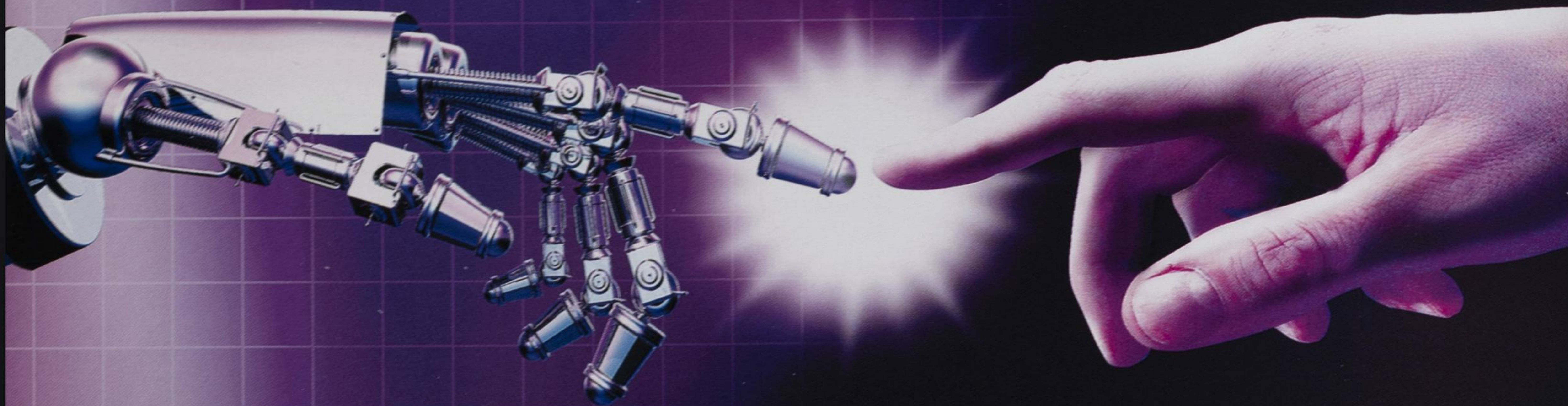
Cubic SiC venture launched by Hoya

Hoya, a Japanese optoelectronic components manufacturer, has set up a company called Hoya Advanced Semiconductor Technologies to develop and manufacture high-quality, large-area, cubic SiC material. Hoya first developed single-crystal cubic SiC substrates in December 2000 and the new venture will now develop large-area wafers.

"The new company has exclusive rights to Hoya's technologies and patents," said Fumio Kitahara, Hoya's new CEO. "These technologies and patents govern the manufacture of cubic SiC substrates at high growth rates, while decreasing the crystal defects that degrade performance."

Hoya has already invested ¥350 m (\$2.8 m) in its new venture and plans to increase its spending to ¥2.6 bn (\$21 m).

Sign up for our free weekly email NewsAlert service at www.compoundsemiconductor.net/articles/news



Partners in growth

Materials Outsourcing is the key to leveraging the most from your IP. With more than 14 years experience in wafer outsourcing, IQE can help you deliver world-class products for next generation applications. For all your semiconductor materials needs from III-V substrates to III-V and Si based epiwafers, ***make IQE your partner to take you into the future.***



USA: +1 610 861 6930

Europe: +44 2920 839 400

Japan (E&M): +81 797 34 6655

Korea (K1): +82 2 597 3961

Taiwan (Conary): +886 22 509 1399

info@iqep.com

www.iqep.com

Emcore receives dicing patent

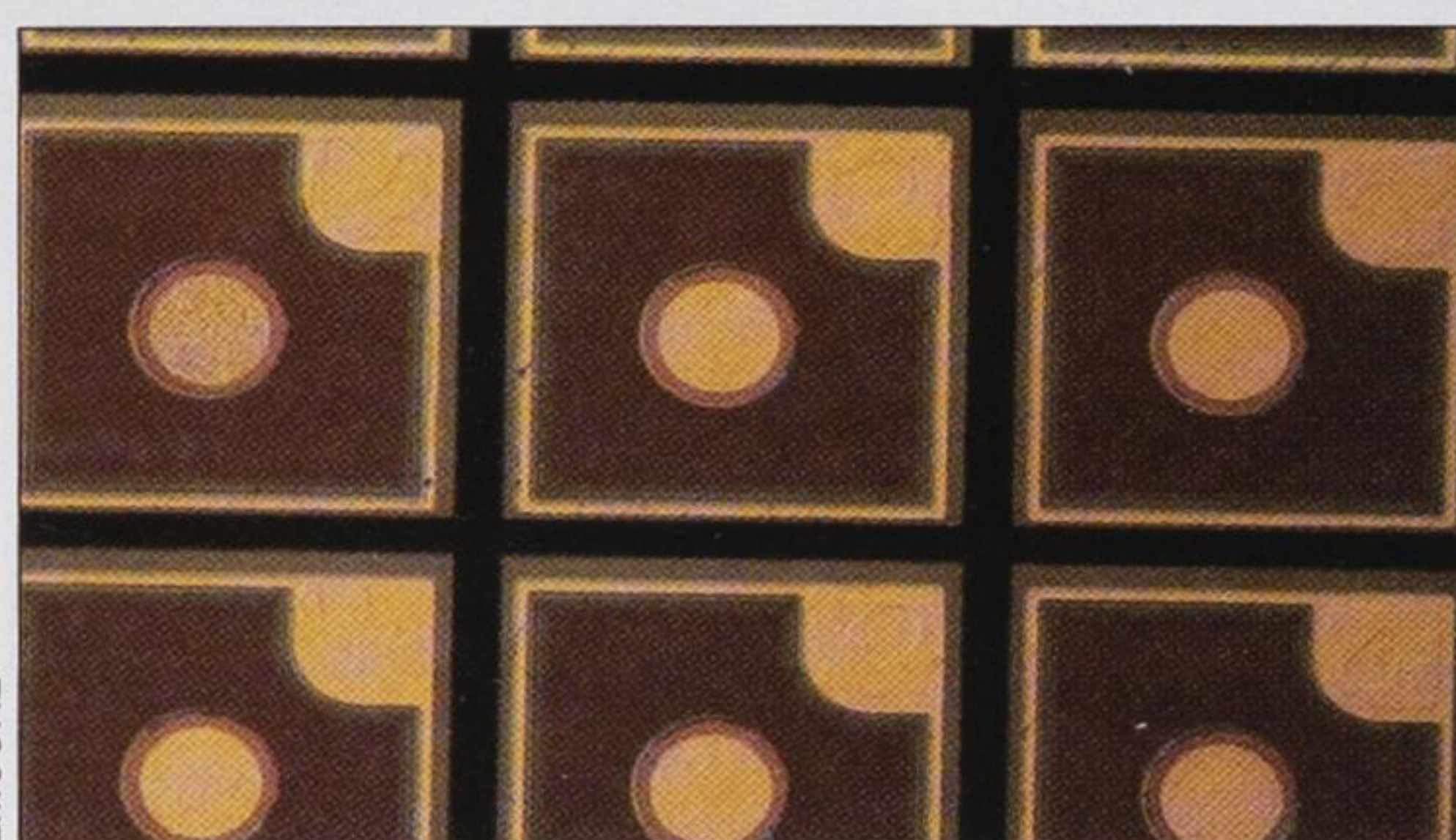
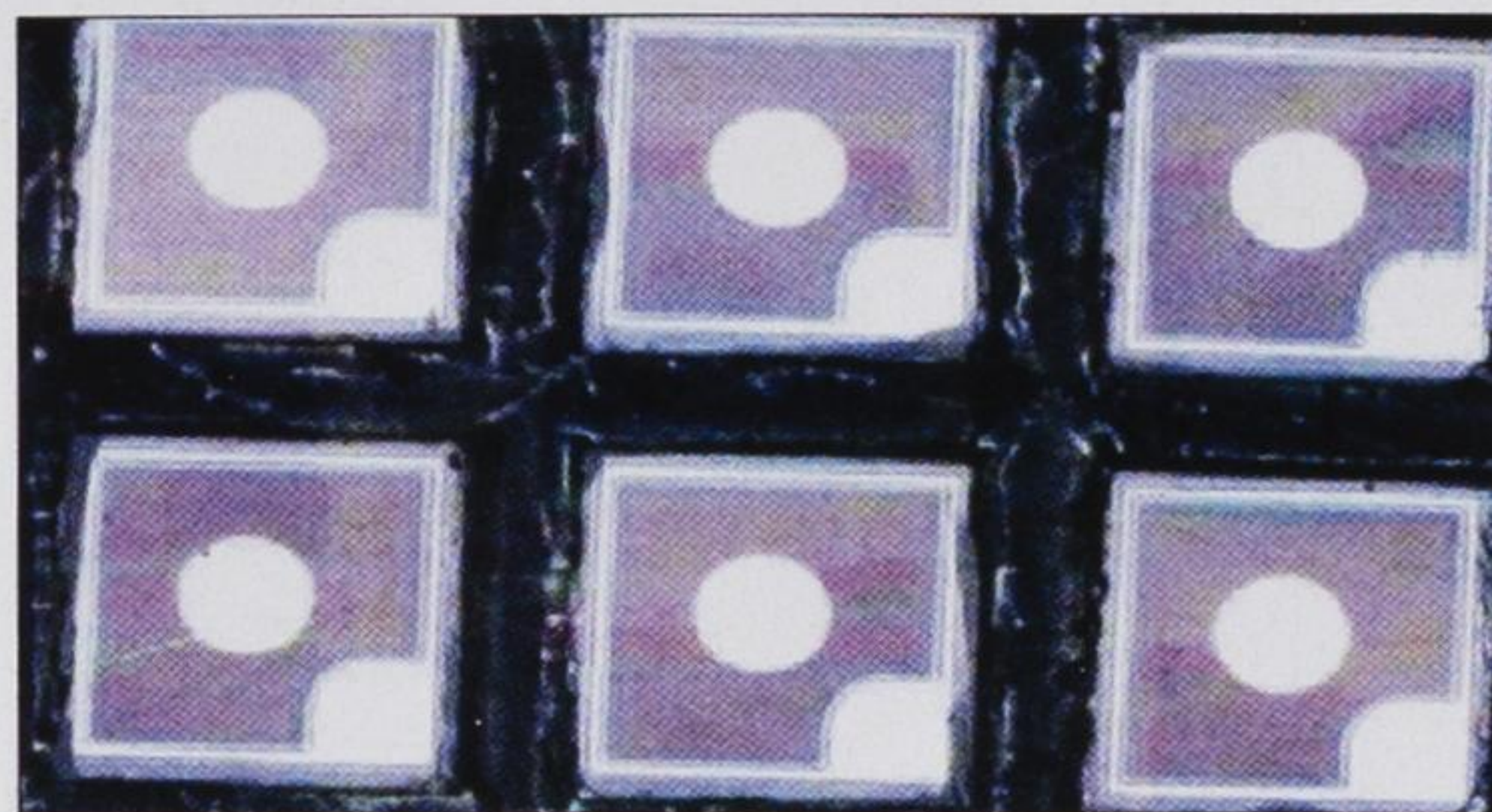
Emcore has patented a new dicing technique that can be used for GaN LED die and other materials grown on sapphire substrates. The technique uses a laser to separate the processed wafer into individual die, and solves problems associated with other separation techniques.

Wafers are typically diced using a scribe and break process. However, sapphire's hexagonal crystal structure means that although the scribe can cleave along one set of crystal planes, it encounters "wandering" in the perpendicular direction that does not lie along defined crystal planes. This reduces the usable area of the wafer and leads to device yields of only 70 to 80% (figure, top). The alternative diamond-saw method causes rough side-walls and a street width of 250 μm that can destroy the LED die.

US patent 6,413,839 B1 describes Emcore's new technique, in which a laser beam passes through optical elements and masks to produce a laser pattern projected onto the wafer surface. With a penetration depth of 50 μm , the laser ablates the material to produce narrow street widths of around 20 μm . The technique has demonstrated aspect ratios of 1:1 (figure, bottom).

Emcore currently runs a research-scale system at its site in Somerset, NJ. According to Tom Ryan, Emcore's marketing director, the process produces yields of 99% for 350 μm LEDs, and typically takes 15–20 mins to complete a 2 inch sapphire wafer.

"By achieving typical separation yields of 99%, LED manufacturers can make signifi-



EMCORE

A new LED die separation method patented by Emcore reduces kerf losses and increases yields from around 70 to 99%. Scribe and break (top) and laser-ablated (bottom) InGaN-on-sapphire LEDs are shown.

cant progress in satisfying capacity demands and expanding the potential market size for new LED applications," said Ryan.

Emcore believes the process will reduce costs and ease the manufacturing of other devices on sapphire substrates, and is currently discussing licensing the technology with a number of major LED manufacturers.

TDI relocates to expanded facility

TDI of Gaithersburg, MD, has moved to a new 32,000 sq. ft facility located in Silver Spring, MD. The facility will initially produce high-volume quantities of GaN and AlGaIn epitaxial wafers.

"The new facility is critical for us to produce GaN, AlN and AlGaIn epitaxial wafers at volume levels," said Vladimir Dmitriev, president and CEO of TDI. "We have been developing these wafers for the past five years, and the move to the new facility is the next step towards their commercialization." The company expects to reach a production capacity of thousands of GaN epiwafers a month, by the end of the year.

TDI also plans to use the facility to accelerate the development of bulk GaN substrates.

Rubicon boosted by new funding win

Rubicon Technology, a Chicago-based manufacturer of exotic optical-grade materials, has raised \$9.5 m in its second round of investment. Rubicon plans to extend its production of single-crystal sapphire substrates, and develop larger diameter sapphires and new exotic materials for optoelectronic applications.

"We are enthusiastic about the emerging market potential for Rubicon's high-growth target applications within the broader optoelectronics market," said Don Aquilano of Gazelle Tech Ventures, one of the venture capitalist firms that funded Rubicon. "Rubicon is in the right place at the right time."

"This investment is a strong endorsement of our business strategy and market focus," added Chris Moffitt, CEO of Rubicon.

Gallium Arsenide

Indium Antimonide

Indium Arsenide

Indium Phosphide

Gallium Antimonide

Gallium Phosphide

Silicon Carbide

Sapphire

Silicon

Zinc Oxide

wafer technology

High purity MBE source material

High purity indium metal

High purity gallium metal



Wafer Technology

USA: +1 928 468 2204

UK: +44 1908 210 444

Germany: +49 451 59 6500

Scandinavia: +46 8 571 62640

Japan (E&M): +81 797 34 6655

Korea (Semivac): +82 2 573 3786

Australia (M.M.R.C): +61 3 9885 1752

www.wafertech.co.uk

Wafer Technology is part of IQE plc

Quantum-dot researchers target blue and UV lasers

By Jon Newey

Quantum-dot (QD) lasers are no longer a laboratory curiosity and are now becoming a commercial reality. Work in this field has been driven by the realization that QD lasers exhibit lower threshold currents and a broader gain spectrum than their QW counterparts (*Compound Semiconductor* June 2002 p14). The successful demonstration of III-V QD growth and device fabrication has been extended to other material systems including II-VIs and III-nitrides.

Before epitaxial techniques were developed to grow QDs, theoreticians were able to model the electronic and optical properties of such structures. Much of the early theoretical work on QD lasers was done by Yasuhiko Arakawa's team at the University of Tokyo. In the early 1980s they calculated the spectral characteristics that could be expected from QD lasers. They also found that lower threshold current and temperature dependence would be a feature of QD lasers compared with QW lasers.

However, it was not until the late 1980s and early 1990s that the ability to grow real semiconductor QDs emerged and the theoretical models were put to the test. Early attempts focused on the etching of QW layers to form arrays of QDs. However, etching introduced non-radiative defects to the dot mesas. Self-assembly through Stranski-Krastanow growth has become the favored method for growing III-V QDs, but much work has also been done on selective-area growth.

Arakawa's team, in collaboration with NTT Photonics Laboratories, is currently investigating GaN-based QD blue and UV lasers, and has fabricated QD laser structures using self-assembly and selective-area growth. Theoretical calculations are being performed by Takaaki Kakitzuka and colleagues at NTT. "We made a numerical analysis of the threshold current of QD lasers using a simple model," said Kakitzuka. "It was found that the threshold current reduction in GaN-based lasers was large compared with GaAs-based lasers."

The threshold current for lasing increases with the electron effective mass, which in turn increases with bandgap energy. As a result, the threshold current density for an InGaN QW laser is about 1 kA/cm², while for a GaAs-based QW laser it is typically 100 A/cm². If QDs are used, the population of carriers in

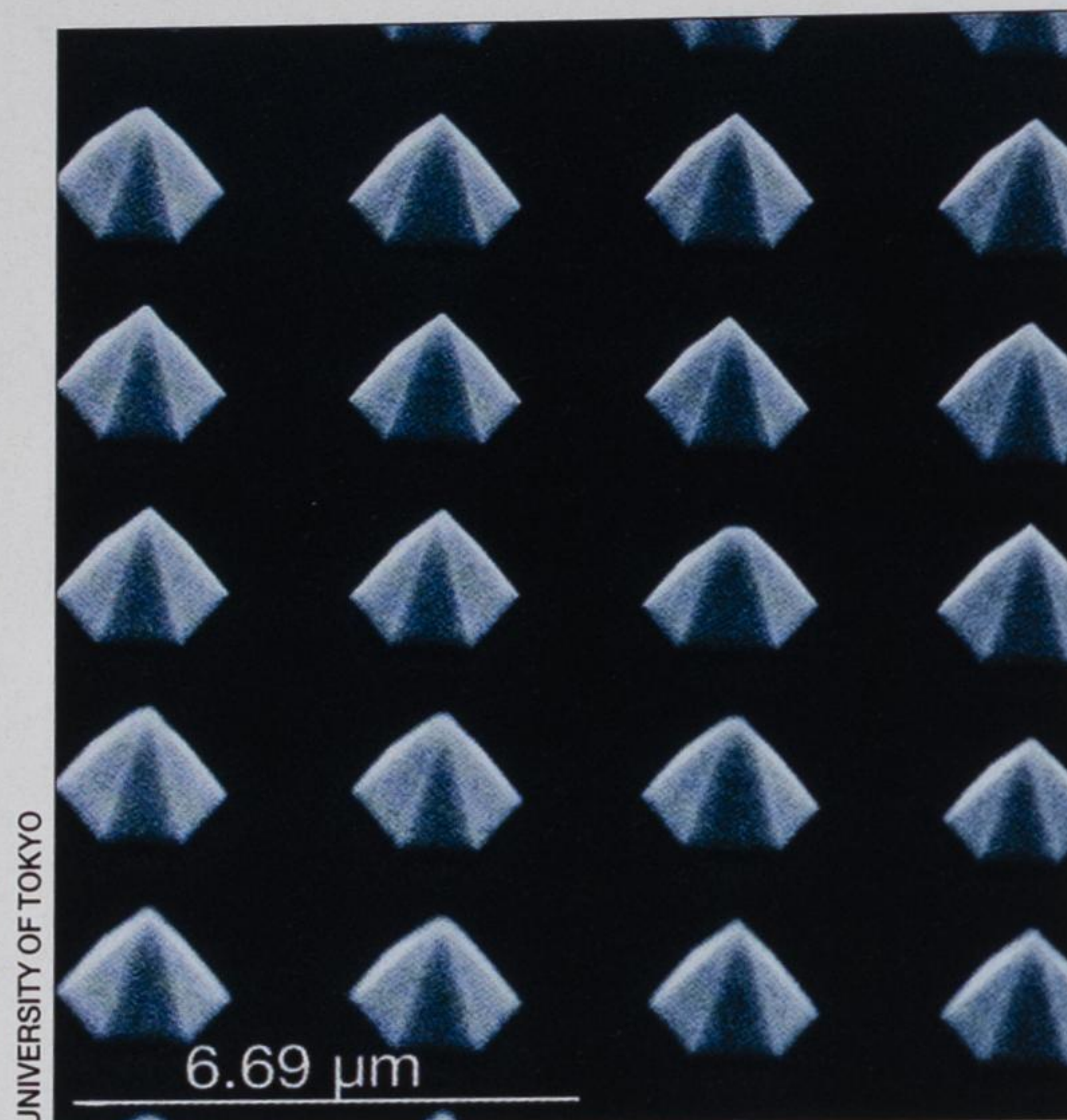


Fig. 1. A SEM image of GaN/InGaN pyramids, which are formed by selective-area growth into 2 x 2 μm holes in an SiO₂ layer sputtered onto a GaN epitaxial layer.

the higher subbands can be ignored and the threshold current density for QD lasers in either material system is similar at about 10 A/cm². The effect of using QDs in GaN-based lasers can therefore reduce lasing threshold current density by a factor of 100, compared with 10 for GaAs-based devices.

Self-assembly by MOCVD

Arakawa's group is using MOCVD for InGaN QD formation by self-assembly and selective-area growth. Sapphire substrates are used and growth begins with a low-temperature nucleation layer, followed by a high-temperature GaN layer 2 μm thick, onto which the InGaN dots are grown. InGaN dot density increases with InGaN coverage. By varying coverage between 5.3 and 18.4 monolayers (MLs), dot density can be selected between 1.2 x 10⁹ and 1.4 x 10¹⁰ dots/cm².

Dot dimensions are controlled by selecting the growth temperature, though this also has some effect on density. Keeping coverage at 1.5 ML and increasing growth temperature from 675 to 770 °C decreases dot density from 2.1 x 10¹⁰ to 4.5 x 10⁹ dots/cm². At 675 °C the average dot diameter and height is 8.9 nm and 2.1 nm, respectively. At 770 °C these rise to 16.8 and 3.5 nm.

Lasers require a high density of dots and so several dot-containing layers are successively grown to stack the dots vertically. Each layer of dots is buried in a 5 nm thick In_{0.02}Ga_{0.98}N

Selective-area QD formation

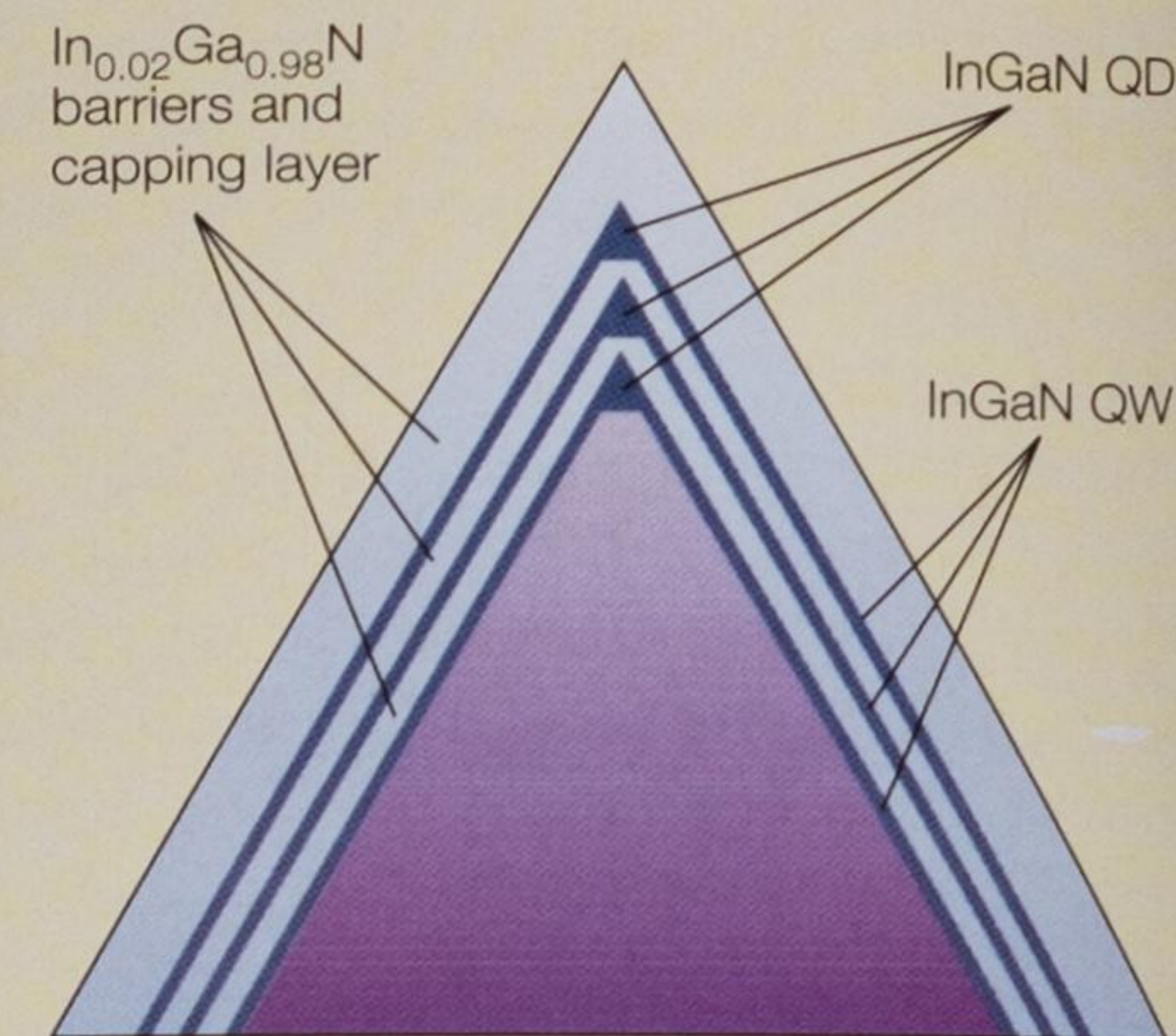


Fig. 2. An InGaN QW layer is grown onto the GaN pyramid. A QD forms in the QW layer at the peak of the pyramid. The well layer is followed by an InGaN barrier layer. By depositing successive well and barrier layers, the QDs can be stacked.

layer. Arakawa has found that InGaN dots can still be grown after 10 repeats, though the dot density reduces slightly at each repeat.

The University of Tokyo team has also fabricated InGaN dots using selective-area growth. After the GaN layer has been grown, an SiO₂ mask 40 nm thick is deposited and patterned with 2 x 2 μm openings at 4 μm intervals. GaN is then selectively grown into the openings, forming an array of pyramids (figure 1). Over the top of the pyramids, three InGaN QW layers are grown, each 2.4 nm thick and separated by 4.1 nm In_{0.02}Ga_{0.98}N barrier layers. In this way, QDs are formed in the tops of the pyramids (figure 2).

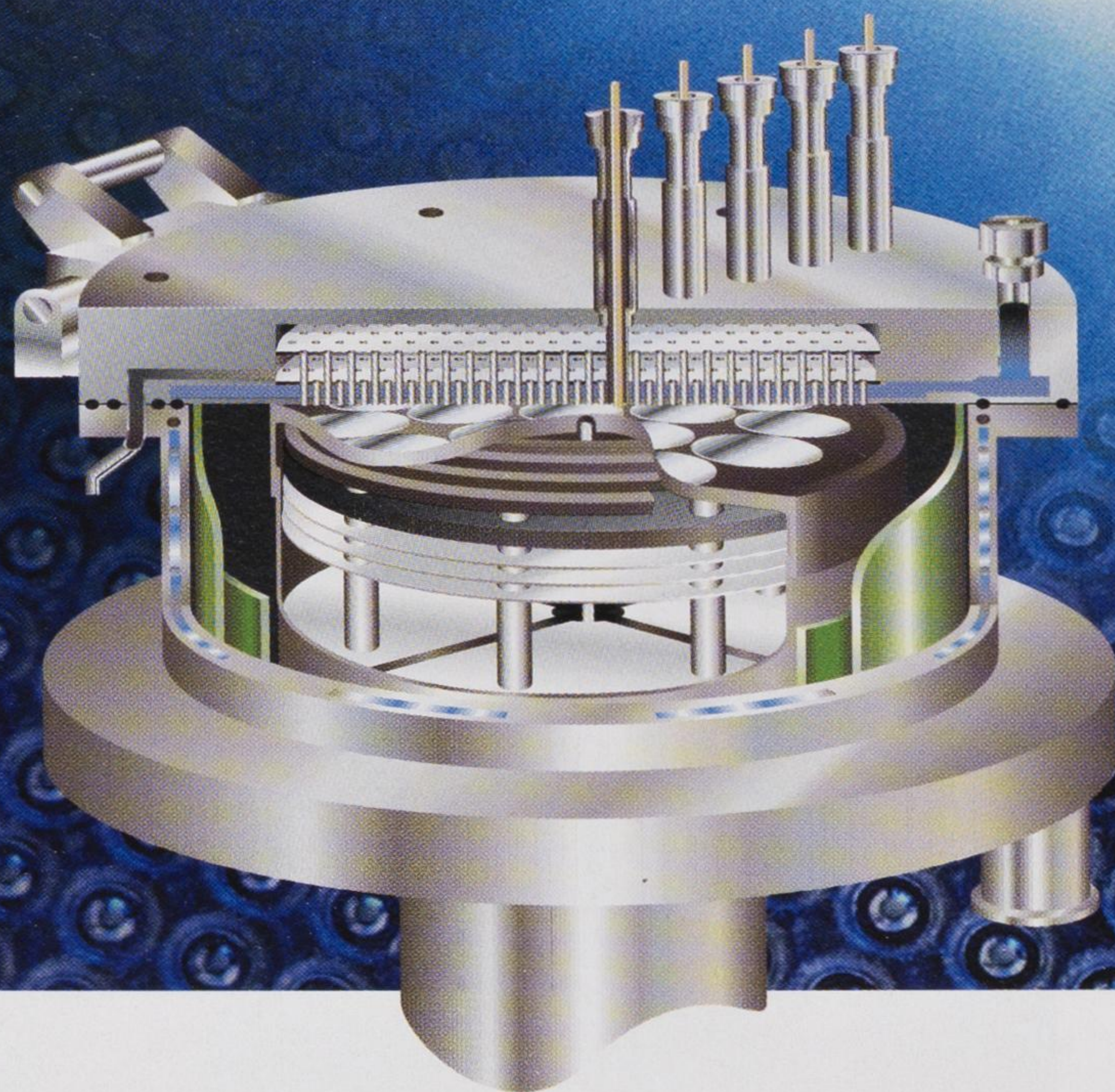
Photoluminescence (PL) measurements have been made at room temperature using a 0.7 mm diameter laser beam that illuminates about 25,000 dots. PL spectra show a sharp intense peak at 365 nm, corresponding to luminescence from the GaN layer. A broad, low-intensity peak is seen centered on 430 nm, corresponding to emission from the dots. The peak is broadened because emission is coming from a large number of dots with slightly varying sizes, each emitting at a different wavelength. The QD peak is less intense than the GaN peak because the QDs have a much smaller volume than the GaN.

The team's efforts are now concentrated on better control of dot size and distribution during self-assembly, and also on achieving electrically pumped lasing from the structures.

CCS MOCVD Systems

Your future... is our business

- World leading supplier of MOCVD solutions
- Unique Close Coupled Showerhead (CCS) Technology
- Truly scalable reactor concept
- A range of Production and R&D systems available
- Low cost of ownership
- High yield
- Proven for a wide range of compound semiconductor materials
- Global service and support network



Thomas Swan Scientific Equipment Ltd

Anderson Road, Buckingway Business Park, Cambridge, CB4 5FQ. UK. Web: www.thomasswan.co.uk
Tel: +44 (0) 1223 519444 Fax: +44 (0) 1223 519888 email: sales@thomasswan.co.uk

A member of the AIXTRON group of companies



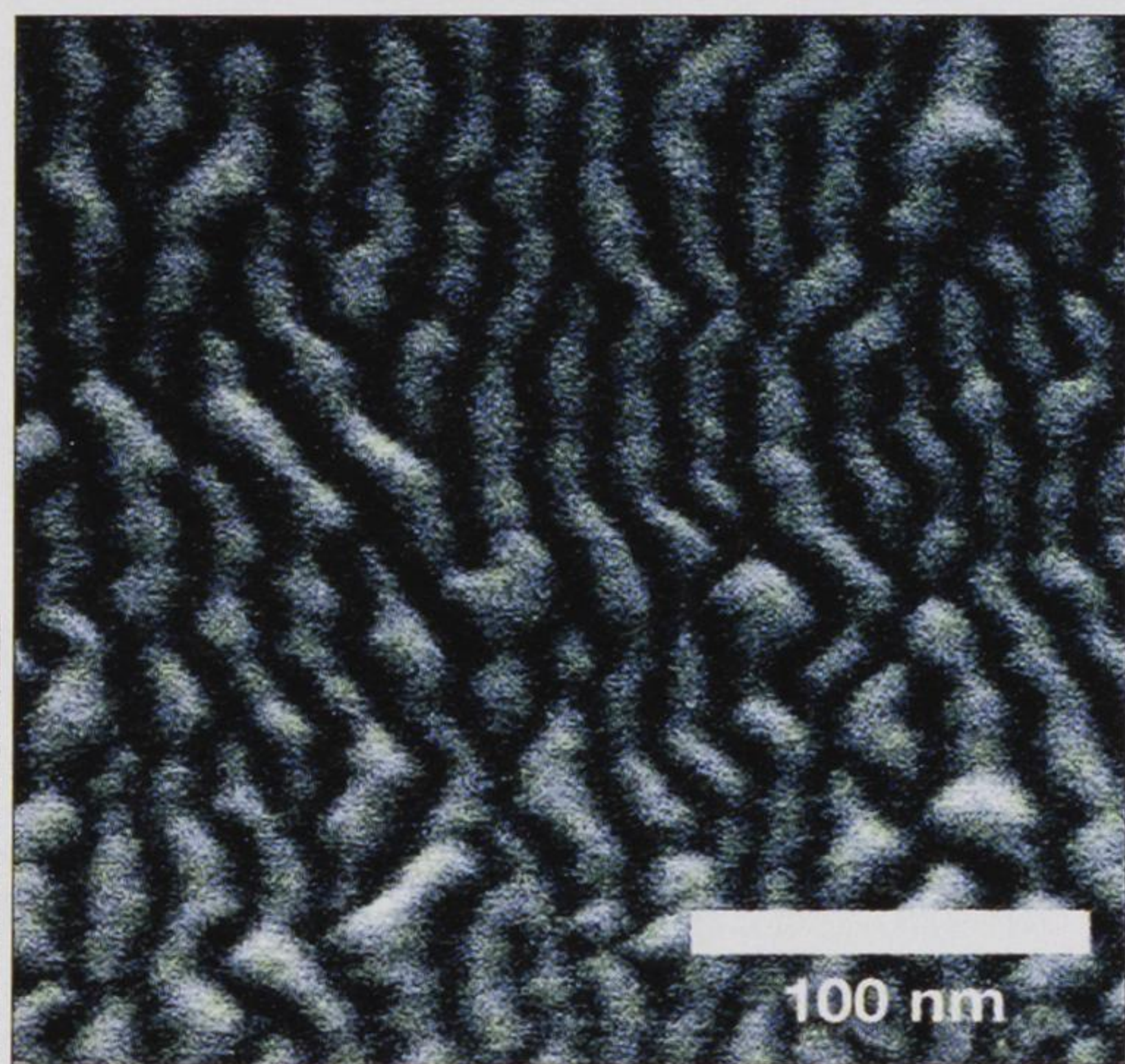
Epichem Ltd. (UK)
Tel: 44-151-334-2774
www.epichem.com
Epichem, Inc. (USA)
Tel: (1) 610-706-0606



**Discover the
Epichem Difference!**

**Global Supplier of Specialty Chemicals
for the Semiconductor Industry**

Quantum-dot devices get €2.7 m funding boost



WURZBURG UNIVERSITY/IEEE

An SEM micrograph of InAs quantum dashes. If used as the gain material in lasers, the devices could have a gain bandwidth that is three times broader than that of a typical QW laser.

European scientists have launched a €2.7 m (\$2.7 m) project called "Bigband" to develop ultra-wideband InAs quantum-dot (QD) lasers and amplifiers for telecom applications. Project leader Johann Reithmaier of the University of Wurzburg in Germany and colleagues across several European research organizations plan to make external cavity lasers that tune over 300 nm, as well as directly modulated chirp-free 1.5 μm distributed-feedback lasers and high-speed optical amplifiers for multiwavelength applications.

QDs are three-dimensional semiconductor structures that are only nanometers in size (*Compound Semiconductor* May 2002 p14). Reithmaier says that if QDs are used as the gain material in lasers, the devices have a gain-bandwidth product that is three times larger than that of a typical QW laser. The lasers also

exhibit a faster recovery time for optical amplification, as well as multiwavelength amplification and a reduced chirp factor.

Reithmaier's team plan to grow the QD structures using gas-source MBE with group V gas precursors. "We have had a lot of experience with this type of system and have excellent control over dot formation," Reithmaier told *Compound Semiconductor*.

Laser growth

Using GS-MBE, the researchers have already grown quantum-dash lasers based on a separate confinement heterostructure design. Grown on an S-doped InP wafer, the laser structure comprised a 200 nm thick Si-doped InAlAs bottom cladding layer and a 480 nm thick AlGaInAs inner waveguide. The active region, comprising four self-assembled InAs quantum-dash layers separated by 25 nm AlGaInAs layers, was embedded in the waveguide.

By altering the thicknesses of the layers in the active region, the emission wavelengths were adjusted from 1.54 to 1.78 μm . The structure was then completed with a 100 nm AlInAs layer, a 1700 nm InP layer and a 150 nm GaInAs cap.

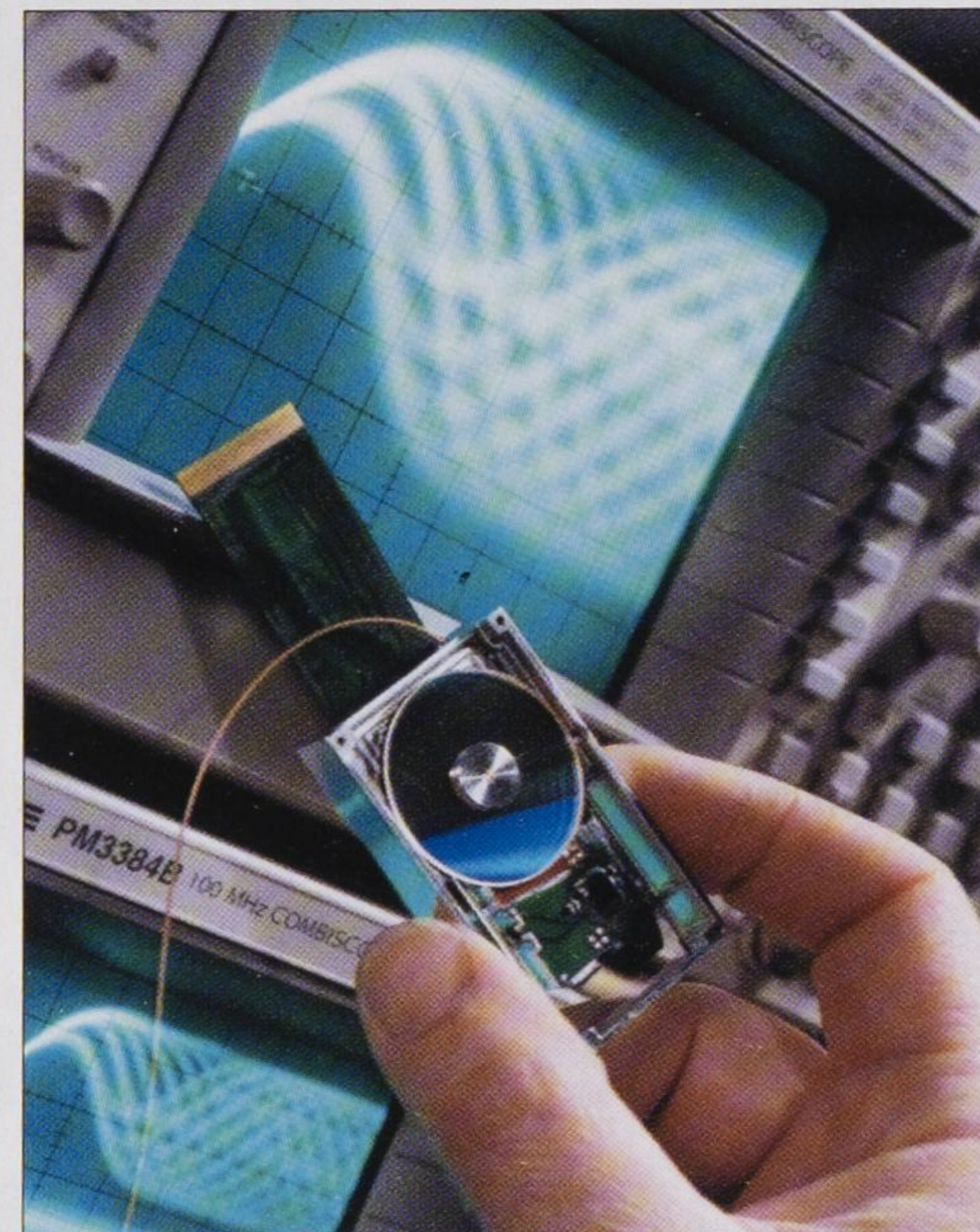
With their latest funding, Reithmaier says that his team has already improved the threshold current densities and efficiencies of its lasers. "The first devices will be SOAs and distributed feedback lasers, and we will also develop external-cavity lasers during this time," he said.

The other organizations that are involved in this project are Politecnico di Torino of Italy, the Technical University of Denmark, Thales Research and Technology of France, the Israel Institute of Technology and Nettec Photonics of France.

therapy, solid-state laser pumping and fluorescence and vision systems.

With 1.5 and 2.5 W powers, both lasers have a 400 μm core and 0.22 NA fibers with SMA connectors. The modular packages are industry standard and contain thermoelectric coolers and monitor photodiodes.

Philips unveils next-generation optical disk drive



PHILIPS RESEARCH

The miniature disk drive from Philips uses a Nichia GaN-based laser. The oscilloscope shows the read-out characteristic of the 3 cm optical disk.

Philips of the Netherlands has revealed its latest optical disk drive. The drive uses a 405 nm laser diode – which is manufactured by Nichia – to store up to 1 Gbyte of data on a 3 cm diameter disk. Philips says that the disk size matches the constraints of digital devices such as wireless phones, digital cameras and personal digital assistants, and the company has plans to decrease the size of the drive even further.

To minimize the size of the drive, Philips used a plastic objective lens, rather than glass, to focus the blue laser onto the disk. The company claims that this is the smallest objective lens which has ever been used for blue-laser recording, and that this enabled the height of the drive to be reduced from 12.5 to 7.5 mm. Philips also says that another key development was an "ultra-thin" actuator, which positions and focuses the beam onto the disk.

The device currently operates in read-only mode, although Philips now has plans to develop a rewritable drive. The company also hopes to move from prototype to product, however it says that this could take some time.

In brief...

High Power Devices reveals visible laser diodes for optical systems

High-power laser-diode manufacturer High Power Devices of North Brunswick, NJ, has recently developed 635 and 670 nm laser diodes for photodynamic

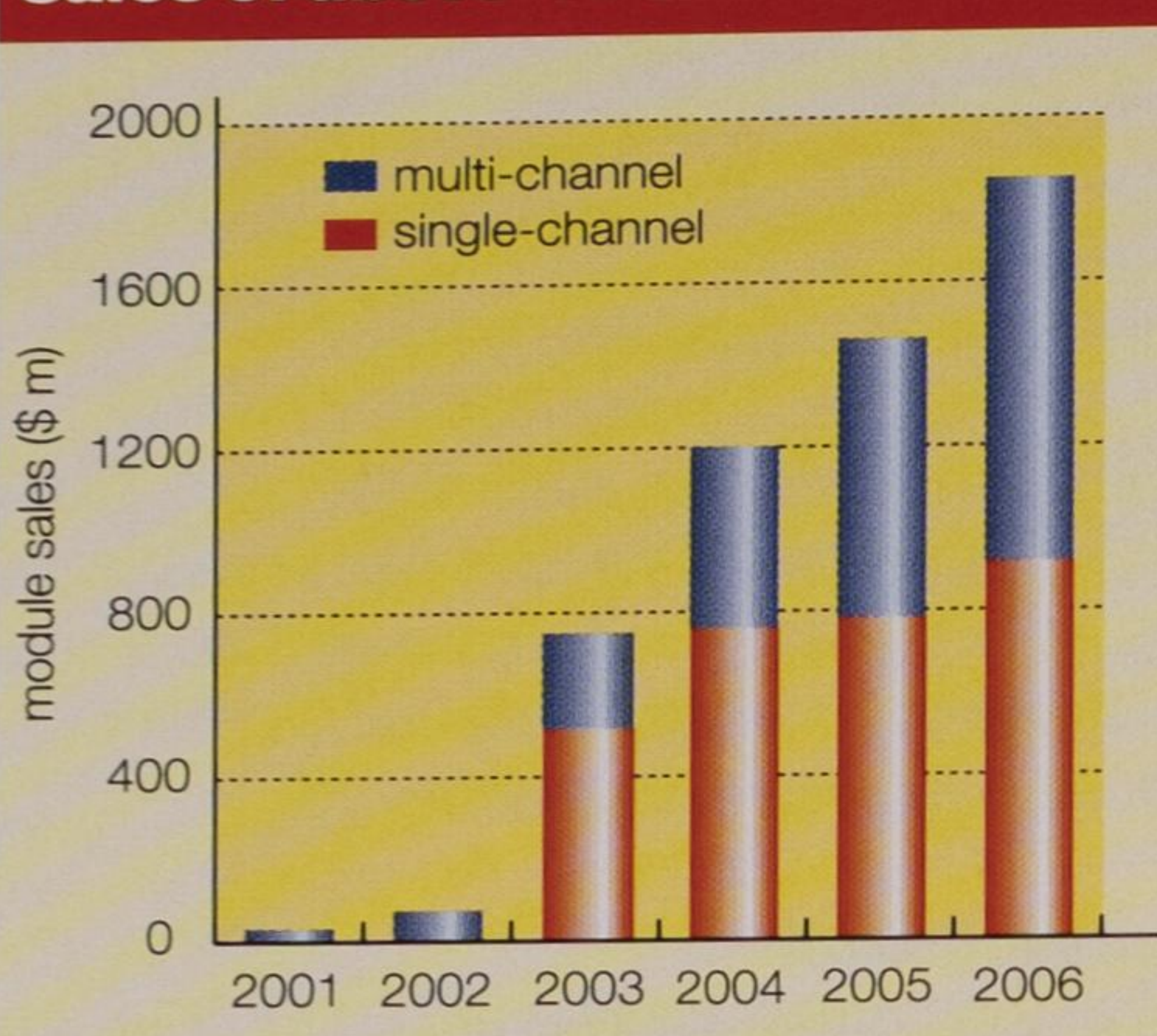
40 Gbit/s components poised for growth

As 40 Gbit/s per channel components edge closer towards commercial availability, ElectroniCast is predicting that they will be widely used in long-haul and ultra-long-haul networks by late 2004.

"The first significant commercial deployment of 40 Gbit/s per channel long-haul and ultra-long-haul network segments will occur in mid to late 2004," said ElectroniCast chairman Jeff Montgomery. "In the meantime there will be increasing demos and trials."

Point-to-point fiber links that transmit data rates of at least 40 Gbit/s typically fall into one of two categories; those using single-channel, singlemode edge-emitters, or those using multi-channel/multi-fiber multimode VCSELs that support up to 3.7 Gbit/s per channel. Edge-emitters are aimed at long-haul and ultra-long-

Sales of above-10 Gbit/s modules



Sales of single- and multi-channel above-10 Gbit/s transmitter/receiver modules are predicted to reach \$1872 m by 2006.

haul markets, while multimode VCSELs are used in metro/access, LAN, MAN, WAN and intra-equipment markets.

ElectroniCast forecasts that sales of single- and multi-channel/multi-fiber transmitter/receiver modules for above-10 Gbit/s networks will increase by more than 20 times over the next four years. Combined sales from 2002 to 2006 are set to soar from \$76 m to \$1872 m, with the multi-channel module gaining market share from its single-channel counterpart.

But while component sales are set to increase rapidly beyond 2003, ElectroniCast says the market value will not track this growth. "The substantial consumption growth from 2003 to 2006 will be almost matched by price drops," said Montgomery. "This will leave only moderate market-value growth."

Fiber component manufacturers still fighting industry downturn

Amidst claims that the economic downturn has bottomed out, fiber component manufacturers are still adjusting to telecom losses. InP-based linear optical amplifier maker Genoa is to reduce its 100-strong workforce by 20% in a bid to cut costs. Jim Witham, VP of sales and marketing at Genoa, blames market conditions and a change in focus from early-stage research and development to customer product engineering. At the same time, chief executive Rick Gold has stepped down and will be replaced by Fariba Danesh, senior VP of operations.

Laser-diode maker nLight Photonics has also altered its future plans. Reports from analyst ElectroniCast reveal that the start-up has pushed back production in its newly built \$16 m fab to late 2003. nLight opened its manufacturing plant in Clark County, WA, in September of last year, following a \$53 m cash injection. Initially aiming to start production in October 2001, nLight is currently making prototypes.

Consolidations

This month also brings a spate of consolidations. Bookham Technology is to concentrate production at two of its four facilities. The manufacture of ASOC components will continue at its Milton, UK, facility, with the production of active components remaining at

the former Marconi Optical Components site in Caswell, UK.

The company plans to close its other two facilities in Maryland, US, and Swindon, UK, and believes that with current and predicted demand levels for its components, the two remaining UK sites will be able to handle all production and development needs.

Bookham hopes that these closures will reduce the company's cash burn and also allow it to maintain its current production levels, while having the capacity to meet future increases in demand.

In a similar move, ADC is set to close its tunable laser plant in Jarfalla, Sweden, and transfer operations to its other tunable laser production site located in Minnesota. The company cites poor worldwide market conditions for tunable lasers as the reason behind the closure.

"ADC hopes to finalize its plans [for the closure] and execute them quickly," said Rob Clark, ADC's director of public relations.

ADC took on the Swedish facility when it bought tunable laser start-up Altitun in May 2000, and only recently completed a major overhaul of the site. The Jarfalla facility was equipped to handle all of the production processes including InGaAsP/InP epitaxy through to packaging and testing for ADC's Anywave tunable laser products.

Zia and CyOptics team on QD lasers

CyOptics, a manufacturer of InP electro-absorption modulators, is to provide Zia Laser with InP foundry services. Zia Laser is a start-up manufacturer of long-wavelength 1310 and 1550 nm lasers that are based on quantum dots (QDs) (*Compound Semiconductor* June 2002 p14). These structures are formed by a three-dimensional growth mode that occurs under specific epitaxial growth conditions.

"Zia Laser is bringing a fabless business model to the optical components industry, which will give us access to industry-leading manufacturing facilities and expertise," said Tom Brennan, CEO of Zia Laser.

Under the terms of the agreement, CyOptics will collaborate with Zia to develop the processes required to manufacture 1550 nm tunable-gain QD lasers and 1310 nm uncooled QD lasers, including fabricating InP wafers and packaging laser samples. CyOptics will also buy 1310 nm lasers from Zia commencing from the end of this year.

Zia's 1550 nm tunable gain chip is designed to be the core of a tunable external-cavity laser system covering the S-, C- and L-bands. The company's 1310 nm uncooled DFB laser operates at up to 10 Gbit/s with 5 mW of output power. This laser can be used in modules to provide uncooled 80 km transmission without the need for isolators, simplifying and reducing packaging costs.

VertiLas wins first-round funding

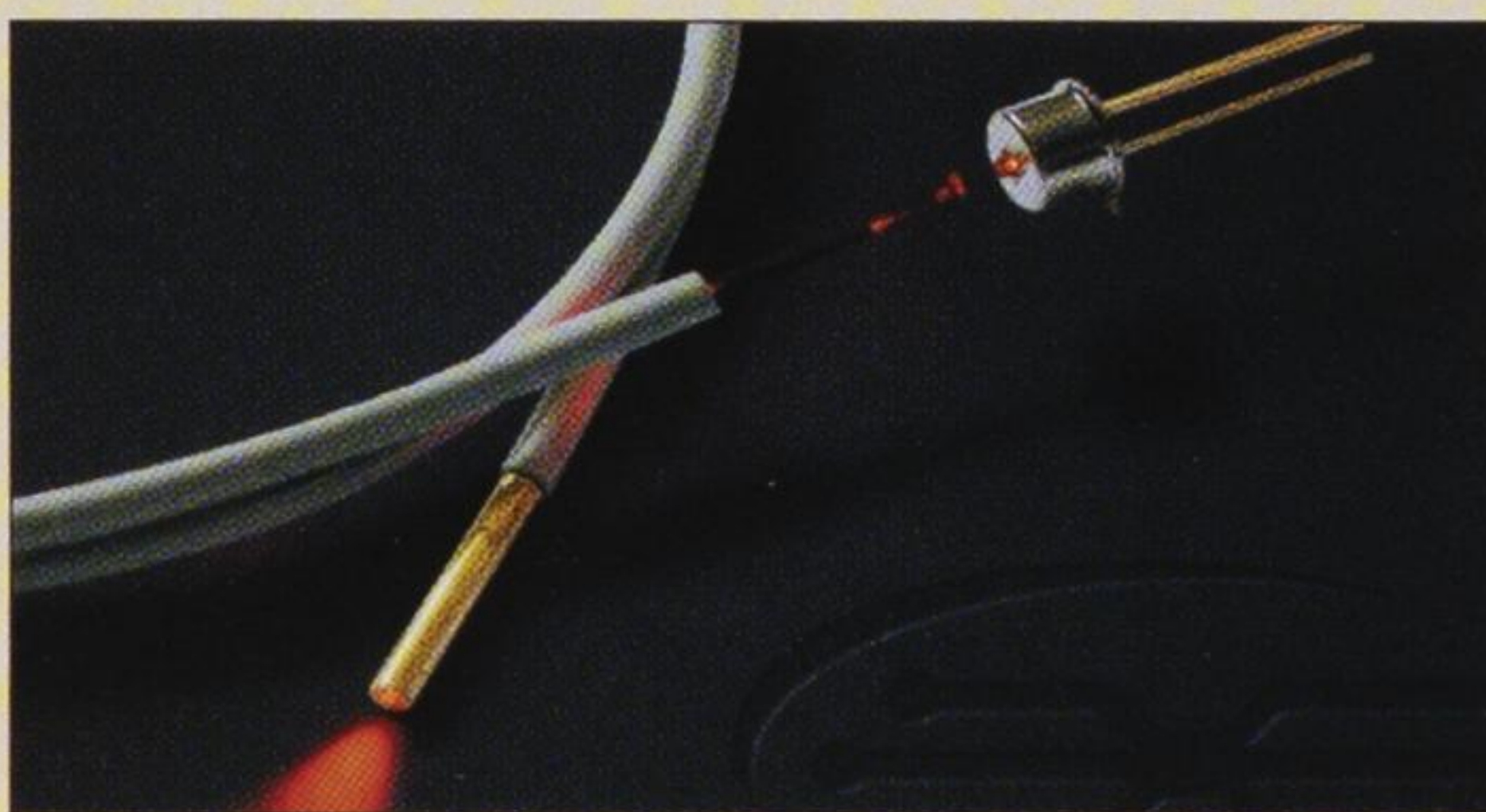
Long-wavelength VCSEL start-up VertiLas of Munich, Germany, has secured first-round financing to commercialize its products. The value of the funding was not revealed.

VertiLas, a spin-off from the Walter Schottky Institute of the Technical University, Munich, is focusing on 1310 and 1550 nm (InGaAl)As/InP VCSELs, as well as 2–3 nm tunable devices for the 1.6–2 μm wavelength range. These devices are based on a buried tunnel junction design (*Compound Semiconductor* October 2001 p44).

“With our breakthrough technology we are targeting attractive markets in telecoms, sensing and measurement,” said CTO Markus Ortsiefer. According to Ortsiefer, the company has manufactured 1550 nm VCSELs with multimode output powers greater than 7 mW and singlemode powers approaching 1 mW. “For 1550 nm VCSELs we have also demonstrated CW operation up to 110 °C, with 0.5 mW power at 80 °C,” he said. “For 1.83 μm VCSELs, CW operation was possible up to 90 °C.”

Plastic fiber-optic applications linked by Zarlink's RCLED

Zarlink Semiconductor's AlInGaP-based 650 nm RCLED is designed for short-distance, high-speed plastic optical fiber (POF) applications. Supporting data rates of 500 Mbit/s over 50 meters of graded-index POF, the ZL60003 will link appliances such as PCs, storage devices, digital cameras and set-top boxes.



EpiWorks joins with University of Illinois

Epitaxial wafer manufacturer EpiWorks has announced a new VCSEL development program in collaboration with the University of Illinois. The project will focus on developing an 850 nm VCSEL capability at the university, and on studying novel designs and materials for next-generation applications. Engineers from both EpiWorks and the University of Illinois will contribute their design, growth and testing expertise to the project.

“We plan to develop a high-performance VCSEL structure and then implement novel designs to explore new capabilities and applications,” said Kent Choquette, a researcher at the University of Illinois and former employee of Sandia National Labs.

“EpiWorks has a long-standing relationship with the University of Illinois, developing devices such as InGaP/GaAs and InP-based HBTs,” said Nada El-Zein, EpiWorks' director of R&D. “It is critical for both the material and device experts to work closely together.”

How About UV-LED?



We have started to provide 370nm GaN wafers and chips for LED.

Applications

- Deodorant: With photo-catalyst
- Light source for sensor etc.

Please ask

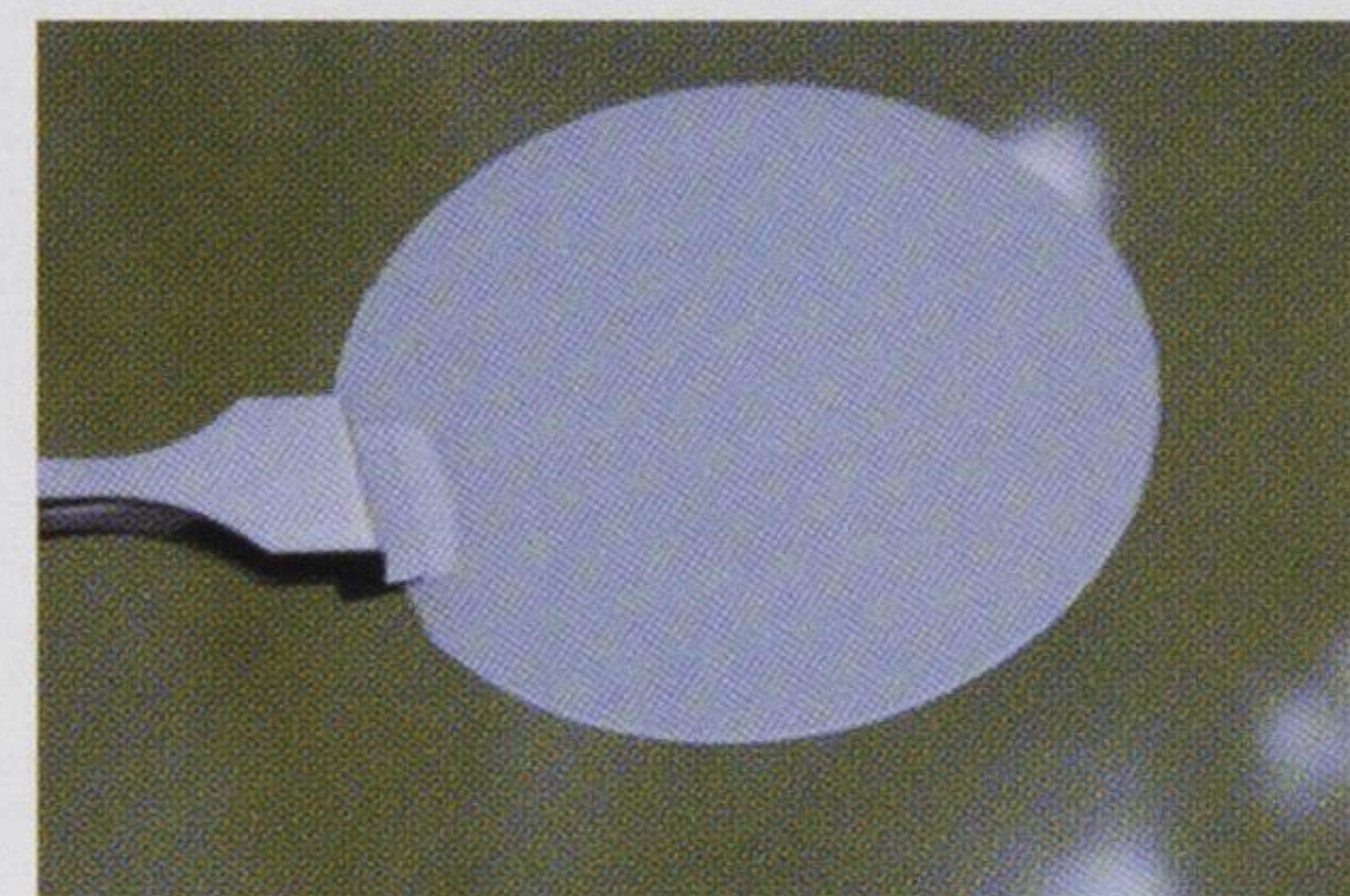
nitride@nitride.co.jp

NITRIDE
SEMICONDUCTORS
Co., Ltd.

115-7 Itayajima, Akinokami, Seto-cho,
Naruto-shi, Tokushima. 771-0360 Japan

TEL +81-88-683-7750
FAX +81-88-683-7751

<http://www.nitride.co.jp/>



Emcore gets Qusion modulators

Qusion Technologies, a manufacturer of InP components based in North Brunswick, NJ, is to supply Emcore with wide optical bandwidth electroabsorption modulators. At the same time Emcore, a supplier of VCSELs and VCSEL-based transponders to the fiber-optic market, announced an investment in Qusion, which it

says will provide early access and influence on new product developments at Qusion.

"We expect that Qusion's technology will enable us to extend the reach and data rate of our fiber-optic products," said Emcore's president and CEO Reuben Richards, who is a member of Qusion's board of directors.

Eblana earns more venture financing

Eblana Photonics, a manufacturer of lasers for metro and access optical applications, has announced new funding that brings its total investment to €3.6 m (\$3.6 m) in just over a year. The Irish start-up plans to use the cash to commercialize its products.

Eblana originated from a photonics advanced research program run by Trinity College Dublin, the National Microelectronics Research Centre and Enterprise Ireland, and was established as a start-up at the end of last year. Currently sampling GaAs 980 nm pump lasers for mini-amplifier applications, as well as singlemode InP 1310 and 1550 nm transmitters, the company plans to start ramping up to volume production levels by the end of this year.

Rather than make the lasers internally Eblana outsources its manufacturing, which, according to chief executive James O'Gorman, is crucial to their success. "We focus on areas where we bring added value, such as device design, and sub-contract out the more highly capital-intensive parts of the business," he said.

One area of product design that Eblana has been working on to manipulate its devices' lasing properties is post-growth processing. The company takes epiwafers and, using "photon bandgap engineering", etches microstructures or waveguides into the wafer's top epilayer. A key advantage of this step is that it takes place after the initial growth of the epitaxial layers, avoiding the need for regrowth that is typically required in laser-diode manufacturing.

O'Gorman says that avoiding regrowth removes the heterogenous interface problems that arise at the boundary of two different materials. "This means you don't have problems with defects propagating from this boundary through the microstructure," he said.

In their simplest form the microstructures typically comprise a series of ridges and grooves that alter the refractive index of the semiconductor layers. By altering the topology of these microstructures, researchers at Eblana can modify device characteristics.

"By etching these microstructures into the laser we are controlling the mode structure into which charge carriers recombine," explained O'Gorman. "As a result, we affect the device's lasing mode and its specifications; for example we have fabricated a singlemode device with a 55 dB side-mode suppression ratio."

Eblana is now expanding its workforce and intends to target its products at global markets.



Japan Energy through its ACROTEC brand is a well-known supplier of consumable semiconductor materials.

Our line of products includes Indium Phosphide and Cadmium Telluride Wafers along with high purity metals such as Indium, Cadmium and Tellurium for epitaxy processes. We can supply epitaxial deposited wafers. Our latest product is Zinc Telluride single crystal.

SINGLE CRYSTALS
InP (Dopants: None, Sn, S, Zn, Fe)
CdTe
CdZnTe
ZnTe

HIGH PURITY METALS
(For LPE, MBE and crystal growth)
In: 7N, 6N
Cd: 7N, 6N
Te: 7N, 6N

MOCVD EPITAXIAL WAFERS
MBE EPITAXIAL WAFERS

JAPAN ENERGY

ACROTEC Semiconductor Materials

Asian Region

Japan Energy Corporation, Head Office:
Compound Semiconductor Marketing Dept.,
10-1 Torimachi 2-chome, Minato-ku,
Tokyo 103-8407, Japan
Tel: +81 (0) 3-5573-6592
Fax: +81 (0) 3-5573-6779
Internet: www.j-energy.co.jp

North American Region

Nikko Materials (Japan's Energy's wholly owned subsidiary)
125 North Price Road, Chandler, AZ 85224
Tel: +1-800-646-8321
Internet: www.nikkomaterials.com

European Region

Japan Energy (UK) Ltd.
Level 8, City Tower
40 Basinghall Street, London EC2V 5DE,
Tel: +44 (0) 20-7588-9442
Fax: +44 (0) 20-7588-9443
email: jeuksemi@dircon.co.uk



Epistar reassures customers as Lumileds asserts AlGaInP patent

Lumileds Lighting has sent letters to several LED packaging companies in Taiwan to advise them about the patent situation surrounding high-brightness AlGaInP LEDs. The letters state that United Epitaxy Company (UEC) is the only vendor in Taiwan licensed to sell LED chips that employ the structure described in US patent number 5,008,718, which is owned by Lumileds. The patent describes absorbing- and transparent-substrate (AS and TS) AlGaInP LEDs with a window layer to improve light extraction and reduce current crowding.

The patent in question was the subject of a long-running battle between Lumileds and UEC. In mid-2001, the two companies agreed to dismiss all claims and counter-claims against each other. In a separate agreement, Lumileds granted UEC a license to sell AS LEDs covered by the 718 patent (*Compound Semiconductor* October 2001 p18). Lumileds is the only legitimate source for TS LEDs covered by this patent.

Epistar, the other major manufacturer of AlGaInP LED chips in Taiwan, has not entered into a licensing agreement with Lumileds because it does not believe that the Lumileds patent affects its products. Li Pin-Chieh, Epistar's general manager,

LED production at Epistar

	AlGaInP LEDs	GaInN LEDs	Total
2001 monthly productivity (million units)	75	2	77
proportion of revenue in 2001	76%	24%	
Q1 2002 monthly productivity (million units)	140-150	13-14	158
proportion of revenue in Q1 2002	66%	34%	
2003 estimated productivity (million units)	200	20	220
unit price	NTD 0.4-0.5 (~1 cent)	NTD 3-4 (~14 cents)	

The table shows how Epistar has made substantial increases to its production capacity in recent years, for both AlGaInP-based and GaInN-based LEDs.

says that Epistar owns a patent for its high-brightness product, which employs indium tin oxide to form a transparent contact layer. "Not only is the process different, but we received a patent for it in 1997, so Epistar's products do not infringe the Lumileds patent," said Li.

Even so, this issue is of concern to Epistar, which has already contacted its customers to advise them that Epistar's products are not involved in any patent infringement. Although the patent only applies to products sold in the US, where less than 1% of Epistar's LEDs are sold, the psychological influence on customers can be quite considerable. UEC lost clients in Japan when it

was in conflict with Lumileds, and spent around NTD 90 m (\$2.7 m) in litigation fees, so the LED industry in Taiwan is paying a great deal of attention to Lumileds' latest action. Epistar has already received enquiries about this matter from customers in Japan, and reports that some smaller packaging companies are considering purchasing chips from UEC to avoid both disturbance to their supply chain and also the need to pay royalties. However, large packaging factories such as Everlight Electronics and UNI will not transfer their orders provided that Epistar issues guarantee letters taking full responsibility if the patent rights of other companies are violated.

GB-LED helps boost UEC revenues by 30%

UEC's chairman, Huang Kuo-Hsin, believes that his company's revenue can increase by at least 30% per year in the next five years, and that UEC will become one of the world's top three LED chip manufacturers within three years. Speaking at a general meeting of shareholders, Huang added that as well as successfully introducing its GB-type LED product this year, UEC has increased its output of blue LEDs and has also penetrated the European car market.

Earlier this year, UEC introduced its GB range of high-brightness AlGaInP LEDs to compete with Lumileds' transparent substrate devices. UEC's new LEDs are made using glue bonding to stick the AlGaInP-on-GaAs LED wafer to a sapphire wafer, before removing the GaAs substrate (*Compound Semiconductor* March 2002 p10). Starting with a

production run of one million LEDs in March, UEC expects its output to reach 10 million chips in July and 50 million per month by the end of this year. Next year the monthly output will double.

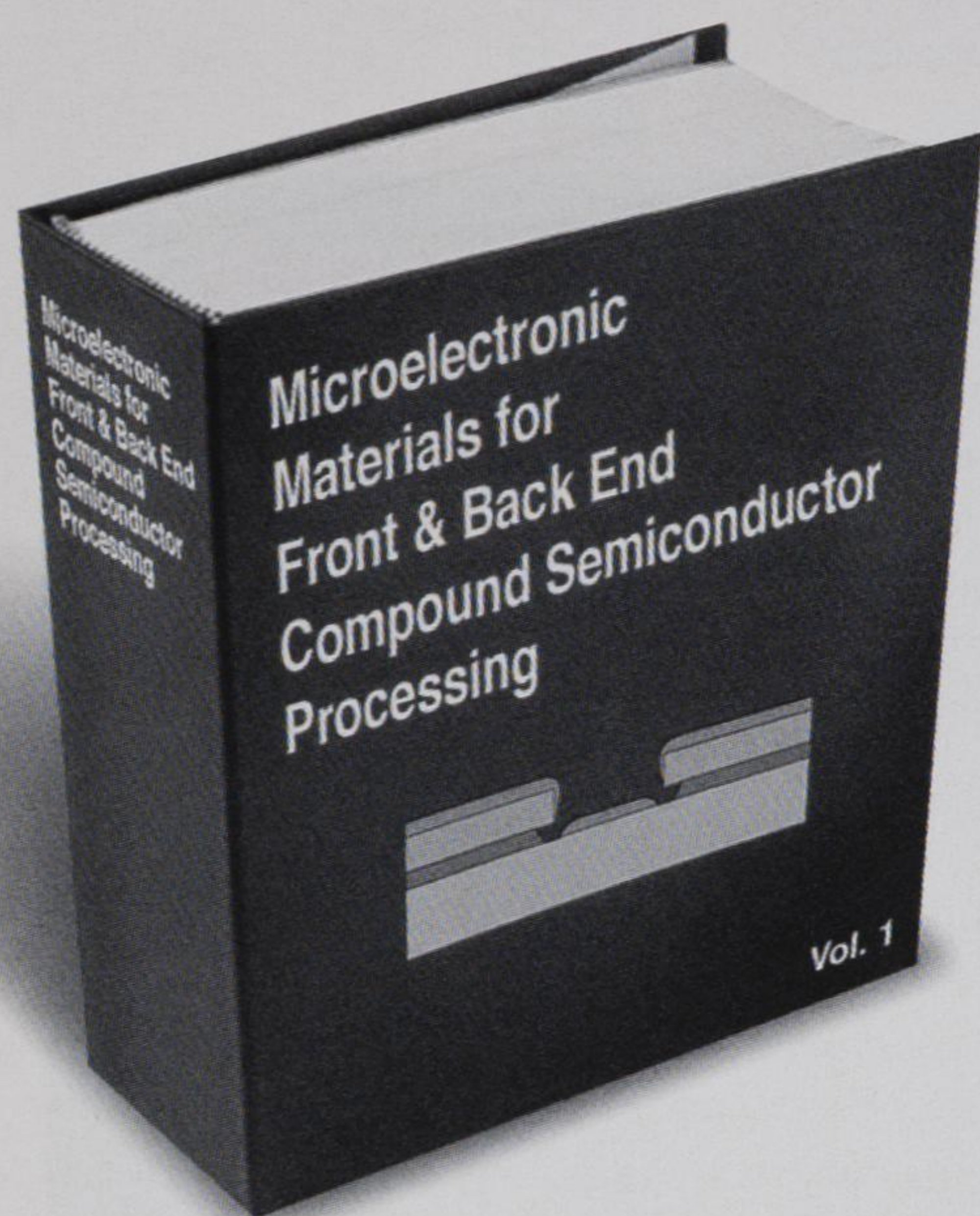
Due to a rise in the number of LEDs needed for mobile phones, backlight boards and traffic signal lights, UEC says that it is unable to meet the demand for many products, including blue LEDs, and so is boosting its blue LED output. "Because of increased orders from mobile-phone makers this year, the supply of blue LEDs is unable to meet the demand," said Huang Kuo-Hsin. "UEC has an output of around 20 million chips per month, but the level of orders is 30-40 million. This could lead to price rises sooner or later."

UEC's monthly output of 2000 2-inch blue LED epiwafers is to be doubled by the

end of this year. Blue LEDs have a gross profit rate as high as 40%, and the average selling price of each blue LED is around NTD 3.5 (11 cents).

According to UEC's general manager Chen Tse-Peng, UEC recorded a loss last year for the first time in its history, due to the economic downturn and an investment of NTD 2.7 bn (\$82 m) in factory buildings at the Tainan Science Park. "Also, the price of high-brightness LEDs fell by 40%, and new product introduction was delayed until the start of this year," said Chen. Production is now being ramped up at the Tainan facility, especially for high-margin products such as blue and GB-LEDs. "We are very optimistic about economic conditions in the latter half of this year, and hope that prosperity can continue until the beginning of next year," Chen added.

We're Writing the Book



PMGI & LOR Resists
for Lift-Off Processing

PMMA & Copolymer
Resists for Processing
Multi Layer T-gates

Protective Coatings for
Wafer Thinning

Want more information?

Visit us at
www.microchem.com

Or call us at
617.965.5511

MICRO • CHEM

USA • Europe • Asia

Intel seeks Taiwanese partners

Intel, which has been moving into the optical communications market over the last several years, has decided to strengthen co-operation with component and module suppliers in Taiwan. In May, Gordon Hunter, general manager of Intel's optical products group, traveled to Taiwan to visit several suppliers of laser diodes and transceiver modules. Although Intel is the leading manufacturer of silicon semiconductors, it does not have expertise in manufacturing III-V devices, and is actively seeking co-operation in this area.

Intel is looking to carry out joint development of DFB lasers and VCSELs, as well as identifying OEM suppliers for OC-48 transceivers and developing lasers for OC-192

applications. The company is likely to provide investment through its venture-capital wing.

Among the laser manufacturers visited by Hunter were Gigacomm, a spin-off from Epistar that makes 850 nm VCSELs and 1310 nm Fabry-Perot lasers; Truelight, a VCSEL specialist; Infomax Optical Technologies; and New Elite Technologies, which is funded by several companies including United Epitaxy Company. One of Intel's aims is to reduce the cost of active components, which can account for around 30% of the overall transceiver cost.

In April 2001, Intel acquired optical-transceiver maker LightLogic, and has invested in components companies such as Novalux, Nova Crystals, CyOptics and VSK Photonics.

Opticis stretches display applications

A new optical graphical extension cable from Opticis, a Korean manufacturer of VCSEL-based data transmission modules, extends the distances over which data can be transmitted for digital visual interface (DVI) display applications. The M1-100U graphic extension uses 850 nm GaAs-based VCSELs to transmit data. Operating at 165 MHz, Opticis says it is the first cable that can carry the high-resolution graphics standard – ultra XGA – at 60 Hz, across distances of up to 1640 ft.

The DVI interface in the latest 22–24 inch TFT-LCD panels requires higher core fre-

quencies to support the high resolutions and refresh rates of these displays. While copper analog and digital DVI cables can carry these frequencies, data transmission distances are limited to 20 ft before signal losses begin to degrade the resolution and refresh rates.

“Traditionally the length and signal quality limitation of legacy copper cables have hindered digital display development,” said Byeong-Ho Park, VP of marketing. “But with VCSELs we can optically preserve the front-of-screen integrity of ultra XGA signals for display technology deployed over long distances.”

Opticis is currently sampling its cable, which it says is suited to a range of applications including medical imaging, animated 3D outdoor signs and flat-panel message boards.

Union Technology opens new plant

Union Technology, a Taiwanese foundry company, opened its new plant at the beginning of June. According to Chen Yu-Feng, chairman of Union, the company is concentrating on the manufacture of SAW filters, blue LEDs and laser diodes. Union has successfully developed SAW filters, with several products receiving customer accreditation, and the company has a capacity of 6000 4-inch wafers per month. Laser-diode products have already been developed and will be supplied to DVD optical head manufacturers. Union is also developing blue LEDs, focusing on cost considerations and on avoiding patents owned by Japanese businesses. The company is now applying for patents for these new products.

SIC transfers opto division to OpNext

Hitachi and OpNext are discussing the transfer of the opto-device division of Hitachi's semiconductor and integrated circuits group (SIC) to OpNext, formed in September 2000 from Hitachi's fiber-optic components group. The transfer is slated for October 1, 2002 and will cover the opto-device division of SIC, as well as the opto-electrical device development and manufacturing team, and fabrication facilities from Hitachi Tohbu Semiconductors.

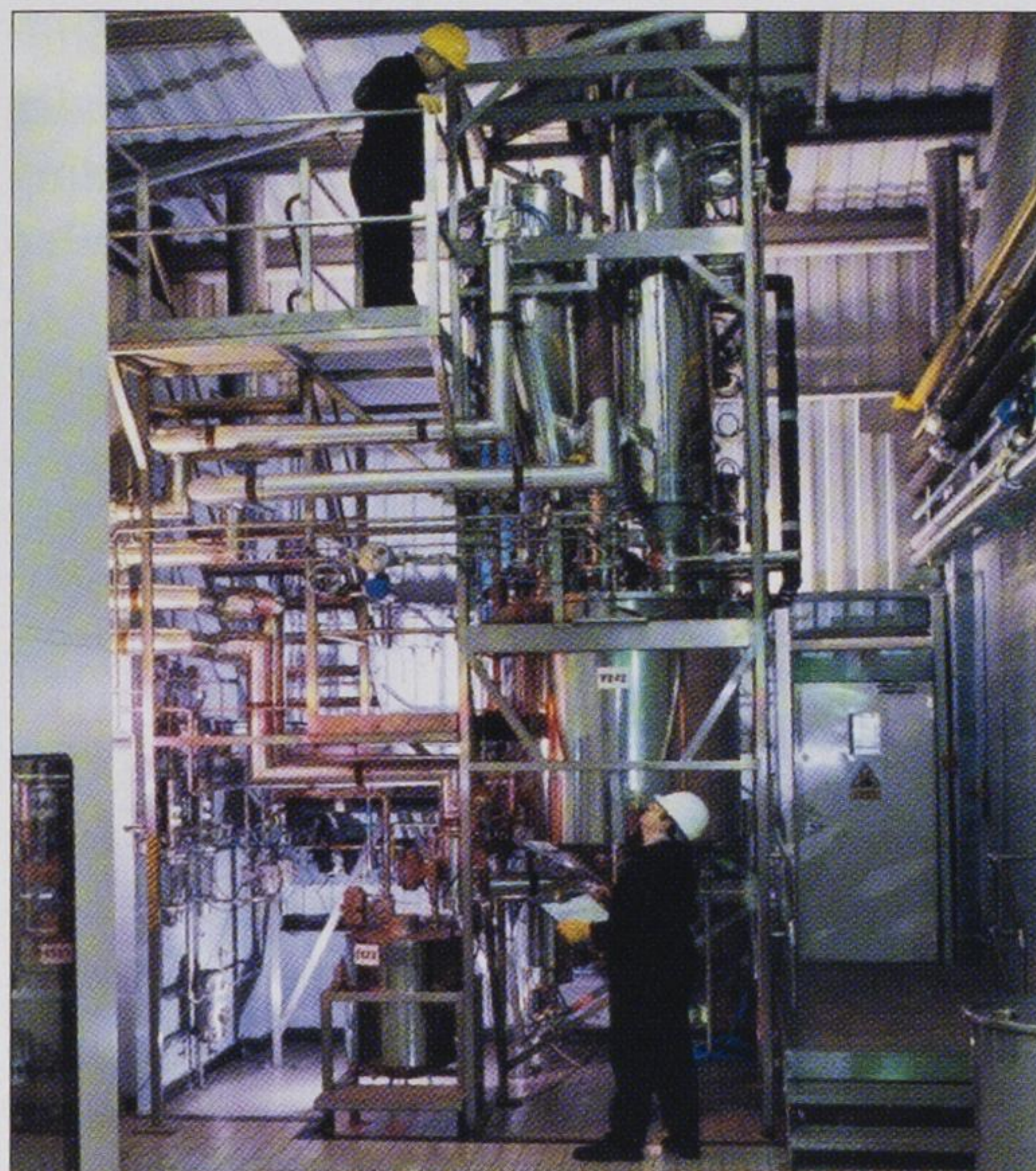
SIC has developed unique technologies in lasers, receivers and packaging, and maintains low-cost mass-production capabilities. As a result of this transfer, OpNext will enhance its product portfolio of transceivers, transmitters, receivers and laser-diode modules.

Epichem installs plant to meet rising TMG demand

Epichem has commissioned a multi-ton-capacity trimethyl gallium (TMG) production plant that aims to provide enough TMG to meet the growing needs of LED and solar-cell manufacturers. Built at the company's headquarters in Bromborough, UK, the plant is the largest of its kind in the world, claims Epichem.

The plant features a multi-kilogram batch size, which Epichem says will reduce product variability and provide batch-to-batch consistency. "The plant has the capability to produce leading-edge TMG at a reduced cost," said a company spokesperson. "It is also able to meet worldwide demand well into the future."

Epichem manufactures a range of metal-organics that are used in vapor-phase epitaxy to deposit thin films. The company has just finished building a new \$5 m production facility at Haverhill, US, that will take on the increased demand for metalorganic compounds from the US and Asia.



Epichem says that its new production plant in Bromborough, UK, will be able to meet the growing worldwide demand for TMG.

Palomar to offer development and prototyping services

Automated production equipment supplier Palomar Technologies is offering support for process development and prototyping. The new service is intended to meet the needs of companies developing or validating new products, but which require design, engineering, prototyping, assembly and automation expertise, and/or metrology resources

to bridge the gap between a product concept and automated production.

To facilitate the new service, Palomar has recently expanded its applications engineering division and test facilities, and has also increased its staff numbers. The company will offer different levels of service. This could include the designing of a complete process for an optoelectronic package up to prototype level, including dispense, interconnects, fiber align and attach, and test, or it could involve a truncated service based on providing a customer-designed package for automation.

IntelliEPI moves to expanded facility

Intelligent Epitaxy Technology (IntelliEPI) has moved to newly constructed headquarters in Richardson, TX. The 23,000 sq. ft facility contains 12,000 sq. ft of space that is dedicated to the production of GaAs- and InP-based epiwafers. This more than doubles the size of IntelliEPI's original facility and triples its office space.

"The completion and operation of the new headquarters represents an important milestone in our continued growth," said Yung-Chung Kao, president and CEO. "Since the company was founded in 1999, IntelliEPI has enjoyed a steady annual growth in its business. And as a result of this growth, we simply ran out of space in our old facility."

With the operation of the new headquarters, IntelliEPI will now have enough space for more MBE systems, and for more large-area testing and post-growth testing equipment. "In addition, we are now able to dedicate small systems for R&D, and we can also provide more staff for customer services. We believe that this new facility will allow us to grow for many years to come," concluded Kao.

CVD Equipment buys Conceptronic assets

CVD Equipment Corporation of Ronkonkoma, NY, has acquired the assets of Conceptronic, relating to its surface-mount technology business. Conceptronic specializes in solder reflow ovens and rework stations for PCBs and the chip-scale package industry. The new addition expands CVD Equipment's existing range of CVD reactors, which includes Si and SiGe UHV systems, MOCVD, LPE and VPE, as well as RTP-based products and services. This is the second takeover by CVD Equipment, which last year acquired Research International, a maker of SMT equipment for solder reflow ovens used for PCBs and packaging.

"This acquisition substantially strengthens our position in the electronics assembly and semiconductor packaging sector," said Len Rosenbaum, CVD Equipment's president and CEO. "With our expanding marketing, sales, engineering, manufacturing and service capabilities, CVD Equipment is uniquely positioned to provide high-quality support and field service to the surface-mount customer base."

News in brief...

● **JMAR Technologies** has received an additional \$5.3 m to complete its collimated X-ray point-source lithography system, which will target sub-130 nm GaAs circuit processing. The DARPA contract was supplied by the US Army Robert Morris Acquisition Center in Adelphi, MD, which also

provided the company with \$7.8 m last July. This contract also adds to last month's \$10 m DARPA award for XRL mask development. The new tool is expected to be ready this summer.

● **Philips Analytical** has decided to discontinue its semiconductor ellipsometry

equipment-manufacturing activities, which are based in Almelo, the Netherlands, from July 2002. The company has decided that it can no longer justify the investments which are needed to continue with the product line, but it will meet existing service and support commitments to customers.

Johnson Matthey invests in plant

Johnson Matthey Gas Purification Technology (GPT) group is to move into a new facility located in West Chester, PA, that has been built to house the mass production of its gas-purification products.

The company says that the move follows the significant growth of its "PureGuard" family of products. The GPT division manufactures gas purifiers based on a number of

different technologies, including Pd membrane, getter, nickel, catalytic and adsorbents, to provide ultra-high-purity gases.

The new building is double the size of the GPT division's existing site and includes three clean room areas. As well as building the new facility, Johnson Matthey is also increasing its research and development of gas-purification technologies.

Emcore wins R&D and Infineon awards

Emcore has won one of Infineon Fiber Optics' "Top Supplier in 2001" awards for supplying its TurboDisc tools for the manufacture of electronic and optoelectronic devices. Selecting from over 250 companies, Infineon judges its supplier's performance in terms of quality, technology, cost, logistics and management commitment.

Emcore has also won a joint "R&D 100

Award" with Sandia National Laboratories for the development of advanced fiber-optic modules. Awarded by *R&D* magazine, the prize recognizes the partnership's work on the MTR8500 very-short-reach OC-192 parallel array transponder.

The MTR8500 provides very-short-reach interconnections over parallel fiber links at SONET OC-192 data rates. Based on a 1×12 array of 850 nm VCSELs, the transponder is designed to solve data bottlenecks at distances of less than 300 meters within central office or point-of-presence environments.

Five manufacturers make VLSI's top 10

VLSI Research has published the results of its annual customer satisfaction survey for semiconductor processing equipment suppliers. Five prominent manufacturers of compound semiconductor processing equipment featured in the company's 10 BEST Awards for 2002.

Suss MicroTec appeared in four categories and was top in Test and Material Handling Equipment, and second in Small Suppliers of Wafer Processing Equipment, beaten to the top spot by Tegal who featured in this category for the fifth consecutive year. Aixtron and Oxford Instruments Plasma Technology were also placed in the top 10 in the Small Suppliers of Wafer Processing Equipment category, making it the fourth year running for Aixtron. Philips Analytical appeared in the top 10 Process Diagnostics Equipment category.

VLSI's 10 BEST Awards are presented in seven categories and compiled from a global poll of 55,000 engineers and managers working in semiconductor manufacturing facilities.



The Right Choice
The Intelligent Choice

Intelligent Epitaxy Technology, Inc.

- ◆ Pure-Play Epi Foundry
- ◆ Industry's First "Productions Ready" 4 x 4 inch InP Epi Capabilities
- ◆ Real-time in situ growth sensor technology

We supply the following best-valued epi wafers

- GaAs-based
 - PHEMT
 - HBT (C-doped, Be-doped)
 - MHEMT
- InP-based
 - HBT (4 x 4", DHBT, SHBT)
 - HEMT
 - RTT, RTD
- Opto-electronics
 - 980 Pump lasers
 - VCSEL
 - PIN
 - QWIP
 - Lasers

201 E. Arapaho Road, Suite 200, Richardson, TX 75081
Tel: 972-234-0068 • Fax: 972-234-0069 • E-mail: info@intelliepi.com • www.intelliepi.com

KINGMAX

OPTOELECTRONICS INC.

HBT Technology

- Pure-Play Epi Foundry state-of-the-art
- 6 and 4 inch InGaP/GaAs HBT Epi Wafers
- Excellent Uniformity Reproducibility and Reliability

We are also VCSEL, RCLED, and LD Epi Wafers excellent player.

Visit us at:

OPTO SHOW

TAIWAN 2002

AUG. 15-18, 2002

Kingmax's Booth No: A908

KINGMAX
Where Epi Grows Best

Kingmax Optoelectronics Inc.

No. 1 Kuang Fu North Rd. Hsin-Chu Industrial Park,
Hu Kou, Hsin-Chu 303, Taiwan, R.O.C.
Tel: +886-3-5970888 / Fax: +886-3-5970999
http://www.kingmax-opto.com.tw

Vendors team on RF test software

Cascade Microtech and Microvue are partnering on RF test software that improves productivity during the on-wafer characterization and modeling of RF devices. These measurements include S parameter, DC bias and I-V curves.

Cascade Microtech will exclusively distribute Microvue's Wavevue Measurement Studio, a software package developed to characterize RF and microwave high-speed components. The program also complements Cascade's probe software and can be used with manual probe stations or the company's semi-automatic probe stations. Versions will be available for either lab-based testing or as an office program designed to analyze test

data and modify test setups at the desktop.

"The combined strength of our products enables Cascade to provide a comprehensive measurement solution for design engineers," said Charlie Woodin, Microvue's president and CEO. "Wavevue's Enterprise Vision architecture, modular design and measurement project concept means reduced training costs, increased equipment use, and faster and more accurate measurements."

Equipment sales

● **Emcore** has sold two Enterprise 300 MOCVD production reactors to Taiwanese LED manufacturers. **United Epitaxy Company** (UEC) purchased an E300 GaNzilla production tool to grow high-brightness green and blue LEDs at its facility in Hsinchu, Taiwan. The purchase adds to 10 Emcore reactors currently employed by UEC. **South Epitaxy Corporation** also purchased an E300 GaN system for use in its high-brightness blue and green LED production program. The company already has several Emcore reactors.

● **Aixtron** has installed an AIX 2400/2600G3 production reactor at **Nippon Sheet Glass**, a manufacturer of glass products, displays, micro-optics and communications components located in Tsukuba, Japan. The system will be used for high-volume production of the switches, LEDs and InP-based detectors used in the fiber-optics and wireless technology markets.

● **Accent Optical Technologies** has sold a DIVA Dynamic I-V analyzer to the Microwave Laboratory of the Microelectronics Center at **Chalmers University** in Sweden.

● **Formosa Epitaxy** of Taiwan has bought two AIX 2400/2600G3 HT systems from Aixtron. The new systems have a capacity of either 11 × 2 inch or 24 × 2 inch wafers, and are intended to boost the manufacturing capacity of Formosa's InGaN-based epitaxial wafers and high-brightness LED chips.

● **Tegal** has sold a 901 g plasma etch system to a manufacturer of optical network components based in Northern California. The system will be installed by the end of June, and represents Tegal's first sale to this customer.



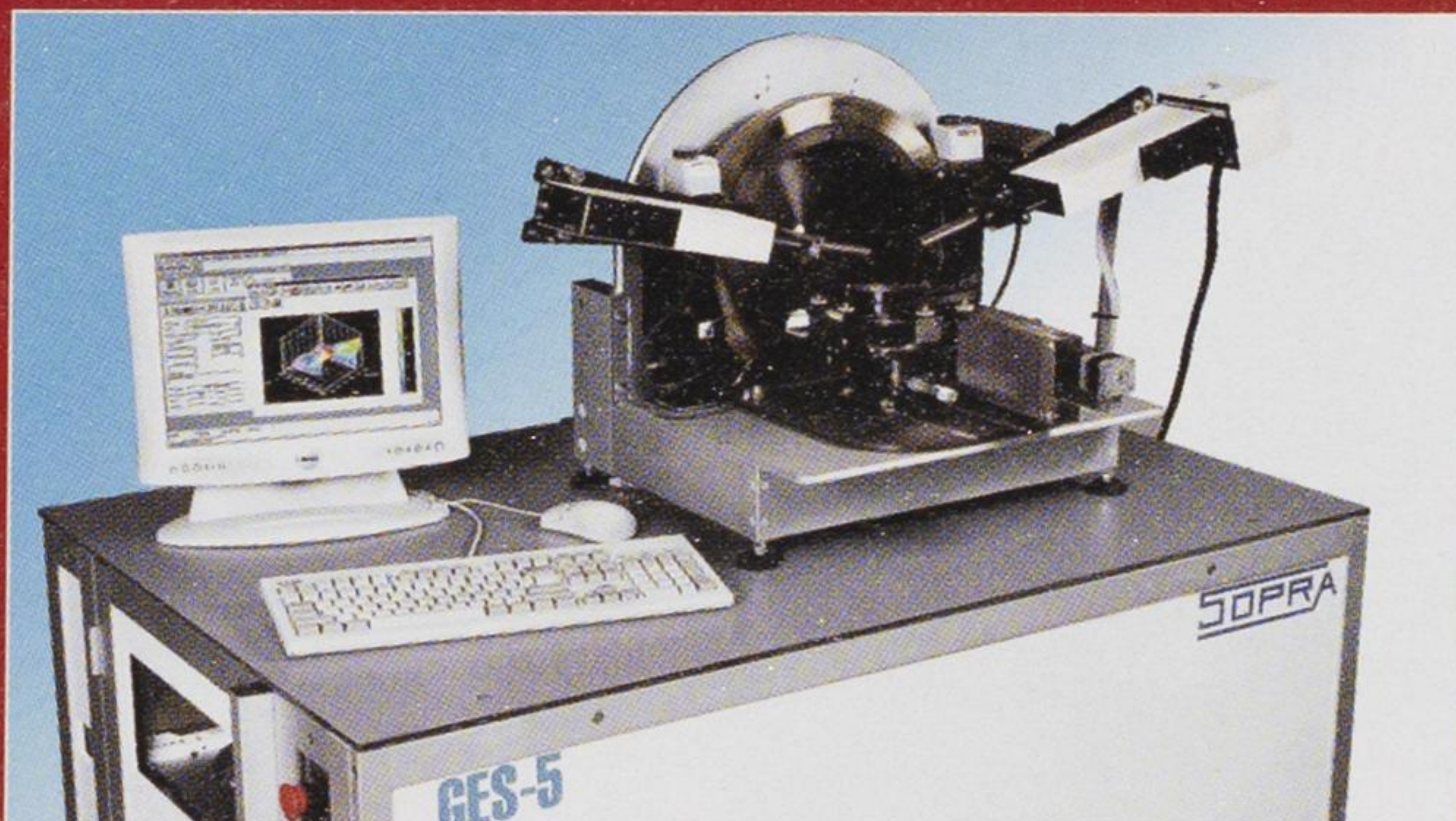
We guide you

1550nm
1310nm

through the PHOTONICS world

A different way of controlling waveguides, MEMS, optical coatings and other devices

- > Spectroscopic Ellipsometry
- > Variable Angle Ellipsometry



- > **N&K, T** extraction in single and multi-layers
T : from 1 nm to 20 μm
N : 2.10⁻⁵ resolution
- > **Prediction** of optical behaviour

> sales@sopra-sa.com
> www.sopra-sa.com

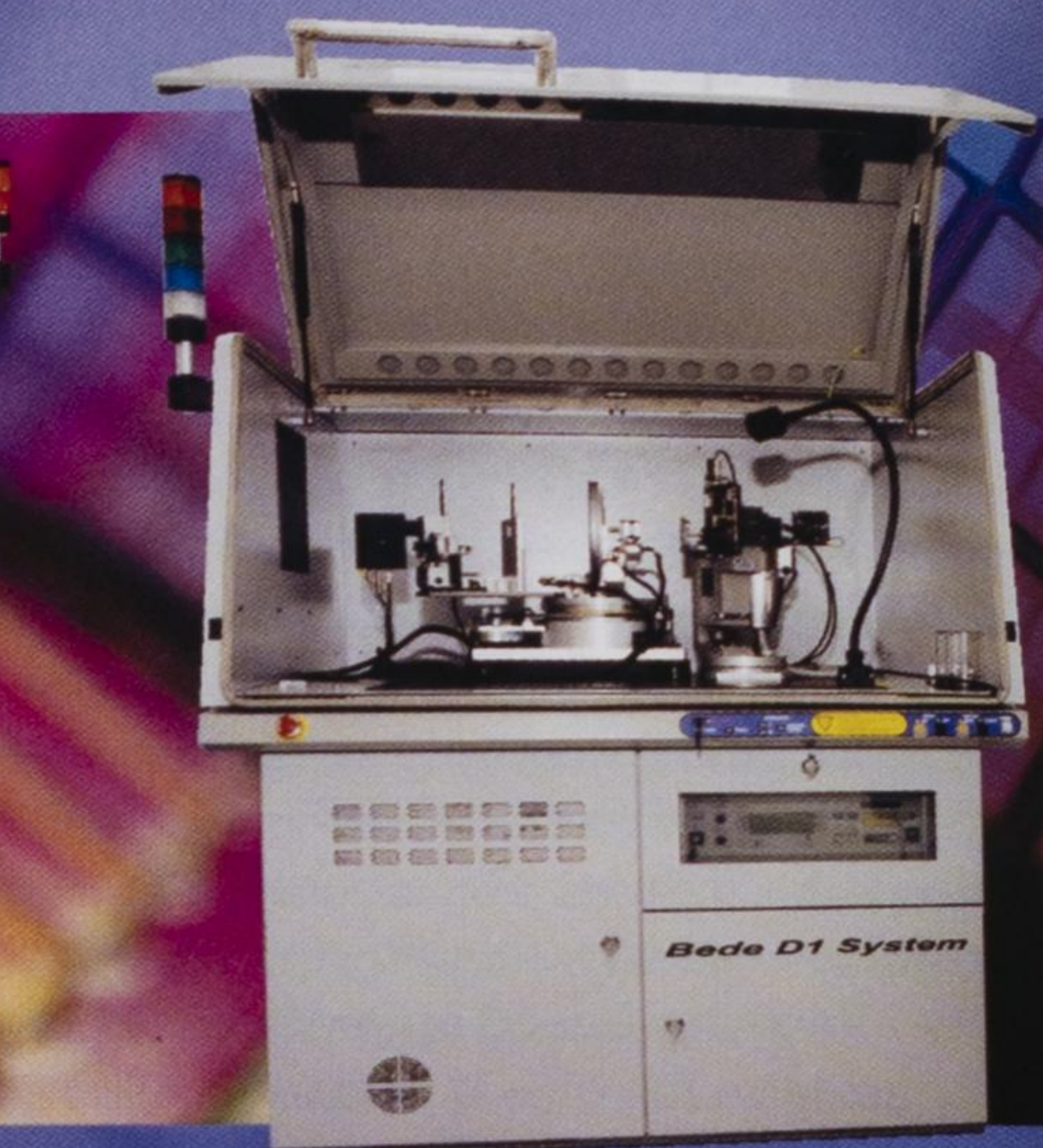
from the lab to the fab™



Bede QC200™



Bede FAB300™



Bede D1

A range of X-ray solutions for R&D and quality control environments

Bede X-ray tools non-destructively determine key parameters of most important advanced materials automatically, quickly and safely:

- Silicon and compound semiconductors
- Si, SiGe and SOI device structures
- GaAs, InP and GaN epitaxial device structures
- Thin films including:
 - High-k dielectrics
 - Low-k dielectrics
 - Diffusion barriers
 - Damascene copper
 - SiO₂ and oxynitride
- Metallic & magnetic multilayers
- Ceramics
- Polymers

Solutions for each stage of Si semiconductor production:

- Process development in the R&D lab
- Pilot lines
- Full-scale production in a fab
- Suitable for high capacity compound semiconductor foundries

Solutions for the general purpose high resolution X-ray research lab:

- Ultimate performance and versatility for semiconductor, pharmaceutical and other applications
- Widest possible range of techniques
- Used worldwide in industrial, university and government research laboratories

solutions
partnership
expertise

bede 

a bede plc company

UK

T +44 (0)191 332 4700
F +44 (0)191 332 4800
E info@bede.co.uk

USA

T +1 (303)790 8647
F +1 (303)790 8648
E sales@bede.com

Asia

T +86 (0)21 64594811
F +86 (0)21 54867218
E info@bede-asia.com

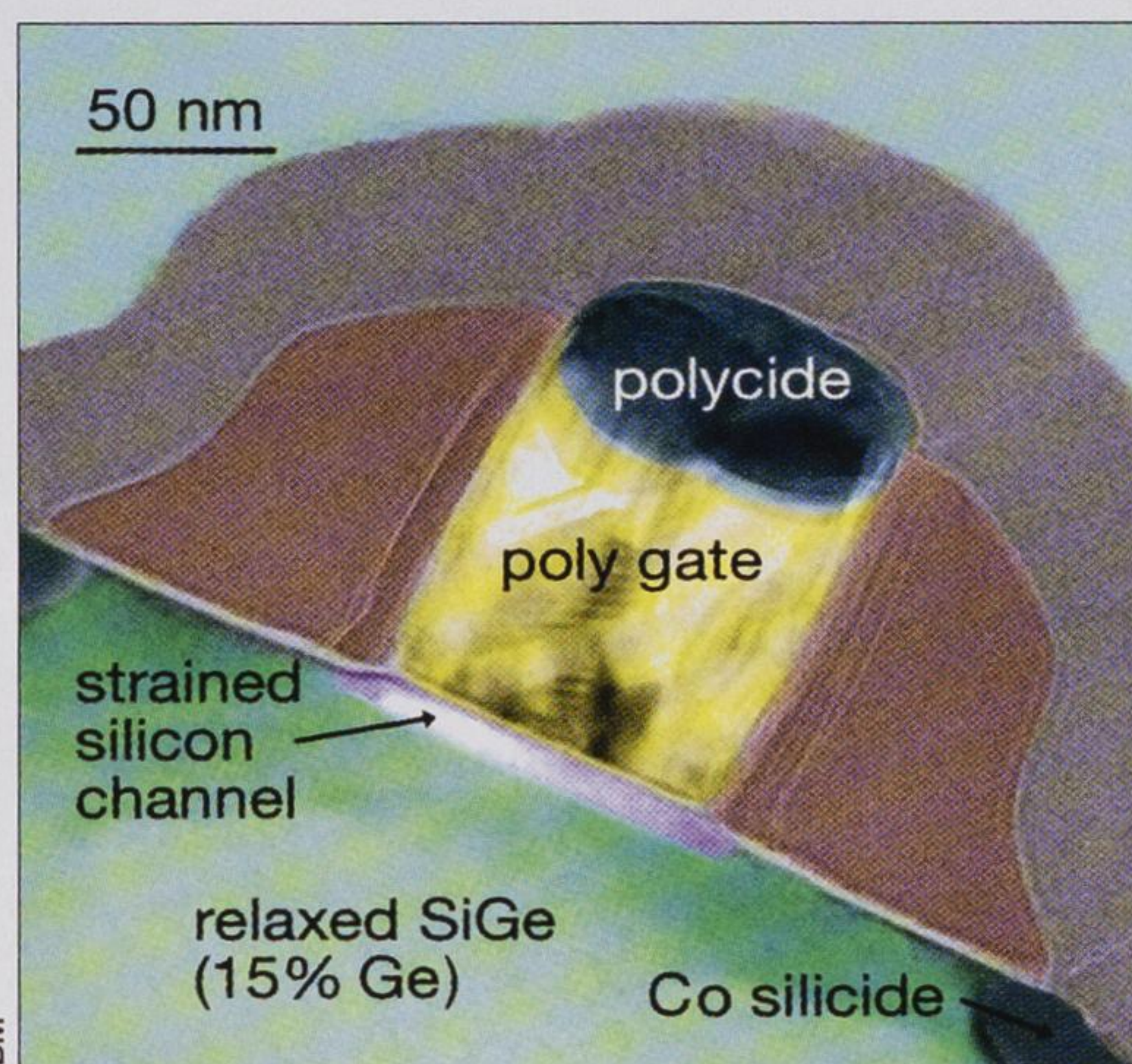
www.bede.com

IBM expects strained silicon by 2005

IBM is likely to introduce strained silicon into its mainstream CMOS process in the next five years. According to an article in *EE Times*, Bijan Davari, VP of technology development at IBM Microelectronics, said that IBM plans to introduce strained silicon at the 65 nm technology node, which is expected to see its first introduction in 2005.

Strained silicon structures consist of a thin silicon layer deposited on top of a thicker, graded buffer layer of SiGe (see figure). The lattice mismatch between the layers creates strain in the silicon layer, which forms the channel of subsequently fabricated CMOS devices. As a result of the strain, the silicon channel has a much higher mobility than bulk silicon.

Davari added that IBM plans to create the



A TEM cross-section of a transistor that contains a strained silicon channel grown on a relaxed Si_{0.85}Ge_{0.15} buffer.

strained silicon structure on top of a silicon-on-insulator (SOI) substrate, in order to reduce losses for RF applications (*Compound Semiconductor* August 2001 p37).

When IBM first announced its strained silicon work last year, most observers believed that it would not reach the manufacturing stage for many years. However, Davari says that moves to introduce high-k dielectric materials (see Motorola story, below) are pushing strained silicon into the mainstream. Although high-k dielectric materials reduce gate leakage, they also reduce the mobility in the channel of CMOS ICs. IBM therefore feels that the benefit of moving from SiO₂ to a high-k dielectric will not be realized unless SOI and strained silicon are also introduced at the same time.

Motorola team develops promising insulator material

A research team has identified lanthanum aluminate (LAO) and lanthanum aluminum oxynitride (LAON) as being potential replacements for silicon dioxide as a gate dielectric for future 65 nm CMOS technology. Motorola's Semiconductor Products Sector, along with Nanjing University and the Institute of Physics at the Chinese Academy of Sciences, have jointly characterized the material properties of LAO and LAON thin films, which have a dielectric constant that exceeds 20.

"Traditional materials will last one or two more generations, whereupon the industry will need a new material to continue down the path of faster, smaller, better electronics," said Karen Guo, director of the Motorola China R&D Institute. "We are very excited about the potential of this material. While more research is required, lanthanum aluminate is the most promising material we have seen," Guo added.

Gate dielectric film thickness scaling is one of the most urgent material problems that is currently facing the silicon industry. Traditional device materials reach fundamental physical limits when the scaling continues down to deep submicron levels (below 0.10 μm). As device dimensions continue to scale down, the thickness of the silicon dioxide layer must also decrease in order

to maintain the same capacitance between the gate region and the channel region. The 65 nm generation requires a thickness of less than 2 nm. At this point, electron tunneling effects will become a problem if SiO₂ is used.

There are many materials currently under consideration as potential replacements for silicon dioxide as the gate dielectric material for 65 nm CMOS technology, even though this is at least two generations away from today's production technology. However, most of these materials, which have a dielectric constant that is greater than 20, either are not thermodynamically stable when in direct contact with silicon, or they can generate diffusion problems that cause a significant degradation of device performance.

According to Motorola, LAO and LAON demonstrate the best thermal stability among all known possible high dielectric constant (greater than 20) materials, and they can also be economically integrated into a traditional CMOS process flow.

- Soitec, a manufacturer of silicon-on-insulator wafers based in Bernin, France, has received a Supplier Recognition Award from the Semiconductor Products Sector at Motorola. Soitec supplies its Unibond silicon-on-insulator material to Motorola, which uses it in the manufacture of its 1 GHz embedded microprocessor ICs.

Atmel unveils SiGe BiCMOS process

Atmel is offering a new SiGe BiCMOS process designed for transistor speeds up to 70 GHz. The new process is designated AT46700 and takes over from the company's existing process, which peaks at 45 GHz (*Compound Semiconductor* August 2001 p10).

Using the upgraded technology, devices can be designed to work with either 3.3 or 5.0 V power supplies, and also as passive components such as resistors, capacitors or inductors. Atmel, which has facilities in Colorado Springs, CA, and Heilbronn, Germany, says it is targeting fabless semiconductor companies and manufacturers of telecom, wireless LAN, cellular and satellite communications components.

The company will supply a full design reference manual by the fourth quarter. The kit supports mixed-signal simulation for digital, analog and RF circuits. For prototyping, Atmel says manufacturers can choose between a full engineering run and a lower cost multi-project-wafer approach.

"In addition to mixed-signal and wireless ICs, we can now offer our customers an enabling SiGe BiCMOS process to develop system-on-a-chip solutions," said Chris Baumann, director of BiCMOS products. "We currently have several customers evaluating silicon prototypes for next-generation telecommunication and high-speed data applications using our design kit."

Memscap and Jazz forge IC alliance

French MEMS manufacturer Memscap has teamed with Jazz Semiconductor, the foundry spin-off from Conexant Systems, in order to manufacture and market MEMS-based ICs for RF applications.

Jazz will manufacture SiGe wafers, while Memscap will add on-chip passive components such as high-Q inductors and capacitors.

Jazz intends to market the ICs, and Memscap will focus on design and production.

"We have seen high interest in SiGe/MEMS integrated circuits for RF applications," said Memscap's CEO Jean-Michel Karam. "Partnering with Jazz Semiconductor means we [can make] a technology that addresses today's space and price constraints."

French partnership to promote MEMS

Two French organizations, Tronics Microsystems, a MEMS manufacturer, and CEA Leti, the French Atomic Energy Commission's Laboratory of Electronic and Information Technologies, have signed a three-year contract to drive MEMS development forward.

The partnership will dedicate R&D capabilities to advance the manufacture of SOI-based MEMS. This deal follows the transfer of SOI-based MEMS manufacturing technologies from CEA Leti to Tronics Microsystems in May 1997.

Max Planck Institute to invest in SOI

The Max Planck Institute (MPI) of Microstructure Physics in Germany has just bought a CL200 Fusion Bonder from Suss Microtec. MPI will use the fusion bonder to test SOI and fusion-bond applications. Silicon fusion bonding is a fast, front-end-compatible process that permanently bonds wafers. It is used to bond SOI for the manufacture of MEMS-related devices. The CL200 cleans, aligns and bonds substrates in a single, high-temperature, pressurized chamber, and according to Suss Microtec, processes two substrates at the same time.

Communicant's CEO quits suddenly

Klaus Wiemer has resigned suddenly from his post as CEO of German SiGe foundry start-up Communicant Semiconductor Technologies. Although no reason was given for the abrupt departure, Communicant said Wiemer would stay on as an advisor while the company looks for a replacement. Wiemer was involved with Communicant since its inception early last year, seeing it through to its recent \$325 m funding round from investors such as Intel (*Compound Semiconductor* June 2002 p31). The investment will finance part of a new \$1.3 bn foundry IC facility in Frankfurt (Oder).

New products from NEC and Cypress

● **NEC** has developed an IEEE802.11a-compliant 5 GHz wireless LAN chipset, comprising base-band, RF and synthesizer chips, supporting data rates up to 54 Mbit/s. The RF portion is designed using a SiGe bipolar process.

NEC says the transistors have a breakdown voltage of 5 V and offer "considerable cost advantages" over high-frequency GaAs transistors. "To increase the breakdown voltage we used a technology based on our

original SiGe self-alignment process," said a company spokesperson. "Through selective epitaxial base growth we have reduced parasitic resistance and capacitance, and can raise the breakdown voltage while allowing a much wider operating frequency range."

Volume production is scheduled for September and NEC is targeting a production capacity of 10 million units per month by March 2003.

● **Cypress Semiconductor** is sampling a 2.5 Gbit/s SERDES circuit, the first device fabricated on the company's new 0.21 μm SiGe BiCMOS process. Cut-off frequencies over 110 GHz are supported by the process, making it suitable for 40 Gbit/s IC designs. Drawing 0.6 W and housed in an 11 $\times$ 11 mm² package, the company says the device consumes less than half the power and occupies less than half the board space of competing 16-bit solutions.

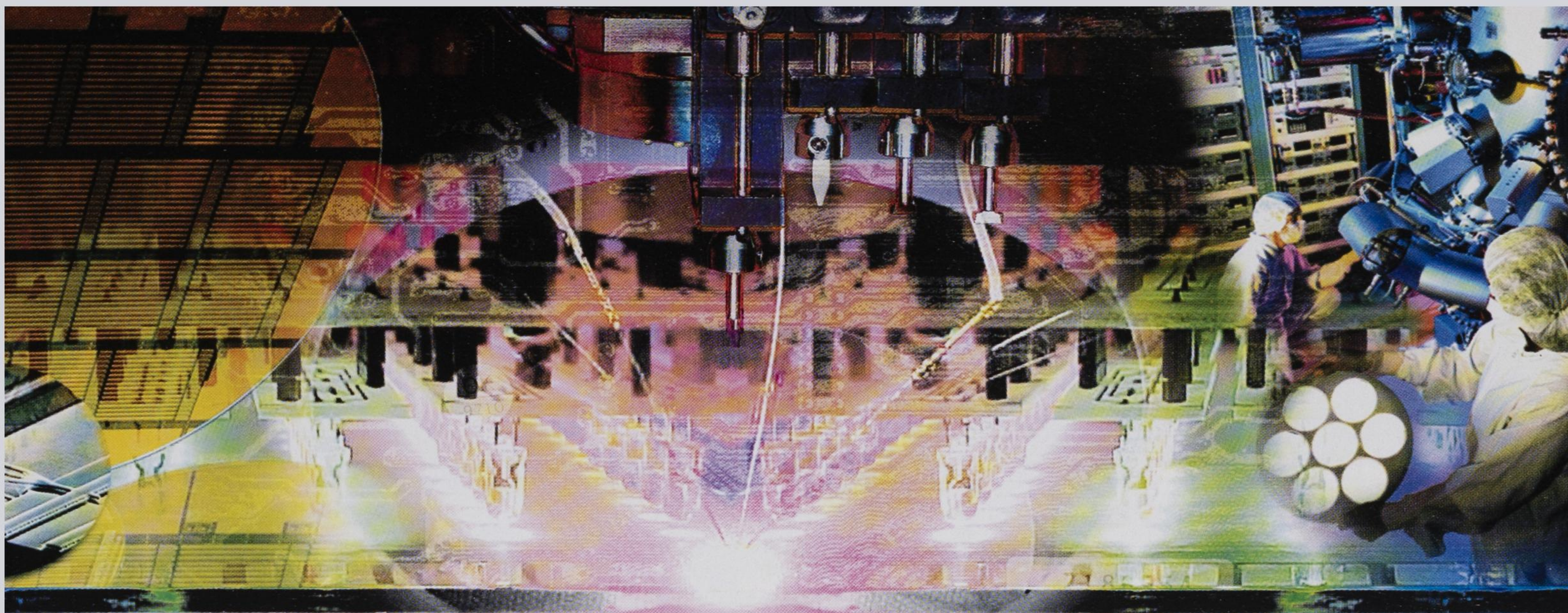
Manufacturer
of Molybdenum
Components for MBE.

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



San Jose, California – McEnry Convention Center

Compound Semiconductor Manufacturing Expo

November 11–13, 2002

Dedicated to the high-volume manufacturing of compound semiconductor devices, CS-MAX combines a technical conference with the industry's largest trade show.

Visit **cs-max.com** for more information.

GaAs and InP ICs, LEDs, laser diodes, fiber-optic components, GaN and SiC devices, detectors, and solar cells.

Special session on new silicon heterostructures, such as SiGe, SOI, strained silicon and crystalline oxides.

Showcase your products at the industry's largest trade show.

For exhibition information, contact:

Bob Finnegan

Tel. +1 516 576 2440 Fax +1 516 576 2481

Email: rfinneg@aip.org

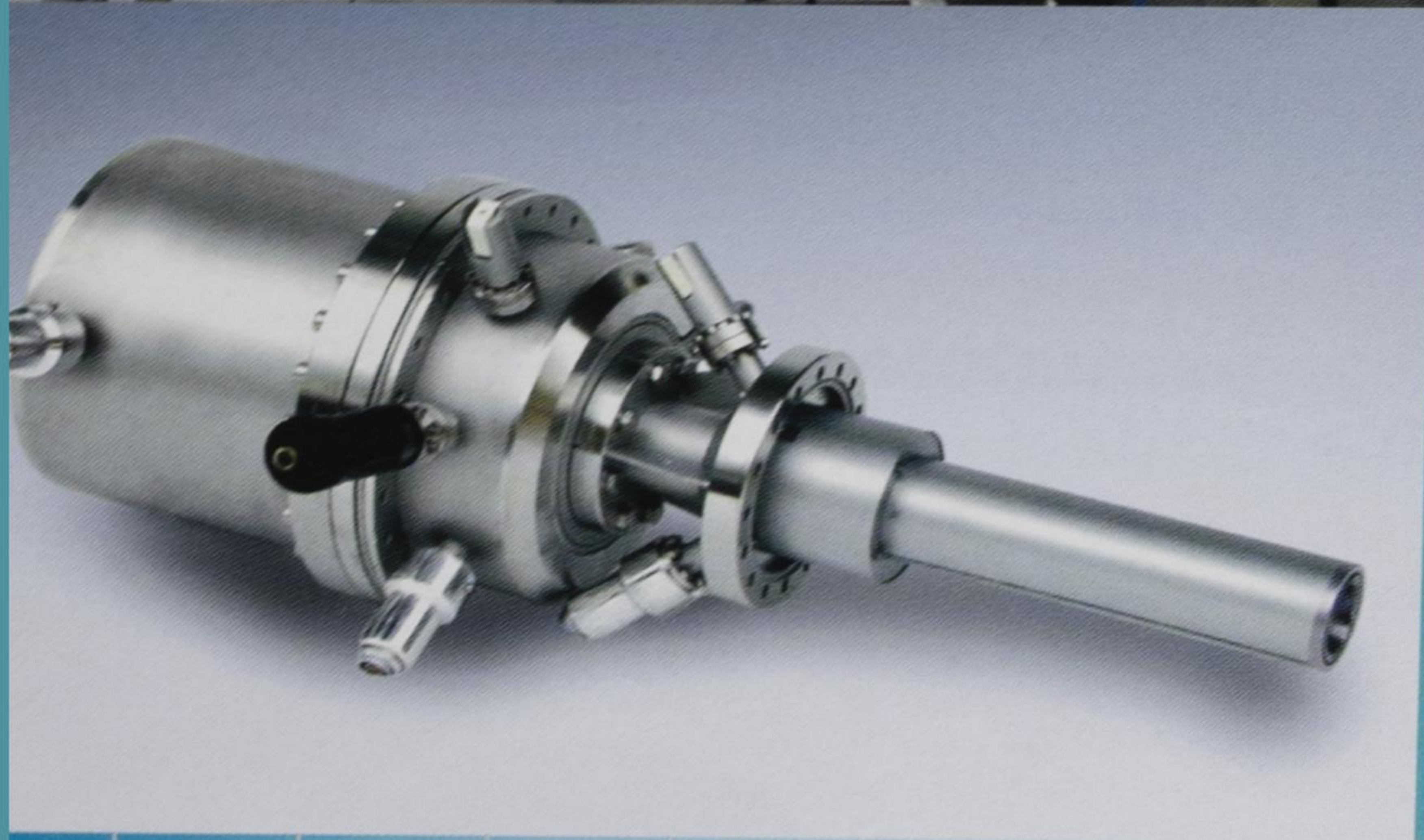
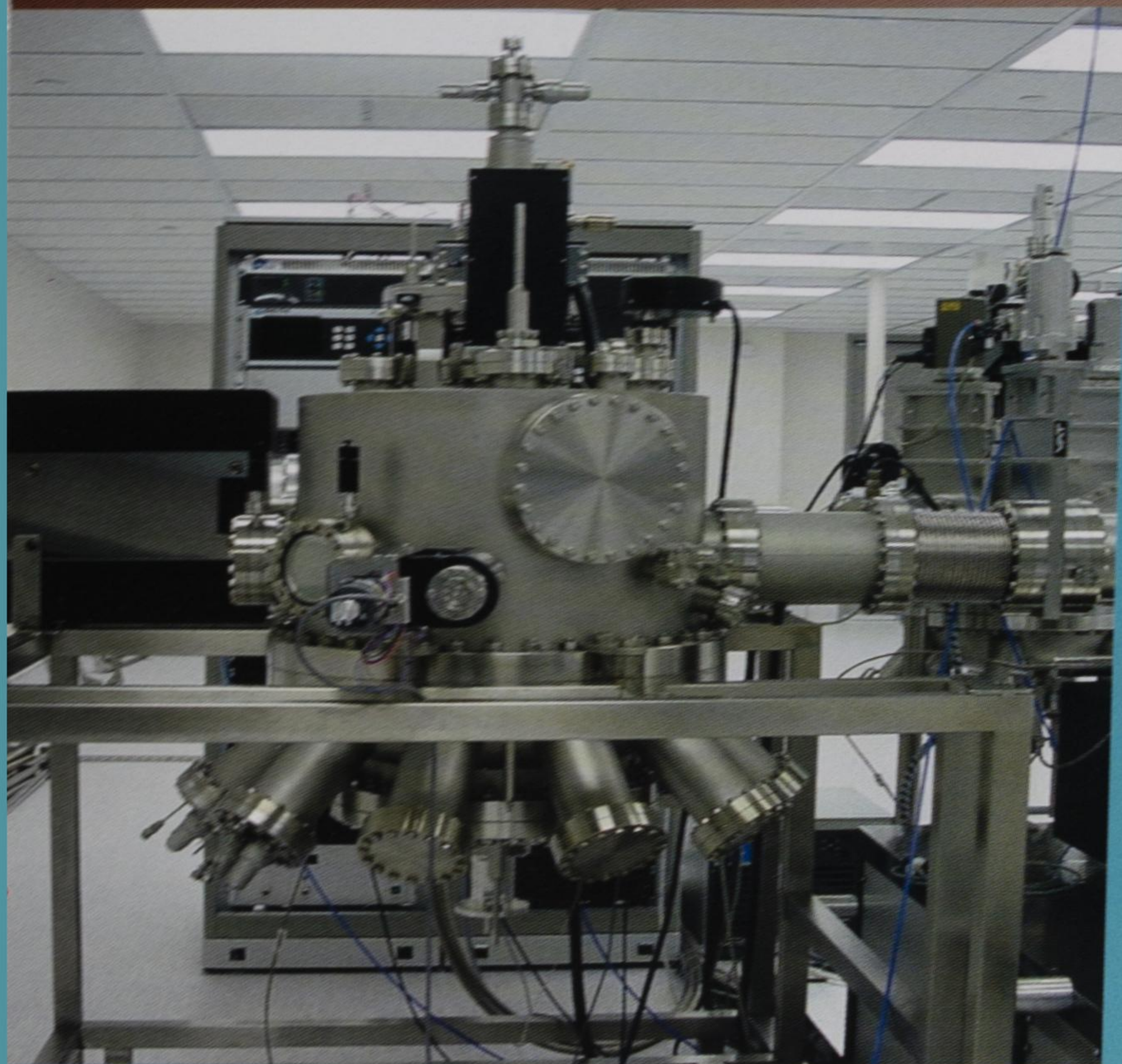
Organized by

**COMPOUND
SEMICONDUCTOR**

cs-max.com



Proven Technology for Production MBE



DCA production MBE systems now cover wafer capacities of 3x2", 4x4" and 7x6". The P600 and P900 systems, with 3x2" and 4x4" capacities, are designed for the precise production of high-quality complex compound semiconductors.

The P7X6 system provides the highest throughput with the possibility to process seven 6" wafers simultaneously.

These production MBE systems complement DCA's wide range of R&D systems for III-V, GaN and Si/Ge epitaxy.

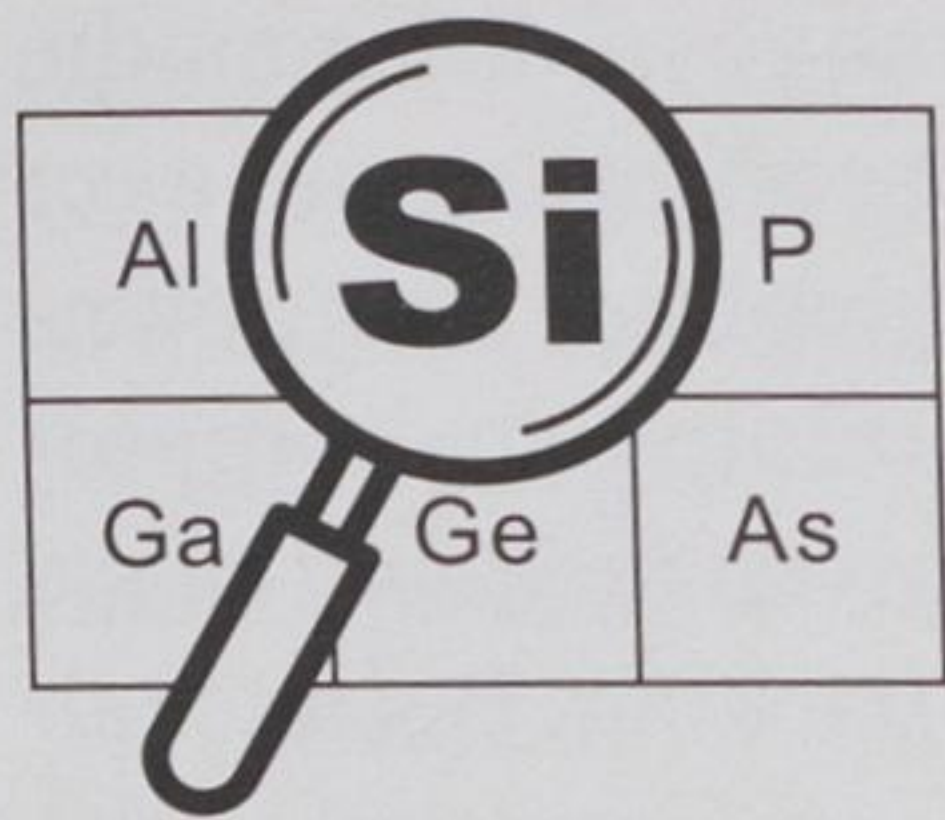
DCA High Capacity Effusion Cells and Crackers are known for their rugged design and long lifetime. The cells and crackers are now available as a retrofit for most production MBE systems on the market.

For your nearest representative please visit our web site at: www.dca.co.uk
or email us at: dcausa@worldnet.att.net

DCA
INSTRUMENTS

The shape of things to come

The ability to assemble and solder thousands of individual chips simultaneously into a circuit may spell the beginning of the end for the pick-and-place assembly of components.



The image of atoms, molecules or macroscopic objects spontaneously self-assembling into a useful structure is almost magical.

When we think of chemistry we often find ourselves thinking in terms of bond strengths (either covalent or ionic), or the electronic bandstructure created as a result of these bond energies. These drive the self-assembly of individual atoms to desired lattice sites that in turn create the periodic crystalline structure which is so important for all of our electronic and photonic devices. While it is convenient to think of the material growth of a crystalline structure as a form of self-assembly, the term implies that this is a spontaneous, naturally occurring process, driven simply by bond energies and minimization of free energy, and requiring little or no engineering. However, material growers will tell you in no uncertain terms that while crystal growth is indeed a natural process, it is the fine tuning of parameters such as substrate temperature, growth rates, and the many tweaks to optimize their growth equipment, that makes the difference between state of the art material and something only suitable for the toxic waste dump.

But still, the image of atoms, molecules or even macroscopic objects such as individual die sponta-

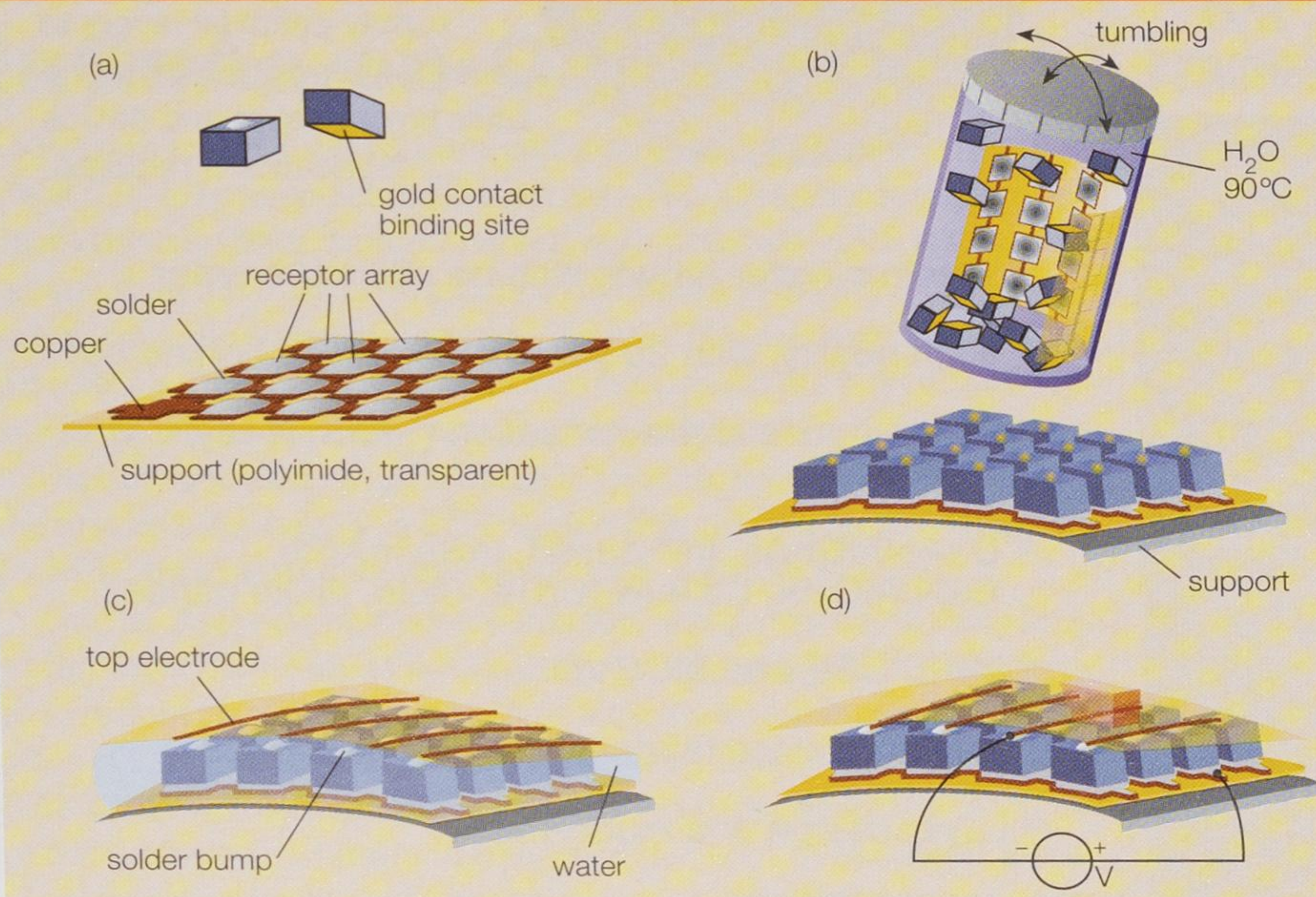
neously self-assembling into a useful structure is almost magical. Now some engineers are attempting to master such magic. They are developing techniques that require little more than a solder-bumped substrate, several thousand die immersed in a water-filled beaker, and a few minutes of agitation, to produce an assembly of die that have adhered, aligned themselves and formed electrical contact to the solder bumps. The successful implementation of such an intrinsically parallel (and therefore quite fast) process has the potential to eliminate the need for serially driven pick-and-place and wire bonding techniques.

Researchers at the University of Minnesota have recently detailed such a process in which 1600 Si blocks ($300 \times 300 \times 400 \mu\text{m}$), each representing a Si die, and 113 LED die ($280 \times 280 \times 200 \mu\text{m}$) were self-assembled onto cylindrical membranes (Jacobs *et al.*). The figure illustrates the detailed steps in the self-assembly process of LEDs onto a cylindrical membrane (suitable for cylindrical displays). Each individual LED die had two gold contacts, a small circular cathode contact on the front of the die and a large square anode contact covering the back. The target substrate consisted of an array of $280 \mu\text{m}$ copper squares that were coated with a low melting point (50°C) solder. The self-assembly of the LEDs onto the solder-coated squares occurs by placing both the cylindrical substrate and the LED die into a container of water that is made slightly acidic (pH 3.0) in order to remove the oxide from the surface of the solder. This is heated to 90°C to make the solder molten.

After one to two minutes of agitation, each solder point (referred to as a receptor) has a die attached to it, where self-alignment of the die to the center of the solder bump automatically takes place to minimize the overall interfacial energy of the junction. Furthermore, to ensure that only the larger anode contact mates with the receptor, the intensity of the agitation and the temperature of the water are optimized, so that if a temporary contact is made with the smaller cathode contact the resulting interface is unstable and breaks.

The second step of the self-assembly process was to form the top contacts to the LED die. This was performed by dip coating both the copper wires (supported in a transparent polyimide film) that were used as the cathode contacts and the cathode contacts themselves on the top surface of the LED die. In this prototype demonstration, the copper wire grid was placed by hand in roughly the right position on the LED array, and then

Cylindrical display assembly



(a) The LED chips have top and bottom gold contacts. The larger bottom contact is designed to bond to the solder receptor array. (b) The LEDs assemble and bond onto the receptors during agitation. (c) A polyimide sheet contains the top electrode array that is hand-placed on the LED array before accurately self-aligning. (d) The array is electrically contacted and tested.

Self-assembly processes may become very important in reducing production times, improving yields and lowering costs.

the entire structure heated above the solder melting point. With the same process that centered the LED die on the solder bumps, the copper wire grid then realigned itself to self-locate to the center of each cathode. The total time required for all 113 die to self-assemble was less than four minutes.

In a more aggressive experiment, a 5 cm² polyimide substrate containing a 40 × 40 array of solder bumps (for a total of 1600 receptors) was used along with 5000 Si blocks in the mixing container. After three minutes of agitation, self-assembly was achieved on 98% of the receptor sites. Analysis of the resulting 2% defects indicated that they were not caused by bonding errors between the Si blocks and the solder receptors, but by defects in the Si blocks and solder receptors themselves. These defects were typically due to the receptors only partially being covered by solder, or geometrical defects such as Si blocks that were rounded rather than square.

One of the most important aspects of these results is the ability of the receptor to only contact to the larger area anodes by utilizing its greater adhesive force, compared with the smaller binding energies possessed by the smaller cathode. This is in essence a size filtering process that chooses the desired die side for self-assembly. Further progress in this area will undoubtedly come

about by not only tailoring the size of the contacts being used, and controlling the agitation and temperature, but also by the shape of the receptor and die contact.

While most of us consider only the inorganic aspects of chemistry (bond strengths and 2D crystal growth), the reactions that take place in organic chemistry rely on the ability of one molecule to geometrically lock in place to another, just like puzzle pieces coming together. When this type of behavior is exploited in the development of self-assembly, a wide range of different die shapes and sizes should be able to self-assemble over substrates with very complex topographies. This potentially opens up a whole new methodology to complement, or even replace, the serially driven pick-and-place approach that currently dominates packing. Because so much of the III-V community is now involved in the move toward multichip modules, such as handset PA modules and the integration of electronic and optoelectronic functions for optical communications, such self-assembly processes may some day become very important in reducing production times, improving yields and lowering costs. ●

Further reading

H Jacobs *et al.* 2002 *Science* 296 323.

5th International Conference on Mid-Infrared Optoelectronics Materials & Devices

September 8-11, 2002 • Annapolis, MD

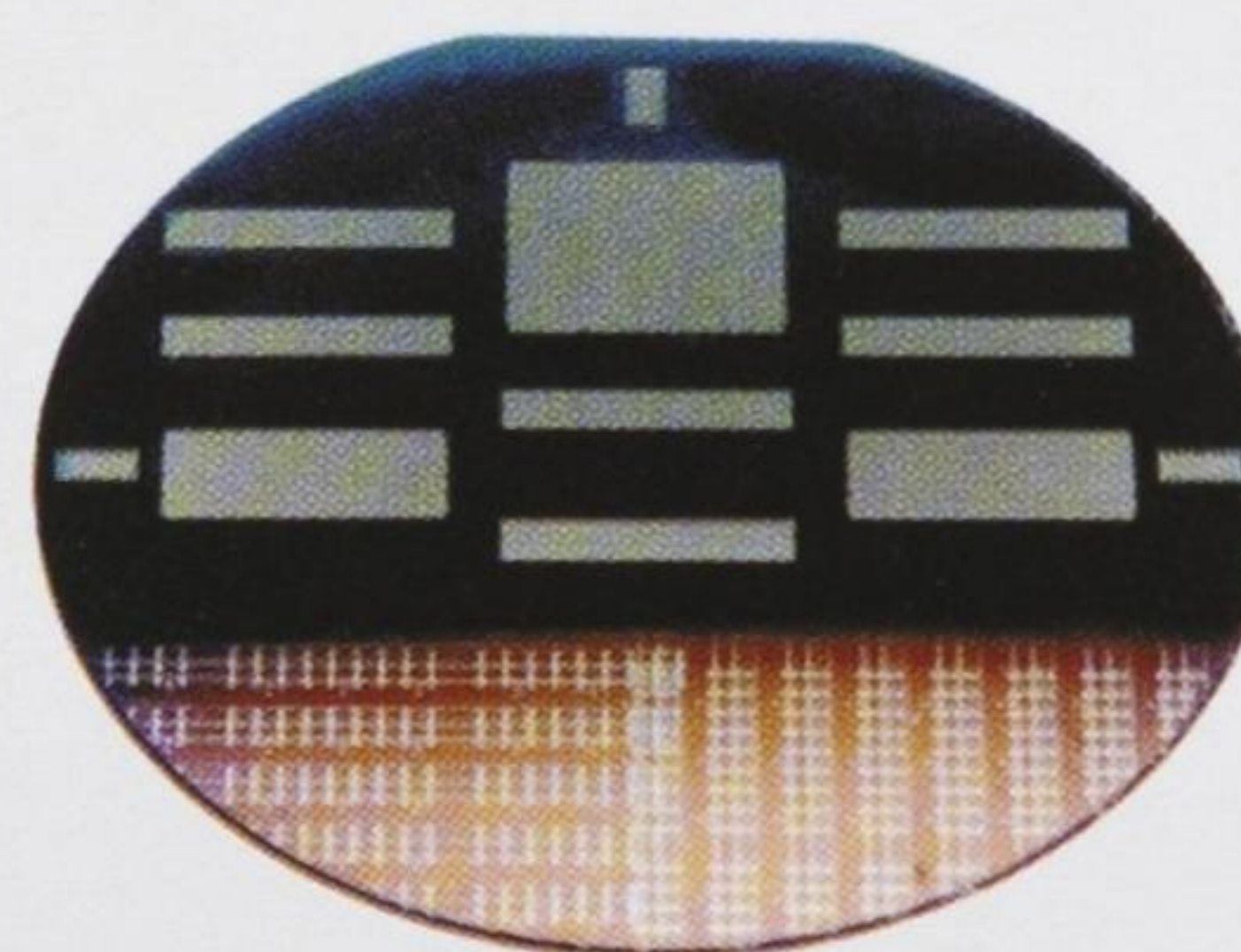
AVS topical conference sponsored by MDA, AFRL, DARPA, ARO, and ONR.

Topics include: LED, Laser, and Detector Requirements • Bandgap and Band-Structure Engineering • Bulk and Epitaxial Growth, Improved Interfacial Properties • Advanced Mid-IR Detector Designs, Sensitivity and Stability Issues • Electrically and Optically Pumped Mid-IR Lasers, Mechanisms Limiting RT Operation • Quantum Cascade Lasers • Alternative Mid-IR Sources • Nanostructures Based on Mid-IR Material

For more information, visit
www.miomd.org,
e-mail miomd02@avs.org,
or call 212-248-0200.

M O M D - V
Annapolis 2002

Custom Epitaxial Solutions



QinetiQ offers custom epitaxial growth and characterisation solutions for today's fast-changing environment. We can supply epitaxial layers to stringent specifications, and offer layer design and device fabrication if required.

- Custom wafer growth with no minimum order
- High quality, with 20 years of expertise behind us
- Full in-house characterisation (SIMS, X-ray, CV, Hall, PL)
- GaAs/AlGaAs, InP-based, InSb/InAlSb, GaN/AlGaN, CdTe/HgCdTe, SiGe, dilute nitrides
- MBE, CBE and MOCVD
- Custom device fabrication and assessment
- Layer design and modelling

Tel. +44 1684 89 5365
Fax. +44 1684 89 4311
electro-optics@QinetiQ.com
www.electro-optics.co.uk

QinetiQ was formerly DERA, the UK's
Defence Evaluation and Research Agency

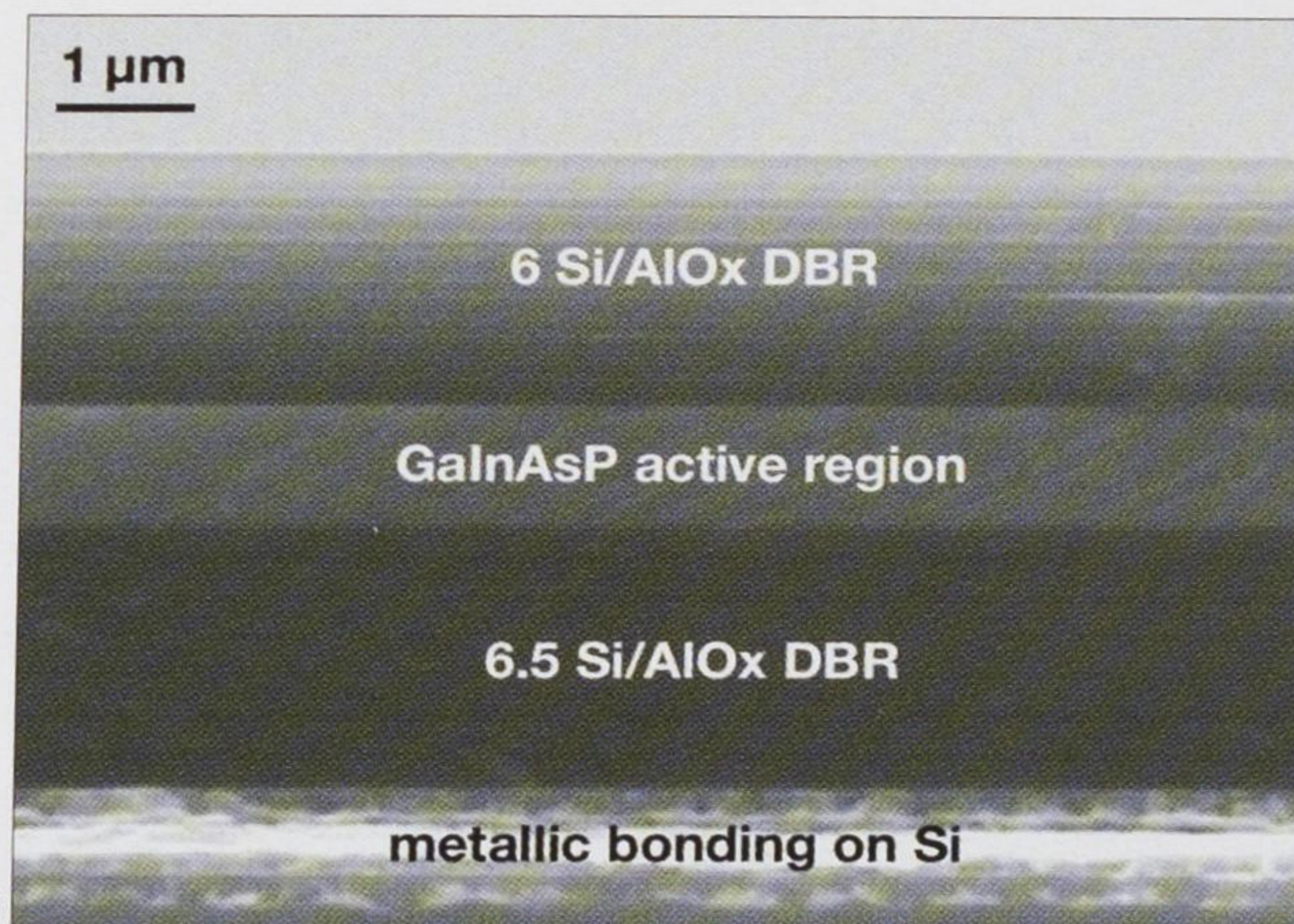
QinetiQ

St. Andrews Road, Malvern, UK

New metallic bonding technique enables efficient VCSEL production

High-efficiency, low-cost VCSELs emitting at 1.55 μm are being developed for wide-bandwidth fiber-optic communications. At present the most efficient 1.55 μm VCSELs utilize wafer bonding to integrate the DBRs with the GaInAsP/InP active region. Complicated fabrication steps such as chemical-mechanical polishing, crystalline alignment, and high-temperature annealing are required to ensure successful semiconductor-to-semiconductor bonding. To reduce these complications, a group at the University of Illinois at Urbana-Champaign, led by Norman Cheng, has developed a metallic bonding technique for integrating different types of materials, including semiconductors and dielectrics, in optoelectronic devices. Using the metallic bonding process, the group successfully demonstrated 1.55 μm GaInAsP VCSELs on Si substrates (*Elec. Lett.* 2002 **38**(11) 516).

The GaInAsP active region of the VCSEL was grown on an InP substrate by MOCVD. A 6.5 period Al-oxide/Si lower DBR was deposited on the as-grown wafer by electron-beam evaporation. Due to the large refractive index difference, Si/Al-oxide DBRs provide an excellent reflectance in less than 10 periods, with a low



SEM cross-section of the GaInAsP/InP VCSEL cavity bonded to a Si wafer using the metallic bonding process.

thermal resistance and broad stop-band. The DBR/GaInAsP/InP wafer and a Si substrate were then coated with the AuGe/Ni/Cr metallic bonding medium and bonded together at 320 °C. Following bonding, the InP substrate was removed to expose the active region. After defining the VCSEL mesa and forming contacts, a 6 period Al-oxide/Si upper DBR was deposited on top of the mesa to complete the device. The fabricated VCSELs lased at room temperature under pulsed operation. For a $30 \times 30 \mu\text{m}^2$ device, the threshold current was 12 mA with a turn-on voltage of 0.8 V. The emission showed a single-mode spectrum at 1.545 μm .

In contrast to other bonding methods, the metallic bonding interface is formed outside the VCSEL cavity at a low annealing temperature. The mechanical and thermal impacts on the VCSEL's active region are therefore minimized. In addition, the metallic bonding medium also enhances the total reflectance of the bonded DBR mirrors. Cheng's team believes that the metallic bonding technique has an excellent process latitude and integration capability for long-wavelength VCSELs and other optoelectronic devices.

XenICs to use MBE for InGaAs-on-GaAs IRFPA

Most commercial InGaAs infrared focal-plane arrays (IRFPAs) operate at 0.9–1.7 μm and consist of an $\text{In}_{0.53}\text{Ga}_{0.47}\text{As}$ photodiode grown on an InP substrate. Longer wavelength detectors with In contents greater than 53% are grown lattice mismatched to InP or GaAs substrates and allow detection out to 2.6 μm . These longer wavelength detectors suffer from larger dark currents due to the high defect density in the lattice-matched material. A team from IMEC and III-V photodetector specialist XenICs, based in Leuven, Belgium, have reported the first InGaAs-on-GaAs IRFPA operating at 1.3–2.3 μm to be grown by MBE on a GaAs substrate (*Elec. Lett.* 2002 **38**(12) 588).

The $\text{In}_{0.78}\text{Ga}_{0.22}\text{As}$ photodiode structure was grown on a 5 μm AlInAs buffer layer on a 3 inch GaAs substrate. An array was bump bonded to a readout circuit and mounted on a thermoelectric cooler for operation at 250 K. The backside-illuminated spectral response peaked at 0.68 W/A for 1.6 μm photons, giving an external quantum efficiency of 55%. Uniform illumination showed that 90% of the pixels fitted a Gaussian distribution of photoresponse, with 5% having an unacceptably low response. The authors say that while there is room for improvement, this is still close to the 95–99% operability seen in commercially available 1.7 μm InGaAs IRFPAs of a similar size. The use of a backside anti-reflection coating is likely to increase the external quantum efficiency to 70–75%.

Self-heating measured in strained Si MOSFETs

Strain in Si can increase carrier mobility by inducing changes in the electronic bands. Strained Si MOSFETs can be created by the lattice mismatch caused by growing the active Si region on a layer of SiGe. Such MOSFETs should exhibit greater output current than their conventional counterparts. However, the SiGe layer has a much poorer thermal conductance than Si, and strained Si MOSFETs are expected to exhibit significant self-heating, which acts to reduce mobility. Keith Jenkins and colleagues at IBM have demonstrated a way to measure the effect of this self-heating on the electrical performance of strained Si transistors (*Elec. Dev. Lett.* 2002 **23**(6) 360).

The output characteristics of the devices were measured using pulses of a few nanoseconds with a low repetition rate, thus avoiding self-heating, which requires times of hundreds of nanoseconds. For an nFET with a 0.1 μm channel, the output current is as much as 15% higher than the corresponding DC measurement. By measuring the current at a variety of temperatures, and comparing the pulse measurement to the DC value, it was shown that the temperature of the MOSFET channel can increase by as much as 100 °C during DC measurement. Although self-heating is not expected to impact digital circuits, in which the transistors have low duty cycle, it is always present in the traditional DC device characterization, and must be accounted for during technology development or device modeling.

Do you package this device?

If your answer is yes, Ismeca can handle any of your Surface Mount LEDs, reliably, flexibly and at very high speed.

At Ismeca, we understand LED packaging means versatile handling platforms that can automatically feed in devices, connect to spectrometers to conduct optical measuring, and efficiently integrate sorting and/or taping. Some LED applications also need other functions such as automatic visual inspection and laser marking. Or for fast, cost-effective multi-grading output, our standard handler can be utilized as a pure sorting unit with 32, 64 or 120 bins.

When Ismeca commits to high speed, we meet sustained performance of up to 18,000 ppm within real-world production environments. And with all of the above functions combined in one machine, that superior performance can be delivered in a very small amount of floor space.

As the pioneering inventor of multi-up, high-speed turret systems, Ismeca continues to lead with new innovation across all of today's device-handling challenges. Our global organization also assures consistent service and support for any location throughout the world.

For a free brochure, contact the Ismeca office near you or visit our WEB site:

WWW.ismeca.com

USA

Ismeca USA, Inc.
2365 Oak Ridge Way
Vista, CA 92083-8348
Tel. + 1 760 305 6200
Fax + 1 760 305 6290

HONG KONG

Ismeca Asia, Limited
Room 2001, Metro Center 1
32 Lam Hing Street,
Kowloon Bay
Kowloon, Hong Kong
Tel. + 852 2873 3213
Fax + 852 2873 1027

SWITZERLAND

Ismeca Europe S.A.
Rue de l'Helvétie 283
CH-2301 La Chaux-de-Fonds
Tel. + 41 32 925 71 11
Fax + 41 32 925 71 15

Designed to adapt



ismeca

PHOTONICS MANUFACTURING

Low-cost manufacturing is key to the future of photonics

The latest OIDA workshop challenged all players in the photonics industry to develop a roadmap to guide the industry to the next stage of manufacturing maturity, reports **Richard Dixon** from Photonics Manufacturing, a workshop held at Boston University.

To manufacture at high volume and lower cost, the photonics industry must adopt production practices that emphasize design for manufacturing, reliability standards, common packaging and automation. This premise proved to be a major talking point at Photonics Manufacturing: Design, Automation, Packaging and Standardization.

Since the telecoms crash, component prices have dropped by as much as 40%, largely due to excess inventory. Industry sources suggest that prices are likely to remain at this level even when market demand returns, because growth sectors such as metro and access applications will be very price sensitive. These lower prices will squeeze profit margins if companies cannot cut manufacturing costs. As a result, implementing strategies to reduce costs, such as design for manufacture and automating assembly processes, is vital.

David Krohn, a managing partner of Light Wave Venture, the investment company that jointly organized the one-and-a-half day workshop with the Optoelectronics Industry Development Association (OIDA), summarized the situation. "If we want to make photonics much more pervasive, we need to get the [manufacturing] costs down by about 90%," he said. "To be really serious about manufacturing, you have to address a lot of issues facing the industry, or be out of business in two years' time."

Krohn's comments set the tone for the meeting at Boston University, which featured a series of presentations by vendors, component manufacturers and network providers.

Highlights of OIDA's five-year roadmap for the photonics industry

	2002	2004	2006
Design for manufacturing	not widely used; limited software & support	widely used; outsource support available	mandatory simulation and customer interface; outsource support
Integration	planar integration; hybrid integration dominates	planar integration provides more sub-modules; hybrid integration dominates	fewer components or alignments; integrated test
Packaging (issues: fiber & thermal management)	large number, similar functions; MSAs defining footprints	consolidate package types; broader standardization; semi-automation	standardized packaging & interfaces; optimized thermal management
Automation (issues: still manual, standards limitations, insufficient volume, cost)	semi-automated alignment & attach; semi-automated test	design for manufacture supports design for automation; automation in areas with sufficient volume	used in low, moderate & high volume; in high volume with material handling systems; interchangeable platforms
Contract manufacturing	large manufacturers moving to contract; services: assembly & packaging, foundry & fiber assembly	lower costs due to supply chain management; more automation; services: add design, test	dominates manufacturing; drives standards; services: add simulation, reliability certification
Relative cost	100%	50 to 81%	20 to 59%

Breakout sessions were incorporated to discuss a roadmap for the photonics manufacturing industry over the next five years.

The OIDA's executive director, Fred Welsh, believes that a roadmap is critical to identifying cost-cutting opportunities. He said that during a previous workshop on low-cost manufacturing, held during Strategies Unlimited's "Strategies in Optical Manufacturing" conference, a number of recurring themes led to the development of a prototype roadmap. This formed part of the discussion at the Boston meeting (see table).

"The roadmap outlines several areas that need attention," said Welsh. "The design for manufacturing process is one aspect the industry has not paid enough attention to. Also, there's too much variation in today's components to realistically expect to get more standardized packaging sooner rather than later."

Welsh says that in the longer term the industry needs a family of packages similar to those in the semiconductor industry, so that

manufacturing and test equipment makers, as well as contract manufacturers, can take advantage of industry volumes.

"Another important aspect is how to automate appropriate parts of the production process," he added. "Making headway on the design for manufacturing and standard packages will help us achieve consistent production through automation." Welsh suggested taking a semi-automated approach for the time being to improve yield, consistency and quality, and also to emphasize designing for larger scale production and manufacturing.

Design for manufacturing

Mark Garlock of Kodak gave a presentation describing the company's use of design for manufacturing and assembly. Kodak employs simulation packages and design services that provide information on problem areas early in the design process, and enable predictions that allow assembly costs to be accurately predicted and met.

PHOTONICS MANUFACTURING

"We iterate designs early and often in the process, using design for manufacturing at the conception and design phases," said Garlock. He stressed that to be effective, the design for manufacture process must be involved before the prototype phase.

Hybrid wafer-level integration

A talk from Digital Optics compared optical sub-assemblies manufactured using current discrete methods, with the company's approach that uses micro-optical sub-assemblies. Kevin Drehmer, president of Digital Optics, described their photonic chip technology, which involves photolithographic etching of 6 inch wafers to produce passive components. The wafers are bonded into a stack and electrical contacts etched in. The stack can then be flip-chip bonded to active components such as lasers and detectors, and then diced into chips. The optics can also be attached to the wafer stack. The wafers have the advantage that they can be very accurately processed ($<1\ \mu\text{m}$ accuracy) and the critical components are already aligned.

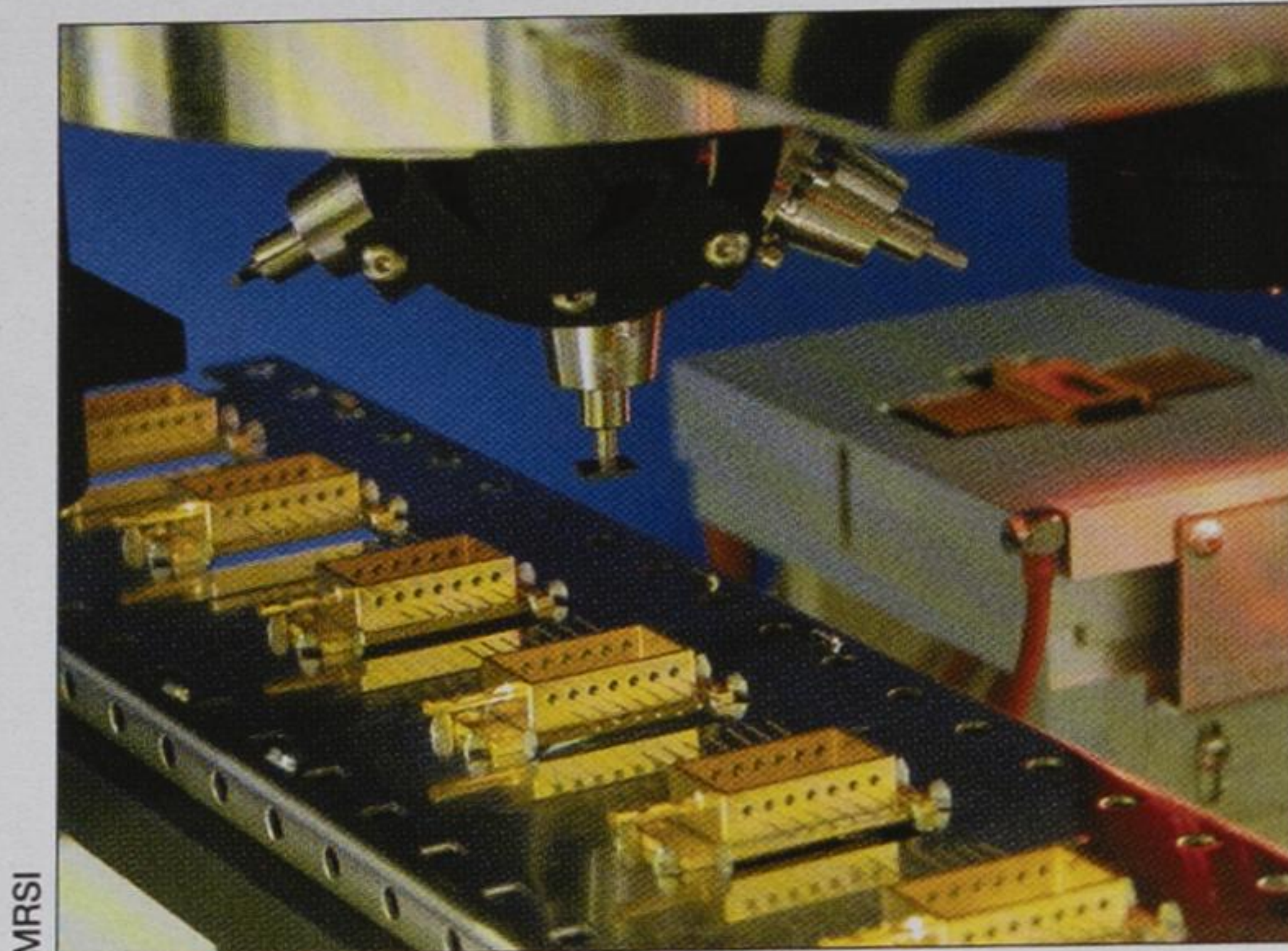
For a wavelength locker, the discrete method typically requires five to seven active alignment steps to assemble the beam splitters, etalon (Fabry-Perot resonator), two detectors and focusing optics. The Digital Optics chip reduces the number of alignment steps to one and also removes wire bonding. The cost savings add up to 33–60% for a device with the same performance and size as one made with the discrete manufacturing method.

The photonic chip offers smaller form factors, said Drehmer, and is scalable to high-volume manufacturing. The process can also be extended to more complicated devices in 14-pin packages.

Automating the assembly process

A presentation by Palomar Technologies emphasized the benefits of automating the assembly processes, including wire and die bonding. Optoelectronic packages differ from microelectronics packages because more kinds of materials are used, leading to additional thermal considerations. The placement accuracy for lasers and fibers is also critical.

According to Palomar sales manager Dale Perry, the equipment needed for the automation of processes and services used for design for manufacture are already available to the industry. To automate assembly, high-yield fully automatic processes require precision motion, machine vision and recipe-driven process control. Armed with these capabilities,



MRSI's automated optical assembly workcell is configurable over several component-attach technologies. It also performs *in situ* functions such as eutectic bonding, epoxy component attach, UV epoxy dispensing and curing.

Palomar's automated laser diode attach cell can increase yields by up to 50%.

Peter Cronin of MRSI described flexible processing systems that automate the assembly of optical components such as lasers on sub-mounts in butterfly packages. The MRSI-505 optical assembly workcell can be configured for several technologies, including the placement of InP and GaAs die, and small thin preforms (see photo).

Defects and reliability

Greg Kelly of Nortel Networks described the reliability issues associated with the lasers, detectors and modulators being developed and manufactured at Nortel. The reliability distribution of such devices conforms to a "bathtub" curve. Initial high breakdowns caused by random failures and infant mortality drop to a steady-state region of a few failures that lasts around 20 years (the bottom of the tub). A region of "wear-out" then causes the failure curve to increase again.

For optoelectronic components, this wear-out mechanism can encroach on the service life of the component. For this reason, Telcordia standards still define the characterization of wear-out as one of the primary requirements in a product-reliability qualification. Kelly said the bathtub model was now obsolete in the silicon industry, which has worked to push wear-out failure well past the typical component service life.

For optoelectronic components, early random failure or infant mortality can be removed by screening for killer defects, but this is costly, said Kelly. "We still don't have an understanding of all failure mechanisms so we can't yet reduce the amount of screening," he said. "But with automation, we are seeing

much better uniformity of epitaxial layers, which is due to improvements in uniformity in multiwafer growth reactors."

A contract manufacturing viewpoint

Alex Rosiewicz, CTO of contract manufacturer EM4 Photonics, noted that the use of expensive materials, low manufacturing volumes and a lack of standard parts is preventing manufacturing at lower costs. He also said that poor component design is a problem; systems designers demand more functionality, complexity and performance, meaning component designers are often forced to supply high-performance components with little or no design margin.

The packaging industry is being caught in the middle, he said, by having to apply tight alignment tolerances to effectively harness every photon. To address these issues, Rosiewicz suggested an industry-wide cooperation to provide sensible quality standards. He believes that this could be achieved if system designers compromise on their demands, and chip designers "over engineer" devices to provide more power than is actually required. This would allow packaging companies to work with larger alignment tolerances to provide lower cost optical modules.

Rosiewicz added that component reliability should also be reassessed. "Why should we be driven by very stringent testing to ensure 20 years of service life when many systems are obsolete in five to ten?" he asked.

The way forward

Several themes emerged from the breakout sessions. One was a need for a greater understanding of the design for manufacturing process at all production levels, from fabricating an initial product to ramping up to volume production. Vendors and contract manufacturers should also provide input earlier in the process to optimize efficiency. In addition, delegates said that design for manufacturing software programs require more dissemination.

Reliability was widely discussed, with some delegates saying reliability requirements were often too stringent. Delegates agreed that while this issue required a longer term project, customers had to be provided with economical products of the right quality in the short term.

The OIDA now plans to generate a framework that supports an ongoing effort in photonics manufacturing. "We will also talk to other manufacturing groups, including NEMI [the National Electronics Manufacturing Initiative] and IEEE, regarding issues that came up in the workshop," said OIDA's Fred Welsh. ●

A **MILESTONE** in SiGe

SiGe With the SIRIUS system, Unaxis became the world's leading supplier of UHV-CVD equipment for SiGe HBT production. Now Unaxis Semiconductors has secured the next milestone.

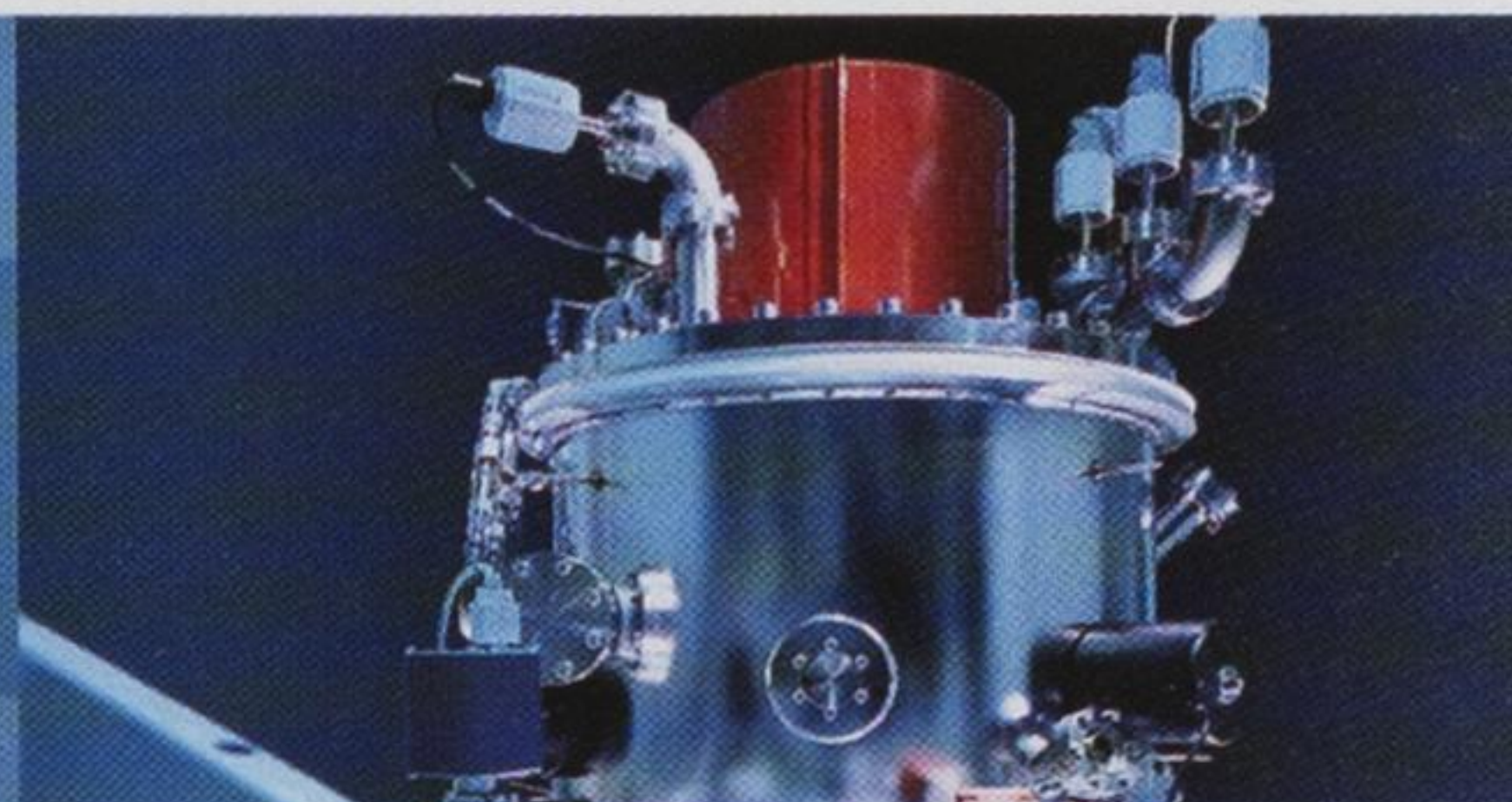
Revolutionary Low Energy Plasma Process know-how from Unaxis sets the benchmark in virtual substrate production by combining our «by factors» faster new Low Energy Plasma Enhanced CVD process with our dry Low Temperature Cleaning Process.

Set a new milestone in the SiGe-Market for your company now. Together we can shape the IT world of tomorrow.

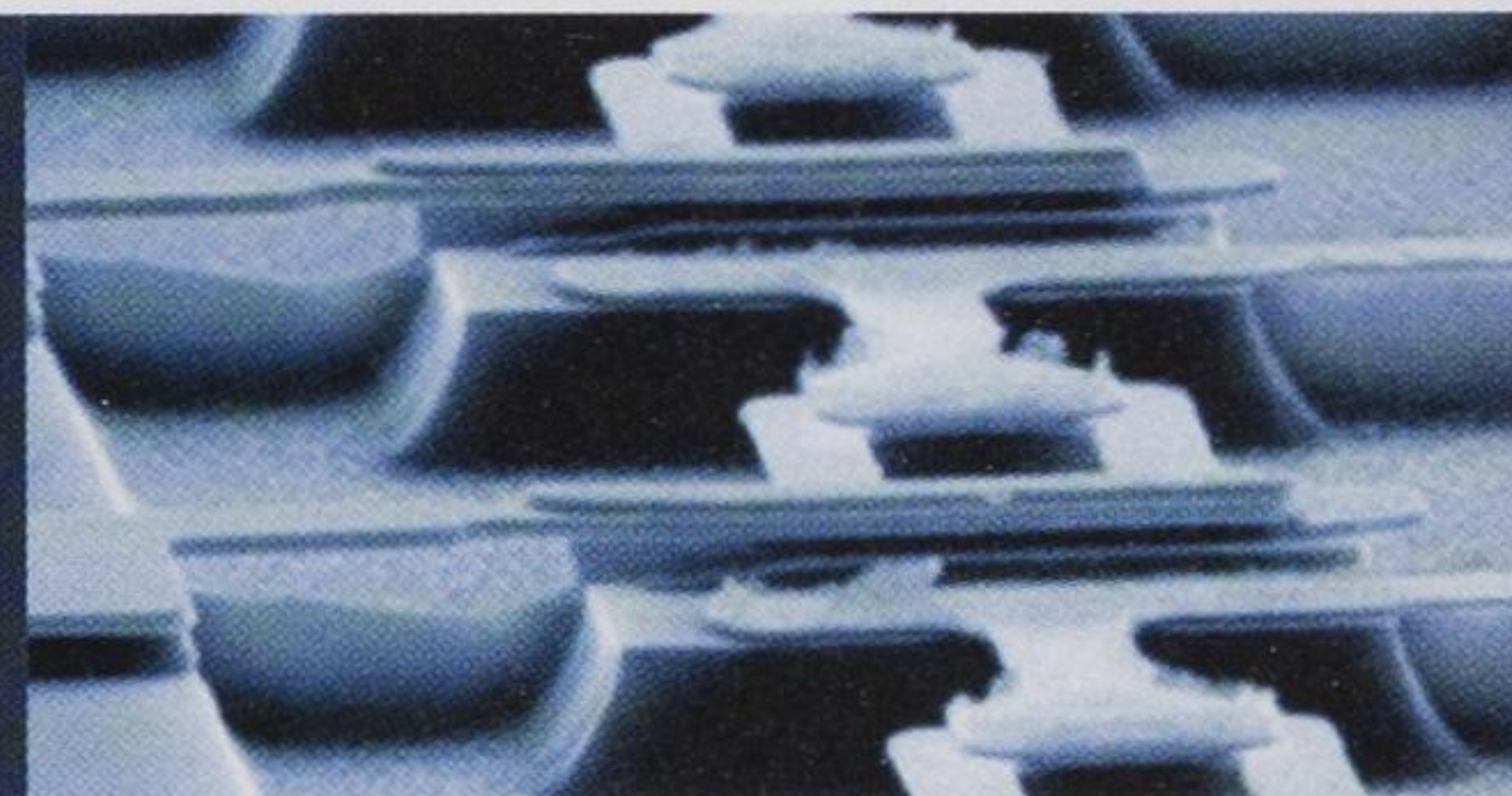
semiconductors.unaxis.com



LEPP 300 Loading Station



LEPP 300 Plasma Cleaning Module



SiGe Hetero Bipolar Transistor (HBT)

email: info.semiconductors@unaxis.com

USA Tel. +1 727 577 4999
EUROPE Tel. +423 388 6237
CHINA Tel. +86 21 5057 4646
SINGAPORE Tel. +65 6890 6288

KOREA Tel. +82 31 708 8666
TAIWAN Tel. +886 3597 7771
JAPAN Tel. +81 3 3225 9020
OTHER MARKETS Tel. +41 81 784 6237

Visit us at Booth 1072
Semicon Taiwan, Taipei

unaxis

making IT possible

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 Application Lab**

In 2002, Riber inaugurates the industry's first indium phosphide application lab to accompany you from start up through full production of phosphorus-containing compound semiconductor materials.

If you want to visit our application laboratory 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



R I B E R

Products and Services for the Compound Semiconductor Industry

In-house production reduces costs and time to market

VSK Photonics, a start-up fiber-optic component manufacturer, took less than five months to build its InP wafer fab, and the project came in under budget, write **John Lungo** and **Ramin Rofagha**.

VSK Photonics of Lake Forest, CA, was founded in December 2000 with a mission to deliver high-performance, cost-effective optoelectronic integrated circuit components and modules for the high-speed telecommunications market. The company's focus on delivering optical receiver solutions for 10 and 40 Gbit/s long-haul and metro markets is based on its proprietary InP semiconductor technology.

After raising its initial equity funding (\$18 m) in February 2001, VSK set out to achieve its goals. This article chronicles the company's decision to build a wafer fabrication plant rather than outsource, the challenges of constructing an in-house fab in less than five months, and the rewards of coming in under budget.

In-house fab vs outsourcing

In this era of mega fabs and the astronomical costs associated with building class 100 clean rooms, it is understandable that a small company would have a difficult decision to make in terms of building an in-house wafer fabrication facility or remaining a fabless operation. Why would a young company undertake the challenge and risk of building a fab? VSK carefully considered the answer to this question.

Building a wafer fab is capital intensive and once the fab is built the operating costs are high. Any small company must weigh the operational benefits against these costs before committing to this business model. Construction of the facility's shell, with proper air-handling systems installed to maintain a class 100 environment, can typically cost in excess of \$1200 per sq. ft. When factoring in the support systems, including de-ionized water, process chilled water, house N₂, process gases and more, this figure can easily exceed \$2000 per sq. ft. These costs do not include purchasing and installing process equipment or the day-to-day operating expenses. Considering these figures, it's easy to see why a small company with limited



Aligning an InP wafer at VSK Photonics' new fab, which was built in record time.

resources would be tempted to purchase their devices from an established foundry. However, after lengthy analysis, VSK chose to build its own fab, and some of the reasons for this decision are as follows:

Cost It costs more to buy a wafer from a foundry than it does to produce a wafer in-house. As a vendor, foundries must recover some of their investment by marking up their processing service fees. The operating expenses and the overhead of the vendor are also included in the cost. Clients that either do not have a facility, or do not have the capacity or equipment set to support the type of wafer processing their company requires, end up paying for this. This cost differential is one of the key factors that VSK considered when deciding whether to be an in-house fab or to outsource for wafers. An in-house wafer fab enjoys one more degree of freedom – it

allows the company to directly control its costs. This freedom is lost when wafer fabrication is outsourced to a foundry.

Intellectual property Any company's intellectual property (IP) and proprietary knowledge are much easier to protect if they are kept in-house. Most foundries will not have all the process expertise readily available to run a client's particular product on their line. This means the outsourcing company must share vital details to the foundry, details that would be better guarded if they did not have to be shared with an outside firm. The foundry will often need personnel and expertise from the client to successfully manufacture the client's products. The question to consider is: how valuable is the company's expertise and IP? Companies go to great lengths to protect their trade secrets (e.g. Kentucky Fried Chicken or Coca-Cola's secret recipes), yet when it comes

to contracting out manufacturing, this point often gets overlooked. There are certainly more benefits to having your own facility for wafer fabrication than simply protecting your IP and trade secrets. However, in VSK's case, this was a key consideration in the decision to build.

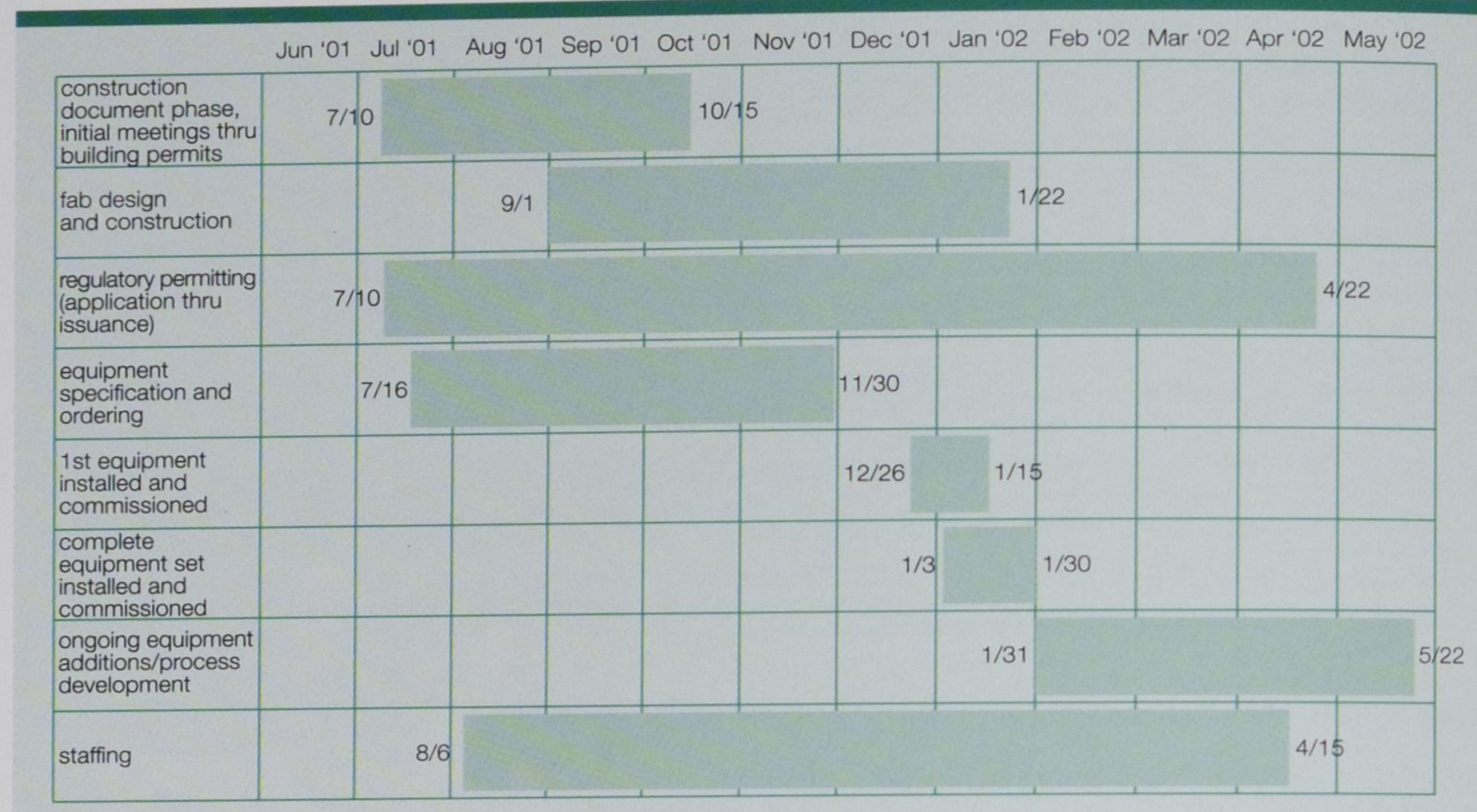
Time to market Having an in-house fabrication facility enables R&D to be fast-tracked. The cycle time is measured in days (not weeks or months), making a young company more agile. There is usually time and equipment available at almost any hour of the day to do a quick study or experiment. Having this accessibility to process development tools creates a shorter learning cycle, which can be crucial to being responsive to new opportunities in the market and, in particular, to key customers. The resulting low cost of R&D also helps in product customization. More importantly, it eliminates supply-chain dependencies that can be disastrous for small companies.

Tangible value One of the key metrics of a successful start-up is its ability to build tangible assets with sustainable value. Many factors go into determining this value. All other things being equal, companies that have tangible, measurable assets have more value than those which have intangible assets. A wafer fabrication facility is considered a hard asset that brings great value to the company. This type of asset is much more valuable than its book value.

VSK's decision to build an in-house fabrication plant was reached after considering the factors cited above. Total ownership of the production process leads to tighter control over costs, quality and supply. It can shorten the learning cycle that ultimately leads to faster design turnaround and consequently faster time to market.

The challenge of construction

Once VSK decided to build its own fab, it developed a very aggressive schedule to achieve this objective in less than five months, starting in September 2001, and with a very limited budget (see timeline figure above). The initial step was to hire a facilities specialist to champion the task of building a 2800 sq. ft class 1000 fab. The right person was key to a successful project. An ideal candidate with a wealth of experience in setting up InP fabs in the Southern California area was found and quickly brought on board. This facilities specialist was mandated to achieve the following objectives in record time:



Timeline showing the different phases of construction, which was completed in record time.

VSK established a very aggressive schedule to build its own fab in less than five months, with a very limited budget.

- find an appropriate building and design modifications to it;
- obtain all of the required permits and zoning approvals;
- select and appoint contractors for the construction and building facilities;
- specify and order the wafer-processing equipment;
- hire wafer-fab engineers and technicians.

In finding an appropriate building to house a wafer fab, a myriad of regulatory issues needed to be taken into account. These included: zoning, air-quality permits, waste-water permits, hazardous-materials disposal permits, Environmental Protection Agency ID number, as well as chemical classification and architectural reviews by the fire authorities.

Any one of these regulatory concerns could cause a setback to the project or put it beyond the budgetary constraints. Furthermore, the building itself had to have the potential for future upgrades to meet all of the wafer fab's facility requirements, such as water and electrical service. Therefore, only buildings that could meet the above-mentioned criteria were considered.

In conjunction with finding an appropriate building and working out the details of a

lease, the process of selecting construction contractors began. Only contractors who had previous wafer-fab experience, solid references, and who could meet the time and budget guidelines were considered. To propel the project, all regulatory and permitting processes were put into motion at this same juncture. Once the building was secured, contractors were selected and the work of designing and modifying the building began. During the design stage, long lead items such as air handlers were ordered. Placing these orders before the building had been cleared of regulatory issues posed a significant risk: most of the equipment ordered was building-specific. This is where VSK relied heavily on the previous experience and expertise of their facilities specialist, who had gone through this process before and was familiar with regulatory issues. The specialist had to carefully weigh the risks of ordering equipment for a building not yet approved, against the potential benefit of finishing the fab in record time.

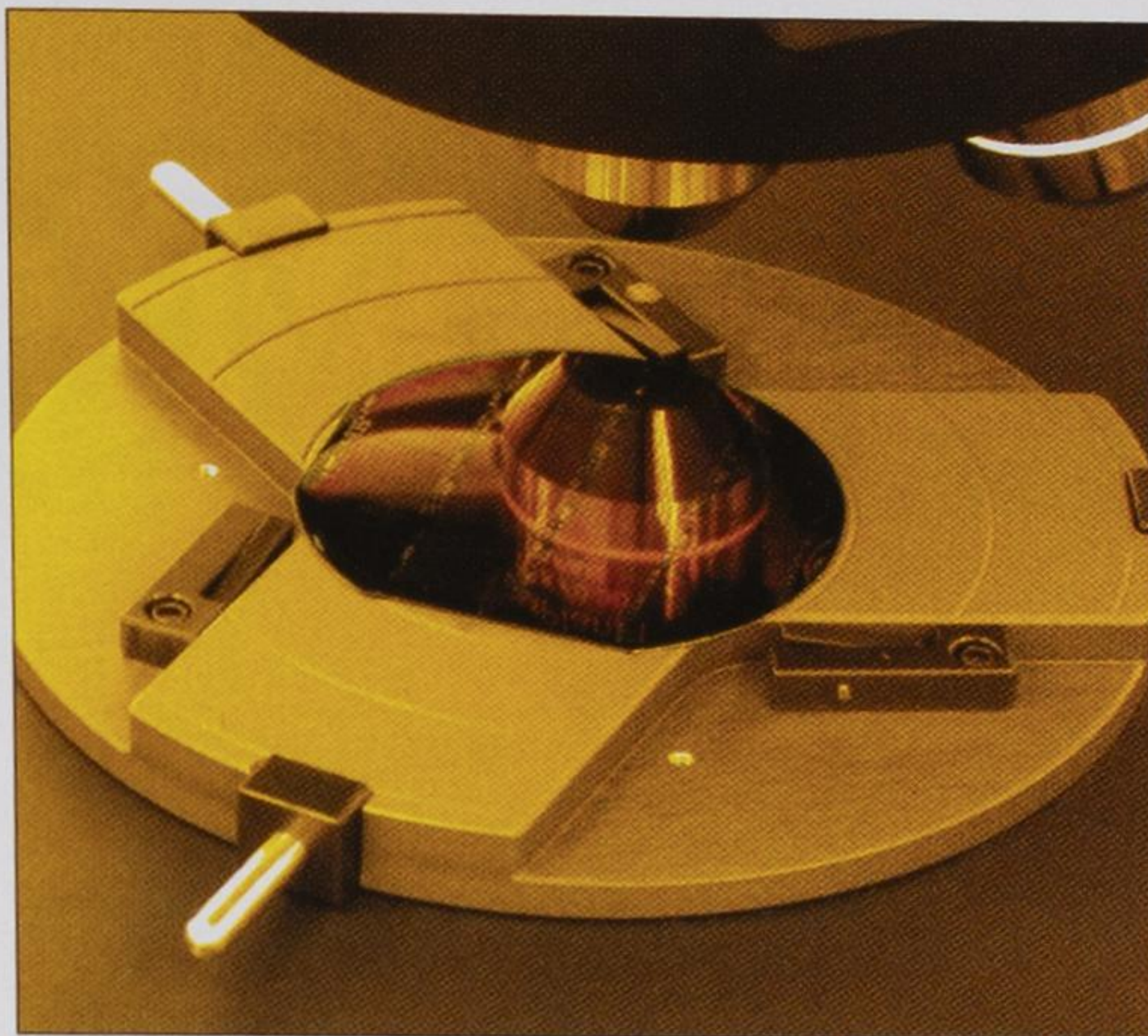
As one might imagine, a number of issues threatened the timely progression of the project. Beyond VSK's control, a few essential pieces of equipment and material, such as HVAC and ductwork, were delayed by three weeks. Since the schedule was so tightly set, leaving little room for error, even a week's delay had a serious impact on the timeline. Additionally, the scope of the project in certain areas, such as process piping and electrical work, kept expanding beyond the actual fab to other areas, including test and packaging areas. This further reduced the possibility of finishing the fab on time. The end date for accepting

the process equipment into a finished fab didn't seem terribly realistic at times.

Through effective managing of contractors and suppliers by the facilities specialist, some of these time delays were kept to a minimum. Overtime charges had to be approved on a number of occasions to bring the schedule back on track. Although not entirely complete, the fab was in good enough shape by the end of December to place the pieces of wafer processing equipment inside as they arrived. Equipment vendors were prepared in advance to install and commission the equipment within one week of being received by VSK. Equipment installation and commissioning proceeded on time and the first wafer was started in the third week of January 2002.

Under five months, under budget

Originally, the design called for a class 1000 clean room with some critical areas being class 100; the timeline from the start of construction to the first wafer start was five months. VSK completed construction in under five months, the entire clean room was built to class 100



Setting up a wafer for visual inspection.

standards, and the whole project came in 20% under budget. The timing of the project was ideal on a number of levels. Due to the poor business climate at the time, contractors and equipment manufacturers were more open to negotiations than ever before, allowing for significant cost savings. Furthermore, process equipment order lead times had been reduced substantially compared with a similar period

just a year earlier. These factors, along with the expertise of the facilities specialist and the collaboration of many vendors and contractors, facilitated the achievement of an aggressive construction schedule.

VSK demonstrated its first line of products, a 10 Gbit/s receiver module and a 40 Gbit/s detector module, during the Optical Fiber Communications conference in March 2002. These modules were built from wafers started in VSK's in-house fab in late January. Just one year after its initial round of financing, VSK introduced its flagship product line.

VSK's decision to pursue an in-house strategy for wafer fabrication has proven to be the best course of action for the company. By controlling its costs, quality, design cycles and supply, VSK is in a position to rapidly address the needs of its customers and aggressively expand its market opportunities. ●

John Lungo is director of semiconductor operations and Ramin Rofagha is a product line manager with VSK Photonics. Tel. +1 949 586 2202. Web www.vskphotonics.com.

The leading online information source for the compound semiconductor industry

COMPOUNDSEMICONDUCTOR.NET features:

- industry news, updated daily
- feature articles from the latest issue of *Compound Semiconductor* magazine
- job vacancies, industry events and a comprehensive Buyer's Guide
- information on new products
- fully searchable news and magazine archives

Use COMPOUNDSEMICONDUCTOR.NET to

- list your company's details in the Buyer's Guide
- upload product and event information directly onto the site
- post your resume or sign up for job vacancy email alerts
- subscribe to weekly email NewsAlerts or to *Compound Semiconductor* magazine

COMPOUNDSEMICONDUCTOR.NET

For information on advertising opportunities, please contact sales@compsemi.iop.org tel. +44 117 930 1033.

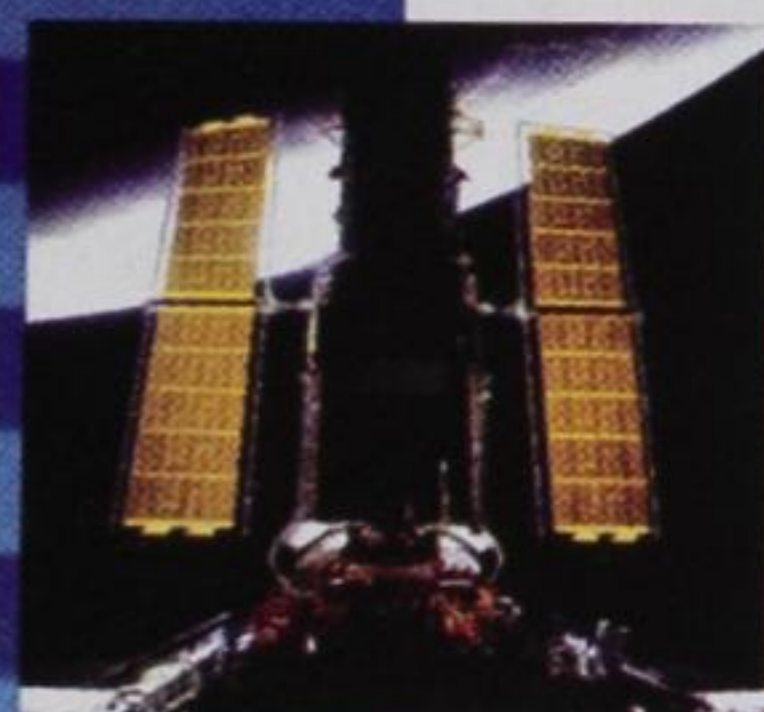
www.metalorganics.com

**Our name
has changed.
Our reputation
for quality,
has not.**

Rohm and Haas Metalorganics is now

Shibley Metalorganics

SOURCES FOR SUPERIOR DEVICESSM



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.



North America

Shibley Company, L.L.C.
60 Willow Street
North Andover, Massachusetts
01845 USA
Tel: 978-557-1700
Fax: 978-557-1701

Taiwan

Shibley Taiwan Company Ltd.
No. 6 Lane 280
Chung Shan North Road
Ta Yuan Industrial Zone
Ta Yuan Hsiang
Taoyuan Hsien, Taiwan
Tel: 886-3-385-8000
Fax: 886-3-385-5989

Japan

Shibley Far East Ltd.
Sanbancho UF Building
6-3, Sanbancho
Chiyoda-ku
Tokyo 102-0075 Japan
Tel: 81-3-5213-2924
Fax: 81-3-5213-2948

Europe

Shibley Europe Ltd.
La Tour de Lyon
185 Rue de Bercy
75012 Paris, France
Tel: 33-1-40-02-54-37
Fax: 33-1-40-02-54-07

South Korea

Shibley Korea Ltd.
Kyungmok B/D 3F
1354-5, Seocho-dong
Seocho-ku
Seoul 137-070 Korea
Tel: 82-2-3474-2179
Fax: 82-2-3487-1767

IPRM showcases advanced InP devices and novel applications

New materials, high-performance devices and next-generation technologies were all covered at IPRM 2002. **Colombo Bolognesi** reports on a show that provided delegates with a glimpse of what the future holds for InP.

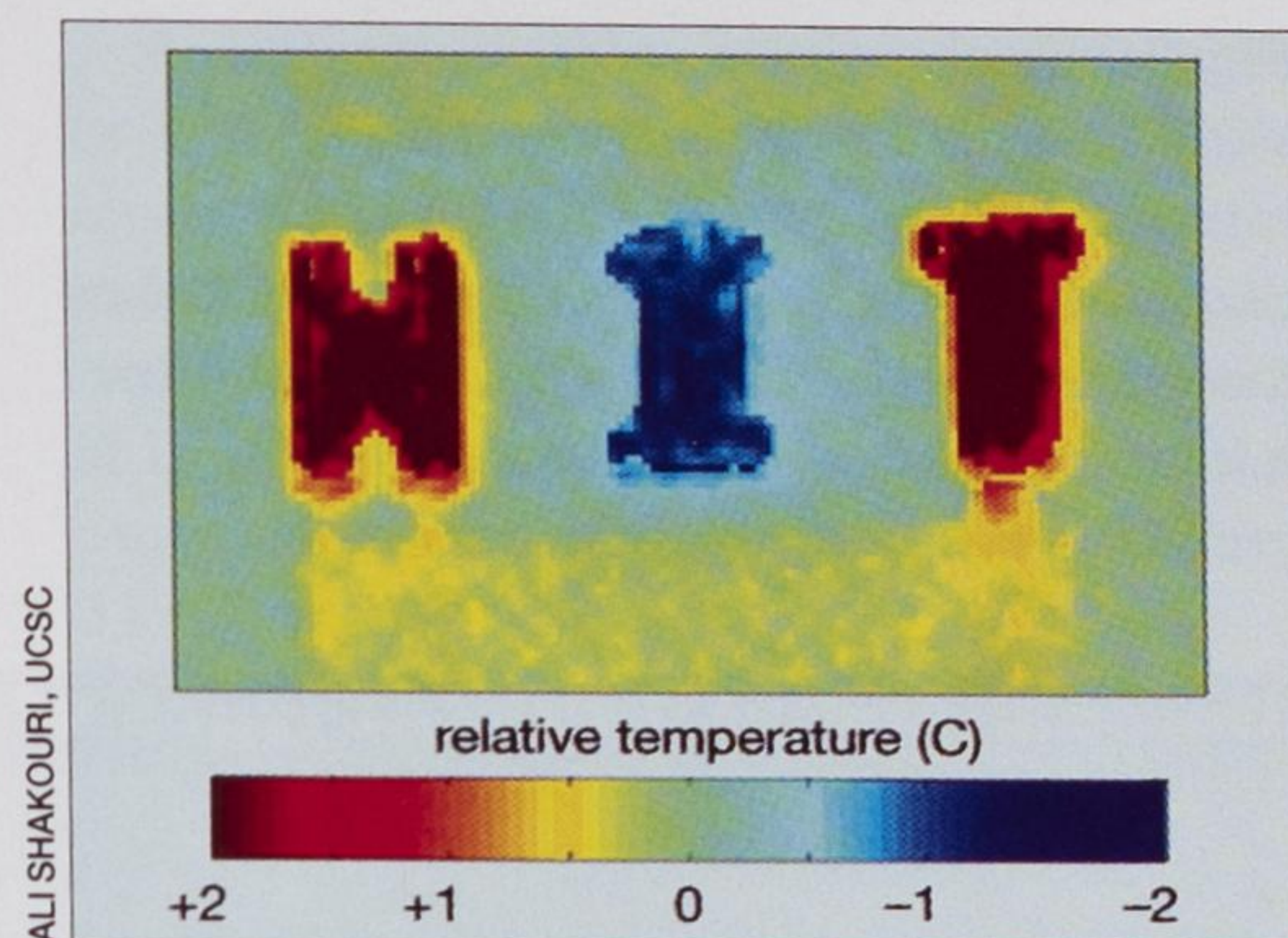
The 14th Indium Phosphide and Related Materials (IPRM) Conference was held on May 12–16 in Stockholm, Sweden. Delegates flocked in from around the globe to see approximately 200 presentations and posters on all of the latest developments and breakthroughs in InP, and its related materials and devices.

Some of the key attractions included comprehensive sessions that covered HEMTs, HBTs, VCSELs and high-speed optoelectronics. Industry and academic leaders also took to the floor to present research on InP epitaxy, reliability and packaging, GaInAsN and related compounds, as well as more niche areas such as quantum-dot physics and devices, and novel materials.

Electronic developments

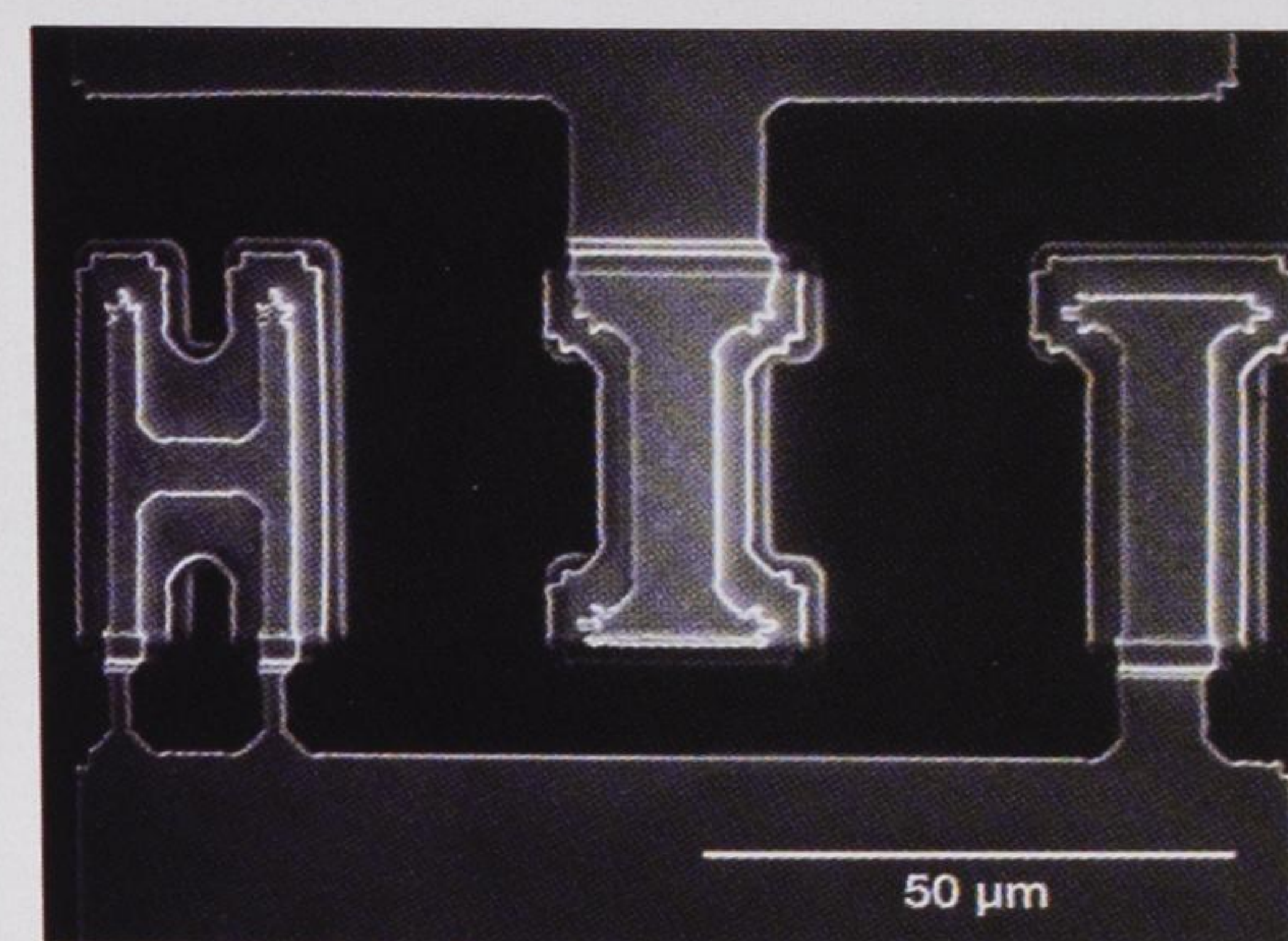
Satoshi Tsunashima and co-workers from NTT Photonics Laboratories revealed their latest digital InP/InGaAs digital-frequency divider, which they say has the highest reported toggle frequency to date (Tsunashima *et al.*). Digital-frequency dividers are a critical component of today's high-speed, wide-bandwidth optical fiber communication systems.

Fabricated with an InP HBT process, the 1/8 digital-frequency divider IC operated at 90 GHz and had an f_t and f_{max} of 155 and 245 GHz, respectively. The researchers used undoped InP emitters to reduce emitter capacitance and designed the IC with a first toggle flip-flop stage that makes use of feed-forward techniques. Additional T-type and master-slave flip-flop stages contain a conventional series-gated emitter-coupled logic configuration.



ALI SHAKOURI, UCSC

Fig. 1. A thermal image of an InP micro refrigerator and micro heaters (left) and a corresponding SEM (right). Thermoelectric coolers are ideal for spot cooling in electronic and optoelectronic devices and could one day replace conventional refrigeration systems.



The NTT device also has a clocked inverter design to enhance the dynamic circuit performance. By combining a feed-forward and clocked inverter the researchers increased the speed of the IC by 92%.

The chip was designed with a 0.5 V_{pp} internal logic swing, compared with the usual 0.2–0.3 V_{pp} logic swing found in SiGe HBT ICs. According to Tsunashima, this result illustrates that InP still has significant headroom for additional performance with respect to SiGe.

The IAF Fraunhofer Institute, Freiburg, Germany, has also been developing record-performance frequency dividers, but by using HEMTs rather than HBTs. Using 0.1 μm gate-enhancement mode metamorphic HEMTs on 4 inch GaAs substrates, A Leuther and colleagues have developed 4:1 dynamic-frequency dividers over the 58–82 GHz range (Leuther *et al.*).

The devices reached an f_t of 200 GHz, which was achieved through careful attention to the gate recess process, and featured a 10 nm AlInAs barrier and a composite channel design with indium mole fractions of 0.53 and 0.65. The devices also contained NiCr resistors, MIM capacitors and a BCB dielectric to minimize the interconnect parasitic capacitance. The median lifetime of a divider, based on a 10% transconductance degradation, was 1.1×10^6 h at 125 °C with an activation energy of 1.5 eV.

Cooling devices

Ali Shakouri of the University of California, Santa Cruz, highlighted the use of thermoelectric coolers for applications such as spot cooling in electronic and optoelectronic devices. When a current passes through a metal-semiconductor junction, the junction is either warmed or cooled depending on the direction of flow. This phenomenon, known as the Peltier effect, can be used in thermoelectric (TE) conversion. In thermoelectric coolers, transferred heat is used to provide a temperature gradient that allows a refrigeration capability.

The usefulness of a material for TE applications is determined by its TE figure of merit Z , which is dependent on temperature and includes contributions from the Seebeck coefficient, and electrical conductivity, as well as λ_E and λ_L which are the electronic and lattice contributions to the material's thermal conductivity. Today's best TE materials are characterized by $ZT \approx 1$, but if this could be increased to around 3, TE coolers could become competitive with conventional refrigeration systems.

Shakouri explained that thermionic emission of energetic carriers over a barrier mimics the Peltier effect and acts in the same way as evaporative cooling. The researchers have developed experimental TE cooling devices that achieve up to $\Delta T = 4.5$ °C near room temperature (figure 1). According to Shakouri, while these are still modest temperature drops they can be achieved with useful cooling capa-

The leading online information source for the compound semiconductor industry

COMPOUNDSEMICONDUCTOR.NET features:

- industry news, updated daily
- feature articles from the latest issue of *Compound Semiconductor* magazine
- job vacancies, industry events and a comprehensive Buyer's Guide
- information on new products
- fully searchable news and magazine archives

Use COMPOUNDSEMICONDUCTOR.NET to:

- list your company's details in the Buyer's Guide
- upload product and event information directly onto the site
- post your resume or sign up for job vacancy email alerts
- subscribe to weekly email NewsAlerts or to *Compound Semiconductor* magazine

COMPOUNDSEMICONDUCTOR.NET

For information on advertising opportunities, please contact
sales@compsemi.iop.org
 tel. +44 117 930 1033.

CONFERENCE REPORT IPRM 2002

www.compoundsemiconductor.net

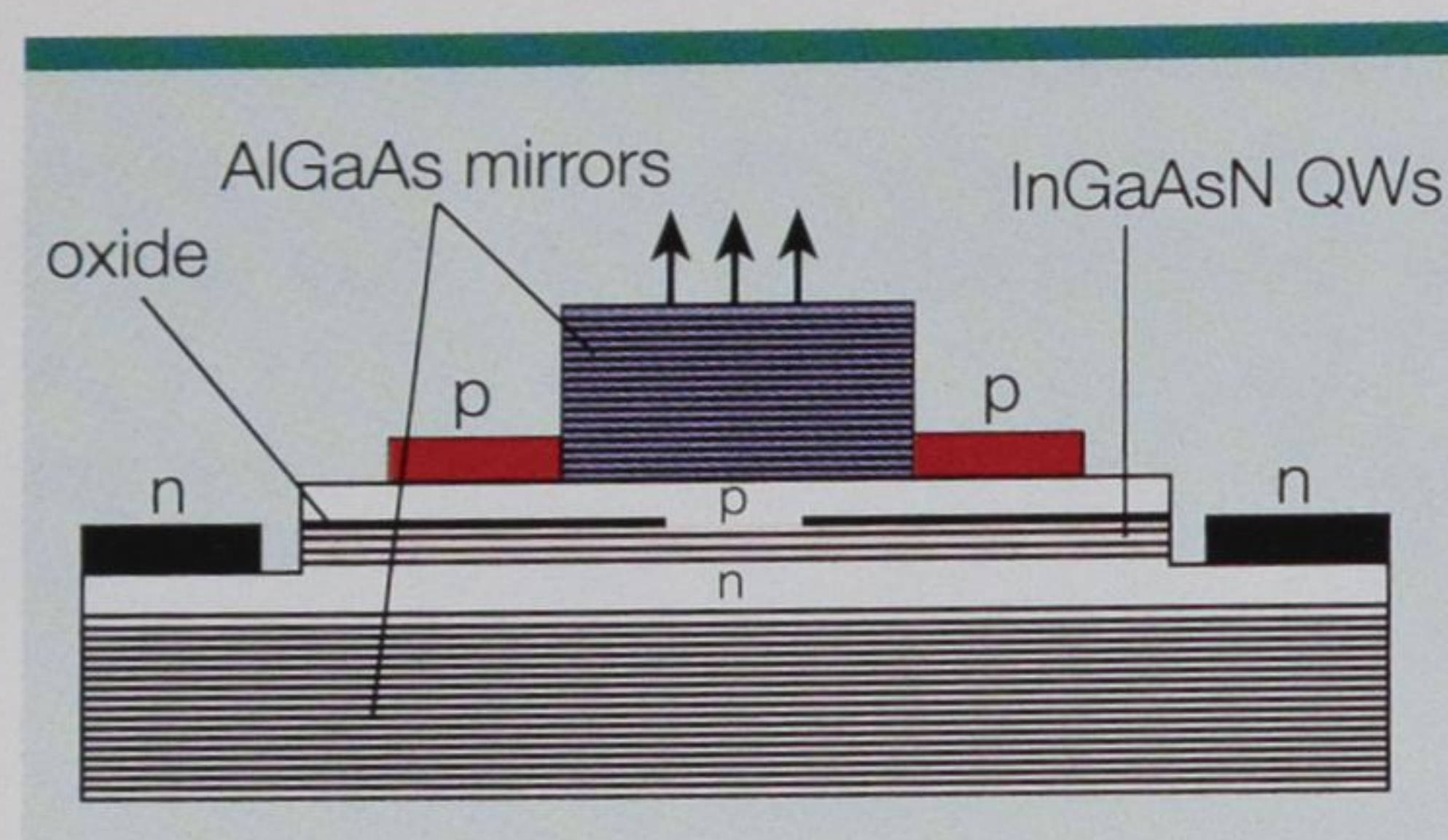


Fig. 2. Infineon's intra-cavity contacted VCSEL structure has undoped AlGaAs mirrors and a conventional p-i-n doping sequence designed to counter optical losses that are more severe at 1.3 μ m wavelengths. A laterally oxidized AlAs layer confines current and covers the active volume.

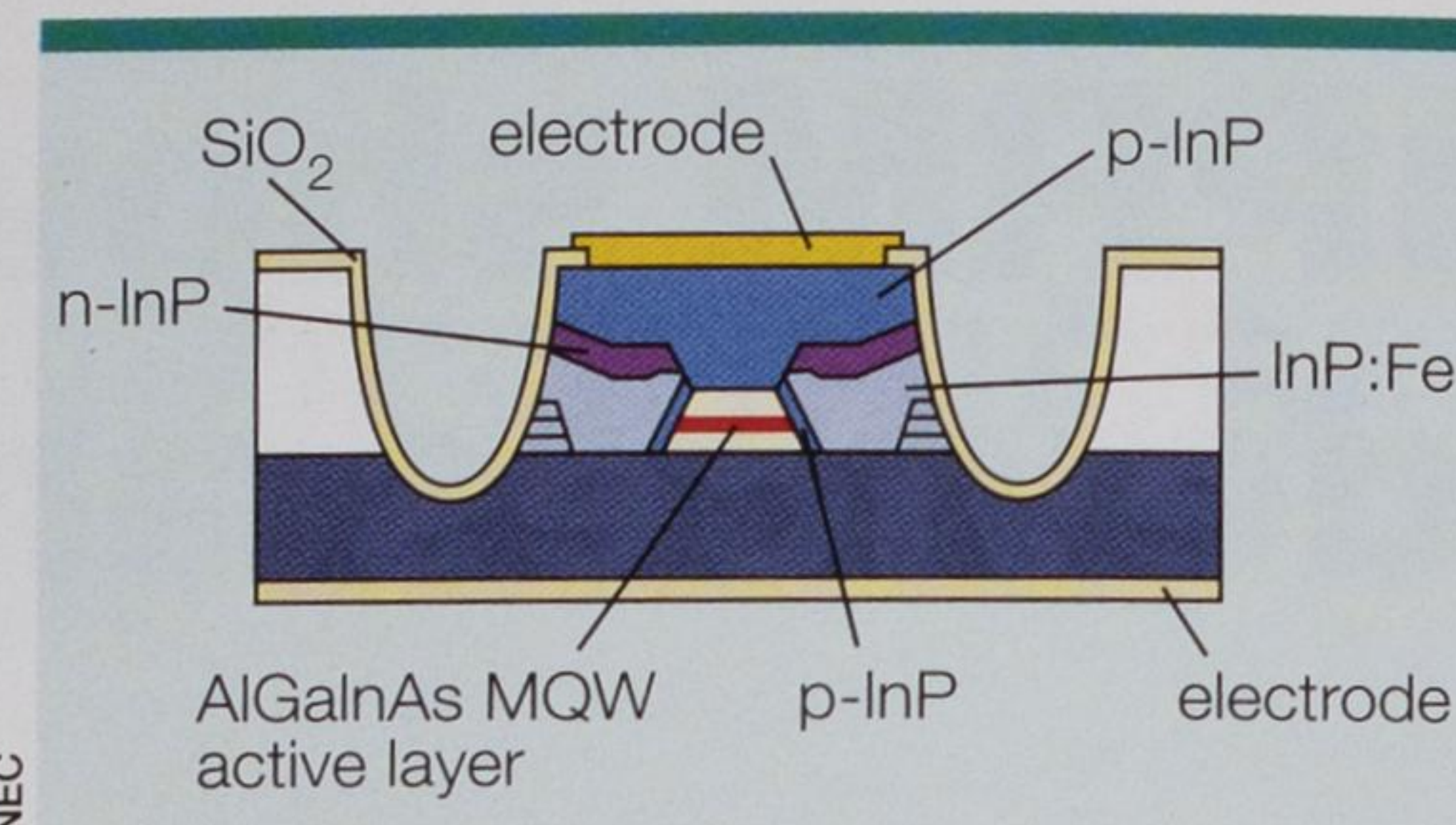


Fig. 3. NEC's buried heterostructure laser contains an AlGaInAs active layer that was grown by narrow-stripe selective MOVPE. Comprising seven compressively strained wells and tensile-strained barriers, the active layer is surrounded by a thick InP layer to prevent oxidation.

Comparison of different types of pin diode

Diode type	$f_{3\text{ dB}}$ (GHz)	Resp. (A/W)*	Advantages	Disadvantages
vertical	120	0.21	low PDL**, independent on λ std packaging concepts, array	
lateral (waveguide)	>50	up to 0.7	packaging concept comparable to laser	higher PDL, coupling λ dependent, requires SSC†
travelling-wave	110	0.6	packaging concept comparable to laser	requires spot-size converter
uni-travelling carrier	152	0.13	independent on λ	backside illumination

*Resp. = responsivity at 1.55 μ m; **PDL = polarization dependent loss; †SSC = spot-size converter.

The properties of the vertical *pin* diode, fabricated by Agethen and colleagues at IPAG, were compared with those of a waveguide, a travelling-wave and a uni-travelling carrier *pin* diode.

bilities of the order of 680 W/cm² at an ambient temperature of 70 °C, which could be very advantageous in a number of applications. Shakouri added that continued technological improvements could lead to an order of magnitude improvement in the ZT product, with InGaAs/InGaAsP TE coolers providing cooling by almost 15 °C near room temperature.

Optoelectronic advances

Optoelectronic devices for telecoms applications emerged as a major theme throughout the sessions. Henning Riechert of Infineon Technologies in Germany reported on developments in GaInNAs/GaAs-based long-wavelength edge emitters and VCSELs (Riechert). The ability to grow 1.3 μ m laser diode structures on relatively cheap, large-area GaAs substrates has sparked interest in developers of telecoms components who are keen to fabricate cost-effective devices for fiber-optic communications systems.

According to Riechert, Infineon has successfully fabricated 1.28 μ m GaInNAs ridge lasers on GaAs substrates using MOVPE and MBE. Riechert says that the lasers have

record low threshold currents of only 15 mA and output powers that exceed 75 mW, both at room temperature. Broad-area lasers have also been manufactured that have thresholds which match those of InGaAsP-based lasers.

Infineon has also manufactured monolithic GaInNAs/GaAs VCSELs that transmit up to 10 Gbit/s with a bit error rate of less than 10⁻¹¹ (figure 2). The MBE-grown singlemode devices emit at 1.306 μ m with a sidemode suppression ratio greater than 35 dB. Riechert says that these devices hold promise for next-generation optical data-link systems.

Researchers at the Photonic and Wireless Device Research Laboratories of NEC are developing uncooled, 10 Gbit/s, 1.3 μ m laser diodes based on AlGaInAs multiple QWs (Nakamura *et al.*). Using narrow-stripe selective MOVPE, T Nakamura and colleagues first grew high-quality strained AlGaInAs multiple QWs on an InP substrate. AlGaInAs MQW buried heterostructure laser diodes that emitted at 1.3 μ m were then fabricated using an Al-oxidation-free process (figure 3).

According to Nakamura, the device properties were similar to those of InGaAsP

multiple QW structures. "Threshold currents as low as 9.0 mA and operation currents below 55 mA for a 10 mW output at 85 °C were obtained," he said. The team also reported a relaxation frequency over 10 GHz and 10 Gbit/s direct modulation, also at 85 °C.

Speaking in the novel materials session, M Agethen of Innovative Processing AG (IPAG) revealed the company's latest photodetectors. The 12 µm diameter GaInAs devices are based on a *pin* design and exhibit -3 dB cut-off frequencies of up to 120 GHz (Agethen *et al.*). At frequencies of more than 20 GHz, waveguides that absorb depletion capacitance are typically integrated into a photodetector to avoid reduced responsivity with thinner absorption layers. To assess the vertical *pin* photodetector against its more commonly-used waveguide rival, the IPAG group characterized their photodetector's bandwidth and responsivity dependence as a function of the intrinsic layer thickness.

The researchers found that with an i-layer thickness of 400 nm, their devices exhibited a 3 dB bandwidth at frequencies up to 120 GHz, while maintaining an uncorrected responsivity of more than 0.16 A/W. This level of responsivity is similar to those achieved in uni-travelling carrier photodetectors, but still below the values achieved for waveguide photodetectors (see table). Agethen says, however, that the strength of the vertical *pin* concept lies in its cost, flexibility and signal quality. He also adds that vertical *pin* photodetectors can be easily integrated into HBTs and HEMTs, which makes them ideal for monolithically integrated optoelectronic ICs.

Laser diodes target WDM

Taking a look at laser diodes, Hajime Asahi and co-workers from Osaka University and the Fukui University of Technology have developed TlInGaAs/InP double heterostructure laser diodes that operate at 300 K with reduced-emission wavelength temperature dependence (Asahi *et al.*). Asahi expects these laser diodes to be used in WDM technology.

The InGaAsP/InP laser diodes that are typically used in today's WDM networks exhibit wavelength variations that arise from bandgap energy changes. To combat this, these devices use Peltier cooling elements to stabilize the temperature of the laser diode.

However, Asahi says the variation in wavelength of his team's TlInGaAs laser diode is only 0.04 nm/K. This wavelength change is significantly smaller than the 0.4 nm/K typically shown by an InGaAsP/InP Fabry-Perot laser

diode or 0.1 nm/K for an InGaAsP/InP DFB.

Using gas source MBE, the researchers grew TlInGaAs/InP double heterostructure laser diodes with a Tl composition of 6% on Si-doped InP substrates. The laser structure comprised a Si-doped n-type InP cladding layer, an undoped TlInGaAs active layer, a Be-doped p-type InP cladding layer and a Be-doped p-type InGaAs contact layer.

Asahi explained how the researchers went on to fabricate "metal-stripe" laser diodes that emitted light with a wavelength variation of only 0.064 nm/K between 190 and 300 K. He revealed that his team achieved pulsed lasing at 1565 nm from 77 to 300 K, with a threshold current density of 0.8 kA/cm² at 77 K and 5 kA/cm² at 300 K.

Researchers at the Heinrich-Hertz Institute (HHI) and Infineon Technologies have fabricated a 1.3 µm buried heterostructure Fabry-Perot laser with a monolithically integrated monitor photodiode and a 45° beam reflector for bottom-side emission. Facets were prepared on the wafer and an optical field transformer function was also included within the Fabry-Perot laser resonator to form the far field.

Packaging a laser's OEICs in the so-called lead frame technology for plastic SMT-packages cuts production costs, and the researchers believe that their device paves the way to the fabrication of low-cost optoelectronic modules. "Compared with hybrid solutions, there are no drawbacks in die size or overall performance," explained K Janiak of the HHI. "We expect to reduce costs during module fabrication and also in on-wafer OEIC characterization."

Further reading

M Agethen *et al.* 2002 *Proc. 14th IPRM Conf.* (Stockholm, Sweden) 673.

H Asahi *et al.* 2002 *ibid.* 701.

A Leuther *et al.* 2002 *ibid.* post-deadline paper no. 7.

T Nakamura *et al.* 2002 *ibid.* 35.

H Riechert 2002 *ibid.* 19.

S Tsunashima *et al.* 2002 *ibid.* 43.

Colombo Bolognesi is professor of physics and head of the compound semiconductor device laboratory at the Simon Fraser University in Canada.

SAES gas purifiers give you the solution for defect-free epi growth. Our wide selection of MonoTorr heated getter and MicroTorr ambient metal supported technologies use the most advanced chemical processes to remove oxygen and carbon species from hydrogen and nitrogen carrier gases in any epi process.

Our specialty gas purifiers for ammonia, arsine, phosphine, HCl and others are proven and tested with analytical and process data to be sure our formula gives you the right answer.

Complete your formula for growth with SAES.



SAES Pure Gas, Inc.
(805) 541-9299

www.PureGasTechnologies.com



Some just talk ...
... we innovate.

invent

**# 1 in delicate wafer and thin
substrate handling**

innovate

**Automated temporary bonding
and debonding**

implement

**Backside lithography for
vias processing**

EVG provides proven technology for automated temporary bonding and debonding of fragile and ultra-thin wafers for compound semiconductor manufacturing. Our precision alignment systems solve the most critical lithography processes and achieve the ultimate in handling safety and reliability.

Wafer Bonders – Precision Alignment Systems – Resist Processing Systems – Wafer and Mask Cleaners – Integrated Systems
SOI – MEMS/MOEMS – Compound Semiconductors – Advanced Packaging – Power Devices – www.EVGroup.com



EV Group
E-mail: CS@EVGroup.at
Europe: +43 7712 5311-0
US East: +1 401 784 0008
US West: +1 602 437 9492
Japan: +81 45 438 0663

Optical monitoring comes of age at IC-MOVPE 2002

MOVPE may be a mature technology that is widely used in manufacturing, but nitrides and optical monitoring provoked much of the discussion at this year's IC-MOVPE, writes **Jon Newey**.

The organizers of this year's International Conference on MOVPE (IC-MOVPE) must have congratulated themselves on a job well done as the meeting closed. Good organization, healthy attendance figures, very enjoyable social events sponsored by some of the big names in the MOVPE world and great weather all conspired to make the event a success. Berlin turned out to be an excellent venue with plenty for attendees to see and do outside of the conference sessions.

Metalorganic supplier Mochem was the center of much attention. As the conference opened, the company announced an agreement to join with Akzo Nobel to create a new metalorganics supplier combining Mochem's expertise in group V sources with Akzo's larger group III operation (*Compound Semiconductor* July 2002 p23). Mochem also ensured that crowds regularly gathered at its stand by installing a large-screen TV to show live World Cup soccer matches.

MOVPE is a relatively mature technology that is now widely used in mass-production environments. As such, much of the technical program focused on its application to the growth of particular structures rather than the MOVPE process itself. These applications included lasers, LEDs and HBTs, covering material systems as diverse as II-VIs, antimonides, dilute nitrides, InP and GaAs. With MOVPE being applied to the production of blue LEDs and lasers, and the development of high-power HEMTs, the III-nitrides were particularly well covered.

The conference may be best remembered as the one at which *in situ* optical monitoring came of age. A large number of talks were given by those implementing optical techniques to monitor and control the MOVPE process (*Compound Semiconductor* June 2002 p41). ORS of StAsaph, UK, and LayTec of Berlin gave presentations on their respective growth monitoring technologies, and

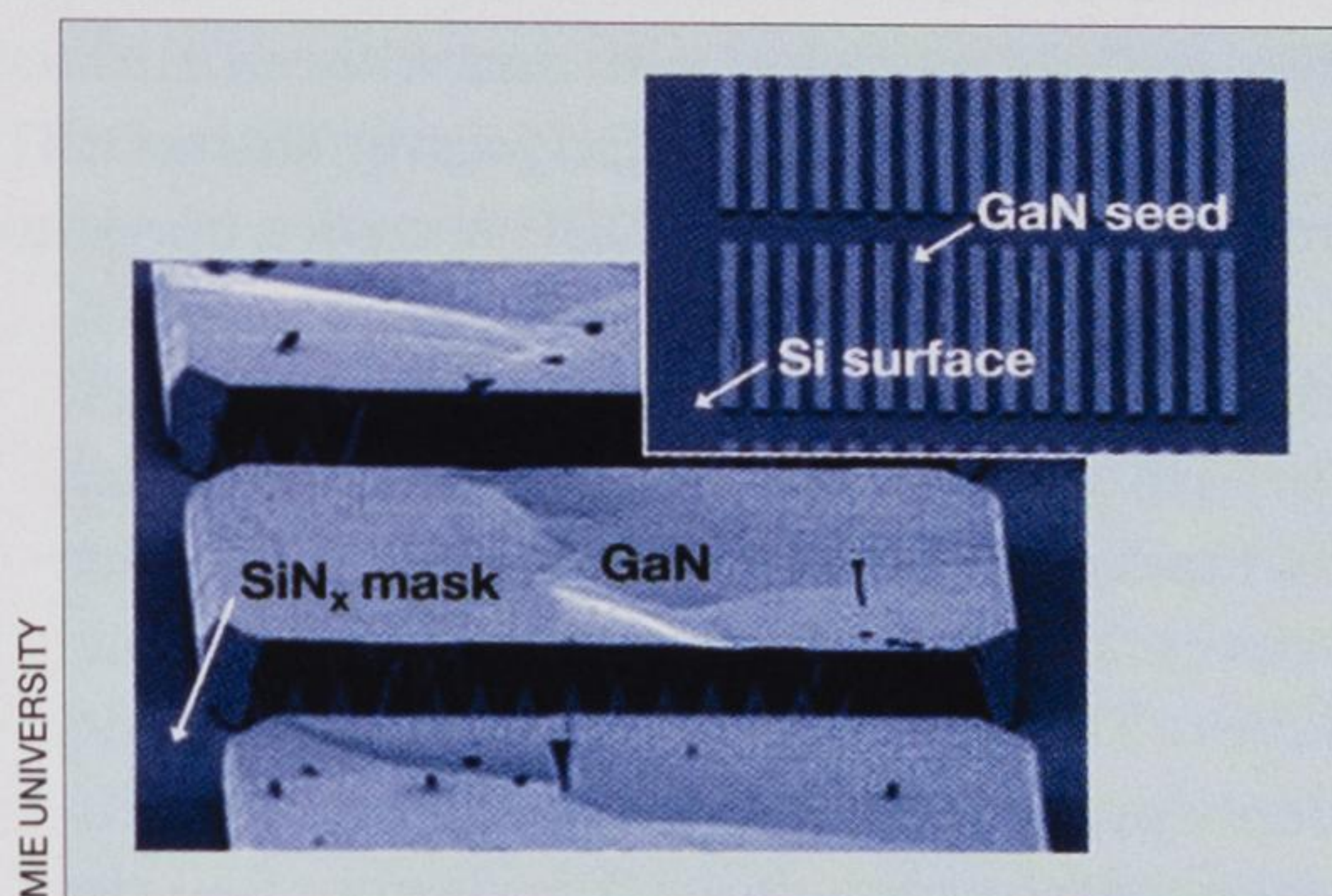


Fig. 1. An SEM image of one of the GaN islands grown onto a grooved Si surface. The inset shows the GaN seed stripes that are left after etching of the GaN and Si, and removal of the SiO₂ mask stripes.

many talks not specifically about growth monitoring made reference to its use. This indicates that such monitoring equipment is now being seen as an essential accessory to an MOVPE reactor.

GaN on Si

An invited talk from Armin Dadgar of Otto-von-Guericke University gave a good overview of the driving forces behind worldwide efforts to grow GaN on Si, and also the difficulties in achieving device-quality GaN on this substrate (*Compound Semiconductor* July 2002 p45). Dadgar pointed out that the main problem was the large difference between the thermal expansion coefficients of GaN and Si, and not the large lattice mismatch. The difference in thermal properties causes cracking as the wafer cools after growth or is cycled to different temperatures during deposition. This prevents large-area, thick, high-quality GaN layers being successfully grown. Dadgar therefore focused his talk on the strain engineering methods his group has adopted to grow thick, crack-free layers for LEDs and transistors.

The first of these methods was selective-area deposition to give islands of thick GaN

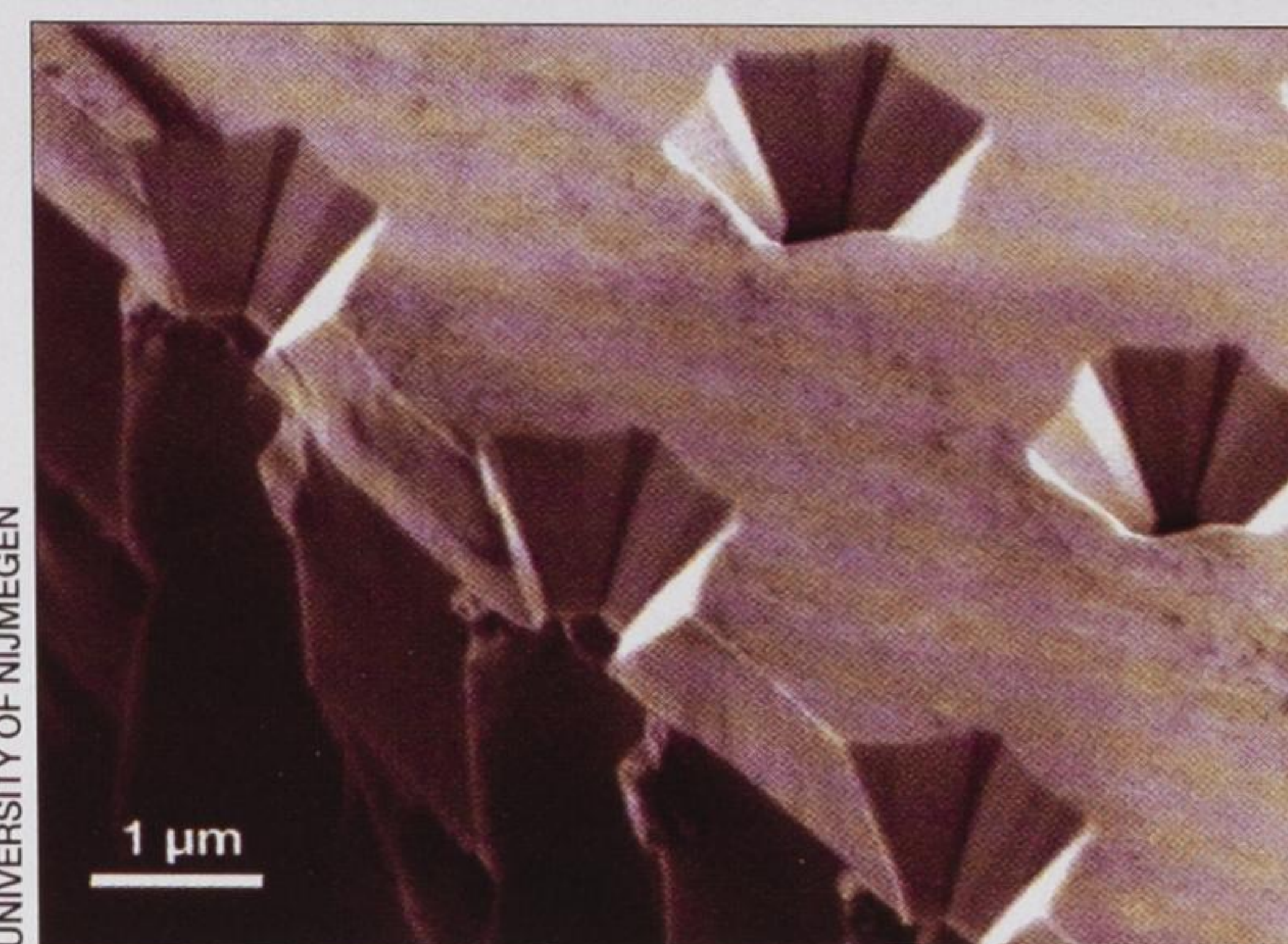


Fig. 2. An SEM of a 2 μm thick GaN layer overgrowing holes etched into a Si wafer. The holes become completely overgrown when the GaN layer is 3 μm thick.

small enough to prevent cracking. Crack-free LED structures containing AlGaIn/GaN multilayers 2.5 μm thick were produced over an area of 300 × 300 μm². Crack-free layers 3.6 μm thick were possible over a 100 × 100 μm² area.

The second approach involved the use of low-temperature AlN interlayers 10–15 nm thick. Using these it was possible to grow crack-free device structures over the whole wafer. The low-temperature AlN layers introduce compressive stress to compensate the tensile thermal stress. Depositing the AlN interlayers at lower temperatures reduces the layer stress and dislocation density. By using this approach Dadgar's group was able to fabricate transistors and blue LEDs.

GaN ELO on Si

Several talks focused on epitaxial lateral overgrowth (ELO) as a route to achieving high-quality GaN on Si. Hiroyuki Naoi of Mie University in Japan showed how his group had successfully produced areas of GaN free from cracks by using grooved Si substrates. A 0.3 μm GaN layer was deposited on a Si wafer, followed by SiO₂ masking stripes 5 μm wide and 100 μm long. The GaN and Si was etched

to a depth of 1 μm and the SiO_2 mask removed to leave behind GaN seed stripes for subsequent ELO. The stripe areas covered the Si wafer in a grid pattern to enable crack-free growth. Each $100 \times 100 \mu\text{m}^2$ area of stripes was separated by 20 μm from its nearest neighbor.

Prior to GaN growth, the Si surface was nitrided in the MOCVD reactor. GaN growth was initiated on the seed stripes without deposition on the nitrided Si. At a growth temperature of 1000 $^\circ\text{C}$ the GaN layer successfully coalesced. The growth temperature was then increased to achieve a smooth surface and the dislocation density in the GaN islands was $1 \times 10^8/\text{cm}^2$ (figure 1).

Paul Hageman of Nijmegen University, the Netherlands, reported an alternative ELO method using overgrowth of holes etched into Si. The holes were 4 μm deep, 1.5 μm in diameter and separated by 2.5 μm . A 100 nm thick AlN nucleation layer was deposited at 850 $^\circ\text{C}$, and GaN growth was at 1170 $^\circ\text{C}$. Figure 2 shows an SEM of a 2 μm thick GaN layer as it begins to overgrow the holes. Deposition starts on the AlN between the holes and then begins to coalesce over the holes. Growth in the vertical direction is faster than the lateral direction leading to inverted pyramid-shaped holes in the GaN layer. Complete coalescence was seen after 3 μm .

TEM of the GaN layer showed vertically propagating dislocations over the AlN. Dislocations in the overgrown GaN were only present in the basal plane and resulted from the bending of vertical dislocations in the GaN adjacent to the holes. On a larger scale, the GaN layer began to crack at a thickness of 2 μm .

Semi-insulating GaN

Semi-insulating layers are important for preventing losses in high-speed devices and are also useful as an underlayer to provide carrier confinement in Hall measurement samples. Transition metals such as Cr and Fe are used to make III-V semiconductors semi-insulating and have the same effect in GaN.

Sten Heikeman from the University of California, Santa Barbara (UCSB) reported Fe doping of GaN using ferrocene (Cp_2Fe) as a precursor during MOCVD. A linear relation between ferrocene partial pressure and Fe doping was established through SIMS analysis of the grown layers. SIMS depth profiles of layers in which the ferrocene flow had been turned on and off showed the Fe gradually decaying as the undoped layer was grown, in contrast to the sharp transients seen for

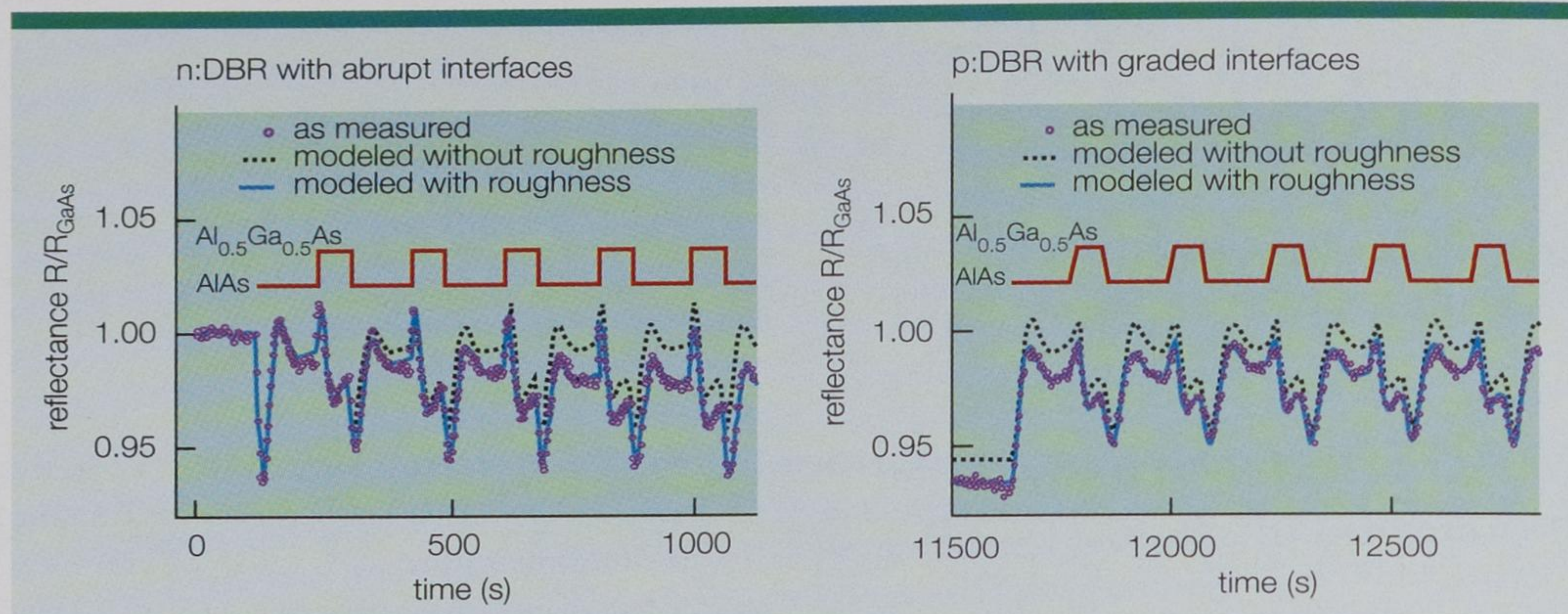


Fig. 3. Data modeled with and without surface roughening, and real data for the n:DBR (left) and the p:DBR (right). The n:DBR shows a pattern of exponentially increasing roughness, while the p:DBR shows a constant level of roughness.

the switching of Si doping in the same layer.

To investigate the cause of this slow decay, an Fe-doped layer was grown and the surface was etched before the growth of an undoped layer. This showed a much sharper SIMS depth profile for Fe, leading the group to propose that the slow tail off in doping was the result of an Fe-rich layer riding on the growth surface that was gradually diminishing as growth progressed. The etch removed the Fe-rich layer allowing a sharper Fe profile.

Production MOVPE

The opening talk of the conference was given by Klaus Streubel and concerned the use of MOVPE for the mass production of high-brightness LEDs at Osram Opto Semiconductors. Streubel gave an overview of the market for HB-LEDs and referenced market figures from Strategies Unlimited which showed that while the semiconductor business as a whole had experienced a bad year in 2001, contracting by 31%, things were a lot better for the LED market which experienced 0% growth. As with other fields in the semiconductor business, the performance of devices has been increasing while relative costs have fallen. Historically, the efficiency of LEDs has risen by a factor of 10 per decade (with III-N LEDs improving at twice this rate) and the cost per lumen has been decreasing at the same rate.

The MOVPE process accounts for 42% of the cost of an LED. This includes capital, labor and materials (wafers, metalorganics and gases). Although calibration, test runs and maintenance all help to improve quality, they decrease production throughput and add to costs. It is difficult to get the throughput/quality balance right, but Osram Opto has been successful in reducing test and calib-

ration runs, while improving wafer-to-wafer and cross-wafer uniformity. It has also extended the useable wafer area by 18% through reduction of the wafer rim exclusion width from 5 to 0.3 mm.

New applications for LEDs, such as general lighting, will require device lifetimes of more than 50,000 hours. Lamp reliability is related to packaging as well as the chip. However, most chip degradation processes are related to the MOVPE process, in particular impurity levels and crystal quality. Streubel unveiled a list of issues that he wanted reactor and source suppliers to address to further improve productivity. These included consistently high source quality, lower rates of deposition in the exhaust and vacuum systems that lead to particle generation, standardized use of *in situ* monitoring for surface temperature and growth rates, and lower lead times for spare parts delivery.

In situ monitoring

With *in situ* monitoring being very much in evidence at the conference, it would be easy to forget that this is a relatively immature field. Although now a widely used tool to monitor and adjust growth conditions, it is often only semi-quantitative. Thomas Zettler of LayTec described the need for quantitative analysis of *in situ* measurements of III-nitride growth to support growth optimization as being urgent.

Zettler's presentation discussed the use of reflectance spectra during GaN growth to quantitatively determine the surface roughness and what he termed "wavyness" – the variation in layer thickness on a 1 μm lateral scale. Both of these factors affect the real-time reflectance transients very differently. By analysis of the decay in amplitude and the

decay in overall reflectance, Zettler was able to establish how wavyness and roughness were changing as growth progressed, and thus was able to minimize these through adjustment of the growth conditions.

Zettler rounded up his talk by highlighting a number of areas where improved quantification is needed. Top of the list was susceptor and wafer surface temperature measurement. With this in mind, Richard Balmer of QinetiQ, UK, discussed the temperature-dependent shift in the SiC absorption band-edge, and how this can be used to monitor wafer temperature during the growth of GaN/AlGaIn HFETs on SiC.

Over 15 growth runs, Balmer noted that while the thermocouple reading remained constant, the temperature measured by pyrometry drifted by 50 °C, highlighting the need for better optical monitoring. Reflectance spectra from SiC were measured *in situ* between room temperature and 1140 °C. The temperature was determined using a thermocouple, which was itself referenced to pyrometry readings from the front surface of the

uncoated susceptor. The absorption edge energy was taken as the energy at which the normalized reflectance value was 0.5.

During 5.5 h of actual GaN growth at a constant thermocouple reading, the temperature from pyrometry was seen to drop by 24 °C. The shift in the SiC absorption edge measured by reflectance corresponded to a drop of 16 °C. This was attributed to changes in heat transfer as the surfaces of the reaction chamber became coated. Using this technique the desired temperature could be set with a run-to-run reproducibility of less than 10 °C. Balmer expects this accuracy to improve when using a higher resolution spectrometer.

***In situ* roughness monitoring**

Zettler's colleague Kolja Haberland discussed how *in situ* optical techniques could be used to monitor the interface roughness of complex structures. In this case the structure was a VCSEL containing an AlAs/AlGaAs n:DBR (bottom mirror) and an AlGaAs/AlGaAs p:DBR (top mirror) with graded Al content at the interface. Interface roughness in the

mirror stack has an effect on the mirror reflectivity and hence VCSEL performance. Haberland monitored the 310 nm reflectance transients normalized to the reflectance from a GaAs wafer. At 310 nm the penetration depth is less than 20 nm, making the measurements surface specific.

The major difference in transients from the two stacks was that the n:DBR gave much sharper peaks with steep slopes due to the abrupt, non-graded interfaces. As can be seen in figure 3, the modeled data was plotted using a roughness factor to fit the experimental data. The n:DBR shows exponentially increasing roughness. This leveled off at 3.5 nm peak to peak roughness after 20 of the 55 repeats. The p:DBR roughness was almost constant with 2 nm peak to peak roughness giving the modeled data the best fit to the experimental data. Haberland proposed two possible reasons for this. First, the active region provides a smoothed surface for the top mirror to grow on, and second, residual indium after the active region growth has a surfactant effect on subsequently grown layers. ●

MBE XII 2002

International Conference on Molecular Beam Epitaxy

San Francisco, CA
15-20 September

Sponsored by IEEE Lasers and Electro-Optics Society

For more information, visit

www.i-leos.org

IEEE






new challenge?

AOI is exploring the boundaries of laser technology and inventing ways to build better semiconductor lasers. We are currently expanding our Houston area manufacturing and R&D groups.

A sample of our current openings:

- Vice-President of Manufacturing
- MBE Growth Engineer
- Quality Control Manager
- RF Packaging Engineer
- Semiconductor Processing Engineers
- Semiconductor Processing Manufacturing Mgr.

for further information or to submit a resume:
jobs@ao-inc.com • 13111 Jess Pirtle Blvd. • Sugar Land • TX • 77478

AOI is an E.O.E.



ATMI

ATMI is a major provider of materials and equipment used by the global semiconductor industry. Annual revenues of \$300 million, plants throughout the US, Europe and Asia, and 1,100 employees worldwide are some of the distinctions that led to us being named one of Fortune's "100 Fastest Growing Companies." Based in our **Danbury, CT** headquarters we have the following opportunity available:

SENIOR RESEARCH SCIENTIST
 -Job Code MLS2002092-

As a key member of the interconnect team, you will:

- develop MOCVD processes for back end-of-line barrier & dielectric materials
- collaborate with product marketing to determine customer needs/requirements
- devise and perform deposition experiments and thin film characterization studies
- prepare presentations and reports for customers and internal/external groups

The right individual will have:

- Bachelor's (or higher) in a Scientific discipline
- proven expertise in R & D and product development
- demonstrated knowledge of thin film materials, deposition processes and their application to semiconductors
- excellent communication, presentation and team-working skills
- experience with the patent process & MOCVD or PECVD desirable

We offer an attractive salary and comprehensive benefits package, which includes stock options and profit sharing. To apply, please email your resume to: kmincieli@atmi.com. You must reference the job title "Senior Research Scientist" and the job code "MLS2002092" in the subject line of your email in order to be considered for the position.

WWW.ATMI.COM

Though all submissions will be carefully reviewed, please note that we can only respond in the event mutual interest exists. Principals only, NO AGENCIES.
 ATMI is an Equal Opportunity Employer

European Conference on Silicon Carbide and Related Materials

ECSCRM2002

September 1-5, 2002, Konsert & Kongress, Linköping, Sweden

**Organized by
 Linköping University, Sweden**



**For more information:
www.ifm.liu.se/ecscrm2002**

To advertise your product in this section, contact Joanna Hook on tel. +44 117 930 1033, or email joanna.hook@iop.org.

MicroLine 500

Micro-Metric Inc

The MicroLine 500 automatically performs critical dimension measurements on cassettes of wafers. The system employs an auto-loading robot, pre-aligner and motorized positioning stage along with pattern-recognition software to load, align, and measure wafers without operator intervention. It provides measurement accuracy of 0.01 micron with 4 nm (one Sigma) repeatability. The system includes an extremely flexible, proprietary programming language (MCL) that offers the user full control of the system's functionality.

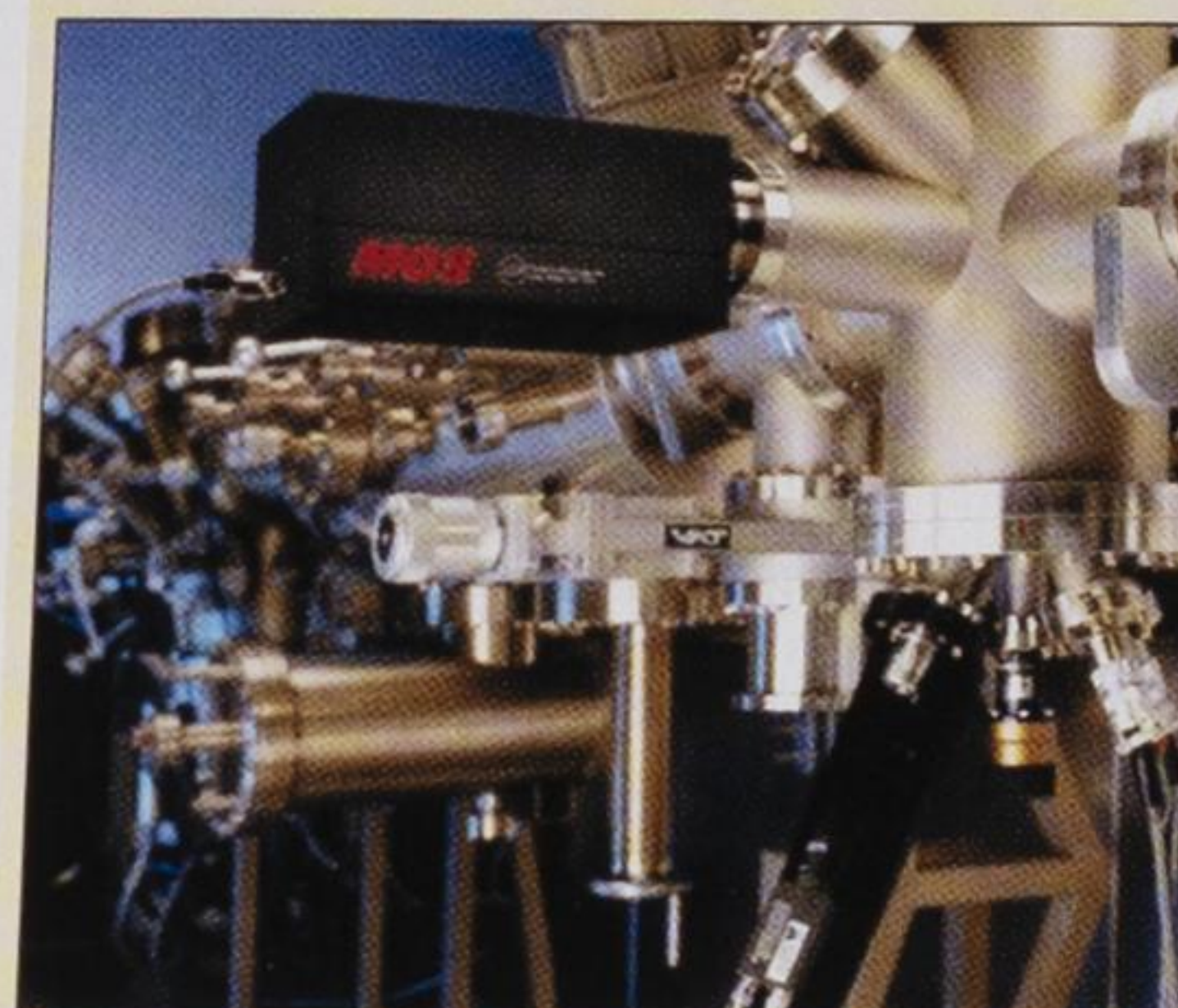


Contact Micro-Metric Inc, Suite 102, 1050 Commercial St, San Jose, CA 95112-1419, USA
Tel. +1 408 452 8505
Fax +1 408 452 8412
Email info@micro-metric.com
Web www.micro-metric.com

Four Products from k-Space

k-Space Associates Inc

k-Space specializes in advanced thin-film characterization products. Our **kSA Multi-beam Optical Sensor (MOS)** provides *in-situ* or benchtop, 2D thin-film curvature and stress monitoring. The **kSA 400 RHEED** analysis package puts the power of analytical RHEED at your fingertips. k-Space is proud to announce two new products. Our **kSA BandiT** uses semiconductor band-edge absorption to monitor wafer temperature, and is perfect for monitoring low temperature growth processes where pyrometers are not sensitive. The **kSA Pro-Rate** offers real-time, *in-situ*, reflectivity monitoring. The Pro-Rate provides real-time deposition rate, film thickness and optical constants with a simple easy to use package.

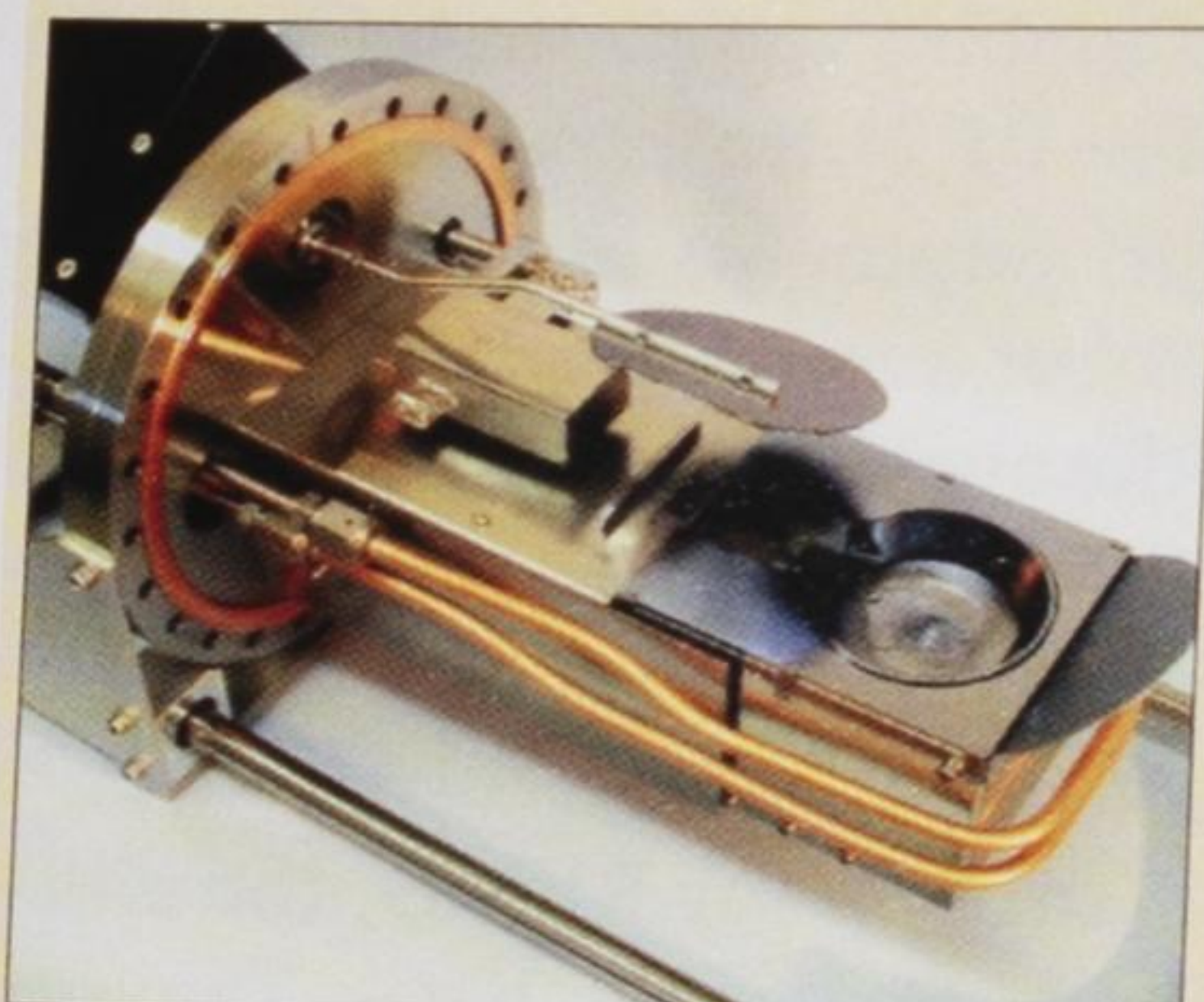


Contact k-Space Associates Inc, 3626 W. Liberty Road, Ann Arbor, MI 48103, USA
Tel. +1 734 668 4644
Email info@k-space.com
Web www.k-space.com

UHV-Electron-Beam-Evaporator

MBE Components

The EBV200-100 is designed for operation in UHV environments. It is CF-flange mounted and fully UHV compatible with a maximum bakeout temperature of 250 °C. For Si or Ge evaporation in Si-MBE systems we provide a specially adapted set of shielding parts manufactured from highest-purity mono-crystalline Si. These plates and rings cover all parts of the metallic body that are potentially subject to electron or ion bombardment and that face the substrate.



The EBV200-100 is optionally equipped with an *in-situ* evaporant refill unit. With a refill under vacuum the source yield between chamber openings is virtually doubled.

Contact Dr. Eberl MBE-Komponenten GmbH, Gutenbergstr. 8, D-71263 Weil der Stadt, Germany
Tel. +49 7033/6937-0
Email sales@mbe-components.com
Web www.mbe-components.com

Tegal 6500 HRe⁻

Tegal

Tegal's 6500 HRe⁻ high-density plasma etch tool is the first etch system to incorporate Tegal's breakthrough in gallium arsenide (GaAs) via etch rate, setting the pace for next-generation etch processes. With an average GaAs etch rate of 10 microns per minute, depth non-uniformity of $< \pm 5\%$ and photoresist selectivity of greater than 20:1, Tegal's 6500 HRe⁻ system enables compound



semiconductor manufacturers to reduce their manufacturing costs through the implementation of new, higher-rate backside via etch processes.

Contact Jim McKibben, 2201 S. McDowell Blvd, Petaluma, CA 94954, USA
Tel. +1 707 763 5600
Fax +1 707 765 9311
Email jmckibben@tegal.com

C2 Optical Surface Analyzer

Candela Instruments

Candela Instruments C2 Optical Surface Analyzer offers fully automated surface inspection for 2 inch to 8 inch optoelectronic or semiconductor wafers. C2 combines scatterometry, reflectometry, ellipsometry and optical profilometry to measure reflectivity and topographic variations across the entire wafer surface.

Applications include: Defect Detection and Classification (particles, stains, pits, bumps, and scratches); Film Thickness Uniformity; and Surface Roughness measurements.

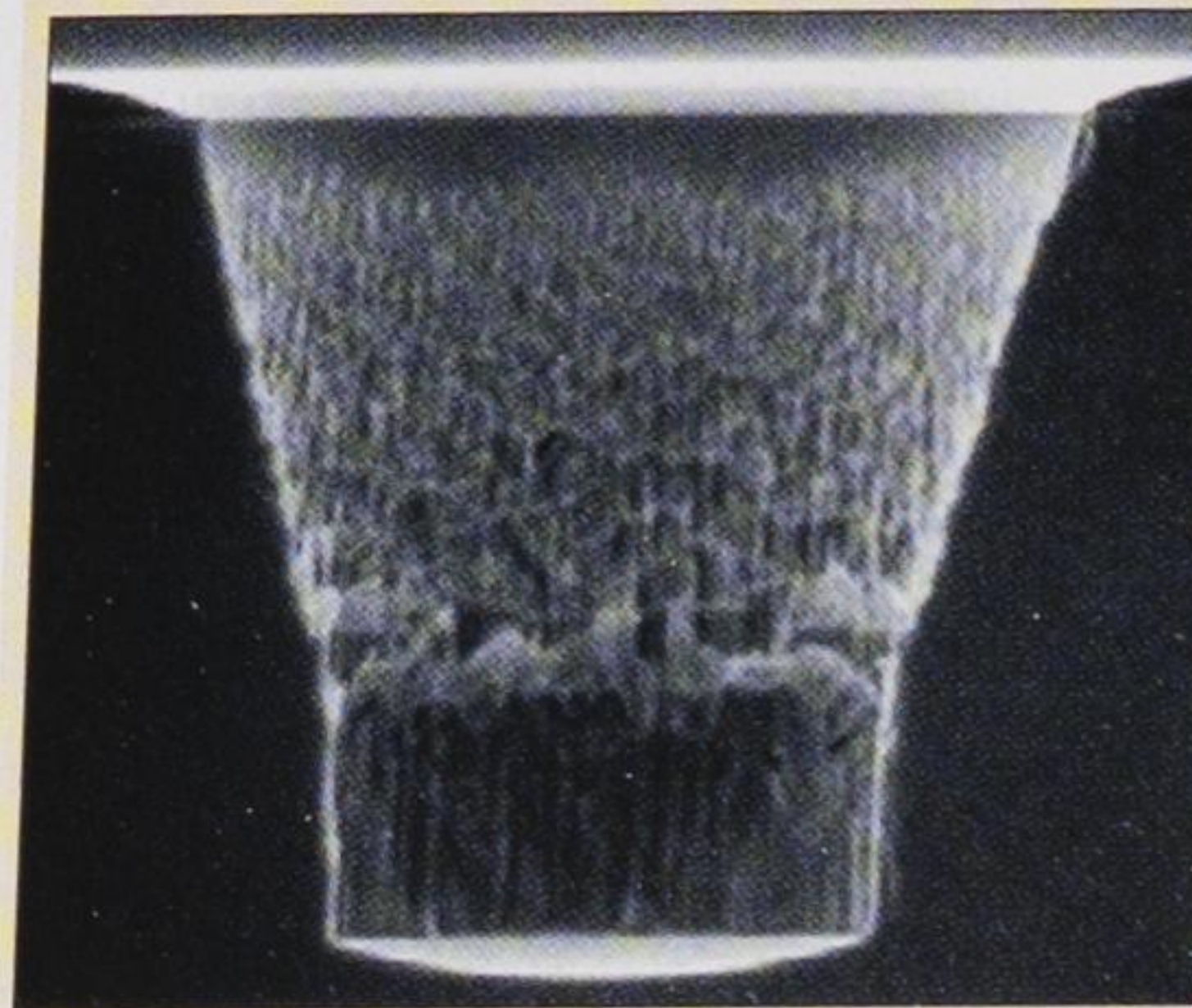


Contact Gale Lane, Candela Instruments, 48890 Milmont Drive, Suite 103D, Fremont, CA 94538-7362, USA
Tel. +1 510 413 0900
Email query@candela-inst.com
Web www.candela-inst.com

High-Rate GaAs Via Etching

Unaxis Semiconductors

Unaxis Semiconductors has now introduced its GaAs via III, 3rd generation high-rate GaAs via etch process solution. Highlights of this breakthrough technology include: Improved GaAs etch rates – Manufacturable etch rates $> 10 \mu\text{m}/\text{min}$ have been demonstrated. Adjustable via slope – Sloped vias help facilitate downstream via metallization. Unaxis has achieved GaAs via etch rates in excess of $15 \mu\text{m}/\text{min}$. Fast etch rates alone are not enough – particularly



if the increased rate comes at the expense of uniformity, via profile or formation of pillars. GaAs via III provides a manufacturable, high-rate, GaAs via etch process.

Contact Notker Kling, Unaxis Semiconductors, 10050 16th St N., St. Petersburg, FL 33716, USA
Tel. +1 727 577 4999
Email nkling@unaxis.com
Web www.semiconductors.unaxis.com

Differing fortunes for RF Micro Devices and Vitesse

RF Micro Devices produces the best quarterly result in a long time, while Vitesse posts a loss and says that the break-even point won't come for at least three quarters.



RFMD is now shipping power amplifiers to all of the top-five handset manufacturers.

For just a brief moment in mid-July, it was a return to the good old days: RF Micro Devices released a good earnings report, and the stock shot up 11% on the news. But then investors recalled that this is 2002, not 2000, and the stock was beaten back below its starting point.

On July 16 RFMD announced that for the quarter ended June 30 the company had generated sales of \$103.9 m – a new record that represented a 3.5% improvement over the previous quarter and a 48.4% increase over the year-ago period. Surprising? Yes indeed, quite literally, as the company announced as late as June 7 that sales would be in the \$98 m to \$101 m range. The prepared announcement explained that the overshoot was due to the fact that “components shipped to the handset market in the last month of the quarter exceeded customer forecasts”. David Norbury, CEO of RFMD, says that there was a surge of orders late in the quarter, some of which the company was able to book and ship quickly.

Moreover, management is predicting that revenue in the September quarter will increase by 5–10%, with a slight increase in profits.

RFMD took a \$22.1 m special charge of obsolete inventory and assets in the quarter. This was done as part of a restructuring announced in July 2001 that has seen the company outsource all of its production packaging and convert its former packaging line to an R&D facility.

The gross profit margin for the quarter decreased 90 basis points (0.09%) compared with the previous quarter, to 39.9%. This was due to declines in average selling prices (ASPs). ASPs, which had held steady in the March quarter, slid 5–10% in the June quarter, and historical patterns suggest that the decline will

total 15–20% over the next four quarters.

Looking forward, management said that it expects to improve its market share in the power-amplifier market at the expense of its competition, while reducing its cost structure. However, they also anticipate that in the near term the gross profit margin will continue to be hurt by declining ASPs, although the impact will be partially offset by higher wafer-fab utilization and continued improvements in yield.

RFMD is now shipping power amplifiers to all of the top-five handset manufacturers, and is expecting to see growth in shipments to all five companies in the September quarter. In the last three months, Motorola was named as a 10% customer for the first time, and RFMD also doubled its shipments to Samsung in the quarter.

David Norbury says that RFMD is now processing 4 inch GaN-on-sapphire wafers in its Charlotte, NC, facility (the former RF Nitro), and that the company expects to begin shipments of GaN “starting material” in the December quarter. Norbury is expecting GaN to dominate the market for high-power amplifiers for base stations.

Tough times for Vitesse

While things are looking up for RFMD, the situation at Vitesse Semiconductor remains bleak. The company posted a huge net loss for the June quarter and announced that it will lay off 200 more workers (around 17% of its workforce). Non-recurring charges relating to restructuring and write-downs of goodwill led to a net loss of \$735.9 m on \$43 m in revenue. Without the one-time charges, which totaled \$695.5 m, the loss would have been \$20.6 m.

Vitesse's share price has dropped more than 73% since the beginning of the year. Following the announcement on July 18, Vitesse shares closed at \$3.18, down 17 cents (5.1%).

And there is more pain to come. The company said that it would take a yet-to-be-determined charge in the September quarter for severance costs related to the job cuts. The company won't reach the break-even point on an operational level until revenues can be boosted to around \$60 m – something which CEO Lou Tomasetta says can't happen until the first quarter of 2003, at the earliest.

Selected RFMD financial data from the last five quarters

	Period ending				
	Jun 30, 2002	Mar 31, 2002	Dec 31, 2001	Sep 29, 2001	Jun 30, 2001
total revenue (\$m)	103.9	100.434	100.551	98.271	70.052
cost of goods sold (\$m)	62.504	59.504	61.658	61.902	65.901
gross profit (\$m)	41.396	40.930	38.893	36.369	4.151
R&D (\$m)	23.051	22.398	19.055	16.977	16.015
net income (\$m)	2.349	2.769	3.501	1.532	-28.386

Vitesse's InP development program has been reoriented towards optical products for the OC-192 market.

Market overview

Company	Symbol	Closing price on July 18	52-week low-high	Market cap*	P/E ratio†
GaAs IC companies					
Anadigics	ANAD	4.14	3.98–21.89	126.6 m	N/A
Celeritek	CLTK	8.43	6.36–16.91	103.1 m	N/A
Endwave	ENWV	1.62	1.50–7.60	14.4 m	N/A
Multilink	MLTC	0.49	0.38–18.40	36.5 m	N/A
RF Micro Devices	RFMD	8.27	5.67–32.53	1.366 bn	137.83
Sirenza Microdevices	SMDI	1.35	1.13–11.65	40.2 m	N/A
Skyworks Solutions	SWKS	4.76	3.01–41.45	658.5 m	N/A
TriQuint	TQNT	6.83	5.55–25.90	897.4 m	N/A
Vitesse	VTSS	3.18	2.29–23.35	638.6 m	N/A
Opto companies					
Agilent	A	21.73	18.00–37.99	10.088 bn	N/A
Agere	AGRa	2.20	1.38–7.00	3.598 bn	N/A
Alcatel Optronics	ALAO	1.52	1.50–10.45	25.1 m	N/A
Coherent	COHR	24.00	23.80–39.50	693.0 m	58.54
Cree	CREE	13.57	10.35–33.32	987.8 m	N/A
JDS Uniphase	JDSU	3.62	2.24–12.44	5.485 bn	N/A
Stratos Lightwave	STLW	0.84	0.81–11.00	56.5 m	N/A
Uniroyal Technology	UTCI	0.21	0.07–8.10	6.0 m	N/A
Semiconductor materials and equipment companies					
ATMI	ATMI	21.30	14.50–37.10	650.7 m	N/A
AXT	AXTI	7.30	6.75–26.55	163.8 m	N/A
Emcore	EMKR	3.99	3.60–27.79	146.3 m	N/A
Kopin	KOPN	6.15	5.30–19.05	426.4 m	N/A
Tegal	TGAL	1.00	0.13–2.85	14.3 m	N/A
Trikon	TRKN	9.11	6.96–15.90	127.4 m	N/A
Veeco	VECO	15.93	15.15–41.70	462.7 m	N/A
European companies (currency data in €)					
Aixtron	AIXG.F	8.95	1.79–3.33	579 m	N/A
Bede	BED.L	1.79	1.05–2.87	52 m	N/A
Bookham	BHM.L	1.25	1.63–7.03	177 m	N/A
Filtronic	FTC.L	2.14	0.47–3.06	158 m	N/A
IQE	IQE.L	0.53	30.00–196.75	87 m	N/A
Picogiga	PGIG.LN	1.60	1.04–5.62	10 m	N/A
Riber	RIBE.LN	1.11	1.05–5.66	21 m	6.76
STS	SRTS.L	1.20	1.01–2.69	38 m	6.48

*Market capitalization = # shares × current share price; †Price/earnings ratio = current share price/(income for the last four quarters/# shares).

Vitesse has also reorganized its operations into four segments: storage, ethernet, transport and networking. Tomasetta said that transport, which is the biggest segment, showed a slight decline in the quarter, as it had done in the previous two quarters. Transport products, which include physical layer chips for long-haul telecommunications, accounted for \$16.7 m, or 39%, of the total sales. The other three areas all showed a slight increase for the quarter. “The further our products are from the core of the network, the better we perform,” commented Tomasetta. However, he went on to say that the other three segments should be starting to show reasonably strong growth by next year.

Shipments of CMOS chips, instead of GaAs, at Vitesse continue to grow. In the June quarter the split

was 77% silicon, 23% GaAs. Tomasetta says that Vitesse is using just 10–20% of its manufacturing capacity. He also commented that Vitesse's InP development program, which has taken the place of the company's original GaAs fab in Camarillo, CA, has been reoriented towards optical products for the OC-192 (10 Gbit/s) market. Products in development include laser drivers, detectors and optical waveguide systems. The original intention behind Vitesse's investment in InP was to develop high-speed digital ICs for the 40 Gbit/s market. However, according to Tomasetta, Vitesse does not expect its customers to be placing orders for such products within the next 16–18 months, and therefore the company is stopping work in that area until the market is closer to emerging. ●

Advertisers' Index

Aeronex	IBC	Kingmax Optoelectronics	26
Aixtron	5	Microchem	24
Bandwidth Semiconductor	10	Micro-Metric	8
Bede	28	MIOMD conference	34
Crystal Systems	10	Mochem	IFC
CS-MAX conference and expo	7, 31	Nitride Semiconductors	21
DCA	32	Praxair	OBC
Emcore	12	QinetiQ	34
Epichem	18	Raboutet	30
European SiC conference	52	Riber	40
EV Group	48	SAES Pure Gas	47
GaAs IC symposium	56	Shipley Metalorganics	44
IntelliEPI	26	Sopra	27
International MBE conference	51	Surface Technology Systems	11
IQE	14, 15	Thomas Swan Scientific Equipment	17
Ismeca	36	Unaxis	39
Japan Energy	22		

ANNOUNCING THE 17th ANNUAL

2002 GaAs IC TECH EXHIBITION

(in conjunction with the 24th Annual IEEE GaAs IC Symposium)

PLACE: MONTEREY CONFERENCE CENTER,
MONTEREY, CALIFORNIA

DATES: October 20-22, 2002

- ◆ The largest forum of its kind showcasing all aspects of the GaAs IC industry.
- ◆ One complimentary Symposium Registration Package per booth.
- ◆ Be a Symposium Benefactor by partially or fully sponsoring a coffee break, lunch or reception for either the Symposium or Exhibition. Appropriate recognition will be given to corporate benefactors in the Advance Program and at the Event.

CONTACT:

Harry Kuemmerle, III, Exhibition Manager
VIP MEETINGS & CONVENTIONS
1515 Palisades Drive, Suite I
Pacific Palisades, CA USA 90272-2167
Tel: (310) 459-4691 Fax: (310) 459-0605
e-mail: harry.k@vipmeetings.com OR vipmtgs@aol.com

visit our website: www.gaasic.org for additional information
on current or previous exhibitors and Symposium program

Palladium Cell Replacement

AERONEX Infinity GPS[®] Provides the Solution to Palladium Cell Troubles

INFINITY GPS

No Damage Due to Power Outages

Low Pressure H₂ Operation

Low Operating Costs

Performance

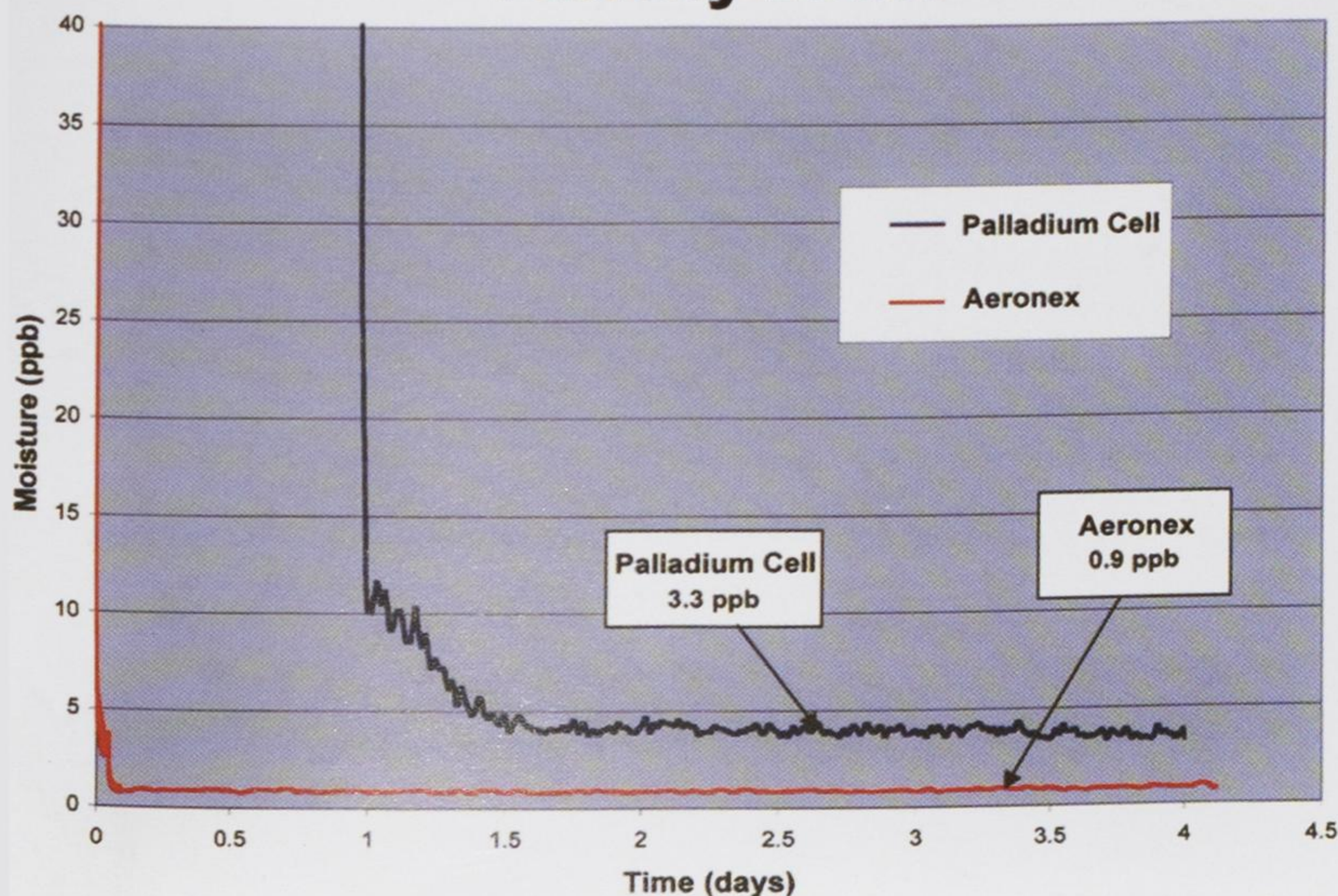
The Infinity GPS provides less than 1 ppb (part-per-billion) outlet purity for removal of O₂, H₂O, CO, CO₂, and hydrocarbons with very low pressure drop at high flows, regardless of source gas pressure.

Value

The Infinity GPS enables savings through the use of liquid H₂, lower utility requirements, and its robust reliable design. All of which translate into a lower cost-of-ownership than palladium cells.



Fast Dry-Down



More Gas Purification
Solutions for
NH₃, AsH₃, PH₃, and N₂
Complete purifier packages for
GaN and GaAs tools

AERONEX
The Source for Gas Purification

www.gaspurifier.com

+1 (858) 452-0124
(800) 511-9761 Toll Free in U.S.
6975 Flanders Drive • San Diego, CA 92121

III
V
—
PRAXAIR

Believe it or not, these numbers do add up. That's because you can go beyond what you thought possible with Praxair's III-V process gases and systems. Our unparalleled Bulk Specialty Gas Delivery System gives you a steady flow of gases at rates that are *three times higher than the industry standard*. And our 6.5-grade Ammonia offers 99.99995% purity for higher-yield blue and white LED production. Factor in our ultra-high-quality Arsine and Phosphine and you have a complete III-V package. **It's not fuzzy math at all when you can solve your III-V challenges at praxair.com**

