

COMPOUND SEMICONDUCTOR

Three-Fives and Silicon Heterostructures

October 2003 Volume 9 Number 9



GaAs MANUFACTURING
**GaAs fabs change strategies to
face up to market conditions**

ALSO INSIDE

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over LED patent**

**Toshiba develops
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**Light-emitting Si
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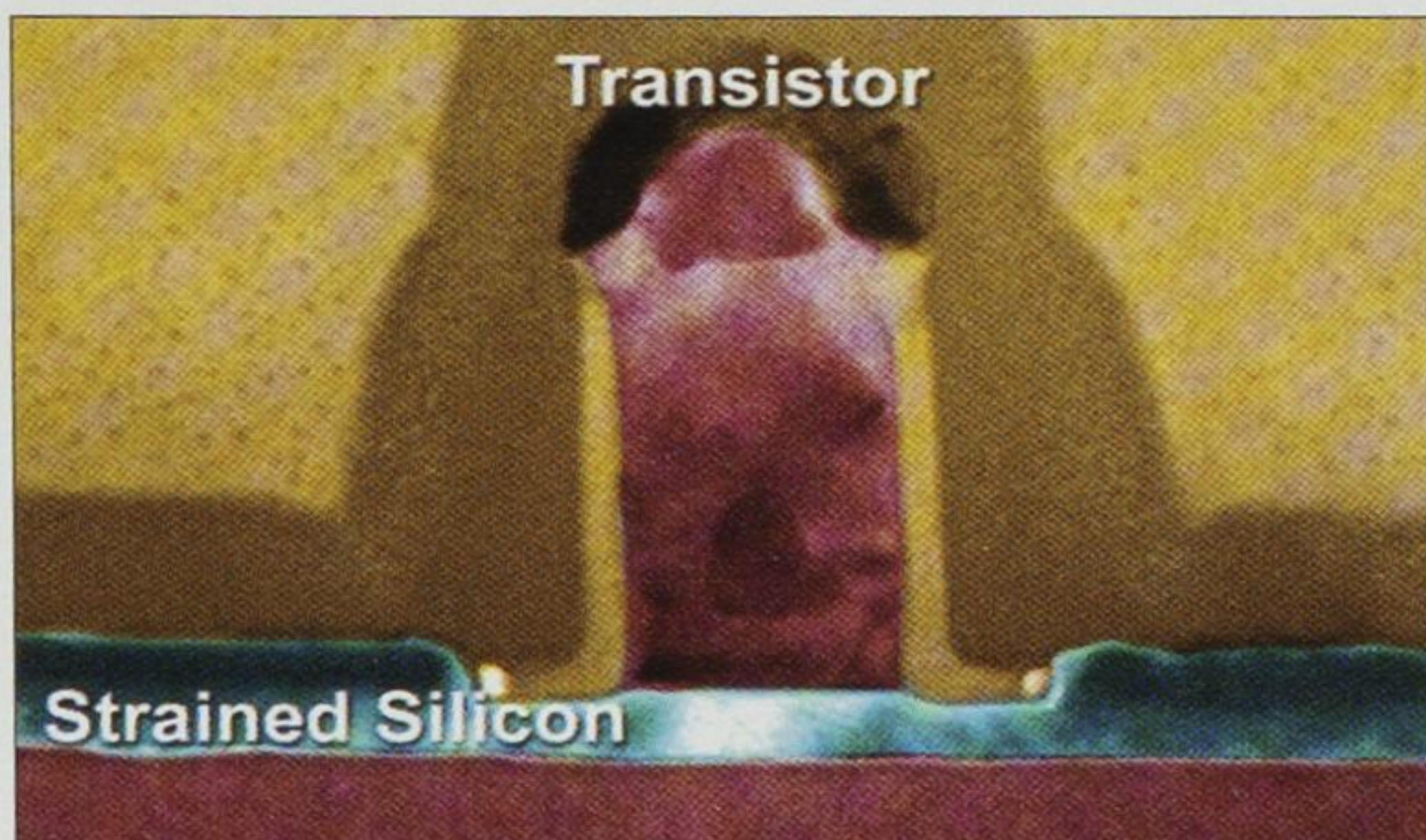
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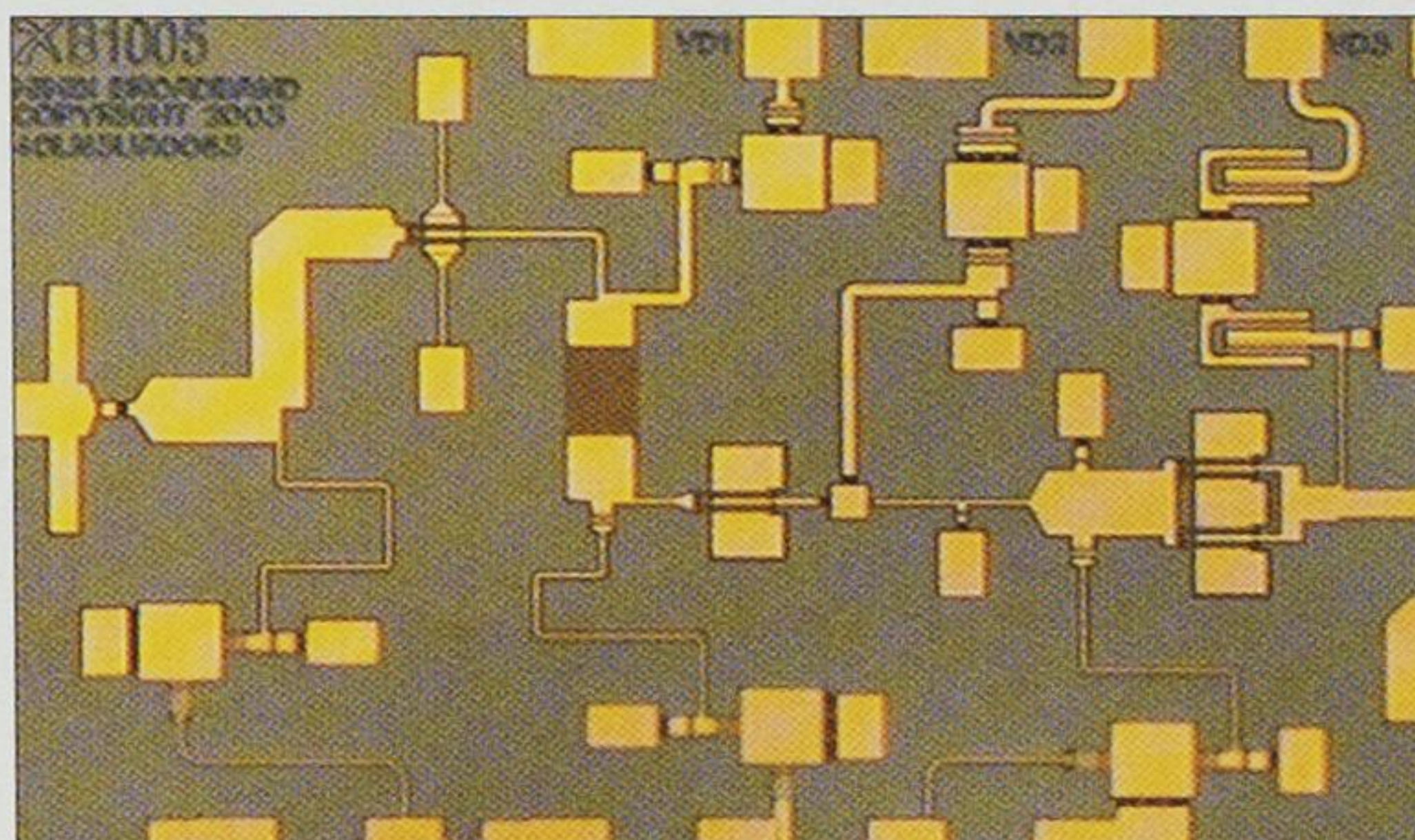
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Three-Fives and Silicon Heterostructures

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Three-Fives and Silicon Heterostructures

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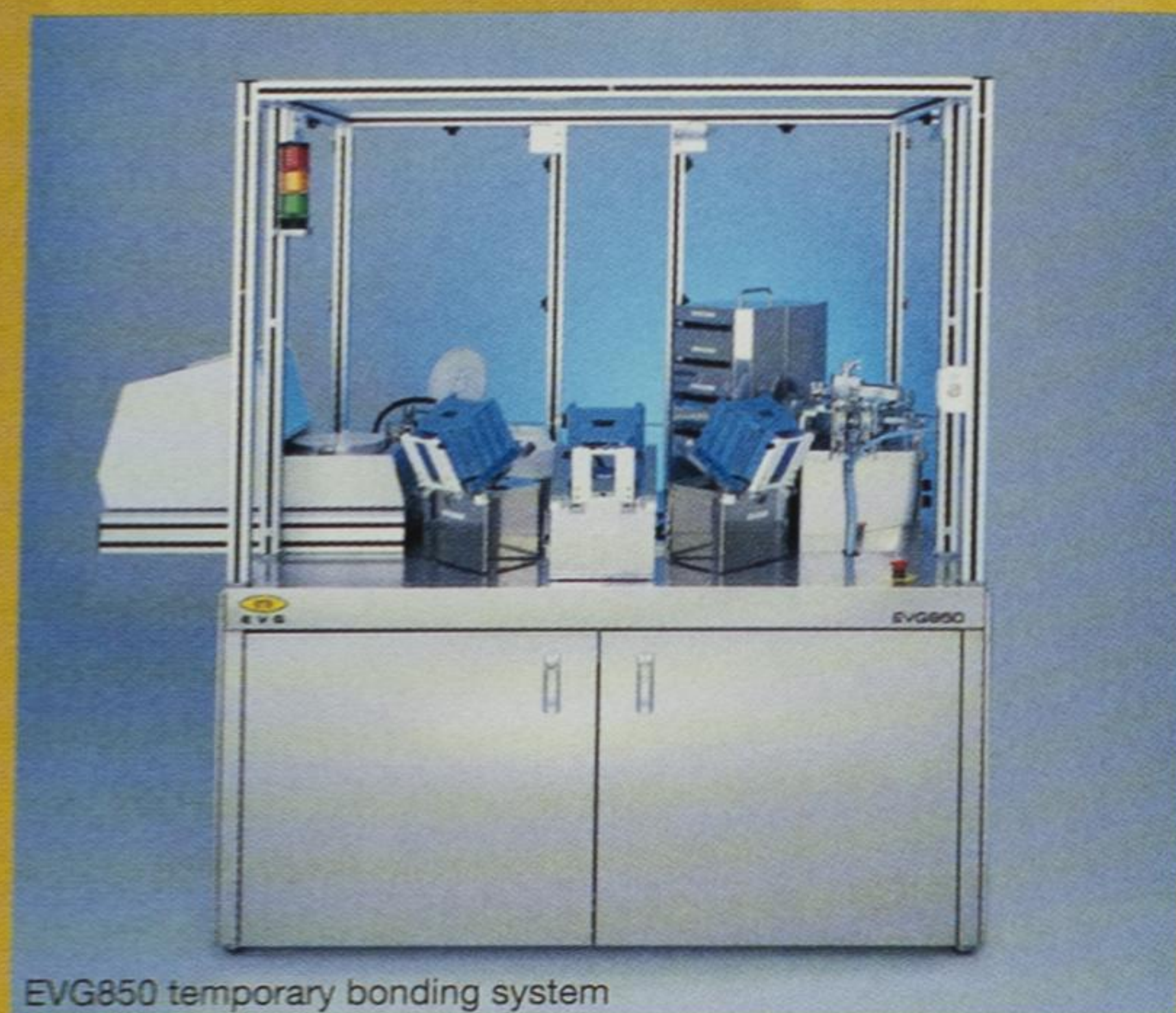


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Nichia sues Taiwanese rival Epistar

By Tim Whitaker

In its latest attempt to defend its intellectual property (IP) rights, Nichia has become involved in legal action against Epistar, a rival blue LED maker based in Taiwan. This marks the first time that Nichia has tackled one of the many Taiwanese manufacturers of blue LEDs, and was an inevitable step given Nichia's frequently stated attitude that it would vigorously defend its patent portfolio.

A number of Taiwanese companies are trying to corner the low-cost, high-volume end of the blue LED market in the same way that Taiwan's LED industry now dominates the AlGaInP LED market. Incidentally, Epistar is also being sued by Lumileds over a patent relating to AlGaInP LEDs.

Epistar is being sued for the infringement of Nichia's Taiwan patent no. 160,722 by Epistar's blue LED products. According to a statement from Nichia, the company was granted a preliminary attachment order by a Taiwanese court, which was executed on

September 22, 2003. The court order freezes some of Epistar's bank accounts in order to preserve funds in the event of damages being awarded to Nichia (see footnote).

This could be the tip of the iceberg as far as Taiwanese manufacturers are concerned. Nichia's statement also says that "even though the current legal action is directed at one of Epistar's products, Nichia intends to take additional necessary legal actions against other Epistar products and/or other products of other companies." To protect its IP and its licensing partners' legal rights, Nichia says it is willing to enforce its IP against any other infringement in any country in the world.

In 2002, Nichia surprised the nitride LED community by reaching a series of separate IP-related agreements with its main rivals in Japan, Europe and the US. Toyoda Gosei, Cree, Lumileds and Osram Opto Semiconductors all struck deals with Nichia that ended (or in the case of Lumileds, prevented) a series of expensive and time-consuming lawsuits.

These companies all held strong IP positions of their own, so it was in Nichia's best interests to settle. However, other manufacturers in Taiwan and Korea do not have the patent portfolios necessary to hold their own against Nichia, and it was inevitable that the Japanese company would challenge its rivals. In July this year, Nichia announced that an unnamed Korean company had agreed to stop producing blue LEDs rather than face legal action from Nichia.

With a large number of companies – Epistar, United Epitaxy Company, Arima and Formosa Epitaxy are among the biggest – producing blue LEDs in Taiwan, and other manufacturers in Korea and China, it seems that Nichia's IP attorneys could be busy for a long time to come.

● As this issue was going to press, a Taiwanese court granted a preliminary injunction order to Nichia, which prevents Epistar from making, selling, importing or using products that allegedly infringe on Nichia's patent.

Bookham acquires New Focus and Ignis Optics

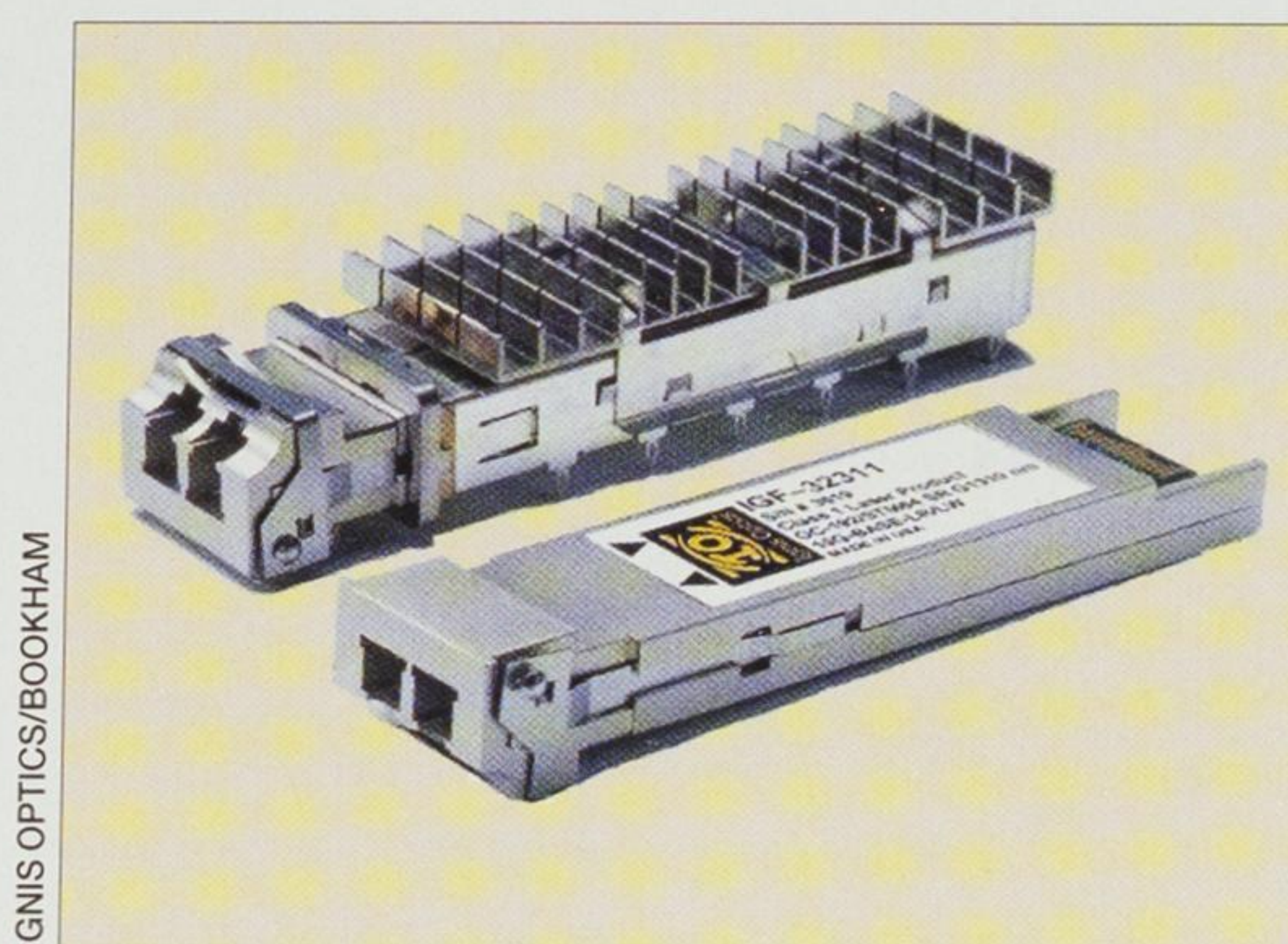
In a busy few days in late September, Bookham Technology announced its intention to acquire New Focus, a provider of photonics and microwave products to diverse markets, including the semiconductor, defense, research, industrial, biotech/medical and telecom test and measurement industries. The acquisition should expand Bookham's non-telecom optical business, reduce the company's dependence on major telecom customers, expand its manufacturing capabilities and increase its cash reserves.

Just days later, Bookham announced that it was also acquiring Ignis Optics, a provider of optical modules for communications networks based in San Jose, CA.

New Focus on non-telecom

Bookham will issue 84 million new shares to New Focus shareholders, valuing the deal at around £118 million (\$191 million). New Focus is expected to have around £65 million in cash to add to Bookham's reserves when the deal is completed in December, at which point Bookham and New Focus shareholders will own approximately 73% and 27% of Bookham, respectively.

While Nortel and Marconi respectively



IGNIS OPTICS/BOOKHAM

The acquisition of Ignis allows Bookham to target the datacom market with products such as these XFP transceiver modules.

accounted for 60% and 13% of Bookham's revenue in the first six months of 2003, the deal will bring important non-telecom customers such as KLA Tencor, ASML and other major semiconductor capital equipment manufacturers, and several tier-one defense contractors. Another attraction for Bookham was New Focus's state-of-the-art manufacturing facility in Shenzhen, China, which is expected to lower Bookham's manufacturing costs.

In between the two acquisition announcements, Marconi revealed that it had sold its

6.3% stake in Bookham for £16.76 million (\$28 million). In July 2003, Nortel sold 30 million shares in Bookham, representing about half its stake in the company.

Ignis Optics opens up datacom

Bookham will acquire Ignis Optics for \$15.5 million of new Bookham shares, to be issued on completion of the deal in early October. Additionally, Bookham shares up to a value of \$1.5 million will be issued in early 2005, should Ignis meet certain performance criteria during the 2004 fiscal year.

Ignis Optics designs and manufactures small-form-factor pluggable (SFP and XFP) single-mode optical transceivers for optical datacom and telecom networks. The company's transceiver design skills provide an excellent match for Bookham's position in optics and electronics design.

Toshiba develops 200 mW violet laser – see p19

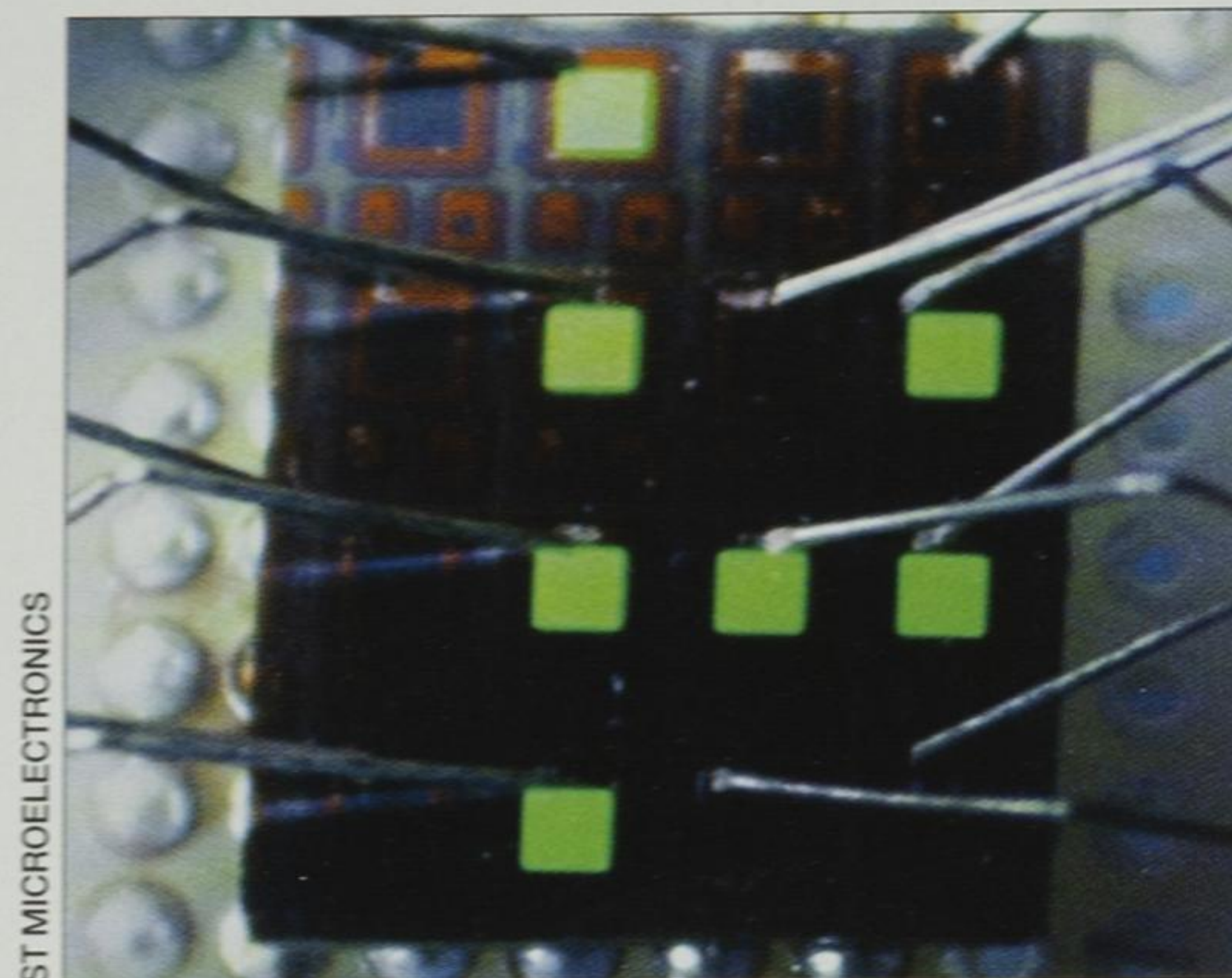
Oxford Instruments buys VG Semicon – see p40

ST moves towards all-Si optocouplers

ST Microelectronics has made further progress with its light-emitting Si devices, and expects to have a commercial, all-Si optocoupler product within six months. At a recent technical seminar, the European Si IC manufacturer disclosed further significant advances in its work towards commercially viable Si light-emitters. Last October, ST announced Si emitters with an efficiency some two orders of magnitude better than the best previously achieved results with Si.

The team has now increased the external quantum efficiency of its light-emitting devices by a factor of 1.5, as well as increasing the maximum emitted power by a factor of 50. As a result, ST is now able to produce more than 1 mW of emitted power for each mm² of Si.

ST uses a structure in which ions of rare-earth metals such as erbium or cerium are implanted in a layer of Si-rich oxide (SRO) – SiO₂ enriched with Si nanocrystals measuring 1–2 nm in diameter. The nanocrystals are coupled with the rare-earth ions in the SiO₂ matrix.



ST Microelectronics' prototype Si LED array emits green light with an output of 1 mW/mm².

Recombination of electron-hole pairs in the nanocrystals causes excitation of the rare-earth ions, which then emit light at a frequency that depends on the choice of rare-earth dopant.

ST has produced fully working prototypes of an all-Si optocoupler that demonstrate how such devices can deliver similar performance

to that of traditional devices while offering the cost benefits of Si manufacturing. "Comparing the performance of our first prototypes with that of existing devices and considering the improvements we have already made to the initial technology, we expect to reach the commercial crossover point in around six months," said Salvo Coffa, research director at ST.

The company also expects to develop entirely new products that exploit the ability to integrate all three functions – light emission, waveguiding and detection – on a single Si chip that can be manufactured at low cost on high-volume production lines. "We already know from our current research that it is possible to increase this performance by at least another order of magnitude," said Coffa. "We are on the threshold of opening up entirely new applications in the fields of displays and even solid-state illumination. In addition to targeting the large existing market for conventional optocouplers, ST will be aggressively pursuing these novel applications."

Celeritek exits wireless handset PA business

Component and subsystem supplier Celeritek is exiting the wireless handset power amplifier business, and will focus on GaAs-based subsystems for the defense market and standard GaAs semiconductors for the defense and communications markets. The company says the move will allow it to concentrate its resources on markets with the greatest potential growth and profitability. Around 20% of Celeritek's staff will lose their jobs as a result of the reorganization.

"We believe the severe pricing pressure and other adverse market conditions in the wireless handset industry will prevent our hand-

set-related business from achieving acceptable gross margins," said Tamer Hussein, president and CEO of Celeritek. "However, there is steady demand for Celeritek products in the defense and communications markets."

Hussein stated that Celeritek's defense business is experiencing an increased demand for engineering proposals and solutions, which should lead to longer-term growth in defense revenues. Also, the company plans to focus its R&D on products that support increased levels of integration; it already produces a growing number of multi-function assemblies for missile guidance and radar

applications. Interestingly, Celeritek believes that there is currently a demand from defense customers for GaAs chips, in addition to integrated subsystem products. The company will also market its GaAs chips to commercial communications customers.

Celeritek was badly hit when Motorola decided to stop second-sourcing its handset PA modules. The company hopes to realize annual cost savings in the range of \$9–10 million, primarily from the consolidation of its headquarters facilities in Santa Clara, CA, the closing of the company's office in South Korea, and reductions in the workforce.

IXYS acquires GaAs IC manufacturer

IXYS Corporation, which makes power semiconductors and specialized ICs, has acquired a privately held GaAs IC manufacturer, Microwave Technology (MwT), based in Fremont, CA. MwT designs and manufactures GaAs FETs, PHEMTs and MMICs, and its products include RF and microwave amplifier modules and functional blocks that operate from low MHz to 30 GHz for wireless

telecom infrastructure, industrial, medical equipment and defense applications.

MwT has about 50 employees, and had annual revenues of about \$6 million in its fiscal year ended March 31, 2003. IXYS will issue around 800,000 shares of IXYS common stock, which values the deal at around \$8 million. As a result of the merger, MwT is now a wholly owned subsidiary of IXYS.

"MwT fits our strategy of expanding our RF technology and products, as part of our new IXYS RF initiative," said Nathan Zommer, CEO of IXYS Corporation. "MwT

has earned a reputation for high-performance and high-quality GaAs devices and active microwave components, based on its proprietary technology. We see great benefits in our continuing to serve the wireless telecom market and the medical market, and to penetrate more into the defense and aerospace markets."

Zommer says that IXYS, a power semiconductor specialist, has recently penetrated the RF market, mainly with Si-based devices. "The GaAs technology that MwT owns allows us to penetrate the higher-frequency range all the way to about 30 GHz," he said.

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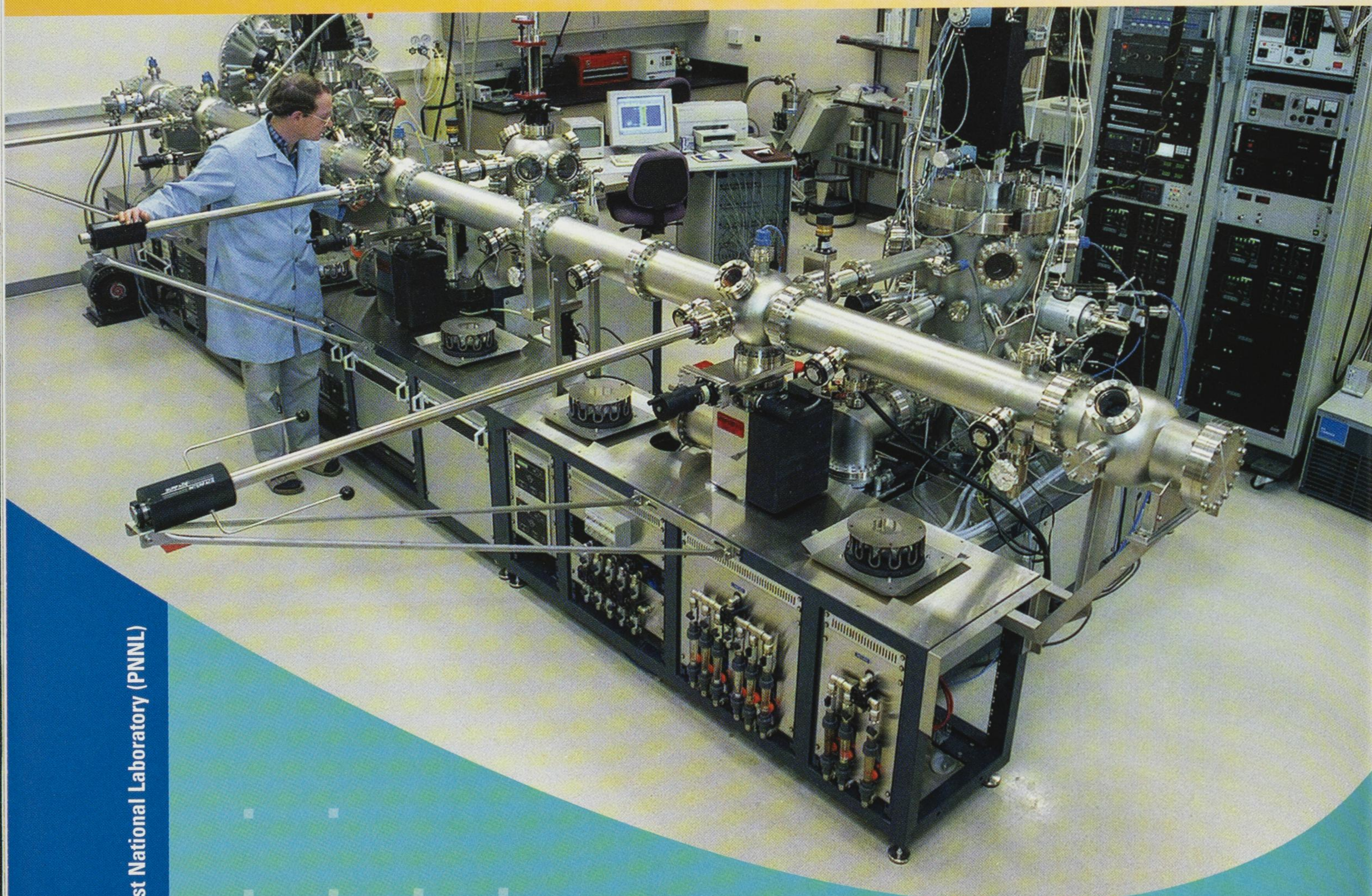
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INSTRUMENTS

GaAs ICs will dominate wireless LAN

According to Strategy Analytics, the market for GaAs ICs in WLAN applications will grow by 139% in 2003, and will show a CAGR of 21% through to 2008. The market research company's report, *GaAs Device Demand from WLAN Applications*, says that switches and PAs will represent the main opportunities for GaAs devices. By 2008, GaAs PAs will account for 67% of the 177 million units shipped. Strategy Analytics predicts that all WLAN switch ICs will use

GaAs technology, with dual-band systems that cover 5 and 2.4 GHz frequencies incorporating up to two switches per system.

"Harmonization of worldwide 5 GHz WLAN operation, and a rapid move towards dual-band systems incorporating 802.11a/g combo devices, will provide the momentum for the GaAs IC market," said Asif Anwar, senior analyst at Strategy Analytics.

"Anadigics, Microsemi and Raytheon are the early leaders in the WLAN GaAs PA mar-

ket," observed Stephen Entwistle, VP of the company's Strategic Technologies Practice. "RFMD and Skyworks are the market leaders for GaAs PAs for cellular handsets, and the WLAN market will be their next target."

The report also finds that the overall market for RF and associated chips for 802.11, including PAs and switches, will grow from \$487 million in 2002 to \$637 million in 2003. By 2008, 75% of shipments will be dual-band 802.11a/g combo devices.

Endwave and Nokia Networks to develop radio modules

Endwave has begun a development agreement with Nokia Networks to design and produce integrated millimeter-wave transceiver modules for next-generation mobile network infrastructure. The products will have twice the performance of Endwave's current transceivers, and once integrated within the radio, will enable significantly increased spectral efficiency compared with the current design.

"This development agreement demonstrates Endwave's ability to lead the merchant microwave transceiver industry, and further strengthens our relationship with Nokia," said Ed Keible, CEO and president of Endwave.

Anadigics opens new application center in Taiwan

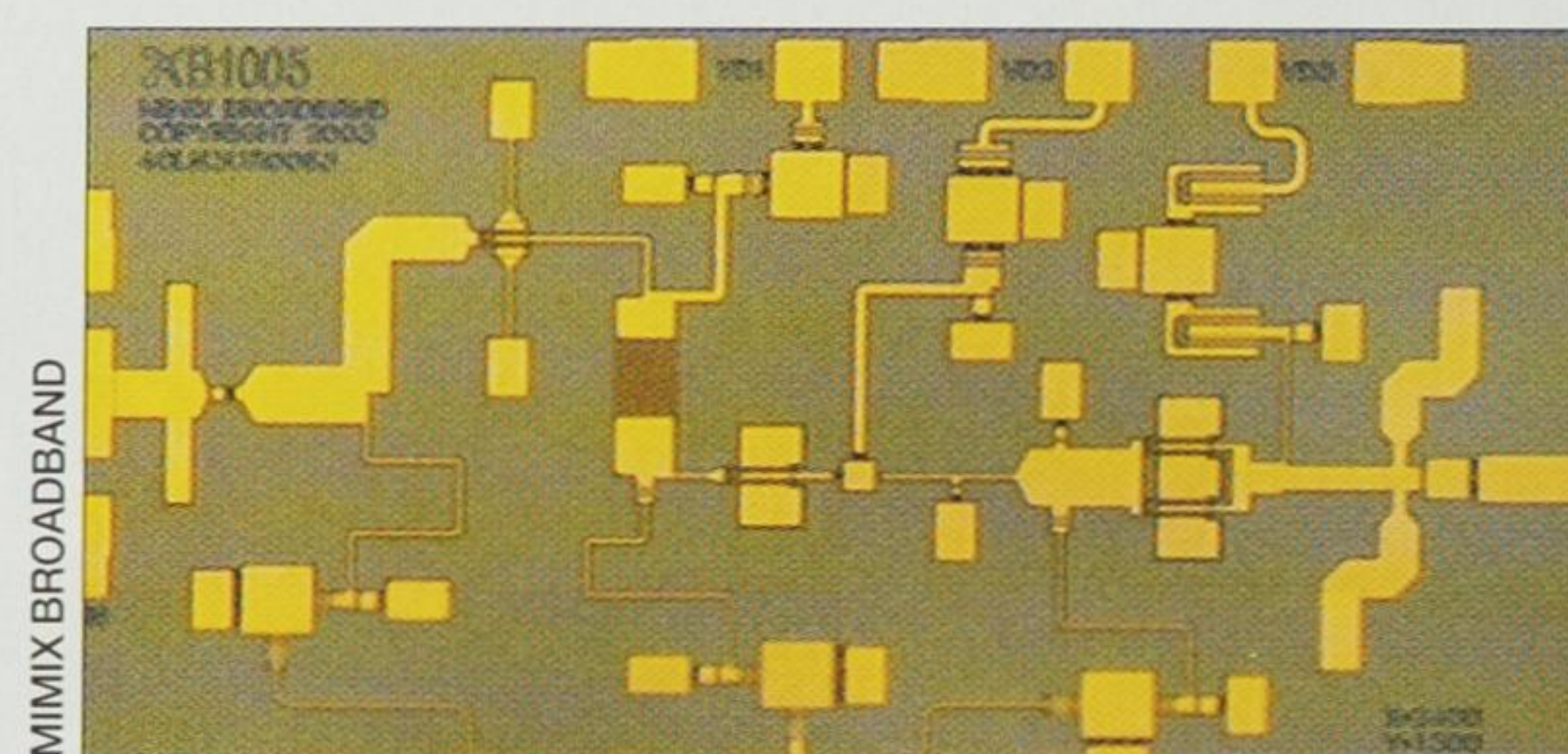
Anadigics has opened a new application center in Taipei, Taiwan, to support growing customer demand for the company's WLAN, CDMA and GSM RF products. The new facility's staff of application engineers will provide local applications support to Anadigics' customer base by facilitating the customer RF design process and shortening time to market for wireless and broadband products.

The center supports Anadigics' strategy to penetrate the large GSM handset market through reference designs featuring the company's new portfolio of quad-band GSM power amplifiers, highly integrated PowerPlexer front-end modules and PHEMT RF switch products.

Mimix raises a further \$6.7 m

Mimix Broadband, a fabless semiconductor company for wireless communications based in Houston, TX, has secured \$6.7 million in its second round of funding, which was led by 3i and First Capital Group. The majority of existing shareholders also participated. The proceeds will be used to expand Mimix's product portfolio of highly integrated, high-power MMICs for the microwave and millimeter-wave wireless communication markets.

"We believe that Mimix's innovative approach to integrating several functions on a single chip enables the market to achieve significant cost reductions and technological improvements," said Marko Maschek, director at 3i and member of Mimix's board of directors. "Our continued investment in



Mimix recently introduced a three-stage, GaAs PHEMT-based buffer amplifier operating at 35–45 GHz, which has a small signal gain of 20 dB with a noise figure of 3 dB across the band.

Mimix is validated by the traction the company has gained with the world's largest MMIC customers."

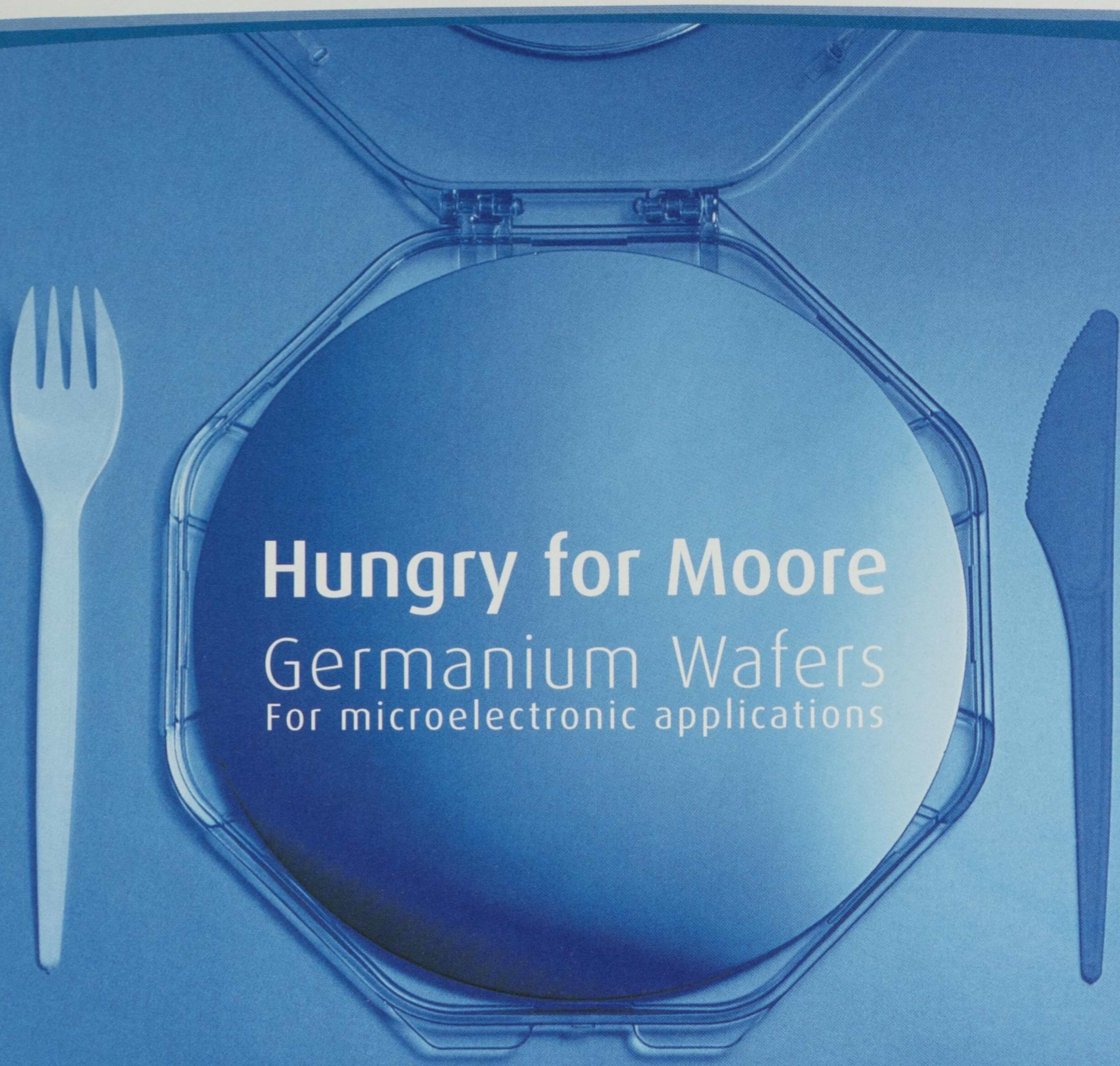
Orders

- **Handspring** is using **RFMD's** RF3140 PowerStar PA module in its next-generation Treo 600 Smartphone, which combines the features of a wireless hand-held device and a mobile phone into a small, narrow design. The quad-band RF3140 contains a GaAs HBT PA and CMOS for the integrated power control circuitry.

- **Vitelcom Mobile**, a Spanish handset designer and manufacturer, is to use a GSM/GPRS cellular system solution from **Skyworks** in multiple new handsets. The Skyworks package includes all major ICs, a full protocol stack, and all the development tools and customer support necessary for building a complete Internet-enabled GSM/GPRS handset.

- **Atheros Communications** has chosen two InGaP HBT PAs from **Microsemi** for six different reference designs, which will be used by Atheros customers to develop individual CardBus, mini-PCI and access point products for 5 GHz and 2.4 GHz wireless LAN installations. The new designs are for either 802.11g or 802.11a/b/g applications.

- **Chi Mei**, a leading Taiwanese handset ODM, has awarded full type approval (FTA) to **RFMD's** Polaris Total Radio transceiver. FTA is the official certificate of conformance to GSM/GPRS standards. Polaris is the first fully integrated quad-band transceiver and the first to provide a fully integrated digital interface between the handset's baseband and radio.



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law to roll on for another decade. The compatibility with gallium arsenide epi-growth and detection capability of 1.31 and 1.55 μm telecom wavelengths create some unique possibilities for integration of opto- and microelectronic applications. Additionally, Umicore produces **thick SOI wafers** for MEMS applications and has recently started sampling **germanium-on-insulator wafers**.

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Cree's blue LED efficiency reaches 35%

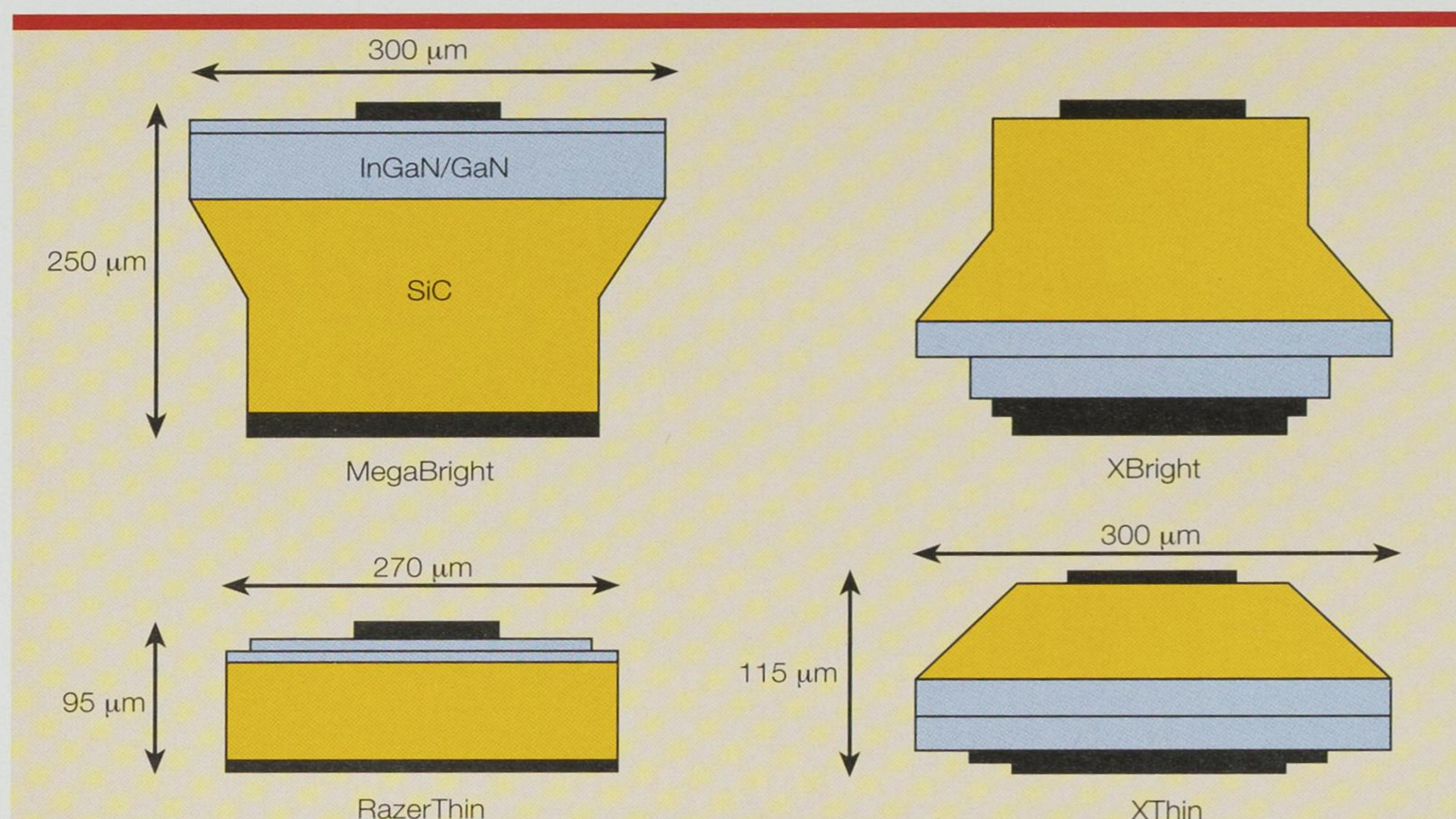
Cree researchers in Durham, NC, and at the company's Santa Barbara Technology Center have demonstrated a record 35% quantum efficiency at 20 mA for blue LEDs based on the company's XBright chip technology.

White LEDs fabricated using these novel XBright chips produced 4.1 lm of light in industry-standard LED packages with an electrical energy conversion efficiency of 65 lm/W at 20 mA. In laboratory packages, the XBright chips produced 4.7 lm of light with 74 lm/W. According to Cree, these are the highest known efficiencies publicly reported for LEDs emitting in the blue and white wavelength spectrum.

XThin LEDs

Cree has also unveiled its latest product line, the XThin series of InGaN-on-SiC LEDs. The vertically structured LED chips are approximately 115 μm in height, representing more than a 50% reduction in the typical height of Cree's LEDs. The XThin devices also have a lower forward voltage than the company's standard XBright products.

XBright chips are geometrically shaped and mounted with the epitaxial layer side down, in order to maximize light extraction efficiency for improved white light conversion. In July 2003, Cree introduced RazerThin LEDs with a typical height of 95 μm , although these devices are not shaped (see figure).



Cree's new XThin device is a thinner version of its XBright chip, which is geometrically shaped to enhance light extraction and is also mounted epi-side down.

Target applications for this product include white LEDs for use as LCD backlights and digital camera flashes in next-generation mobile appliances where brightness, sub-miniaturization and low power consumption are required.

New supply contract with Osram

Osram Opto Semiconductors has expanded its supply contract with Cree as the compa-

nies' relationship enters its seventh year. Cree has agreed to purchase at least 500 million LED chips over a 21 month period beginning in October 2003. The agreement covers Cree's entire opto product line, including standard, mid-brightness and XBright LED chip families, as well as SiC wafers. The amount of revenue to Cree from sales under the agreement will depend on the mix of products that Osram chooses to order.

Valeo's white LEDs increase automotive design possibilities

Valeo, a major automotive supplier, is developing white LED-based front lighting products that could be commercialized within three years. The company's chairman and CEO, Thierry Morin, said that Valeo is extending its LED design and development expertise for rear lighting applications. "Valeo is now extending this technology to front lighting functions," said Morin. "These have the potential to achieve significant performance benefits, especially for adaptive lighting functions." Morin also said that white LEDs create highly desirable styling flexibility, which will differentiate new top-end models by creating distinctive signatures.

Valeo is developing front lighting functions using white LEDs combined with various

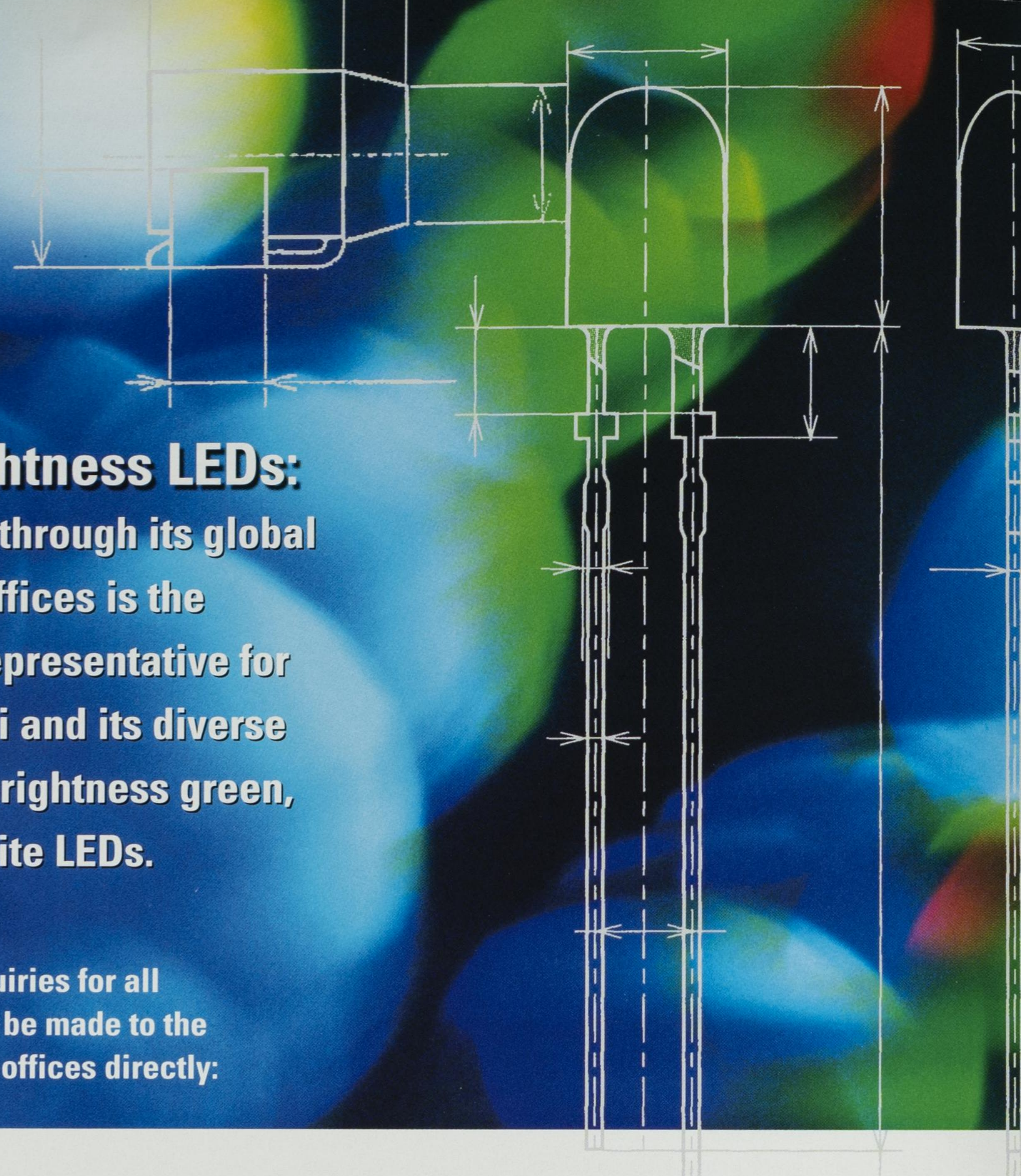
optics approaches. Optical lenses are proposed for direction indicators and daytime running lights, while a reflector or optical fiber light-guide is suitable for position lamps. Other functions such as fog lamps and low-beam headlights will be implemented using special optical modules to create cut-off lines required by lighting regulations. In addition to optics, integrated control electronics and thermal management are essential features of LED front lighting.

As well as consuming significantly less power than incandescent lamps, LEDs have a lifespan longer than that of the vehicle itself, so space does not need to be allocated to allow the LED to be changed. Also, their compact size offers considerable design freedom.

Optotek introduces 600 dpi printheads

Innovative high-brightness LEDs for print-head applications are now available from Optotek, a supplier of customized LED displays and associated electronic subsystems. New ultra-bright AlGaInP LED printheads have been developed for printing and photo-exposure applications at resolutions up to 600 dpi, and at wavelengths of 590–650 nm.

Optotek's unique processing technology accommodates the fabrication of 25 μm square pixels with radiant intensity of 25–75 $\mu\text{W}/\text{steradian}$ at 3 mA, depending on wavelength. A modular construction is used, allowing printheads of any length to be made from common building blocks. This advanced technology is also used for conventional visual device applications such as multicharacter alphanumeric displays and bargraph displays.



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Collaboration develops 81 GHz diamond device

Japanese telecom firm NTT, in collaboration with the University of Ulm, Germany, has developed a diamond semiconductor device with an operating frequency of 81 GHz. The device operates as a millimeter-wave amplifier, the first time this has been achieved for any kind of diamond device. Owing to the properties of diamond, the device dissipates heat very rapidly and can withstand operation at very high voltages.

NTT believes that diamond devices will one day replace the vacuum tubes now used in very-high-frequency and very-high-power applications, leading to increased output power in communication satellites, television broadcasting stations and radar.

Theoretical predictions have shown that ideal diamond semiconductor devices would operate at five times the temperature, 30 times the voltage and three times the frequency of silicon devices. This is because diamond has very high thermal conductivity, a high breakdown voltage and high maximum carrier

velocity, which result in rapid heat dissipation, a long lifetime and high-frequency operation.

The major problem in fabricating diamond devices is that the material tends to contain many more defects and impurities than silicon and other semiconductors. In April 2002, NTT unveiled technology for fabricating high-quality diamond, which eliminated graphite contaminants and crystalline defects from the material and reduced impurities by a factor of 20.

With the University of Ulm, NTT has now made diamond MESFETs using process technology that included the fabrication of $0.2\text{ }\mu\text{m}$ T-gates. The resulting maximum operating frequency of 81 GHz is the highest among diamond devices and about twice as high as the previous record for diamond. The group says that once it establishes device peripheral technologies it will reach a power of 30 W/mm, the level needed for practical use. Further improvements in material quality are expected to increase the frequency to about 200 GHz.

Nitronex is issued GaN-on-Si patent, demos 120 W GaN device

Nitronex, a manufacturer of GaN-based RF power transistors, has been issued US patent number 6,617,060, entitled "Gallium Nitride Material and Methods". It relates to process technology used for growing GaN on silicon.

The patent describes the growth of a compositionally graded transition layer between the silicon substrate and the GaN layer. By reducing the internal stress that arises due to the difference in the thermal expansion coefficients of silicon and GaN, the transition layer results in GaN with a low level of cracks. The transition layer consists of InGa_N, AlGa_N, AlGaIn_N or an AlGaIn_N superlattice, and is usually graded so that the Ga concentration is low adjacent to the substrate.

120 W GaN device

Nitronex has also teamed up with aviation electronics maker Rockwell Collins to demonstrate a single-unit GaN transistor yielding a record-breaking output power of 120 W. Nitronex fabricated the GaN HEMT device

using its baseline process developed for 3G W-CDMA market applications, and Rockwell Collins packaged and tested the device.

The latest results were from a 39 mm gate width device, pulse-tested (pulse width of 11.4 μs at 5% duty cycle) at 2 GHz and 28 V. At 2.0 dB into compression the device exhibited a gain of 11.3 dB with an efficiency of more than 39%.

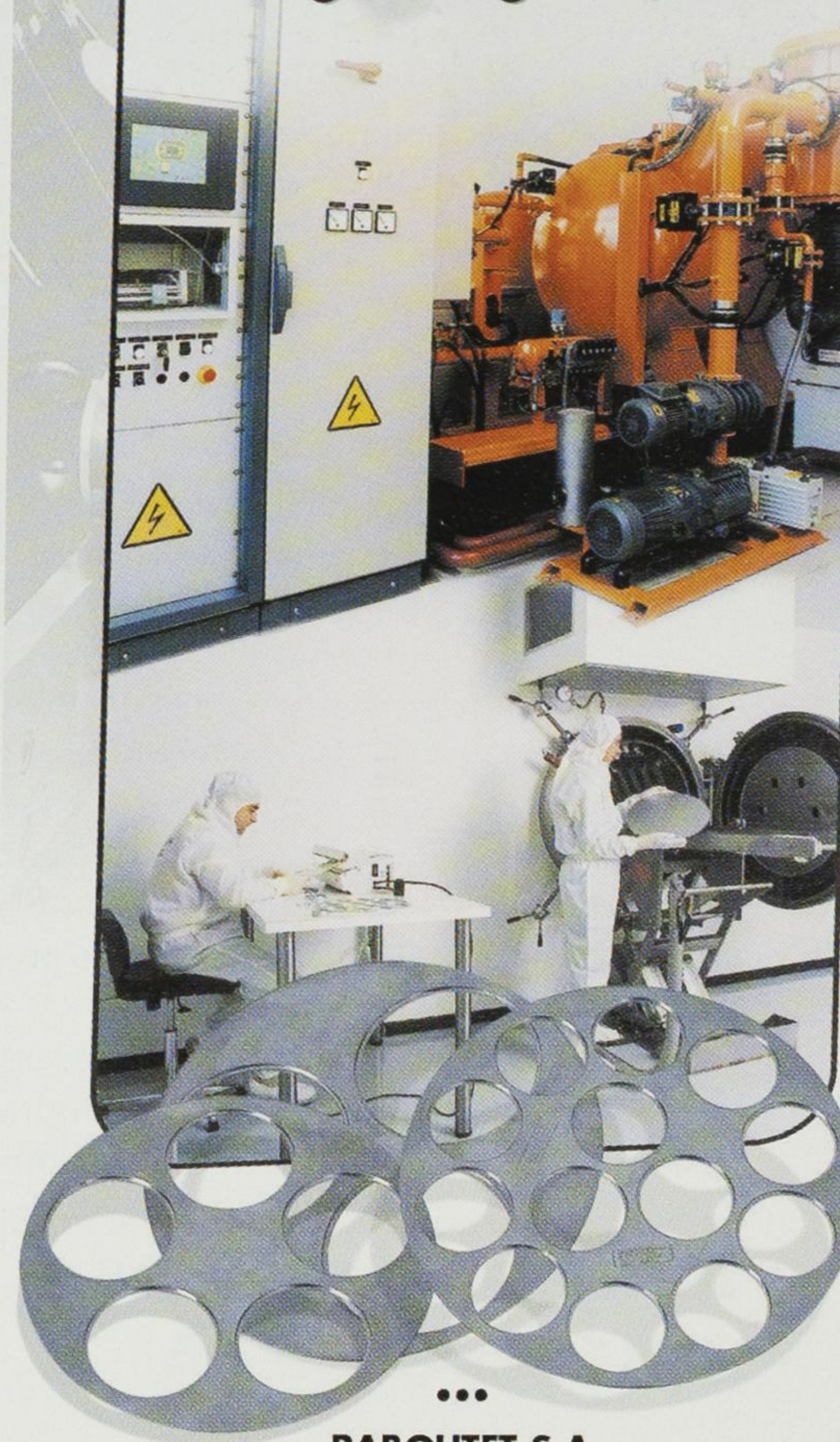
The results indicate that GaN has the potential to play a major role in future RF power amplifier systems, and not just for wireless basestation applications where Nitronex has been targeting its products so far.

Don Landt of Rockwell Collins Advanced Technology Center stated: "We have many applications at Rockwell Collins for these devices, especially in our government systems programs such as Data Link 16 programs, weapons data links, Joint Tactical Radio Systems and flight navigation. High-performance, cost-effective GaN RF devices are essential for these systems."

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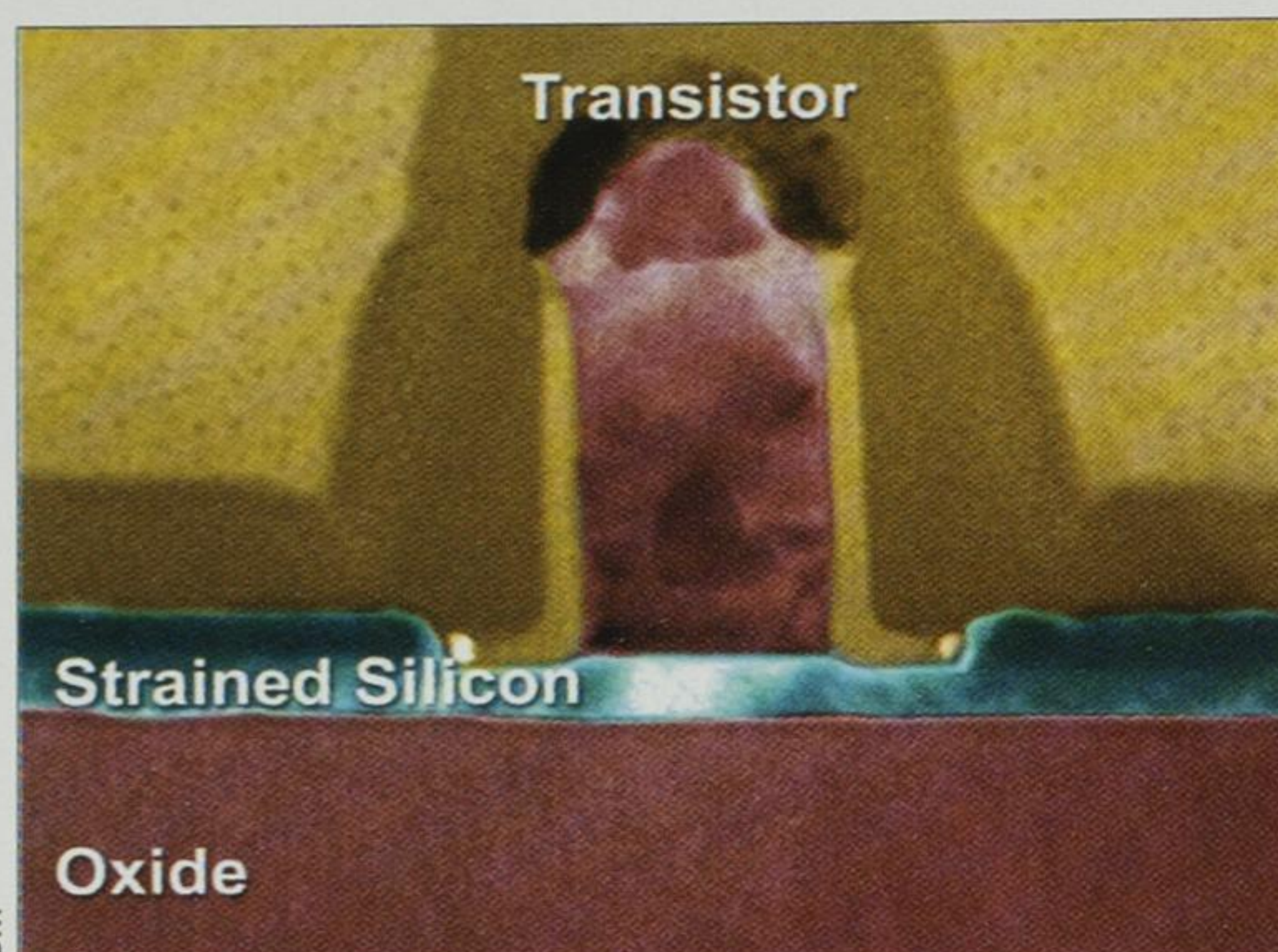
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IBM demonstrates SSDOI transistors

IBM has developed the first transistor to use strained silicon directly on insulator (SSDOI) substrate technology, and has also demonstrated Si substrates with a hybrid of crystal orientations for optimized NMOS and PMOS performance.

IBM and others have reported a 20–30% performance enhancement in NMOS devices using strained Si channels grown onto relaxed SiGe buffers. However, the presence of a SiGe layer causes material and process integration challenges. Several organizations, including IBM, MIT and AmberWave Systems, have demonstrated processes for producing SSDOI substrates, but IBM is the first to have fabricated transistors using SSDOI material (*Compound Semiconductor* April 2003 p25).

IBM's SSDOI structure is created by bonding strained Si, grown epitaxially onto a relaxed SiGe buffer, to an oxidized Si wafer. The SiGe layer is then removed by a combi-



A transistor with a strained Si channel fabricated on an SSDOI substrate.

nation of polishing and chemical etching, thus creating the SSDOI. Strain is maintained in the Si after the layer transfer process and thermal cycles. Electron and hole mobility enhancements have been confirmed in MOSFETs fabricated on SSDOI, and the fab-

rication of sub-60 nm FETs has also been demonstrated.

Another way to improve CMOS performance is to increase the hole mobility in the device channels. For a given level of strain, the mobility enhancement for holes is less than that for electrons. For PFETs, hole mobility is known to be 2.5 times higher on (110) Si than on standard wafers with (100) surface orientation. IBM has created a hybrid-orientation technology where CMOS devices are fabricated on hybrid substrates with different crystal orientations to achieve significant PFET performance enhancement. An enhancement of 40–65% for PFETs has been demonstrated on a 90 nm node CMOS technology.

IBM will present details of the two processing techniques in two papers at the International Electron Devices Meeting (IEDM), to be held December 7–10, 2003 in Washington, DC.

Jazz plans world's fastest SiGe technology

Jazz Semiconductor is planning to introduce a SiGe process technology with an f_t of 300 GHz. According to an article in *EE Times*, Jazz is preparing separate 0.13 μm versions of its SiGe and CMOS processes.

The 300 GHz, 0.13 μm SiGe technology, due out in prototype form in 2004, will be 50% faster than Jazz's current process, making it the world's fastest commercially available

SiGe technology. Jazz is also preparing to launch a new 100 GHz version of its existing 0.18 μm SiGe technology, targeting low-cost integrated wireless and wireline applications. The company is mainly focused on the emerging SiGe foundry business, where its main competitors are IBM, Atmel and Communicant, and uses its CMOS processes to complement its SiGe processes.

Intel banks on CMOS for core radio parts

Intel is busily progressing its plans to be at the center of the convergence of computing and communications by using its CMOS technology to develop core radio components. It aims to make wireless communication truly ubiquitous by using CMOS processes to provide low-cost radio technology.

Intel has used its 0.18 μm CMOS process, normally applied to manufacturing digital devices, to develop core analog radio com-

ponents, including the world's fastest VCO, which operates at more than 75 GHz. Such high-speed analog components are normally considered to be the preserve of materials such as GaAs and InP. Also, Intel is playing a significant role in the development of a next-generation WLAN standard called 802.11n, which will give significant increases in performance over the current WLAN standards such as 802.11a/b/g.

Infineon develops 5.3 GHz SiGe PA

In a presentation at September's European Solid State Circuits Conference (ESSCIRC) in Lisbon, Portugal, researchers from Infineon described the development of a 4.8–5.3 GHz

SiGe bipolar PA with 50 Ω output. The device, targeted at WLAN applications, was fabricated using the company's 0.35 μm SiGe bipolar technology, and at supply voltages of 1.0, 1.5 and 2.4 V, output powers were 17.7, 21.6 and 25 dBm at 5.3 GHz. The respective PAE values were 15.6, 22.4 and 24%, with a small signal gain of 26 dB.

Soitec completes 300 mm SOI production ramp

Soitec has shipped its 10,000th prime 300 mm SOI wafer from its Bernin II facility near Grenoble, France. This marks the successful ramp of production at the new facility using Soitec's proprietary Smart Cut wafer bonding technology. The extra capacity at Bernin II, which is dedicated to 300 mm SOI production, also makes Soitec the largest supplier of 300 mm SOI wafers in the world.

The transition to 300 mm wafers in CMOS manufacturing continues to gain momentum along with the shift towards 90 nm and smaller geometries. "This poses significant growth opportunities for SOI," said Andre Auberton-Herve, president of Soitec. "In fact, by 2005, industry analysts anticipate that 45% of SOI demand will shift to 300 mm. In addition, by 2009, SOI wafers are expected to comprise nearly 50% of the total 300 mm substrates consumed within the industry."

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IBM, Agilent drive optical interconnects

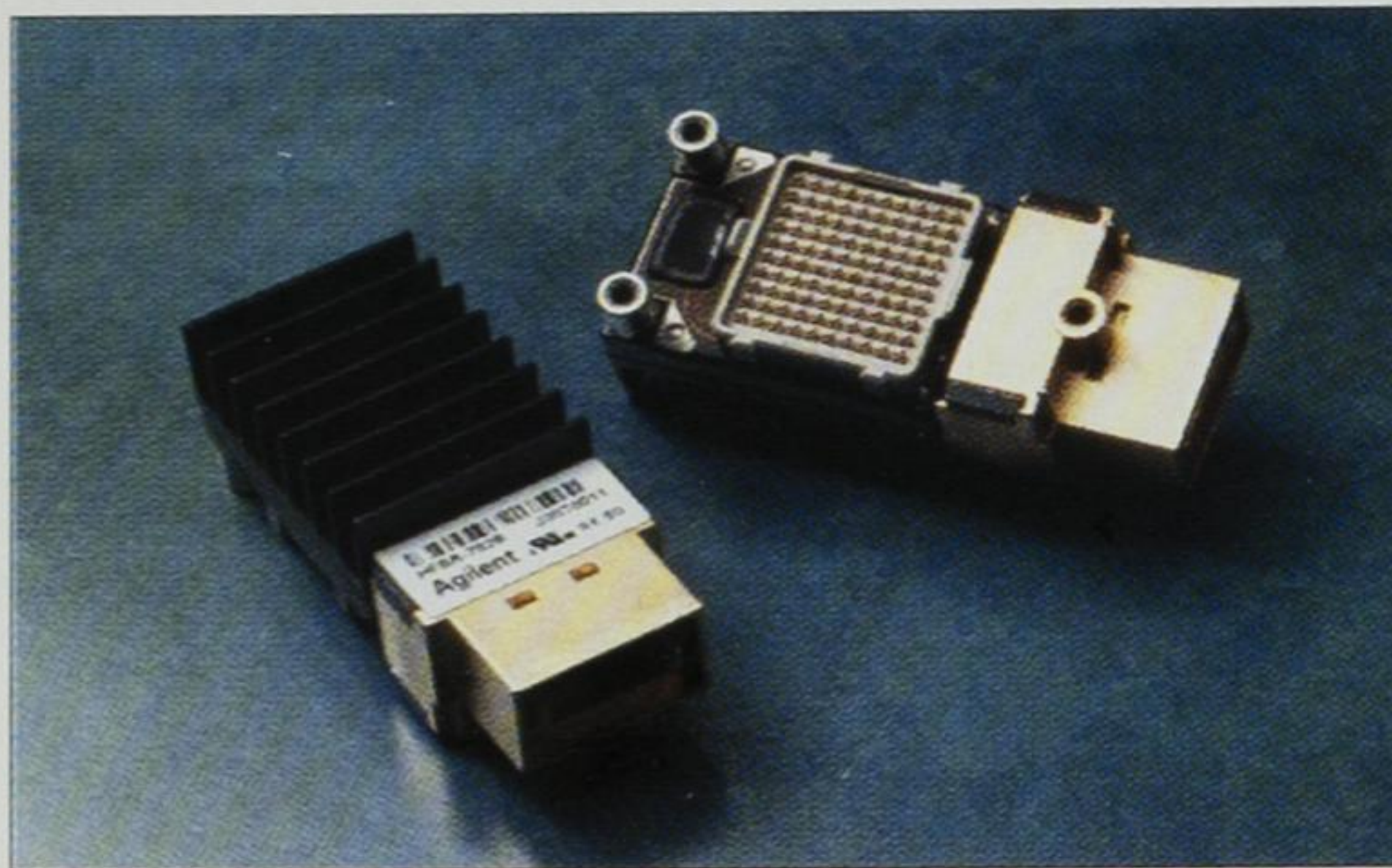
By Jon Newey

The world's best known information technology hardware company, IBM, and the world's largest optoelectronics company, Agilent Technologies, are combining their talents to take optical communication technology down to the chip level. The companies are teaming up to develop chip-level optical interconnects which will deliver vast improvements in bandwidth as part of a three-year, \$30 million project funded by the High Productivity Computing Systems (HPCS) initiative run by the Defense Advanced Research Projects Agency (DARPA).

The total communications bandwidth inside servers has been increasing by roughly 10 times every four years, driven by increases in chip speeds and the number of processors per system. The project will address the increasing bandwidth demand between microprocessors, which is expected to be about 40 Tbit/s by 2010. However, the project will also require Agilent and IBM to address issues of power, cost, density and reliability, at the same time as expanding the bandwidth.

Agilent has been working on optical interconnects since the early 1990s (long before it was spun out of Hewlett-Packard), initially to connect computers via links using fiber optics. In 2000 it began focusing on optical interconnects between boards within systems, and more recently on optical interconnects between multichip modules (MCMs). Some of its past optical interconnect work has been funded through DARPA, but the joint project with IBM is the largest so far.

Agilent, through its Palo Alto Research Center, will be responsible for developing all of the optical components such as lasers and photodetectors, and will drive these to the very



The DARPA-funded work will take optical links from 30 Gbit/s into the Tbit/s regime.

high speeds needed to reach the target bandwidth. IBM has great expertise in IC manufacturing and packaging, and will take the optical components and put them in demonstration systems to show that data can be propagated between MCMs at terabit speeds.

The optical modules prevalent in today's short-reach fiber-optic connections have been steadily reducing in size, cost and power consumption, but taking optical interconnects down to the chip level will mean modules of less than 2 cm², which consume 5–10 mW of power per Gbit/s. "We're not talking about a module that is packaged at all," Waguih Ishak, director of the Communications and Optics Research Laboratory at Agilent, told *Compound Semiconductor*. "We need extremely high density interconnects that give the highest possible values in terms of Gbit/cm², Gbit/W and Gbit/\$. The lasers and photodetectors need to be very close together in large numbers, each driven at a very high speed."

Rethinking the laser

The team will be pursuing a system of waveguides over which the optical signals will propagate. Over very short distances it is pos-

sible to use free-space optics, but these suffer from the problems of mechanical alignment and dirty environments. Although they add manufacturing steps, waveguides allow more freedom in optimizing components.

Such high-density interconnects operating at high speeds will require new approaches to some of the components. "One aspect of the project will be to invent a new laser platform," said Ishak, although he would not be drawn too deeply into what this means physically. VCSELs have become a favorite source for short-reach, rack-to-rack, optical interconnects, but their modulation speed is limited. "We know how to push our VCSELs to high speeds, make them reliable and produce them in large volumes, but VCSELs will only take us so far," said Ishak. "Hundreds of very densely packed channels with an aggregate speed of 40 or 100 Tbit/s will need miniature emitters operating in the 40 Gbit/s regime. It has become apparent that series resistance and capacitance mean that 40 Gbit/s from a VCSEL might not be practical."

Power management will be a key consideration of the project. Sub-mW optical powers from the lasers with very small threshold currents will be sufficient for transmitting over the small chip-to-chip distances in question. However, given the great density of emitters, a significant amount of heat will need to be dealt with. Ishak seems confident that by combining Agilent's experience in optoelectronic packaging and IBM's knowledge of dealing with similar problems in microelectronics, such issues will not be a show-stopper. "Here you have the largest optoelectronics company in the world working with the largest computer company in the world," Ishak said. "If we can't solve it then I don't know who can."

Canadian photonics center set to open in 2004

The National Research Council (NRC) of Canada and Carleton University in Ottawa have established the Canadian Photonics Fabrication Center (CPFC). The aim of the center, which is due to formally open in May 2004, is to support the growth of the Canadian photonics industry by offering companies and universities access to a complete range of fabrication services for photonic and optoelectronic devices. The CPFC will be located at the existing NRC campus in Ottawa, where it

will be able to draw upon expertise and facilities already present at the NRC's Institute for Microstructural Sciences and the nearby Carleton University. These organizations have a 20 year history in developing many of the technologies and processes that are used in photonic device fabrication.

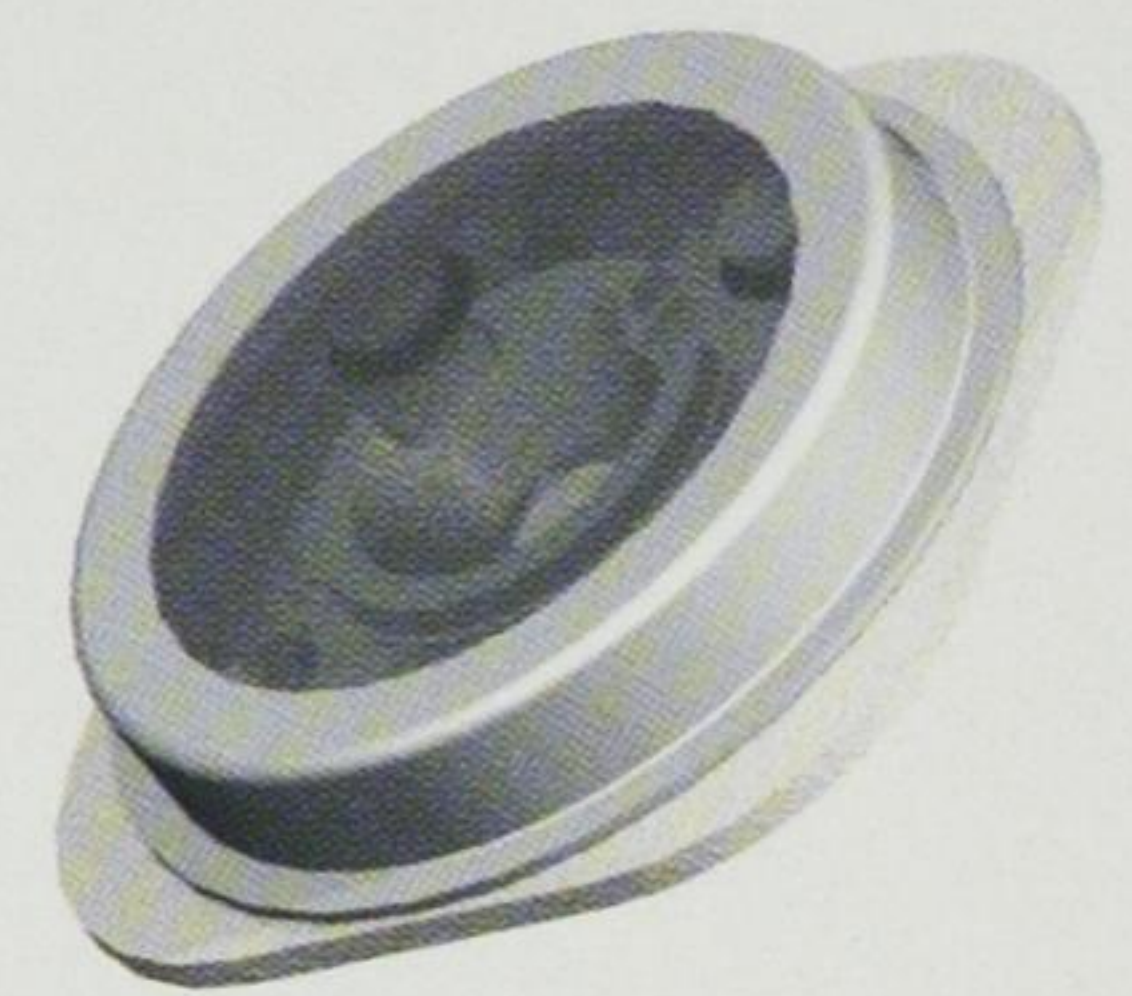
The CPFC will cost C\$43 million (\$31.4 million) over the first five years, with the federal government providing C\$30 million and the Ontario government granting Carleton

University another C\$13 million to assist with the costs of outfitting the facility. Industry and universities will have access to the CPFC's photonic design, prototyping, fabrication and test facilities. These facilities include epitaxial tools such as MOCVD, MBE and CBE reactors, device processing facilities such as e-beam and optical lithography, wet and dry etching, metal and dielectric deposition, and a comprehensive range of material, optical and electrical characterization tools.

365nm, 100mW.

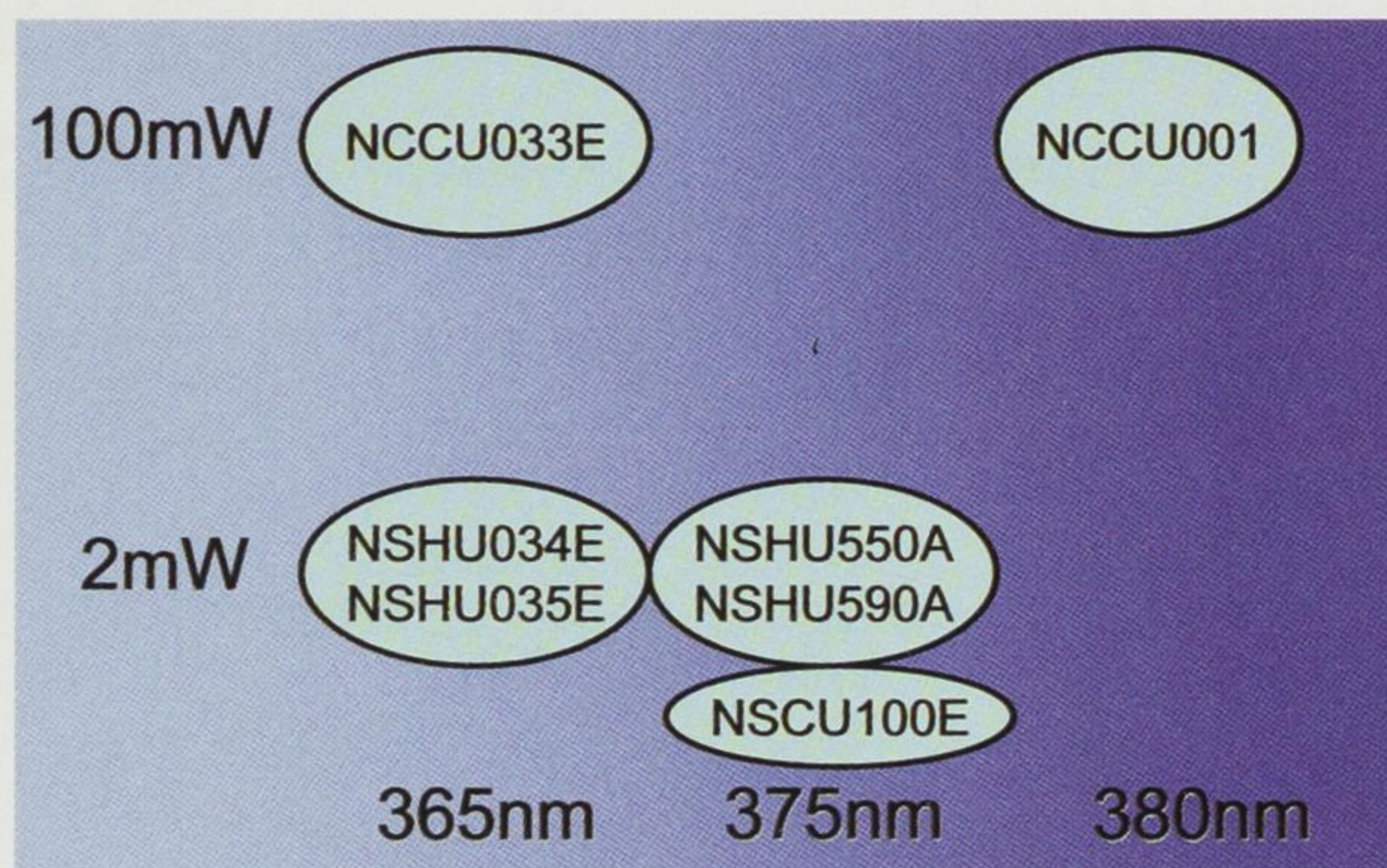
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NSHU034E	365nm	*2.0mW	Flat	2004
NSHU035E	365nm	*1.4mW	Lens	2004
NSHU550A	375nm	2.0mW	Flat	Now
NSHU590A	375nm	1.4mW	Lens	Now
NSCU100E	375nm	*1.0mW	SMD	2003/11
NCCU001E	380nm	100mW	Flat	2003/12

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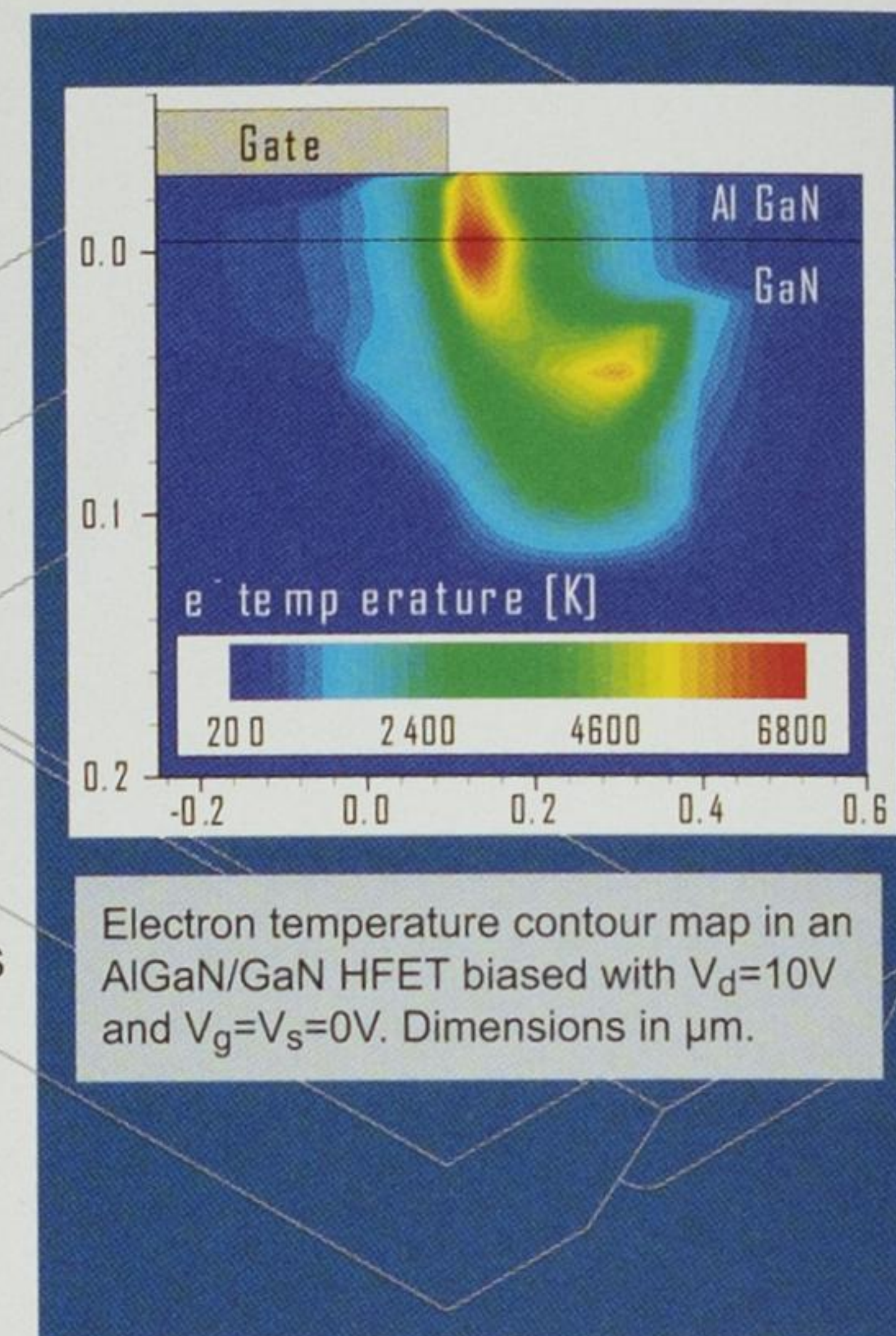


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Toshiba develops 200 mW low-noise violet laser

Toshiba Corporation has announced the development of a GaN-based blue-violet laser with an optical output power of 200 mW and the lowest noise characteristics ever attained. The company says that the performance of the laser meets the requirements for optical disc systems that will emerge in the near future, including the ability to support dual-layer and high-speed recording systems.

Blue-violet lasers for next-generation optical disc players and drives must achieve high optical output power, low noise performance and a stable beam profile if they are to read and write the densely-packed data on next-generation optical discs. This is particularly true in cases of dual-layer disc recording and high-speed recording, both of which require a more powerful laser source than single-layer, standard-speed recording.

As well as having an optical output power of 200 mW in continuous-wave mode at 25 °C, Toshiba's blue-violet laser has a noise level of -132 dB/Hz at 3 mW. These characteristics are attributed in part to the company's facet coating technology.

Toshiba also says that it has achieved high quantum efficiency through the precise optimization of doping levels within the laser structure, which results in a lower operating current at higher optical power output.

The 409 nm laser has a threshold current of 35 mA and an operating current of 164 mA. The beam angle is 12.4° in the parallel direction, and 25.8° in the perpendicular direction.

● In related news, Toshiba and Samsung are to form a joint venture that combines their optical disc drive businesses, which make CD-ROM and DVD-ROM drives.

Shin-Etsu Handotai licenses Lumileds AlGaInP LED patent

Shin-Etsu Handotai, a Japanese manufacturer of materials and LEDs, has taken a license on US patent 5,008,718, a key patent owned by Lumileds in the field of absorbing substrate AlGaInP LED technology. The license also covers other patents and, while specific terms remain confidential, Shin-Etsu Handotai will pay a license fee and royalties in undisclosed

amounts to Lumileds.

Lumileds recently announced that it was suing Taiwanese company Epistar over the alleged infringement of the same patent (*Compound Semiconductor* September 2003 p6). Similar cases brought by Lumileds against United Epitaxy Company and Citizen Electronics have now been settled.

KAST develops grid-type LED curtain

A Japanese company, KAST, has developed a lightweight advertising screen using LEDs. The grid-type LED curtain (G-LEC) consists of polycarbonate tubes 2 cm in diameter, which hang vertically and are spaced 6 cm apart. Each tube contains 16 pixels spaced 6 cm apart, with each pixel consisting of three (red, green and blue) LEDs with a total light output of 1900 cd. The system has a brightness of 500 cd/m². Despite its low resolution, the system weighs only 10 kg/m² and has a picture rate of 25 frames per second, making it suitable for a variety of messaging and display applications.

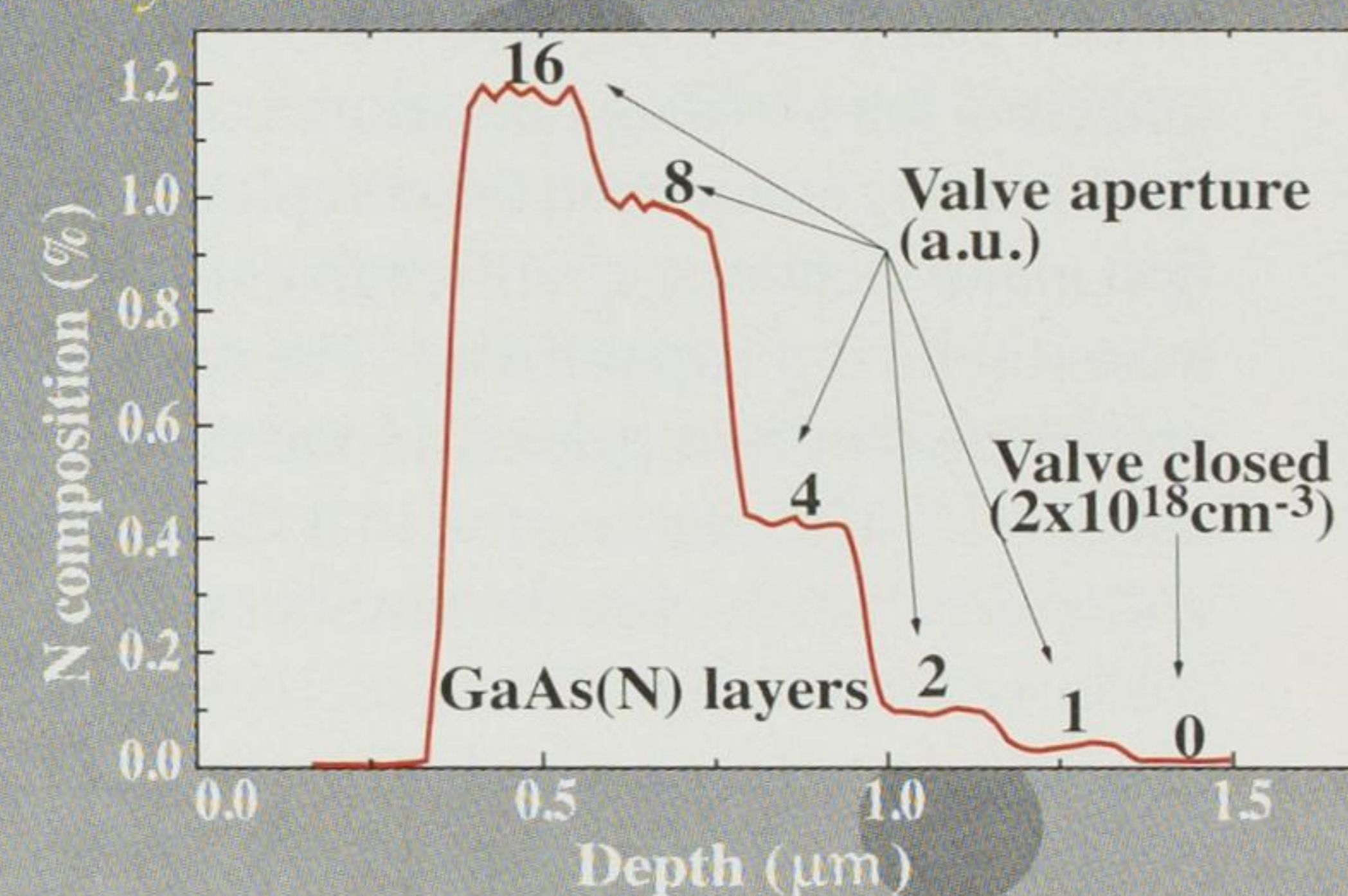
Omron creates front lighting for LCDs

Omron has created an optical system that allows the efficient front lighting of liquid-crystal displays for wireless handsets, PDAs and other mobile messaging terminals. The system uses a microprism optical array to spread LED light throughout the display, reducing loss and creating a brighter screen.

Also, a prism array with 200 nm features reduces reflections, resulting in higher contrast and clear images. Omron has developed the manufacturing technology to combine these two types of optical array, resulting in displays that require fewer LEDs and consume less power.

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GaAs MANUFACTURING

The world's GaAs fabs face up to

Since the GaAs industry's halcyon days in 1999 and 2000, when all the talk was of new fabs and rapid growth, there has been a period of consolidation, retrenchment and closures.

Tim Whitaker and **Jon Newey** spoke to several GaAs IC manufacturers around the globe about their current positions.

The GaAs IC manufacturing industry has undergone considerable change in the last few years. Vitesse, the first company to build and operate a 6 inch GaAs fab, recently announced that it would close the facility in Colorado Springs after failing to find a buyer or partner. Infineon, having sold its GaAs business to TriQuint, has stopped production at its 6 inch GaAs fab near Munich, Germany, after the processes were transferred to TriQuint's US GaAs fabs.

Nortel is closing down its GaAs HBT fab, while Skyworks, Filtronic and Agilent have all closed fabs in California. However, the news is not all bleak; Filtronic and Agilent are now concentrating their respective efforts at their 6 inch fabs in Newton Aycliffe, UK, and Fort Collins, CO.

Meanwhile, in North Carolina, RFMD has finally completed the conversion of its second HBT fab to 6 inch operation. Last month, the company announced the completion of the first major customer qualification of its 6 inch manufacturing capabilities. The move was precipitated by rising demand and the need to cut costs. "The conversion to 6 inch wafers will more than double the number of die per wafer without a significant increase in processing cost per wafer," said Curt Barratt, VP of wafer fab operations at RFMD. The company's first fab, which still handles 4 inch wafers, is now operating close to its maximum capacity of 60,000 wafers per year (*Compound Semiconductor* September 2003 p14).

Changing plans

While some companies went ahead with planned expansions by converting to 6 inch operation (e.g. Motorola and TriQuint) or expanding their existing facilities (e.g. Anadigics), others pulled back from their original strategies. NEC announced plans in 2001 to move to 6 inch manufacturing, but currently still has one GaAs IC fab in Otsu, Japan, pro-

cessing 5 inch wafers. Raytheon, having evaluated a 6 inch conversion, chose to partner with WIN Semiconductor, a new Taiwanese GaAs foundry. Similarly, Alpha did not complete its planned move to 6 inch GaAs before becoming part of Skyworks.

M/A-COM and Sanders

In June 2000, M/A-COM announced a deal to utilize the 6 inch GaAs line being constructed at Sanders in Nashua, NH. (Sanders, which was part of Lockheed Martin, was subsequently acquired by BAE Systems.) M/A-COM planned to send teams of engineers to Nashua to manufacture 6 inch MMIC wafers for communication applications once the fab was completed during the first half of 2001.

However, the downturn in the commercial wireless chip market evidently convinced M/A-COM that it had enough internal capacity to meet its own requirements. "At the start of 2001 we had been gearing up to accommodate M/A-COM," said Alan Swanson, director of the Microwave Electronics Group at BAE Systems. "We had started running wafers and building up the infrastructure, but M/A-COM decided not to inhabit the building and never started running wafers in the production sense."

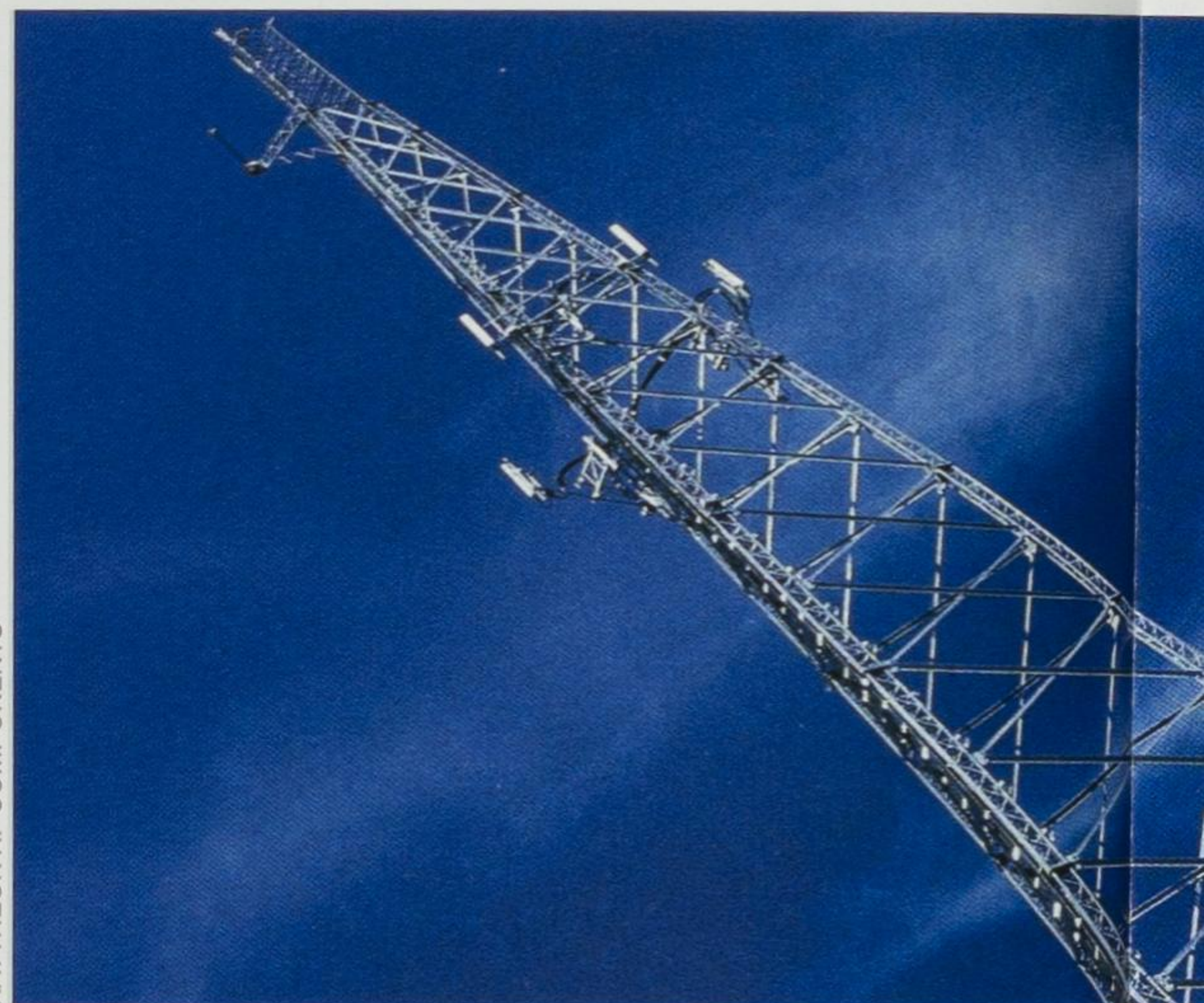
Swanson says that the 6 inch line at the Nashua fab is currently being used to fabricate MESFETs that are used in the F22 fighter plane, while the PHEMT portion of the line is being converted to 6 inch production. "In the past two to three years, our military business has remained roughly constant," he said.

Skyworks stays at 4 inch

Skyworks has undergone consolidation since its formation through the merger of Alpha Industries and Conexant's wireless business. The former Alpha/NDI fab in Sunnyvale, CA, was closed in January 2003, after its products were transferred to Skyworks' other GaAs fabs



Northrop Grumman Space Technology is building phased Advanced Extremely High Frequency (EHF) satellite system electronically rather than mechanically, will enable the five with each other rather than bouncing signals to and from g existing Milstar satellite constellation, providing secure wo

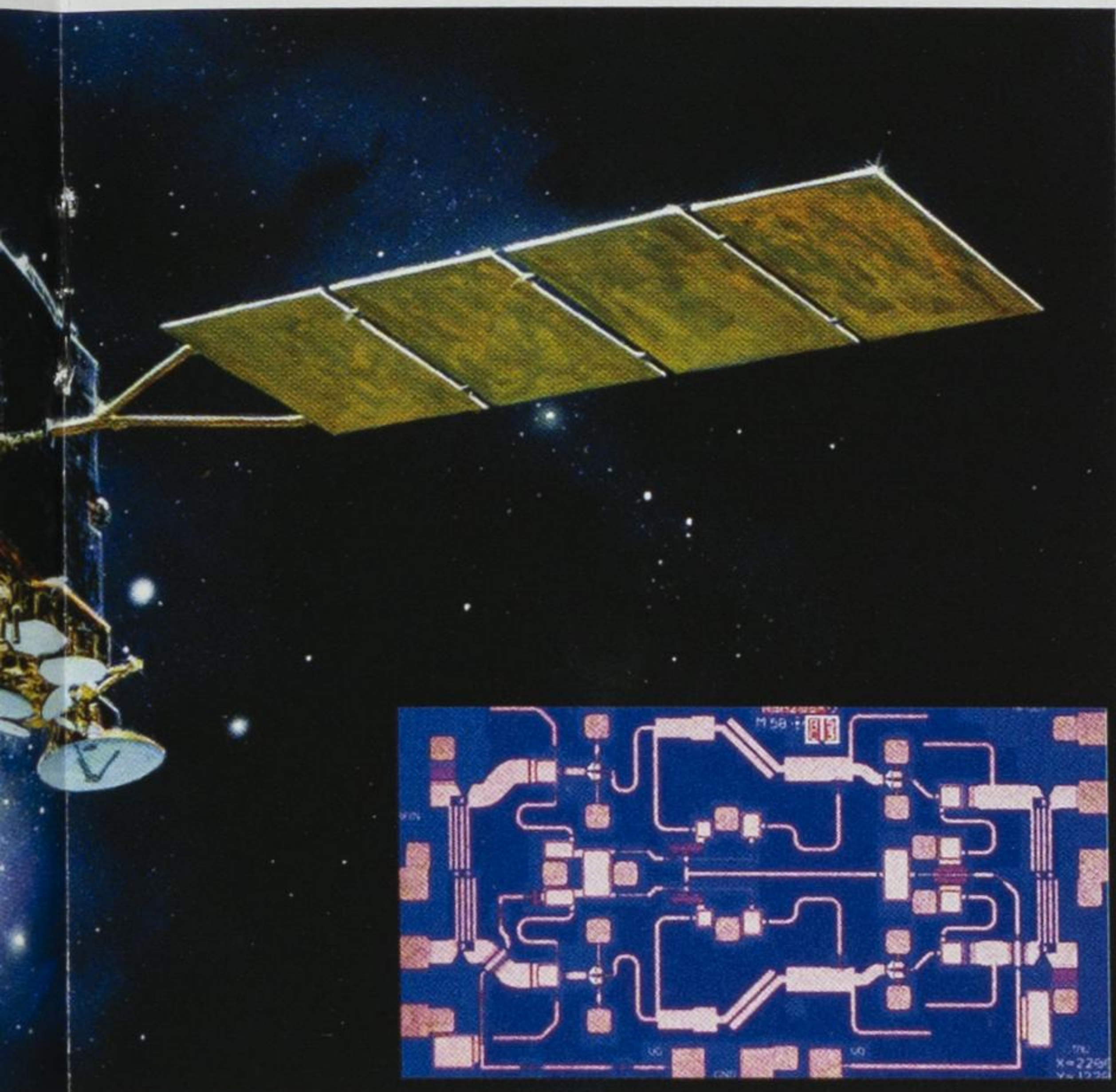


Raytheon RF Components' RMBA09500 2 W linear GaAs p designed for use in cellular and micro- and pico-cell basest

in Newbury Park, CA (the former Conexant fab) and Woburn, MA (the former Alpha fab).

The Newbury Park fab was the first to produce commercial AlGaAs/GaAs HBTs, and has now also introduced InGaP/GaAs HBT products. "New designs are being brought up in InGaP, and these make up a reasonable portion of the starts," said Terry Pope, director of

to changing market conditions



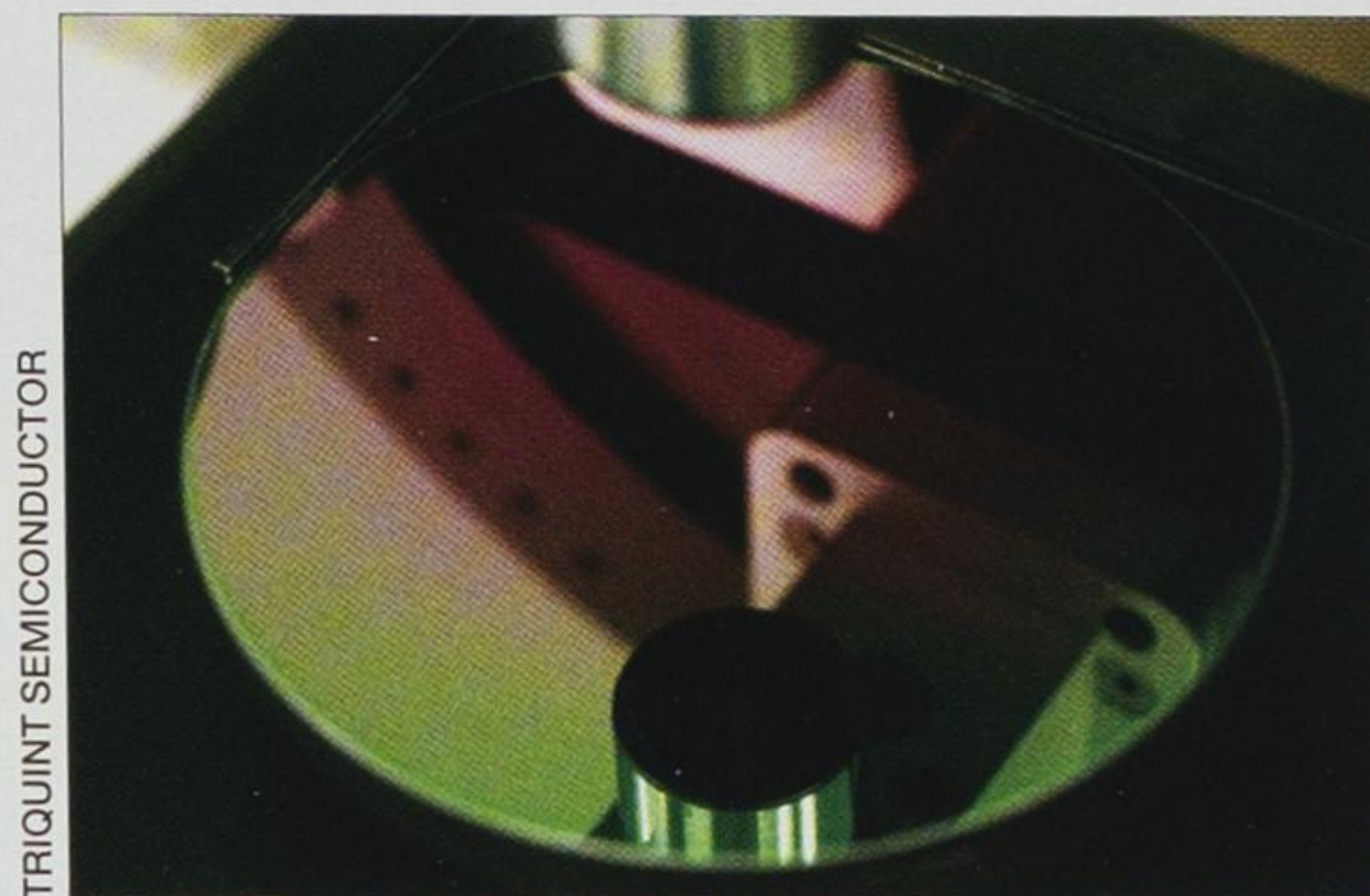
phased arrays containing InP-based MMICs for the system. The arrays, which allow RF beams to be steered, enable the five Advanced EHF satellites to communicate directly with ground systems. Advanced EHF will augment the secure worldwide communications for the US military.



Raytheon GaAs power amplifier (inset) is a PHEMT-based MMIC used in cell base stations, and fabricated in Andover, MA.

the Newbury Park fab. "There are a number of high-volume existing designs that are running in AlGaAs which will be supported for several more years."

All Skyworks' GaAs processes are run on 4 inch wafers at present, and Pope says that the Woburn fab will likely remain at that size. Also, while the tool set in Newbury Park is



TRIQUINT SEMICONDUCTOR

TriQuint has a 6 inch toolset ready to commence production in Richardson, TX.

capable of being converted to 6 inch, there are no plans to make the change. "We believe that there is little or no cost advantage to moving from 4 to 6 inch at this time," Pope explained. "With die shrinks and second source supplies we don't need the capacity." Skyworks has a second-source agreement with AWSC in Taiwan to produce HBT wafers. "A wafer size change requires significant effort with little payback at this point," added Pope.

Nortel exits HBT business

Nortel was one of the first companies to introduce commercial GaAs HBTs for its internal 10 Gbit/s fiber-optic products. In 2000, the company had plans to double its production capacity by building a second HBT fab near Ottawa, Canada, but these plans failed to materialize. Hit hard by the telecom slump, Nortel sold most of its optical component production capabilities to Bookham Technology, and is now closing its HBT fab.

"We announced [in 2002] our intention to wind down our GaAs activity and to work with third parties to meet our needs for [GaAs HBT] devices," said a Nortel spokesperson. "Our decision was part of our overall strategy to exit optical components so that we could focus on the systems side of our optical business, where we see our greatest competitive strength."

Anadigics poised to grow

Anadigics was the first company to build a 6 inch GaAs fab for analog ICs (Vitesse concentrated on digital products), and began production in July 1999. In January 2000, the company announced plans to double the size of the fab by adding a further 10,000 sq. ft of cleanroom space. However, as the downturn

started to bite, the expansion was delayed, and was not completed until June 2002. But even with the infrastructure in place, Anadigics did not fill all the available space with equipment, according to Darryl Heller, the company's senior director of onshore operations.

"Around one-third of the additional fab space is currently occupied, while the original 6 inch fab is essentially fully fitted out with equipment," said Heller. "Our capacity is labor-limited at present; we could probably double our capacity through additional operator hires." Further increases in capacity can also be made fairly rapidly, by adding more fab tools to the expanded facility. "The fact that Anadigics has the capability to quickly increase its production capacity in a state-of-the-art 6 inch line is a source of confidence for our customers," said Heller.

Like any fab, the mix of different wafer types fluctuates, but a typical breakdown would be 50–75% InGaP HBT wafers for handset applications and 25–35% MESFET wafers for cable and broadcast products, with the balance (around 15–20%) being PHEMT wafers for RF switches.

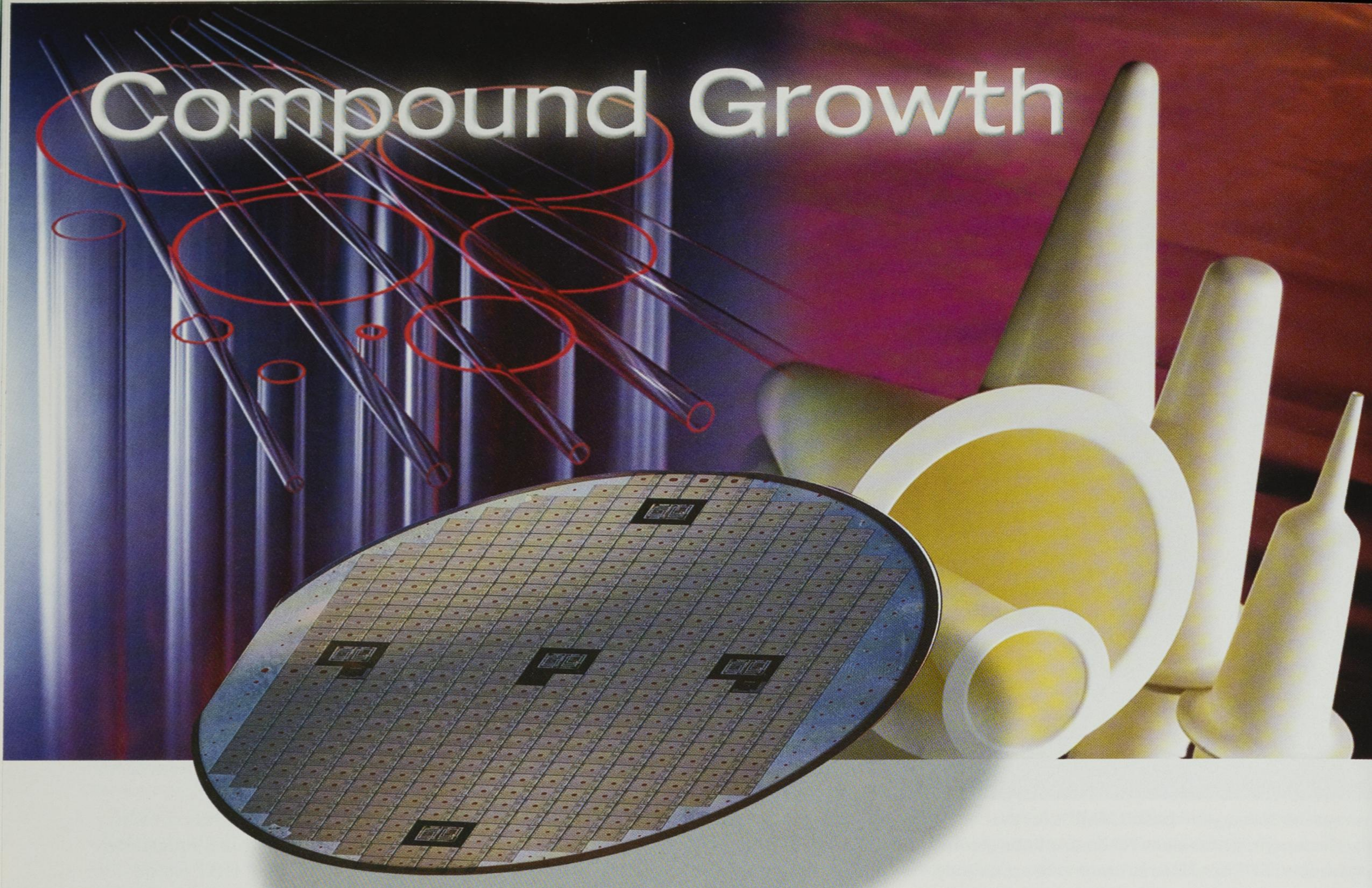
Northrop Grumman

The \$7.8 billion merger of TRW and Northrop Grumman, completed at the end of 2002, brought together two long-established compound semiconductor activities. The former TRW Space and Electronics group, located in Redondo Beach, CA, is now Northrop Grumman Space Technology, which fabricates GaAs and InP ICs, while Northrop Grumman Electronic Systems, located in Baltimore, MD, includes the former Westinghouse GaAs and SiC operation.

"TRW and Westinghouse were teamed with each other in phase 1 of the MIMIC program, so the groups have had a good relationship over many years," says Dwight Streit, VP of Foundation Technologies at Northrop Grumman Space Technology. "The two operations are very complementary; we don't see any transition or consolidation in the near future affecting either facility."

The Space Technology sector operates a newly opened fab at its Space Park campus in Redondo Beach, with 4 inch GaAs and InP lines producing HBT-and HEMT-based ICs.

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The fab produces MMICs for internal Northrop Grumman programs as well as commercial products, particularly for the telecom market, which are sold through the Velocium brand. Streit sees signs of a turnaround in the telecom market. "Business is definitely picking up again," he said. "2001 and 2002 were very difficult, but 2003 is much improved."

As well as being positioned to take advantage of a turnaround in the telecom marketplace, Streit says that Space Technology's business for government and defense applications is very robust. "Because of the focus on defense during the last two years, business has increased significantly, and Space Technology's revenues are up 25% over 2002," he said. "Almost all the military and commercial platforms we build at Space Park utilize our compound semiconductors." Examples include GaAs MMICs for the advanced avionics systems in F/A-22 and Joint Strike Fighter aircraft. The systems allow millimeter-wave communications between aircraft, minimizing the danger of collisions and coordinating threat defense. Northrop Grumman is also supplying InP MMICs for phased arrays to be deployed in a new satellite constellation (see photo on p20).

Raytheon and WIN

Raytheon RF Components (RRFC) chose to take advantage of the capacity installed in Taiwan to develop a foundry relationship with – and invest \$5 million in – WIN Semiconductors, one of several foundry companies to emerge in Taiwan as the GaAs boom reached its peak. RRFC, which operates a 4 inch GaAs fab in Andover, MA, ported its 3 mm InGaP HBT process to WIN's 6 inch fab in 2001/2 (*Compound Semiconductor* June 2002 p35).

WIN now manufactures all RRFC's HBT products for commercial markets, which include CDMA handsets and wireless LANs. These comprise about 20–30% of RRFC's total output, while the Andover fab concentrates on defense-related products serving Raytheon's internal divisions, as well as developing advanced device technologies.

"Defense markets are doing fairly well right now," said Dennis Williams, outsource technology director at RRFC. "The wafer fab [in Andover] is a key element to serve those markets and continues to win major programs." Williams says that RRFC evaluated converting its internal wafer fab to a 6 inch line or new construction, but chose the foundry approach instead. "It made very little sense for us to build a 6 inch fab in the US," he says. "Other

GaAs in Taiwan

Three years ago it seemed that everyone wanted to build a GaAs fab in Taiwan. Even by May 2001, when *Compound Semiconductor* featured an article entitled "Taiwan's foundry race will have few winners", it was clear that the many different projects could not possibly all succeed. At one stage it was predicted that a total of close to 1 million 6 inch-equivalent GaAs wafers would be produced in Taiwan in 2005, but the country's GaAs IC makers have now scaled back their expectations.

Taiwan has two 6 inch GaAs foundries, WIN Semiconductor and Global Communication Technology Corp (GCTC), and several others that manufacture 4 inch wafers, including Hexawave, Transcom and Suntek. Advanced Wireless Semiconductor Co (AWSC), located in Tainan, is a GaAs HBT foundry with a capacity of 800 4 inch wafer starts per week. The company had revenues of NTD41 million (\$1.2 million) for the whole of 2002, but its revenues for the first five months of 2003 were NTD54 million (\$1.58 million).

This increase is partly because AWSC was qualified as a second source for Skyworks in September 2002, but also because the company has delivered more than 2 million 802.11b wireless LAN chips to design houses in Taiwan since the start of 2003. AWSC says that it also has 802.11a

and 802.11g designs in the final qualification stage with customers.

GCTC has altered its plans, which originally called for two 6 inch GaAs fabs with a combined capacity of 20,000 wafers per month. The company's first 6 inch fab was originally intended to have a capacity of 2500 wafers/month, but the poor economic situation over the last three years caused the pace of capital investment to slow down, according to H C Yen, VP of sales and marketing. "We are now working under a plan to increase the capacity in stages to a final level of about 2000 wafers per month," said Yen. He added that GCTC still has the second fab in mind, and will start the planning process once the first fab reaches a utilization rate of about 60% of its final capacity.

Interestingly, GCTC has already adapted its GaAs fab to other purposes, with SAW devices now comprising about 15% of the company's business. Yen says that the strategy was developed because GCTC would like to consider itself as a provider for critical or enabling components for front-ends in communication systems. "As the level of integration increases, multichip/multifunction modules are becoming the trend," he said. "Being able to provide both GaAs and SAW technologies in a 'one-stop' service offers some advantages."

companies went ahead, and it seems some are now stuck with excess capacity, so we feel somewhat vindicated by our decision."

Raytheon was struggling to compete in commercial markets with a 4 inch fab tuned to microwave and millimeter-wave products. "The MMIC cost is buried in the much higher module cost of defense products such as X-band radar modules, but represents a significant fraction of the overall cost of a wireless PA module," said Williams. "Moving offshore for commodity products returned us to reasonable commercial profitability."

Of course, the fact that WIN has a new, modern fab, which is mostly automated, enhances characteristics such as uniformity, reproducibility and yield. Logistics is another advantage; WIN sources MOCVD-grown HBT epiwafers directly from an Asian supplier with manufacturing facilities in Taiwan, and Raytheon's test facility is also located in Taiwan.

Although only one RRFC process has been

ported across to WIN so far, others could follow. "As market pressures drive system prices down, we will move technologies offshore when cost drivers make sense," said Williams, adding that RRFC designers are also looking at using WIN's standard foundry processes such as 2 µm HBT and a suite of PHEMT technologies.

TriQuint Semiconductor

As demand for GaAs ICs blossomed throughout 2000, TriQuint consolidated its facilities in Richardson, TX, acquiring a large amount of cleanroom and office space from DRAM specialist Micron Technologies. This added to the company's 4 inch GaAs IC line in Hillsboro, OR, which was expanded in 2000 and subsequently converted to process 6 inch wafers. TriQuint also acquired surface acoustic wave filter specialist Sawtek in 2001, bringing in house another crucial technology for its wireless communication module business.

GaAs MANUFACTURING

In 2002, TriQuint's business underwent a considerable change that saw it add to its GaAs IC capabilities through the acquisition of Infineon's GaAs business, and then diversify away from GaAs-based microelectronics by acquiring a large part of Agere's optoelectronics business. The Infineon GaAs business shared a facility in Germany with one of Infineon's Si processing operations. The GaAs activity there has now ceased, and the processes and some personnel have been transferred to TriQuint's US fabs. TriQuint has retained some of the former Infineon GaAs staff for its European sales, marketing and circuit design operations.

The Richardson fab is still processing 4 inch wafers and has a capacity of about 25,000 wafers per year. However, it also has an unutilized 6 inch toolset installed and waiting for market conditions to ease before it comes to life. It is intended that the 4 and 6 inch lines will eventually run alongside each other with the 6 inch tools boosting capacity by about 75,000 wafers per year. The fab primarily serves the telecom, military and space markets. It also provides products for optical

communications including TIAs, limiting amplifiers and laser drivers, which complement the company's optoelectronics activities.

The Hillsboro facility is now a fully functioning 6 inch fab with a capacity of about 75,000 wafer starts per year, and is mostly dedicated to serving the wireless communications industry through its HBT, MESFET and PHEMT processes. Interestingly, the fab also does brisk business in GaAs ICs for the physical layer of optical communications, including clock and data recovery and MUX and DEMUX ICs, despite the fact that silicon-based processes are now finding favor for these applications. "We still have a surprisingly strong business in that area," said Rob Christ, TriQuint's foundry marketing director. "We are not investing in this area or developing new products because these applications have all gone to silicon, but devices that we designed in the 1990s are still selling well."

Filtronic focuses on PHEMTs

The UK's first 6 inch GaAs fab got off to a rocky start, coming on stream just as the industry entered its period of contraction. The

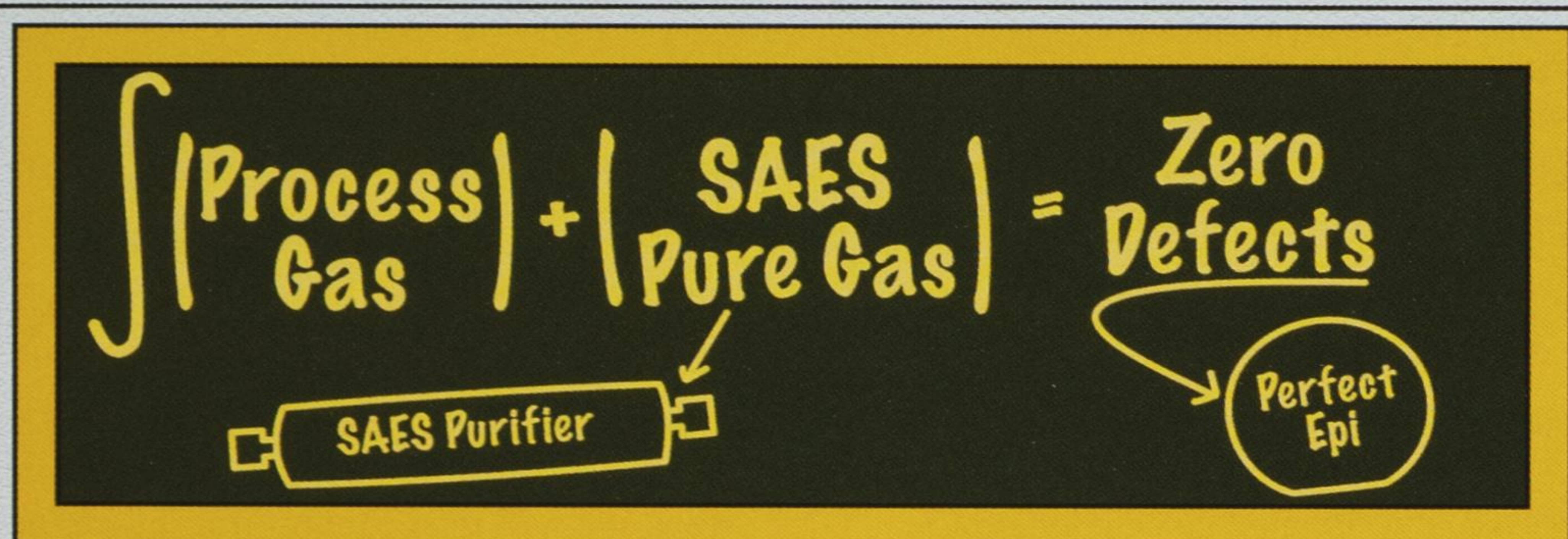
Filtronic Compound Semiconductor (FCS) facility in Newton Aycliffe, UK, is housed in a converted DRAM manufacturing plant acquired in 2000. It now occupies about one-third of the available cleanroom space and has a capacity of at least 30,000 wafers per year, although this depends on the product mix being run and could be significantly more for simpler process routes.

The fab is currently very active, running five 24 hour days per week. FCS's busiest area is in switches for wireless applications using its low-cost, fast-throughput 0.5 μm PHEMT process. It also has a 0.5 μm power PHEMT process for producing discrete power transistors with high breakdown voltage for its parent company's wireless infrastructure business. The company has also successfully transferred the 0.25 μm PHEMT process from its now-closed Santa Clara fab, although a design and sales team still operates at the site. A high-performance power MMIC process is in development, aimed at the growing market in mm-wave applications, and is expected to be in production in 6–12 months.

In late 2001 FCS announced that it had entered into supply agreements with BAE Systems and M/A-COM. Although the M/A-COM agreement does not formally end until February 2004, the inference from Filtronic's financial statement issued in July saying that "our foundry agreement with M/A-COM has not proved fruitful" is that things never really got off the ground. However, the agreement to supply defense contractor BAE Systems with GaAs devices is still going strong and has been extended to include supplying modules. More recently, Filtronic has announced its first orders from an undisclosed customer for high-efficiency power PHEMT-based PAs for 3G WCDMA mobile infrastructure applications.

Ommic targets InP HBTs

Not far from Paris, France, Ommic is busy installing a 6 inch GaAs processing line alongside its existing 3 inch tool set. At present, the capacity of its facility allows about 5000 wafer starts per year. The company does not plan to increase its output, but rather intends that the move to medium-volume 6 inch manufacturing will improve the foundry service to its customers in the space, telecom and defense industries, who often require large-area devices. The existing 3 inch production facilities will remain in place once the 6 inch line is fully operational, as Ommic intends to augment its GaAs IC offerings by becoming Europe's first InP HBT foundry in 2004. ●



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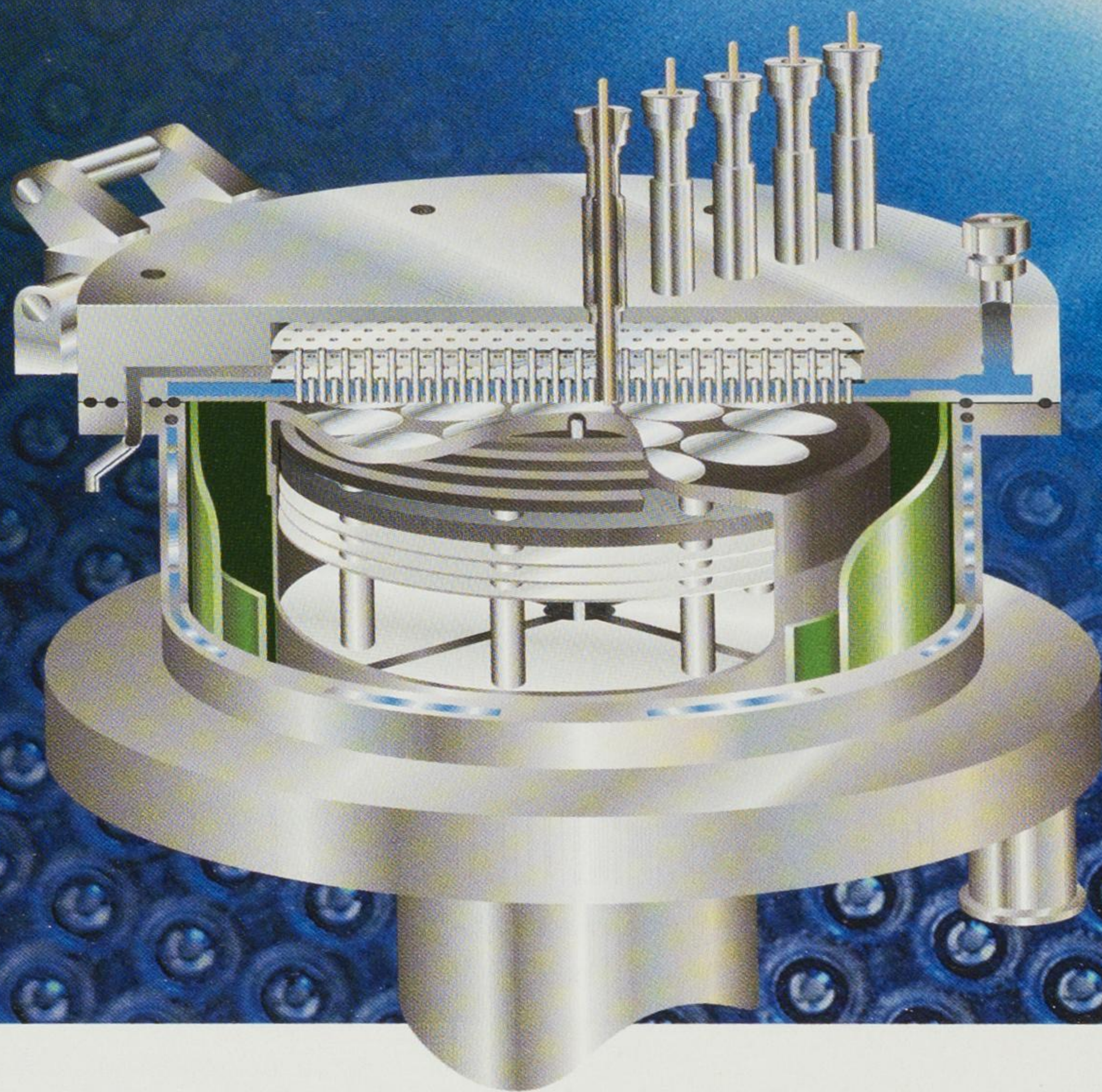
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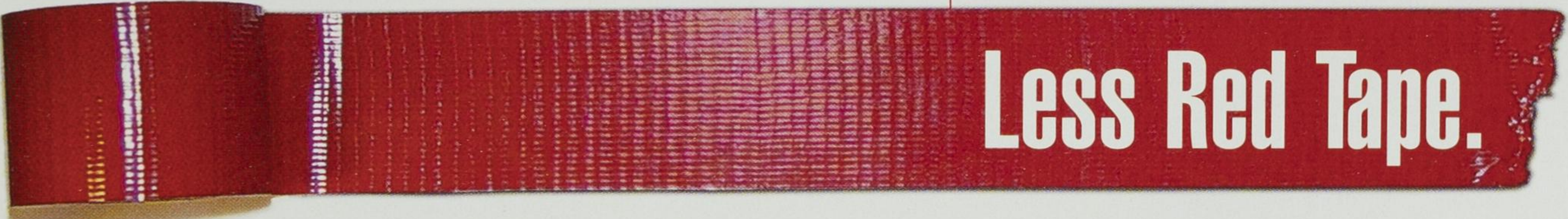
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Non-intrusive techniques help to predict the lifetime of LED lighting systems

New, rapid evaluation methods should help to bring researchers closer to defining the long-term performance of lighting systems based on LEDs, according to **Jennifer Taylor** of the LRC.

Purchasing a new lighting system is no small expense. Consumers therefore want to know what they're getting for their money, including an accurate prediction of how long the system will last. This is especially true when it comes to newer, evolving technologies such as LEDs, which have no comprehensive performance record in lighting systems. However, researchers at the Lighting Research Center (LRC) at Rensselaer Polytechnic Institute in Troy, NY, are getting closer to developing non-invasive methods for measuring the lifetimes of LED lighting systems. Such systems have become increasingly popular during the last five years and are becoming commonplace in traffic signals, exit signs and other forms of display lighting. LEDs are now displacing other types of lamps, particularly in applications requiring colored light, and in the future LEDs are poised to impact general illumination as well.

System lifetimes

Consumers purchasing LED systems usually want to know how long the systems will perform so that they can estimate maintenance frequency and costs. Manufacturers typically estimate their systems' lifespans to be the same as that of the individual LEDs used, often stating a lifetime of up to 100,000 h. However, according to Nadarajah Narendran, director of research at the LRC, this prediction is unlikely to be accurate.

"When LEDs are placed into a system, we have to take into consideration the packaging, the drive current, and the environmental conditions where the system is operating," he said. "All these factors affect the life of LEDs in a system." In other words, LEDs do not perform in the same way in a packaged system as they do under ideal laboratory conditions.

Based on this fact, Narendran and his stu-

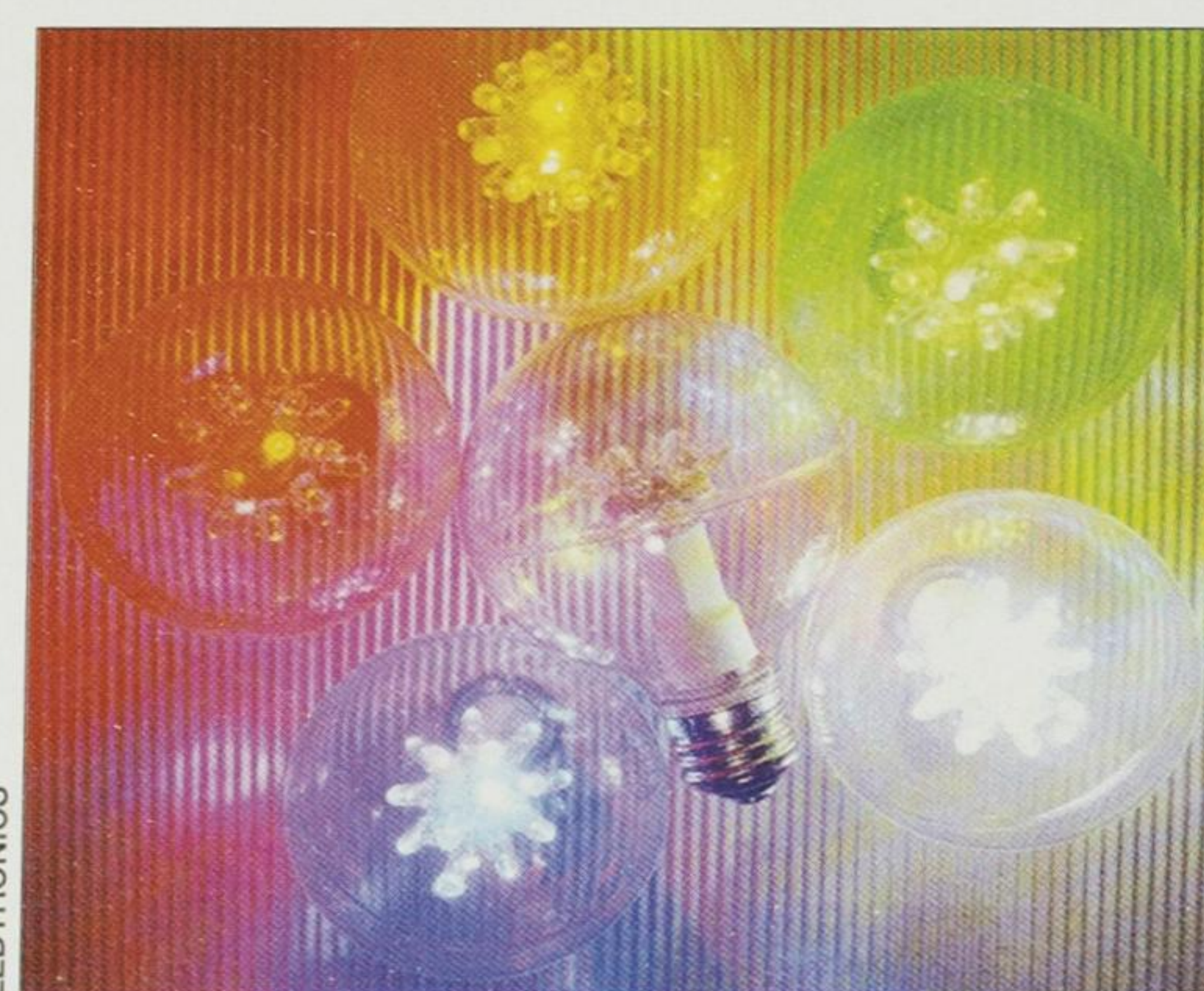
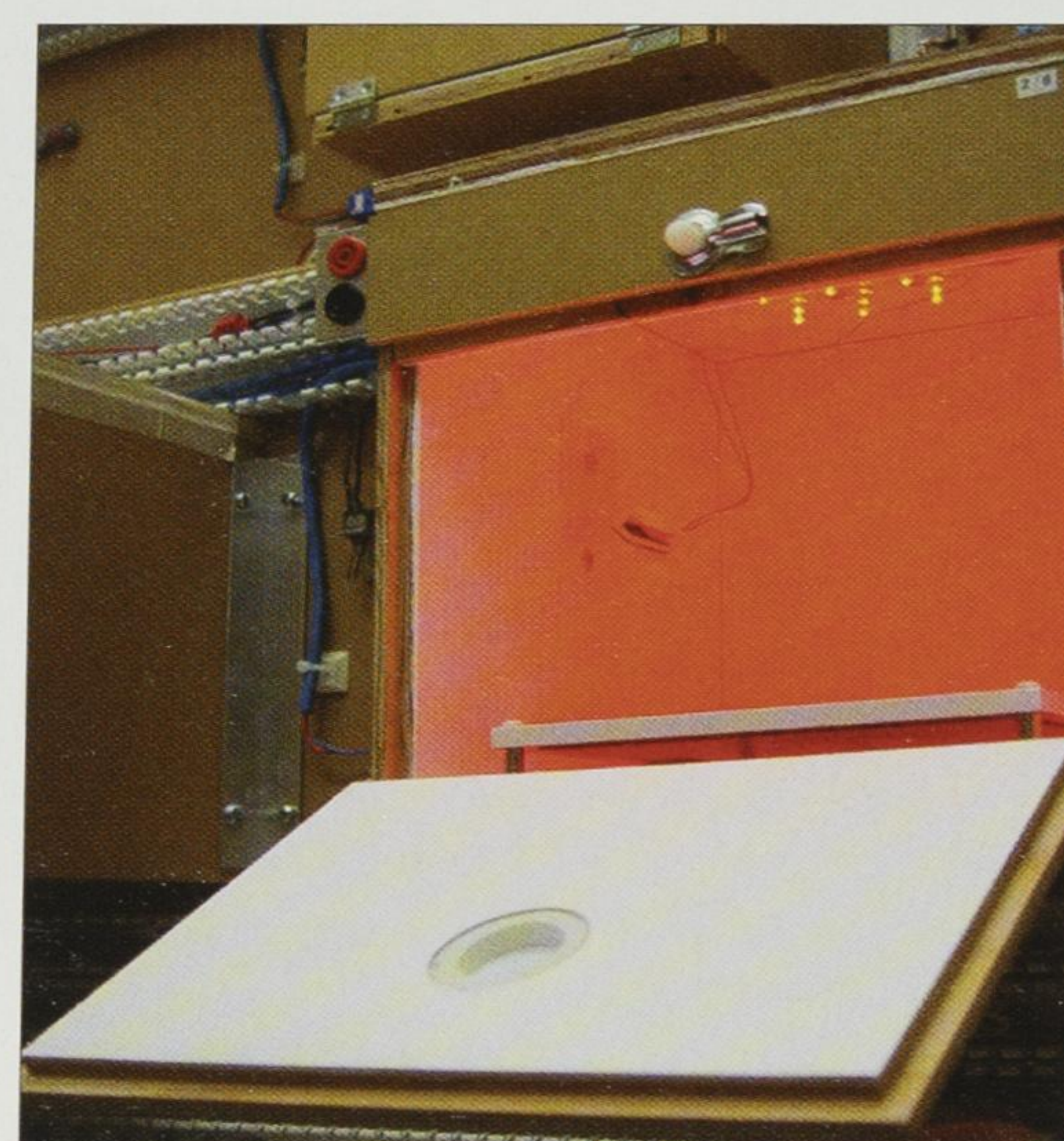


Fig. 1. Laboratory set-up at the Lighting Research Center used to measure the junction temperature and spectral characteristics of standard red and white LEDs.

dents Eugene Hong and Yimin Gu completed two studies to define new methods of determining junction temperature in LED systems (Hong and Narendran 2003; Gu and Narendran 2003). Junction temperature is a primary factor in the degradation of LEDs, and is affected by the ambient temperature and the amount of power used to run a system. While methods for estimating junction temperature are not new, methods appropriate for systems have not been explored thoroughly until now.

"When we started this research, we knew that junction temperature had an effect on the degradation of light output from LEDs," said Narendran. "What we wanted to know was how we could determine the temperature at the junction without opening the system, and if we could use that information to predict system life without long-term life tests."

Narendran says that taking a system apart may affect its integrity and operating life, while long-term life tests are not practical



LED-based lighting products may eventually replace conventional incandescent bulbs.

because they are time-consuming, sometimes taking years to complete. Therefore, these studies focused on finding alternative methods for determining junction temperature, which could then potentially lead to predictions of LED system life.

Determining junction temperature

Two common methods for determining LED junction temperature are measuring the LED lead wire temperature and measuring the potential difference across the junction. However, both of these methods require access to the lead wire of the LED, which means disassembling the system.

Based on a number of previous studies regarding LED emission spectra and how they change with temperature, Narendran and his team chose to investigate whether spectral measurements, which are non-invasive, could be correlated to junction temperature. Because different semiconducting materials and device packaging affect light output degradation in different ways, the LRC researchers started their investigation with the most commonly used 5 mm red (AlGaInP) and white (GaN+YAG:cerium phosphor) LEDs.

The team's first step was to pick a known, reliable method for measuring the junction temperature against which to compare results from spectral measurements. Because the potential difference across the LED junction changes linearly as the temperature is increased within a certain range, junction temperature can be determined by measuring the potential difference across the LED junction. The next step was to compare the measured junction temperature against the spectral power distribution (SPD) of the LED emission.

Red LED systems

Previous studies have shown that the bandgap energies of certain types of LEDs, including AlGaInP, decrease with increasing temperature. As a result, the peak wavelength of the LED shifts to longer wavelengths with increasing temperature. In the study carried out to test red LEDs, commercial LEDs from several different manufacturers were used.

During the experiment, the junction temperature was raised in two ways: by operating the LED at higher drive currents while holding the temperature of the surrounding environment steady; and by increasing the temperature surrounding the LED while driving the LED at a constant current.

The researchers found that the peak wavelength of the red LEDs shifted proportionally to the junction temperature, regardless of how the heat was generated at the junction (figure 2). This behavior was true for all of the commercial LEDs tested in the study. Because LEDs of this type have a similar spectrum shift for a given temperature change, figure 2 demonstrates that the average junction tem-

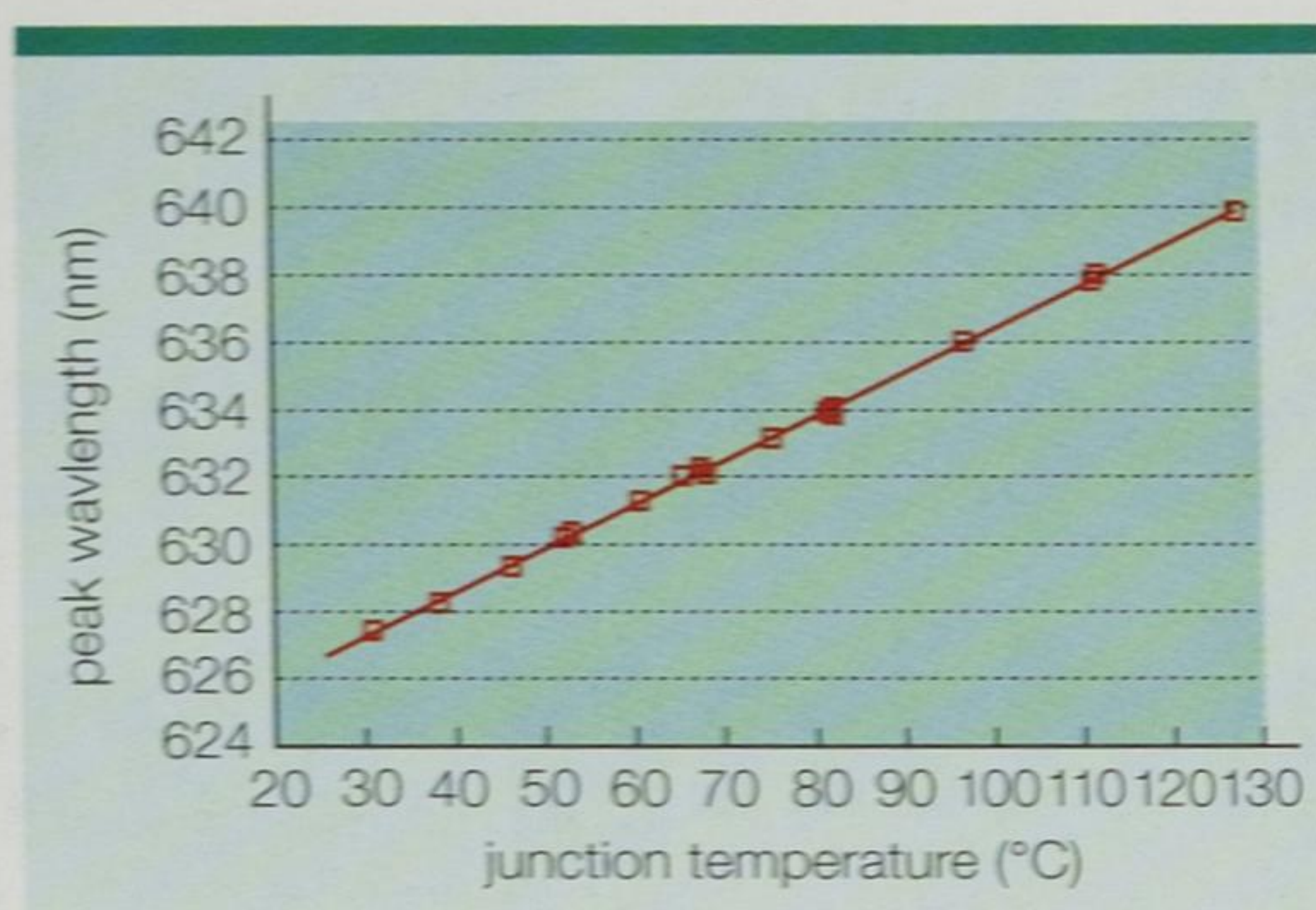


Fig. 2. Peak wavelength as a function of LED junction temperature for 5 mm red LEDs.

By defining quick methods for accurately determining junction temperature and system life, researchers and manufacturers will be able to keep pace with rapidly changing LED technologies.

perature of the LEDs in a system can be predicted by measuring the peak wavelength shift and the initial room temperature.

White LED systems

However, the spectrum shift method does not work well for white LED systems. In these types of LEDs, the wavelength shift as a function of temperature is much smaller (Nakamura *et al.* 1994), making it much more difficult to measure. However, one study of GaN-based white LEDs showed that as the temperature increases, the emission intensities of the blue and yellow components of white light generated by the LED and the down-conversion phosphor, respectively, decrease at different rates (Tamura *et al.* 2000). Based on this information, Narendran's team chose to investigate whether a relationship exists for white LEDs between junction temperature and the ratio of total radiant energy (W) to the radiant energy within the blue emission peak (B).

Again, commercial white LEDs were purchased for this study. Because there are few suppliers of 5 mm white LEDs, the purchased LEDs were from different batches produced by the same manufacturer. Similar to the red LED study, these white LEDs were tested at various drive currents and ambient temperatures. At each of these conditions, the junc-

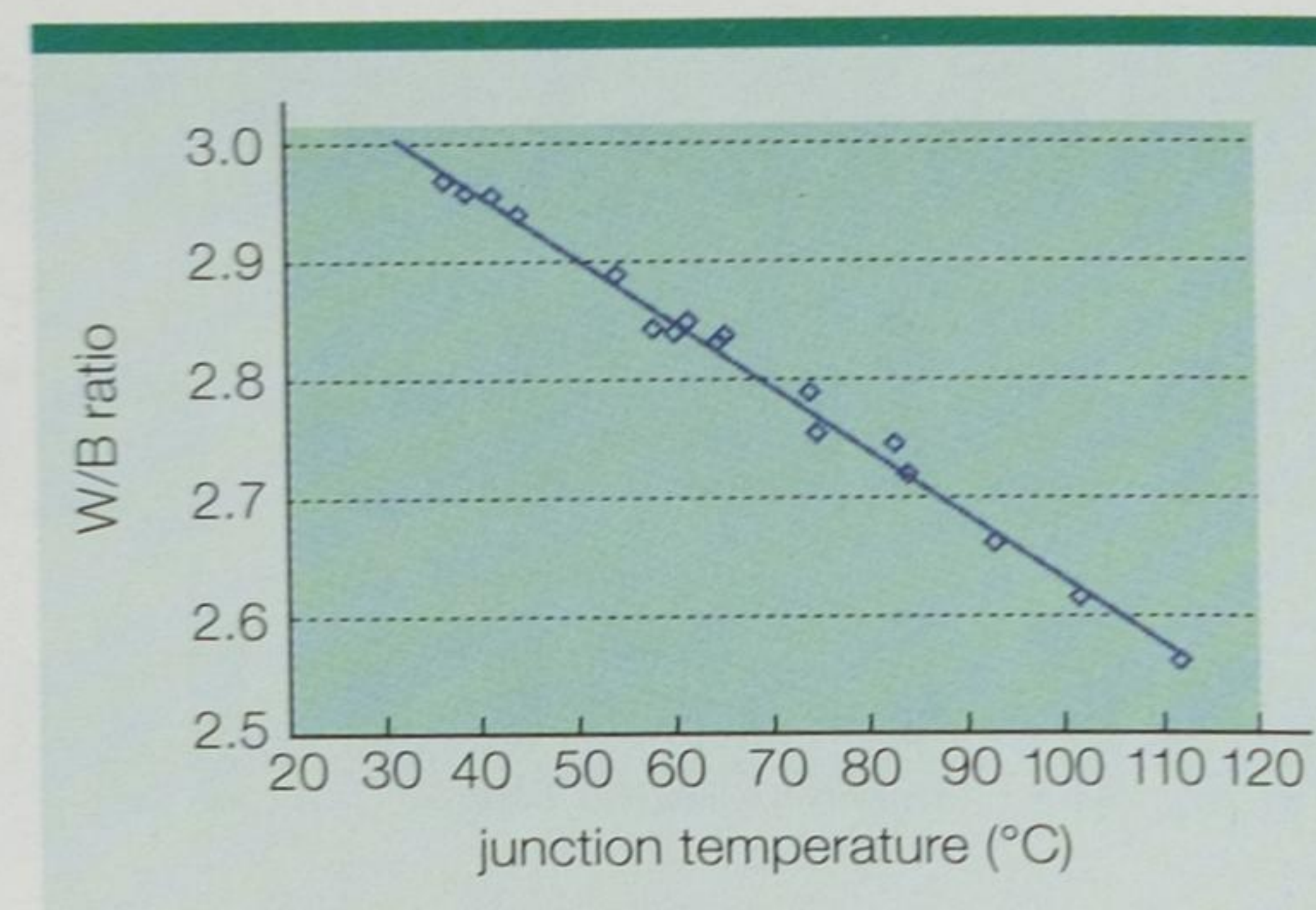


Fig. 3. Effect of junction temperature on W/B ratio for 5 mm white LEDs.

tion temperature and the SPD were measured. By analyzing the measured SPD, the LRC researchers found that a proportional relationship exists between the junction temperature and the W/B ratio (figure 3). Therefore, the average junction temperature of the LEDs in a system can be predicted by measuring the W/B ratio and the initial room temperature.

"These methods show that the average junction temperature of the LEDs in a system can be measured easily without impacting the integrity of the product," said Narendran.

Predicting LED system lifetimes

Estimating junction temperature is only the first step toward accurate system-life predictions. Narendran says that his group is currently working to identify the relationship between junction temperature and the degradation rate for LEDs. In the future, the LRC hopes to develop data showing LED degradation rates at various junction temperatures.

With this data, as well as the non-invasive methods for determining junction temperature, manufacturers will not only be able to provide accurate reliability estimates for system life, but will also be able to develop better quality products.

"If you can measure something, you can make corrections or improvements," said Narendran. Furthermore, manufacturers can use this data as a quality-control mechanism in their manufacturing processes.

Consumers will also see benefits from accurate life predictions. They will be able to purchase the right systems for their needs, and will be able to plan for maintenance and replacement costs.

In the future, Narendran says that research needs to be completed on a broader range of commercial LED products and then put into practice with a number of existing systems. He adds that the effects of humidity and moisture on system life also need to be evaluated.



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As LED systems become more prominent and enter new territories, current and future research will help to establish a history and characterizations for LED usage. By defining quick methods for accurately determining junction temperature and system life, researchers and manufacturers will be able to keep pace with rapidly changing LED technologies and integrate them more effectively into lighting systems. ●

Further reading

Y Gu and N Narendran 2003 A Non-Contact Method for Determining Junction Temperature of Phosphor-Converted White LEDs *Proc. SPIE 5187* (in press).

E Hong and N Narendran 2003 A Method for Projecting Useful Life of LED Lighting Systems *Proc. SPIE 5187* (in press).

S Nakamura *et al.* 1994 *Appl. Phys. Lett.* **64**(13) 1687.

T Tamura *et al.* 2000 *J. Lumin.* **87-89** 1180.

Jennifer Taylor is a communications specialist with the Lighting Research Center at Rensselaer Polytechnic Institute in Troy, NY.

What defines LED lifetime?

The flip of a switch followed by the popping sound of a filament breaking. For a typical incandescent light source, this sound means that the lamp is dead and needs to be replaced. For such traditional light sources, the rated life defined by the manufacturer is the time it takes for 50% of these lamps to "burn out", or fail catastrophically. For LEDs, however, the light output doesn't cease suddenly. As semiconducting light sources, LEDs do not have a filament that wears out, and they almost never fail completely.

So is an LED an everlasting light source? Not exactly. Though it may continue to shine, an LED's light output will degrade over time, producing fewer lumens while still consuming electrical power. As solid-state devices, LEDs may continue to operate past 100,000 h with a diminished output, while a typical incandescent lamp used in the home lasts 1000 h on average before burning out.

Although the lighting industry has no standard definition for LED lamp life, LRC researchers believe it is more appropriate to use the term "useful life" – the time when an LED fails to provide sufficient light output for a given application (Narendran *et al.* 2001). In the case of general illumination, useful life is the time taken for the light output to fall to 80% of its initial value (Bullough 2003). Since LED light output degrades primarily because of the heat generated by electrical currents and the effect of the ambient environment, effective temperature control can promote longer optimal performance.

Further reading

J Bullough 2003 LED Lighting Systems *Lighting Answers* **7**(3) National Lighting Product Information Program, Lighting Research Center, Troy, NY.

N Narendran *et al.* 2001 What is useful life for white light LEDs? *J. Illum. Eng. Soc.* **30**(1) 57.



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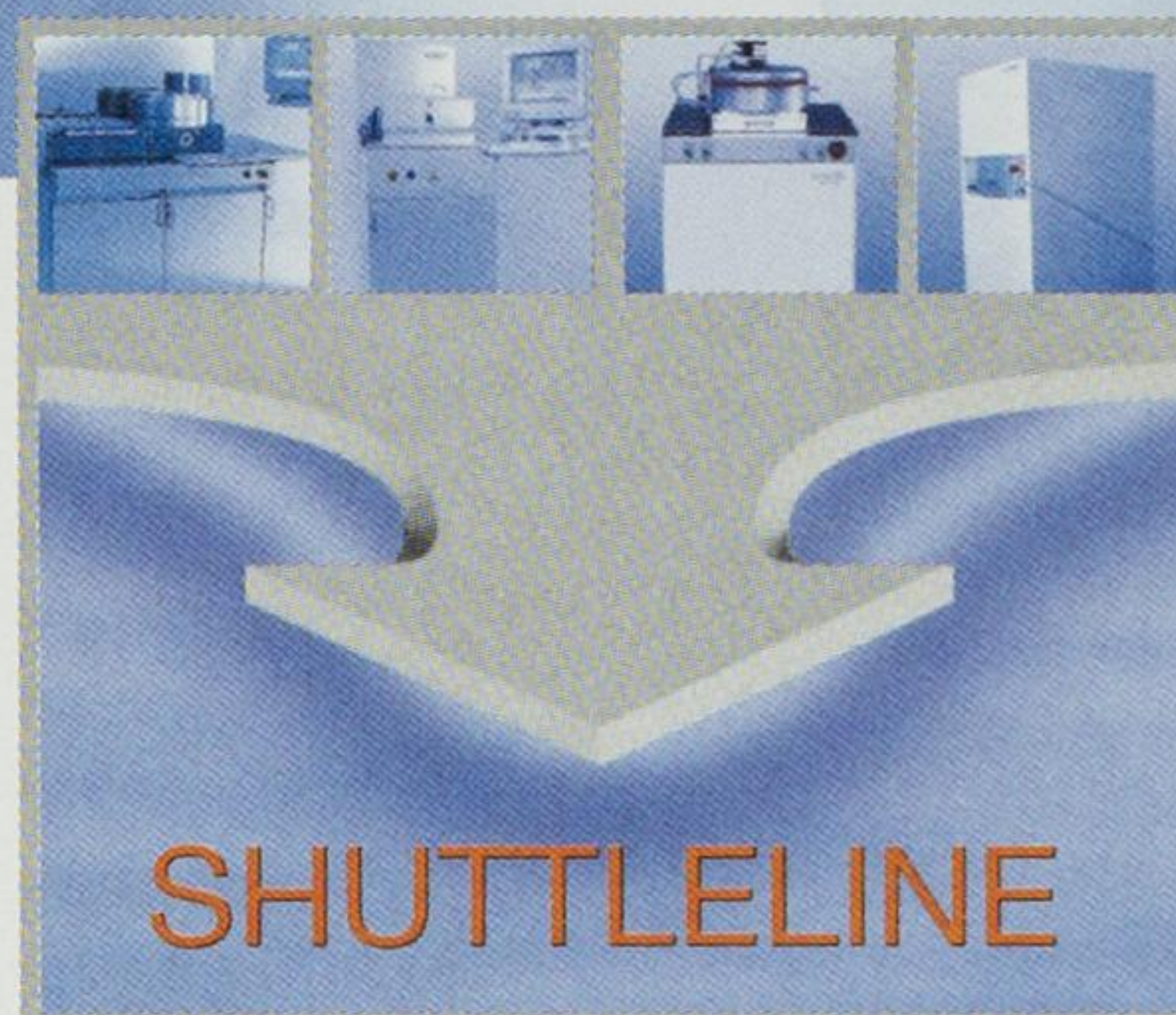
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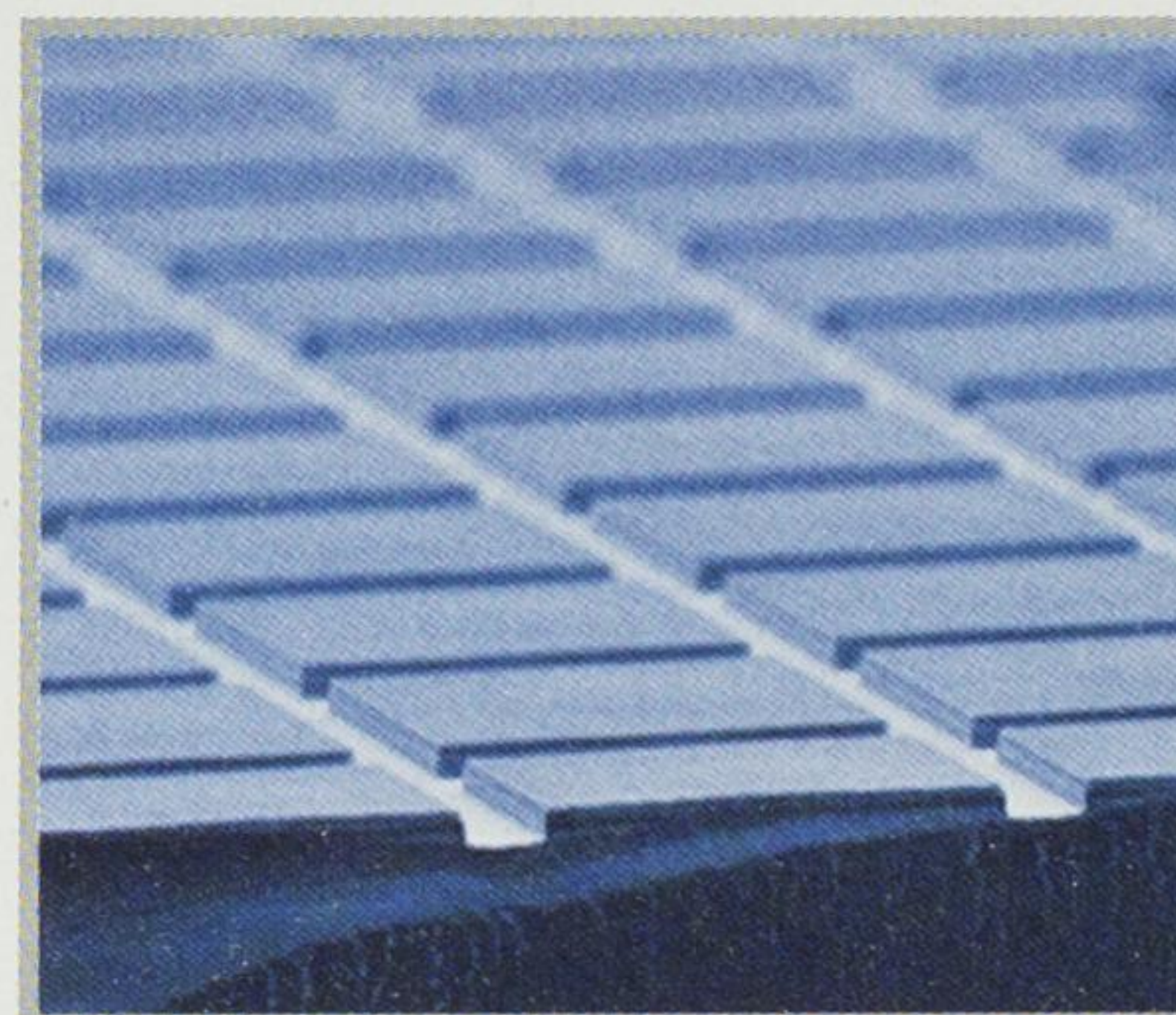
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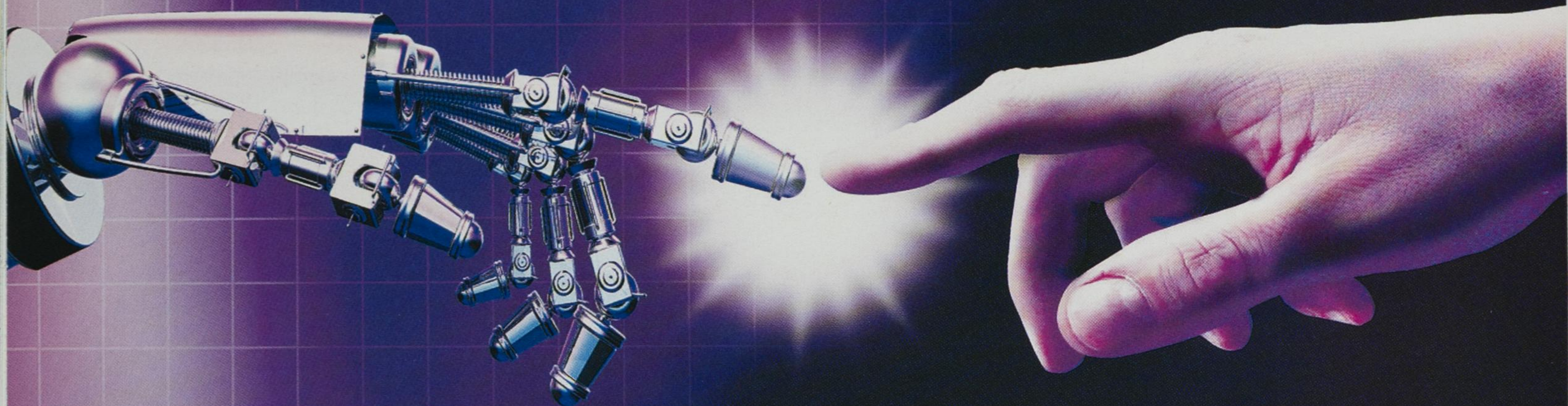
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GaAs MANUFACTURING

A novel approach to metal lift-off for GaAs ICs

The ability to manipulate all thermal, mechanical and chemical variables is crucial in developing a high-yield lift-off process, according to **Mehran Janani, James Thietje** and colleagues.

Sputtering or evaporation of metal over patterned resist followed by metal lift-off have traditionally been used to define interconnects in GaAs wafer processing. In the lift-off process, a sacrificial material such as photoresist is first deposited and patterned on the substrate. The metal is then deposited on top and the sacrificial material is subsequently removed through exposure to solvent soaking and spraying, leaving behind only the material deposited directly on the substrate. These processes are useful for patterning materials that cannot be etched without affecting underlying materials on the substrate. Today, most metal lift-off processes are done in wet benches with megasonics, spray systems or dry systems using CO₂. These methods include acetone or solvent soak, ultrasonic immersions and other recent methods using pressurized liquid CO₂ through an aerosol spray, supercritical CO₂ and dry CO₂ (Burtch *et al.* 2001; Ober *et al.* 2002).

Current trends in lift-off

For acetone or solvent soak, the selection of a particular solvent or mixture of solvents is dependent upon the process and desired results. The metal-deposited wafers are immersed in a bath of solvent which helps in lifting/removing unwanted metal and resist through its reaction with the organic resist material, causing it to swell. One of the drawbacks of this approach is that the solvent must be either frequently replenished or constantly filtered to prevent re-deposition of metal on the substrate. Furthermore, agitation is necessary to completely lift the metal.

An ultrasonic cleaning system is often used to help the lift-off process by dislodging the unwanted metal. Other methods include a hot solvent soak followed by a rinse, and single-wafer processing with heated pressurized solvent spray. Here, each wafer is processed without the need to soak or immerse in a batch. The control parameters include solvent

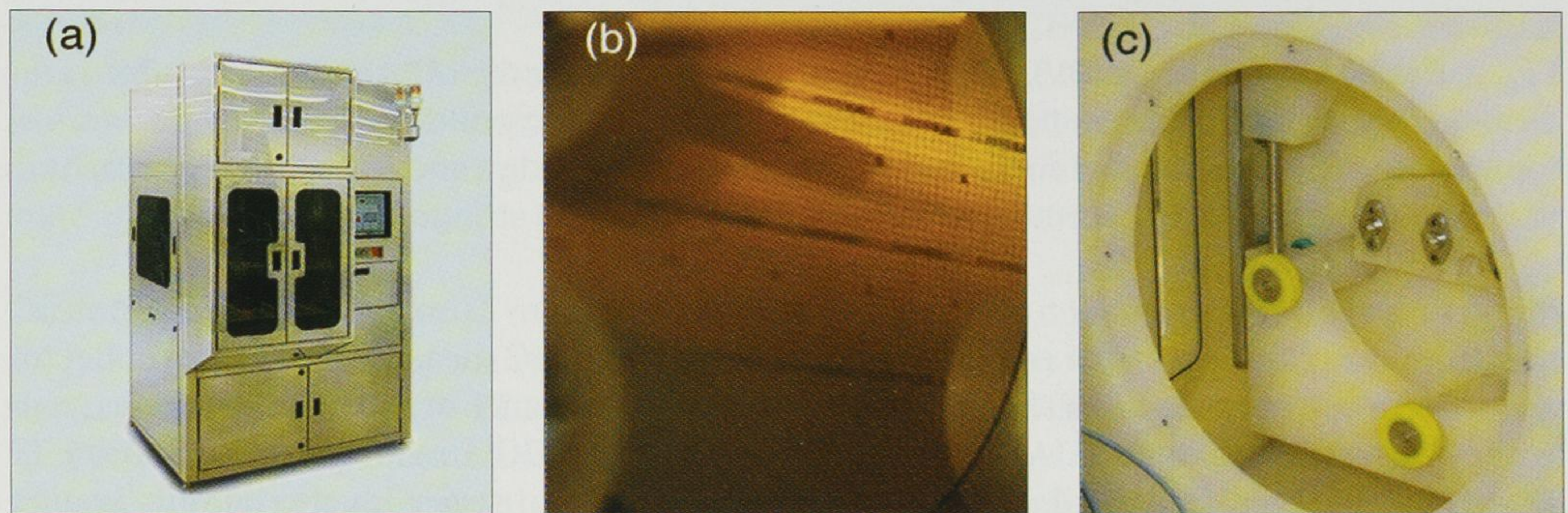


Fig. 1. Planar Semiconductor's RPC-100 R-PHAST system as used in the study with Skyworks (a), a GaAs wafer on a holder, ready for lift-off (b) and the vertical pulse chamber (c).

spray pressures of up to 1500 psi, solvent temperature, spin speed and process time. In addition to low defect density control on the wafer, high throughput, low cost of consumables and low cost of ownership are paramount to ensure successful integration of any lift-off process in high-volume manufacturing.

Lift-off by R-PHAST

Planar Semiconductor, in collaboration with GaAs IC manufacturer Skyworks Solutions, has studied ways to improve the lift-off process while addressing these needs. Planar Semiconductor has developed a vertical non-contact front and backside single-wafer cleaning process that creates discrete droplets of fluid by pulsing the spray using a special pump. This new approach is called rapid-pulse harmonic spray technology (R-PHAST).

The fluid droplets in each pulse interact with the wafer, which rotates slowly in a vertical orientation, to produce a hybrid of laminar and turbulent flow types. Rapid pulsing controls the fluid-mechanical interactions of jets and droplets with any adsorbed contaminants. As a result the chemical concentration gradient at the wafer/liquid interface is always positioned to favor desorption of contaminants. The moderate application of a pressurized solvent allows for a blend of mechanical and chemical energy for lift-off applications. Large

particles are removed at the point of impact of the pulse spray due to the generation of turbulent flow. In the laminar flow regime where the boundary layer is less than 1 μm , the solvent is responsible for dispersing and rinsing small particles and labile layer removal.

Compared with the use of other technologies that use fluids at super critical pressures aided with co-solvents, dry CO₂/liquid approaches and jet sprays, the rapid pulse approach manipulates all of the essential thermal, mechanical and chemical ingredients for effective cleaning, thereby offering a simple, elegant and cost-effective solution.

Figure 1 shows an RPC-100 metal lift-off tool, a GaAs wafer ready for lift-off and the vertical pulse chamber. Additional chambers can be added to increase throughput. The wafer is held from the edges during processing, and DI water or desired chemistry can be sprayed on the backside in the final pulse rinse step to keep the wafer backside clean. It is a dry-in, dry-out system.

In a typical process sequence, a single wafer is delivered to the R-PHAST chamber where the heated solvent is pulsed, followed by a DI pulse rinse to remove photoresist residue and metal stringers. The lifted metal can be reclaimed via a special module underneath the system. The wafer is then dried using a vertical spin or N₂-assisted process with no han-

GaAs MANUFACTURING

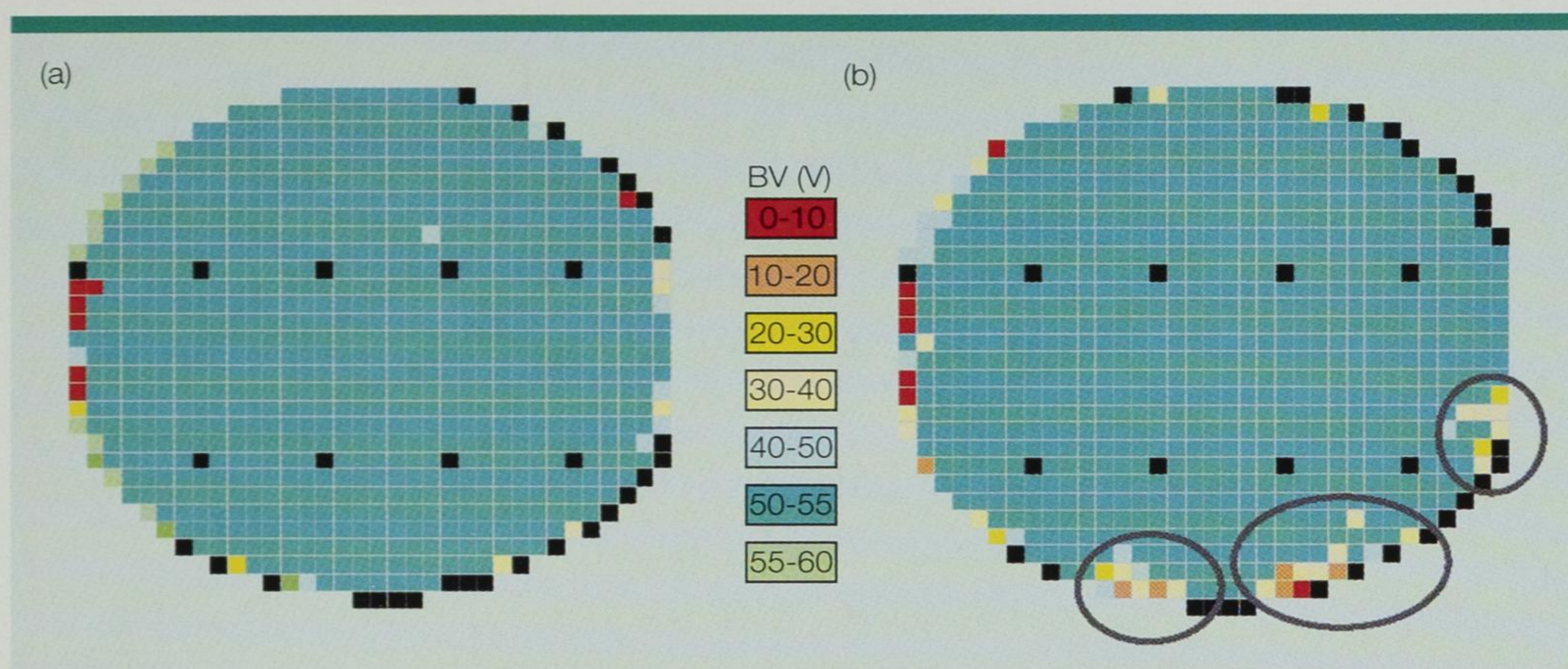


Fig. 2. Breakdown voltage (BV) maps each showing 834 on-chip MIM capacitors after autoclave test, fabricated using (a) standard spray technology and (b) R-PHAST technology. The circled clusters of capacitors at the wafer edge show low breakdown voltage and high leakage current, which coincide with metal stringers or residues.

dling. Process parameters such as fluid pulse pressure, droplet size, wafer rotation speed and solvent temperature can all be varied, and are key factors that allow R-PHAST to be used in a wide variety of front-end and back-end cleaning and lift-off applications.

Experimental

Three types of experimental wafers were used to evaluate R-PHAST for lift-off. Two layers of metal interconnect patterns were fabricated on mechanical-grade GaAs substrates with Au metal of thickness $>1.6 \mu\text{m}$. The aggressive line and space design rule geometries of the pre-metal pattern ($2.0 \mu\text{m}$ line and space) combined with thick Au can be expected to make metal lift-off more challenging using a traditional spray tool. The second type of wafer was patterned with collector contact metal before metal lift-off. Severe topography, along with the orientation-dependent re-entrant profile of the collector contact trench, makes this layer difficult for lift-off applications. The third type of wafer used in this evaluation was blanket coated with polyimide, a dielectric layer, which is in direct contact with the solvent and hardware during the metal lift-off process.

Two different solvents were investigated – a commercially available N-methylpyrrolidone (NMP) and a Lo-Chem series proprietary solvent from Planar Semiconductor known as Pad. To evaluate changes in polyimide characteristics after exposure to the solvents, Fourier transform infrared (FTIR) spectroscopy analysis was performed on the blanket polyimide wafers. Metal conductance, which is a measure of metal-to-metal leakage, was evaluated using a $300 \mu\text{m}$ long serpentine

with minimum $2 \mu\text{m}$ line and space test structures using DC measurements. The collector contact resistance of an HBT device was measured using DC measurement techniques.

In addition, wafer-level reliability testing of 60 nm silicon nitride MIM capacitors with a surface area of about $39,000 \mu\text{m}^2$ was completed before and after pressure cooker tests performed according to JEDEC standard No-22-A. Current-voltage (I-V) measurements were performed using an automatic parametric tester where voltage was ramped across the MIM capacitors while monitoring leakage current through capacitor plates.

FTIR and electrical characterization

In order to examine the surface characteristics of exposed polyimide during metal lift-off with different solvents, FTIR data was collected on blanket polyimide wafers. Using a digital subtraction technique, the surface characteristics of the polyimide before and after exposure to each solvent were investigated. In both cases, more imide (733 cm^{-1} and 1504 cm^{-1}) and aromatic ring (832 cm^{-1} and 1334 cm^{-1}) vibrations were observed after exposure to each solvent. Overall, no change in polyimide film characteristics was noticed after exposure to either chemistry.

Leakage between metal lines was measured using two interdigitated comb structures across sample wafers. Collector contact and interconnect metal conductance were measured by applying a fixed voltage and measuring leakage between the comb structures. Higher conductance values correspond to higher line-to-line leakage, which could be the result of metal stringers, residues or particles on metal lines due to a poor metal lift-

off process. Interconnect metal and collector contact conductance measured from samples processed in the RPC-100 tool using R-PHAST technology was found to be comparable to the standard spray tool, regardless of solvent, with no yield loss.

MIM capacitor characterization

Metal stringers and unlifted metal on resist at the edges of metal lines in the capacitor structures can result in cracks in the silicon nitride passivation due to severe film topology and film stress. In order to ensure a defect-free lift-off process, capacitor-intensive wafers were subjected to the R-PHAST lift-off process, and the soft-breakdown performance of 60 nm MIM capacitors was explored before and after 19 h of pressure cooker testing (autoclave). This test is critical to identify any wafer-level reliability issues due to cracks in the passivation nitride resulting from unlifted resist, metal residues, metal stringers or damaged metal lines during the lift-off process. A crack through passivation nitride leads to moisture penetrating the polyimide layer, resulting in deterioration of MIM capacitors, a decrease in breakdown voltage and an increase in leakage through the capacitor dielectrics.

Jiro Yota *et al.* (2003) reported the fabrication and characterization of high-density MIM capacitors and showed that the breakdown of 60 nm MIM capacitors occurs at a DC potential of $60\text{--}65 \text{ V}$. The breakdown voltage of 60 nm MIM capacitors after autoclave testing is grouped in different bins represented with different color codes, as shown in the wafer maps in figure 2. In figure 2b, the dies near the edge that are encircled and have different color codes from the center dies represent MIM capacitor failures with high leakage current and lower breakdown voltage.

Weak and failing capacitors were mainly observed near the edge of samples processed on the RPC-100 Planar Semiconductor tool using R-PHAST technology. The location of failures matched defect inspection results performed after lift-off. A careful inspection of the failed capacitors revealed metal stringers and residues on or in the vicinity of the MIM capacitors as shown in figure 3. Although these defects may not directly cause a capacitor failure, they would impact the integrity of final passivation nitride and induce damage and cracks, which would lead to moisture penetration into polyimide. This would in turn result in high current leakage of MIM capacitors and degradation in the long-term reliability of the devices.

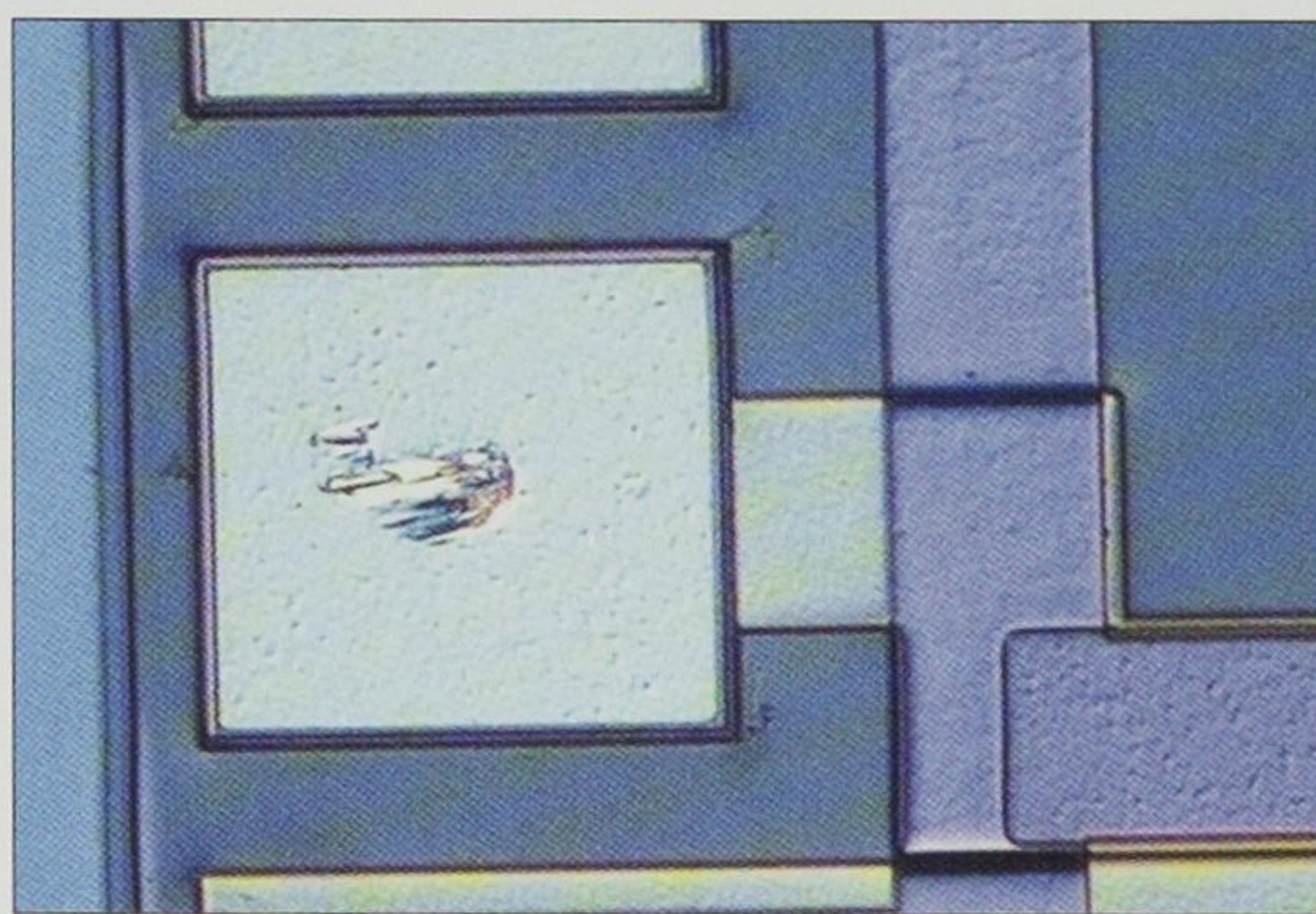
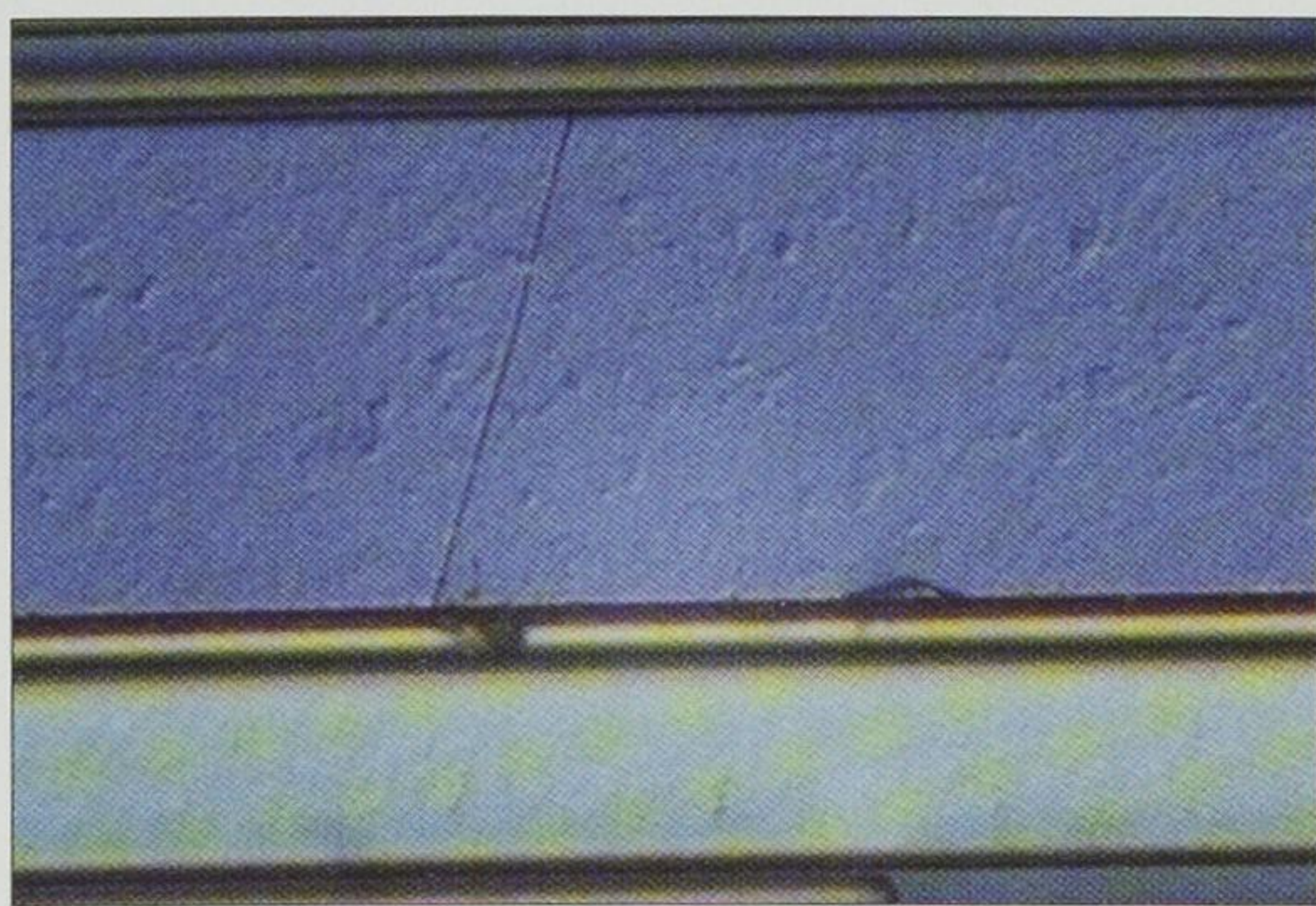


Fig. 3. Optical micrographs of MIM capacitors with low breakdown voltage showing metal lift-off residues, the result of insufficient solvent coverage at the wafer edge.

Further process improvements

Additional studies undertaken suggest that the majority of edge defects are related to insufficient solvent coverage near the edge of the vertical pulse chamber. This is due to a non-automated wafer-holding mechanism adopted for this study to accommodate 100 mm wafers on a 200 mm demonstration head assembly. By using an exact-size head assembly built for 100 mm wafers and additional automation, an adequate solvent coverage to the edge of wafers has been achieved. Also, changing the

spray nozzle configuration during process from a "stationary" to a "non-stationary" (transverse) position has been proven to eliminate edge defects.

Conclusions

A "full metal lift-off" has been achieved in a single chamber using the R-PHAST process. Electrical results generated in this study showed similar or better metal conductance compared with a standard spray tool. Furthermore, wafer-level reliability data collected

from 60 nm MIM capacitors processed on the RPC-100 tool after 19 h of high pressure, temperature and humidity testing did not show any capacitor failures. However, higher current leakage was detected in some MIM capacitors near the edge of wafers. An optimum solvent pulse pressure, combined with appropriate hardware modifications, has been found to be critical for reducing metal stringers, metal line damage and sidewall metal roughness. ●

Further reading

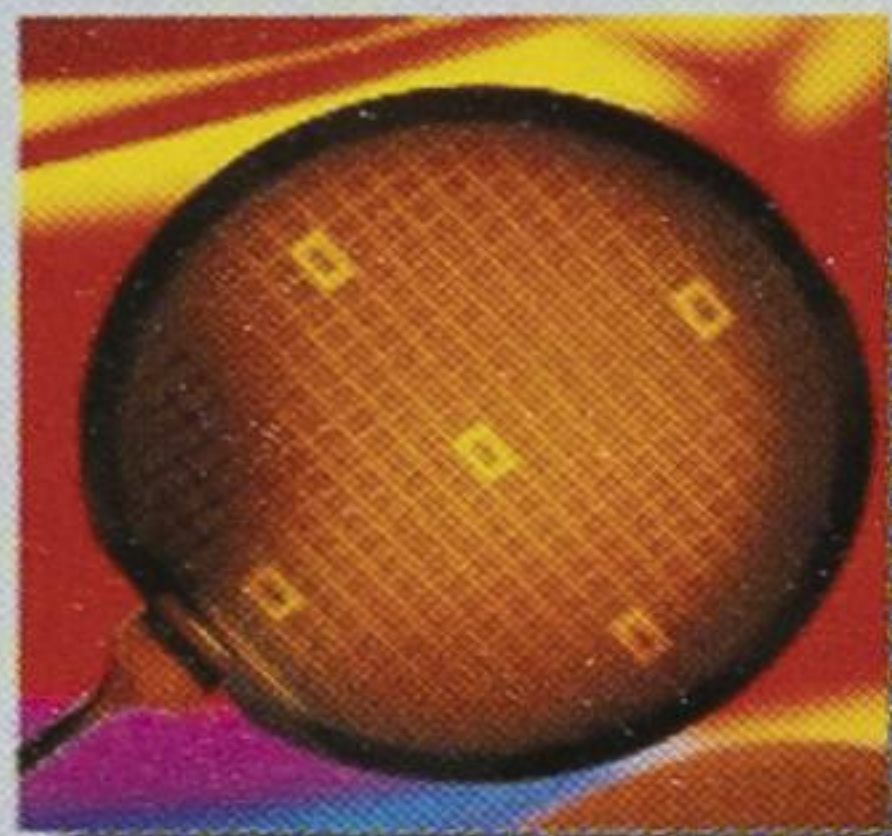
Burtch *et al.* 2001 *GaAs Mantech Technical Digest* 137.

Ober *et al.* 2002 Materials, Physics, Processes and Characterization *NNUN Abstracts* 58.

Yota *et al.* 2003 *GaAs Mantech Technical Digest* 65.

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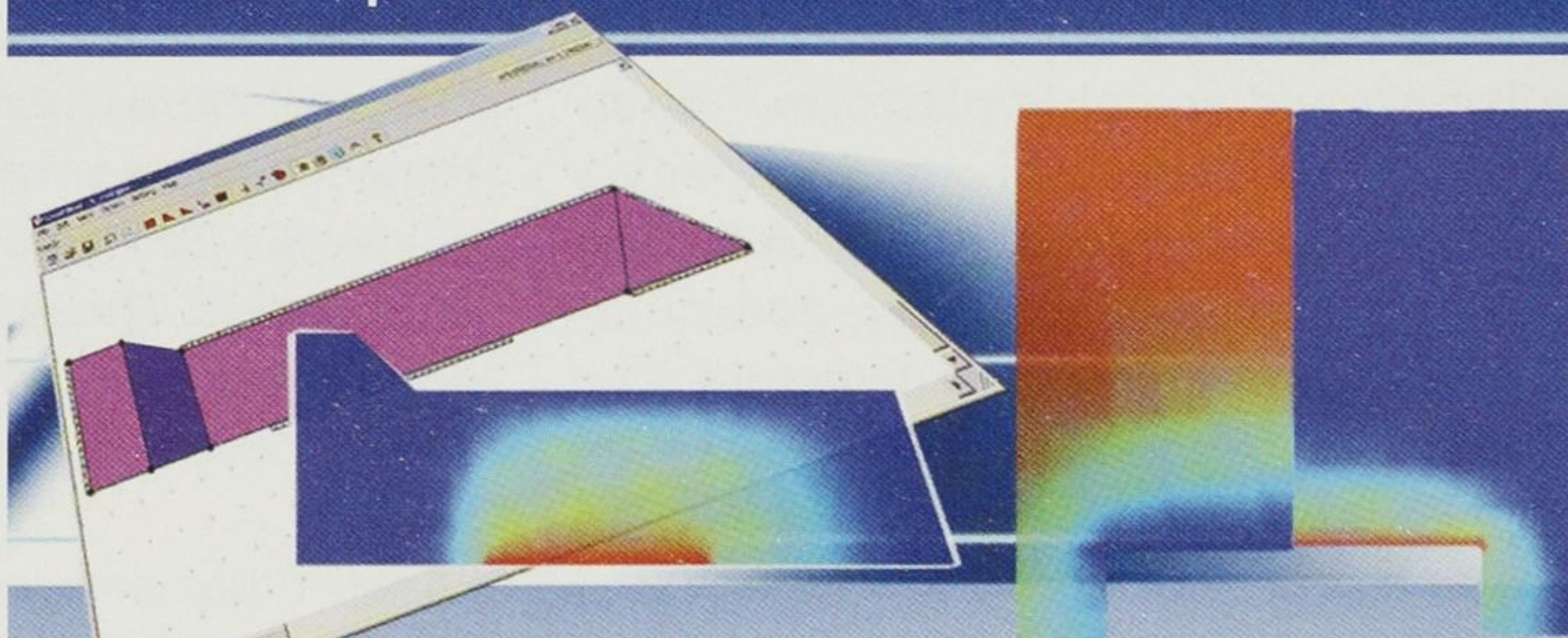
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New companies target SLED market

Two new companies, Exalos and InPhenix, have been formed to produce superluminescent LEDs (SLEDs), optical devices with a stable, broad-wavelength emission. Uses for SLEDs include fiber-optic gyroscopes in applications such as avionics, aerospace and navigation; medical applications such as optical coherence tomography; test equipment such as channel monitors and passive component characterization; and fiber-optic strain sensors for monitoring structures such as

bridges and oil pipelines.

InPhenix, based in Livermore, CA, was formed after the management buyout of certain assets of Axon Photonics, a now-defunct hybrid integration company. As well as SLEDs, InPhenix plans to sell Fabry-Perot lasers and semiconductor optical amplifiers. The company's facilities include MOCVD growth of InP-based devices, AR and HR facet coating, and device and module packaging and testing. InPhenix also plans to offer

foundry services using these capabilities.

Exalos is one of several companies to emerge from OptoSpeed, a Swiss components supplier that recently filed for bankruptcy. The company was set up by the team responsible for OptoSpeed's SLED product line and has a facility in the Technology Park in Zurich, Switzerland, although manufacturing is being outsourced. Other companies could emerge from the ashes of OptoSpeed to continue the company's laser and detector product lines.

Multiplex to offer epitaxy and device foundry services

Multiplex, a manufacturer of fiber-optic components and subsystems based in South Plainfield, NJ, is trying to find a use for its extensive epitaxial growth and device manufacturing capabilities by offering custom compound semiconductor foundry services. The company has several multiwafer Aixtron machines for MOCVD growth of GaAs- and InP-based materials, and also has in-house capabilities for processing, device design, testing, reliability qualification and failure mode analysis.

Multiplex plans to offer epitaxial growth

services for fiber-optic lasers and detectors, infrared photosensors and other custom devices, as well as offering full characterization and device-processing services.

"Multiplex maintains state-of-the-art facilities and expertise," said William Hobson, senior director of technology and manufacturing. "By opening our foundry to other commercial enterprises, we make more efficient use of our capabilities. At the same time, as experts in the field, we also provide valuable services to fabless organizations. It's a win-win situation for all involved."

Kamelian reports SOA design win

BTI Photonic Systems is to use semiconductor optical amplifiers (SOAs) from Kamelian in its new range of amplified CWDM products. "By integrating Kamelian's SOAs, we are able to provide amplifier modules as part of a complete CWDM optical layer solution," said Chris Egner, VP of business development at BTI.

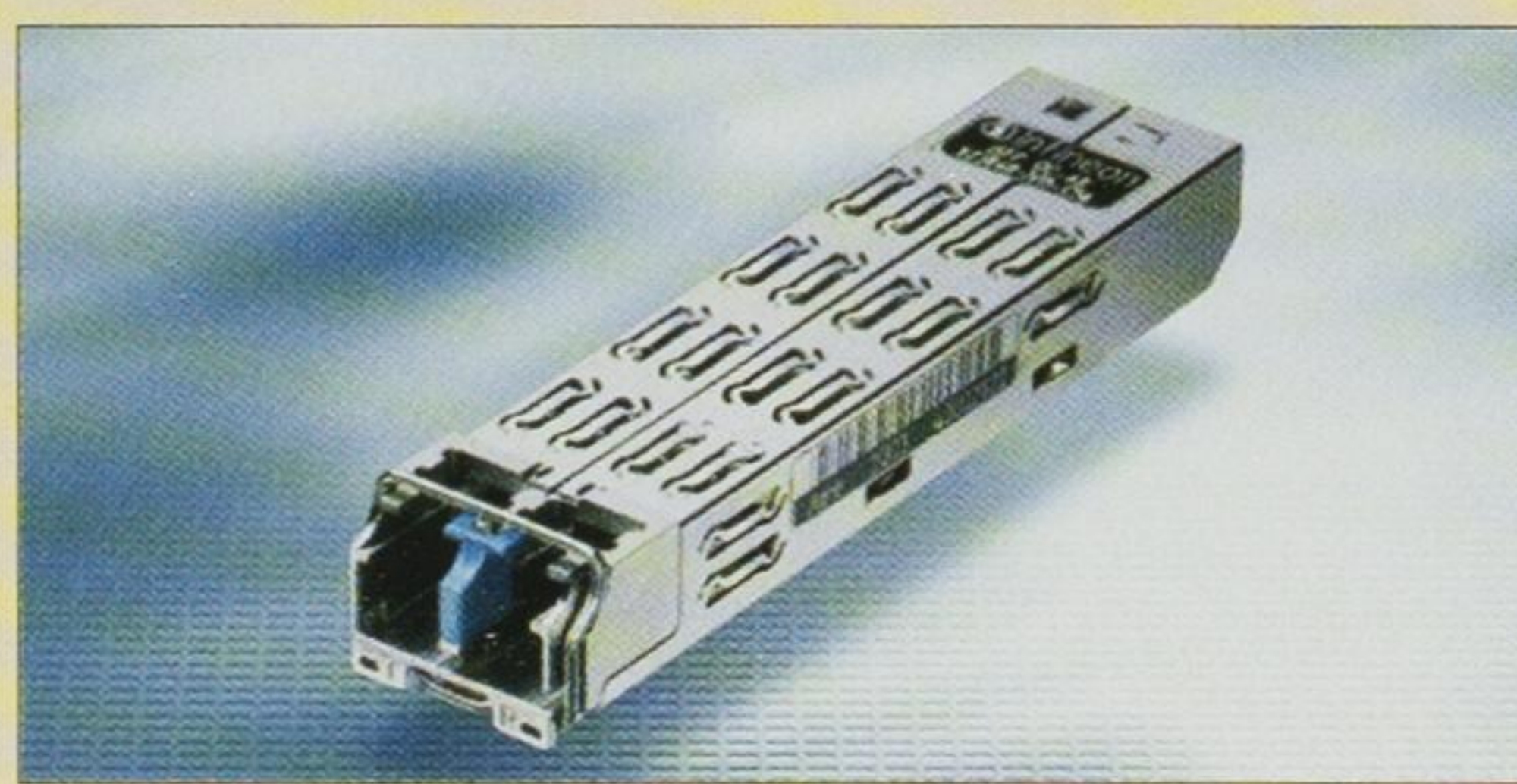
Bob Press, Kamelian's VP of marketing, said: "Not only does the SOA improve on the cost and performance of the EDFA in DWDM systems, but it also offers clear advantages in CWDM systems, where there is no competing amplifier technology."

PLI wins 1480 nm pump module order

Princeton Lightwave, Inc (PLI), which makes near-infrared detectors and high-power lasers, is to supply a major South American telecom equipment vendor with high-power 1480 nm pump modules to be deployed in long-haul optical networks. "Princeton Lightwave is delivering best-in-class performances, built on a robust and scalable platform," commented Yves Dzialowski, the company's CEO. PLI's team designs and delivers Raman and EDFA pump modules, single- and multi-mode lasers, and specialized detectors. The company uses components manufactured by Trumpf Photonics, following the August 2002 deal between PLI and Trumpf that saw PLI adopt a "fab-lite" strategy.

In related news, Holger Schlueter has been appointed general manager of Trumpf Photonics, with responsibility for product development and manufacturing.

Products from Infineon, u2t and Northlight



INFINEON TECHNOLOGIES

Infineon Technologies has unveiled new 4 Gigabit Fibre Channel (4GFC) transceivers in small-form-factor pluggable (SFP) modules with digital diagnostics. These are the first such products to use 1310 nm VCSELs, and an 850 nm version is also available.

• u2t Photonics, a vendor of fiber-optic components based in Berlin, Germany, has introduced two differential *pin*-TIA InP-based photoreceivers. The products, which are the result of ongoing collaborative

design and development work between Inphi and u2t, incorporate TIAs from Inphi that operate at up to 43 Gbit/s, together with waveguide-integrated *pin* photodiodes from u2t. The photoreceivers are available in coplanar packages.

• Northlight Optronics introduced a range of products to coincide with the recent ECOC show. The PGT20410 transmitter optical subassembly (TOSA) combines a cooled DFB laser with integrated electro-absorption modulator, and measures just 18 x 5.8 mm. The TOSA operates at up to 12.5 Gbit/s across the entire C-band. Northlight's corresponding receiver optical subassembly (ROSA) module incorporates an InGaAs *pin* photodiode mounted in a hermetic package, and an integrated TIA. Northlight also introduced 2.7 Gbit/s coax receivers.

Wafer Test

1000 nm

MOSFET SiO_2

100 nm

LED GaN ZnO MOCVD

10 nm

HEMT HBT SiC SiGe MQW MOVPE

1 nm

MOS High K Low K VCSEL GaAs  InGaAs HfP GdE

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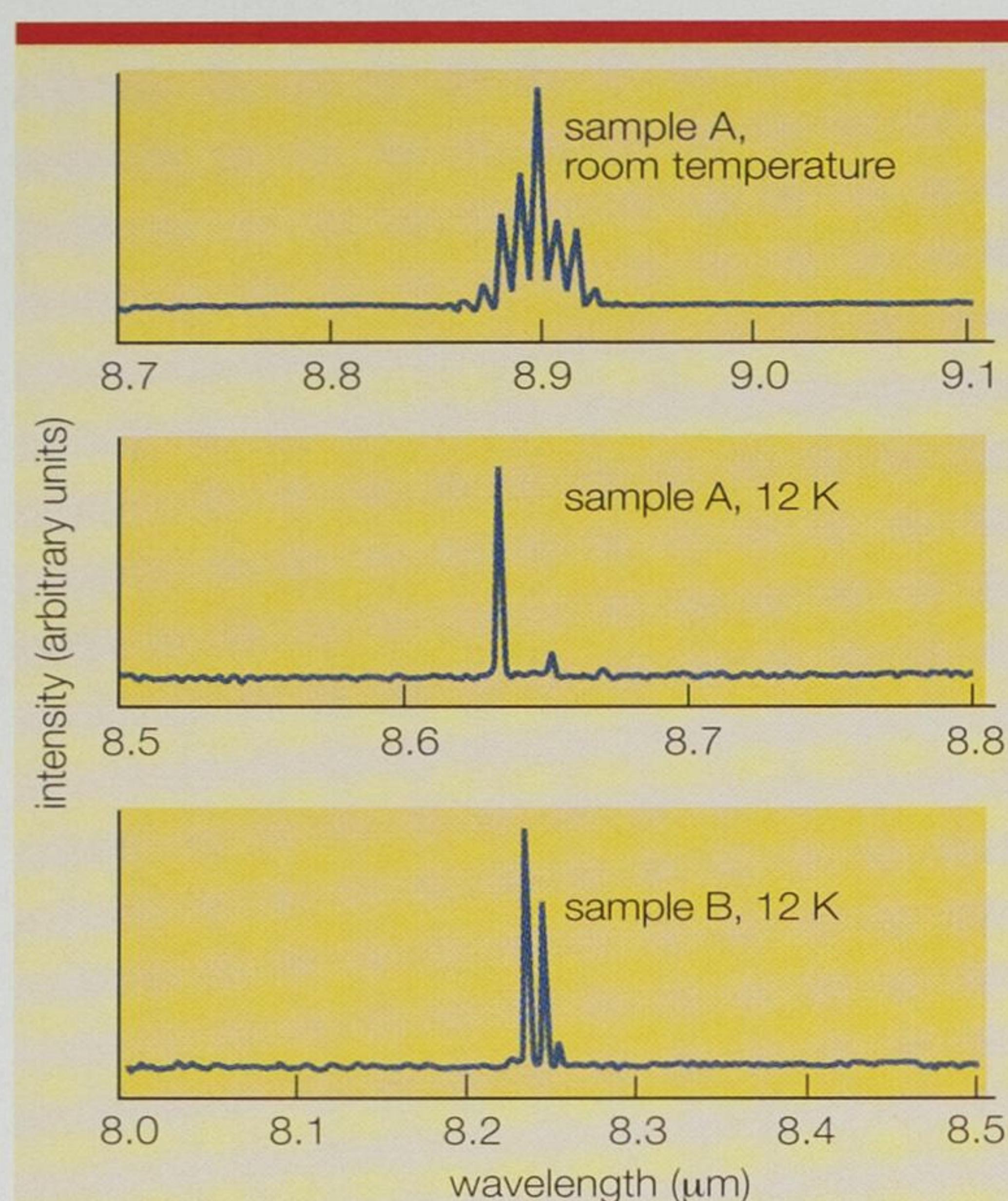
MOVPE makes the grade for QCLs

Quantum cascade lasers (QCLs) are particularly demanding epitaxial structures. A typical 8 μm emitter has a gain region of approximately 25 repeat groups, where each group consists of around 16 separate layers. Stringent requirements are placed on the layer dimensions, which are typically 4–40 monolayers thick and require a single monolayer resolution over the entire gain region.

Two material systems have been studied in recent years, AlGaAs/GaAs or InGaAs/InAlAs lattice-matched to GaAs or InP, respectively. However, for room-temperature operation the larger conduction band offset of InGaAs/InAlAs is preferred. Lasers operating at the mid-infrared wavelength of 8 μm are already commercially available using structures fabricated by MBE or gas-source MBE. In contrast, MOVPE has, until now, had little success at providing equivalent QCL structures. John Roberts and colleagues at the National Centre for III-V Technologies and the department of physics at the University of Sheffield, UK, are working to open up InP-based QCLs to an all-MOVPE process.

There are several advantages in having such an exclusive MOVPE growth technology, including the deposition of low-doped InP cladding layers and the exploitation of the wide range of growth rates that can be accommodated by MOVPE. In principle, the method developed could also be transferred to multiwafer production systems, bringing manufacturability to QCLs and making gas sensors and free-space communication devices more widely and cheaply available.

The group has investigated the abrupt control of reagents and the adsorption and desorption effects present within the stainless steel pipework of the reactor, in order to successfully grow the first AlGaAs/GaAs QCL by MOVPE at atmospheric pressure (*Appl. Phys. Lett.* 2003 **82**(24) 4221). However, this device operated up to a maximum temperature of 135 K at 10.8 μm , providing only a proof-of-concept, rather than a technological solution. The same growth



The emission spectra for QCLs grown at 0.8 $\mu\text{m}/\text{h}$ (sample A) and 2.4 $\mu\text{m}/\text{h}$ (sample B).

technology has now been applied to the growth of QCLs using the unstrained InGaAs/InAlAs system and cladding layers of InP. In this case the reactor pressure was 150 Torr, typical of the processes used commercially for shorter-wavelength InP-based lasers (*Appl. Phys. Lett.* 2003 **83**(10) 1921). The QCL design adopted had already been proven using MBE, allowing the performance of the two growth techniques to be compared.

Ridge laser devices made from the MOVPE QCL material were found to have comparable performances with respect to operating temperature and threshold current to those reported by MBE, potentially opening up MOVPE growth to commercial QCL devices. Since monolayer control of the individual InAlAs/InGaAs layers is essential to provide gain over a narrow energy range, the growth rate had to be limited to 0.8 $\mu\text{m}/\text{h}$. Increasing this to 2.4 $\mu\text{m}/\text{h}$ degraded the maximum lasing temperature of the device, presumably by broad-

ening the gain spectrum. One possible explanation of this effect could be a monolayer jitter within the various AlInAs/InGaAs layers as reagent switching becomes less controlled at the higher flow rates.

The figure shows the pulsed lasing spectra for the two different growth rates where samples A and B refer to gain regions grown at 0.8 and 2.4 $\mu\text{m}/\text{h}$ respectively. The lower growth rate for the gain region of A is effectively counterbalanced by growth of the InP cladding layers. Here, low-doped n-InP low-loss waveguides can be deposited at 2.5 $\mu\text{m}/\text{h}$. The resulting process program requires only 3–4 h to complete and has comparable complexity to the deposition of a 1.5 μm telecom laser.

The group has filed a patent application for its MOVPE technology and is currently optimizing the n-type doping of the bridging layers and the influence of strain-balanced QWs on room-temperature operation. However, even at the present state of development, MOVPE can provide viable 8 μm QCL material.

Progress reported in wafer-bonded GaAs/GaN HBTs

Sarah Estrada and colleagues at the University of California, Santa Barbara, recently reported an AlGaAs/GaAs/GaN HBT that combined the high breakdown voltage of a GaN collector with the high mobility of the well-known AlGaAs–GaAs emitter-base structure (*Compound Semiconductor* April 2003 p41). However, the resulting HBTs, formed by wafer bonding at 750 $^{\circ}\text{C}$, displayed poor output current and low current gain, thought to be the result of dopant and defect diffusion during bonding.

The group has now investigated a broad range of bonding temperatures in order to produce a mechanically stable bond while improving device characteristics (*Appl. Phys. Lett.* 2003 **82**(3) 560). Fusion temperatures as low as 550 $^{\circ}\text{C}$ were found to produce HBTs with electrically active interfaces, and reducing the fusion temperature (T_f) improved the HBT characteristics.

Base-collector leakage current increased with T_f ranging from 4×10^{-5} mA for $T_f = 550^{\circ}\text{C}$, to 20 mA for $T_f = 750^{\circ}\text{C}$. The MBE grown emitter-base I–V characteristics were the same for all devices except for those fused at 750 $^{\circ}\text{C}$. Base currents for devices with T_f values of 550–700 $^{\circ}\text{C}$ were 10–15 mA at $V_{be} = 2$ V, but at a $T_f = 750^{\circ}\text{C}$, the base current was reduced to 4 mA. Current gain was low at 0.29 and 1.2 for T_f values of 550 and 600 $^{\circ}\text{C}$ respectively, and could not be measured for devices with higher T_f as these were dominated by base-collector leakage.

Emitter- and base-collector current increased with T_f , but the observed collector current was not due to emitter-collector leakage, which was an order of magnitude lower than the base and collector currents. The group is now investigating changes to the structure to further improve the characteristics.

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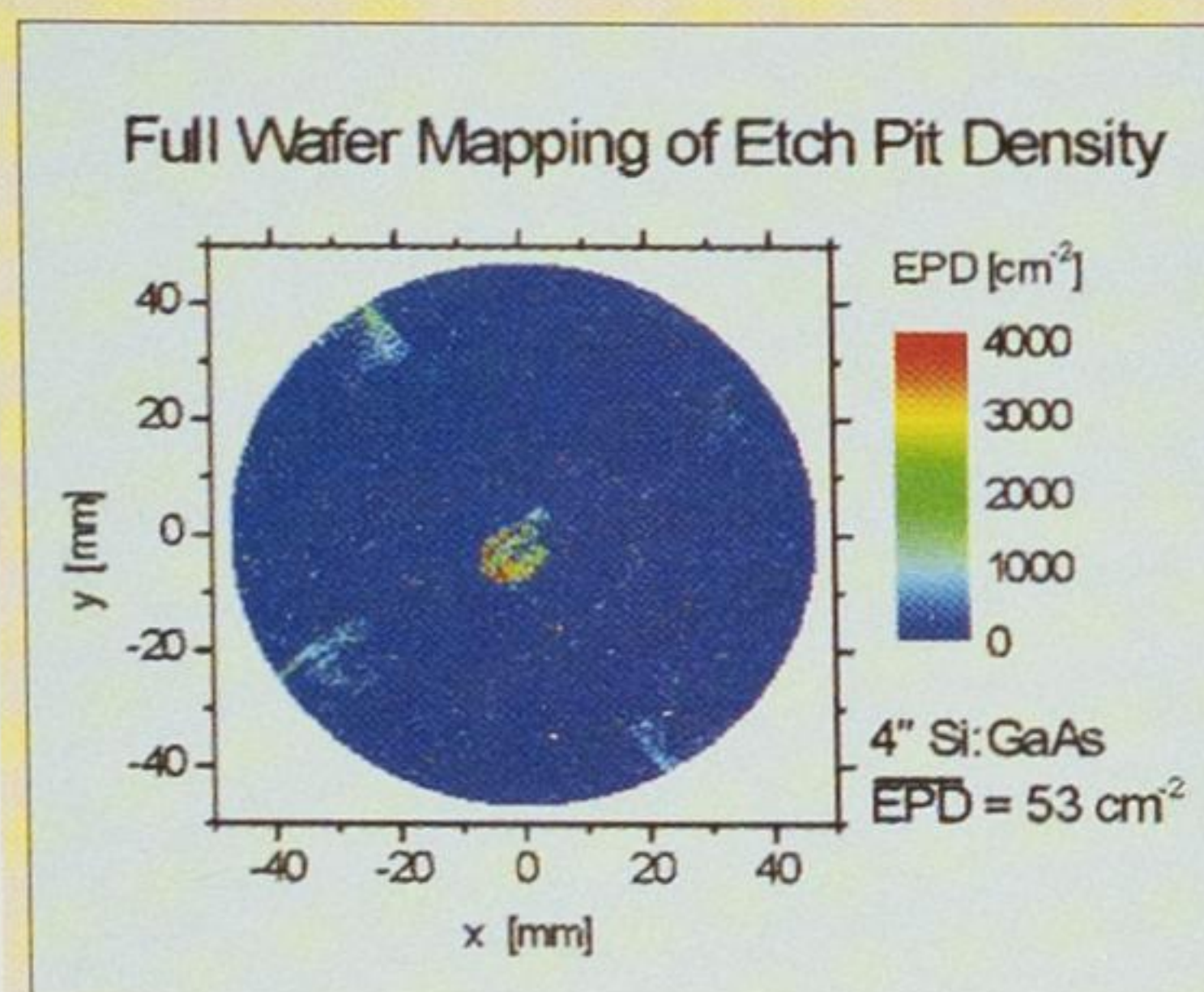


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Oxford Instruments buys VG Semicon

After months of speculation over the fate of MBE equipment supplier Thermo VG Semicon, the company's acquisition by Oxford Instruments Plasma Technology (OIPT) has finally been announced. The supplier of plasma and ion beam processing equipment to the photonics, MEMS and semiconductor industries will pay \$0.3 million in cash for VG Semicon, plus a deferred consideration of \$0.2 million payable in two equal installments on the first and second anniversaries of completion. Further contingent payments may also be made in 2005 and 2006 if exceptional sales

growth targets are met, taking the maximum value of the deal to \$1.3 million.

VG Semicon, based in East Grinstead, UK, was previously part of the giant Thermo Electron Corporation. OIPT, based in Yatton, UK, is a subsidiary of Oxford Instruments, a publicly traded UK instrumentation company.

In the six months to 28 June 2003, VG Semicon reported sales of \$4 million and a break-even operating result before restructuring costs. A cost-reduction program at the company has already taken place earlier this year, with the loss of a large number of staff.

"We had previously identified MBE technology as an area that would offer an excellent strategic fit with our existing business," said Jim Hutchins, who was recently appointed as managing director of OIPT. "VG Semicon is a recognized leader in its field and we believe we can achieve significant synergies in manufacturing, product development and sales and support operations, particularly since we already serve many of the same customers. We look forward to reaffirming VG Semicon's number one position in the marketplace."

Tegal completes financing procedure, secures Nasdaq spot

On September 10, Tegal announced the completion of a two-step financing procedure that raised a total of \$7.2 million through the sale of various financial instruments that will eventually be converted into Tegal common stock.

The total number of issued and outstanding Tegal shares is presently just over 16 million, according to the company's CFO Thomas Mika. "The debentures and warrants will be converted into approximately 26 million additional issued shares," he said. "The timing of the conversion is uncertain, and depends on each investor's objectives." Many of the debentures were acquired by a group of about 20 new institutional investors that will ultimately control about 60% of the company.

Mika says that Tegal needed the cash to ensure that it could emerge from the current prolonged industry downturn. "We expect to see improvement in our markets within our

fiscal year (which ends March 31, 2004). The new cash, combined with our \$20 million cost-reduction program, should provide enough liquidity for at least a year."

Furthermore, Mika believes that the new investors have a keen interest in the company and its value in the market, and can be expected to support its stock price.

Tegal announced more good news on September 17; it has received notice from Nasdaq that its shares will continue to be listed on the Nasdaq SmallCap market after its share price closed at \$1 or more for 10 consecutive trading days. Tegal's shares were transferred to the SmallCap market in early May after a prolonged period below \$1. However, the company may be promoted back to the Nasdaq National Market if its share price stays above \$1 for 30 consecutive trading days, and if it meets other requirements.

Aeronex to stop disputed hydride purifier production

More details have emerged concerning the July settlement of the patent dispute between SAES Getters and Aeronex (*Compound Semiconductor* September 2003 p35). As part of the finalized terms, Aeronex will stop manufacturing ammonia and hydride purifiers covered by patents involved in the litigation. Both companies will dismiss their respective patent infringement and other claims.

Aeronex will assign its US patent no. 6,241,955 to SAES Getters, and neither party will be required to pay damages. Also, Aeronex will progressively stop manufacturing and marketing purifiers falling under the scope of either of the US patents 5,716,588 and 6,241,955, although it will be granted a license under both patents until January 31, 2004 to assure its customers a smooth transition period.

Equipment sales

● **Fuji Xerox**, a Japanese VCSEL manufacturer, has placed an order for a Fox full wafer contact test and burn-in system from **Aehr Test Systems**. The system is expected to ship in early 2004.

● **Aixtron** has received an order for a new AIX 200/4 RF-S from the Electromagnetics Laboratory (ITHE) of **RWTH**

Aachen, as part of a joint research program into GaN-based RF devices between RWTH Aachen, Research Centre Jülich (FZJ) and Aixtron.

● The **National Renewable Energy Laboratory** (NREL) in Golden, CO, has purchased a **Riber** Compact 21 T MBE system to allow the National

Center for Photovoltaics to conduct research on compound semiconductor materials for renewable energy and energy efficiency applications.

● **Emcore** has sold a D125 GaN MOCVD research tool to **Sandia National Laboratories** in Albuquerque, NM. The reactor adds to the Emcore tools already in use at the lab and

expands Sandia's capacity to explore innovative uses for GaN materials.

● **Johnson Matthey** has supplied eight HTG 40 hydrogen purifiers to **United Epitaxy Company** (UEC) of Taiwan. The purifiers will supply ultrapure hydrogen to MOCVD reactors at UEC's third LED fab in Tainan.

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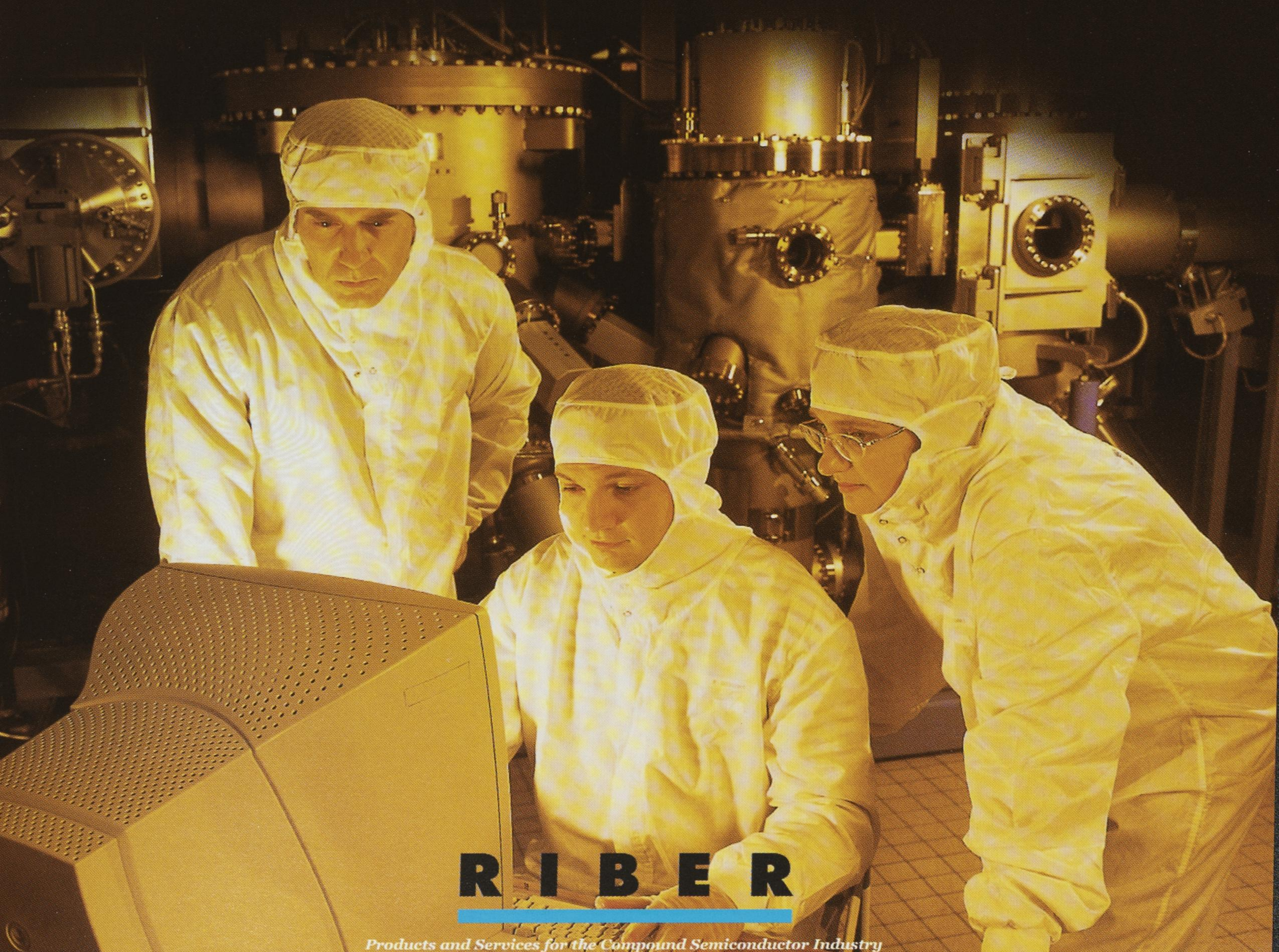
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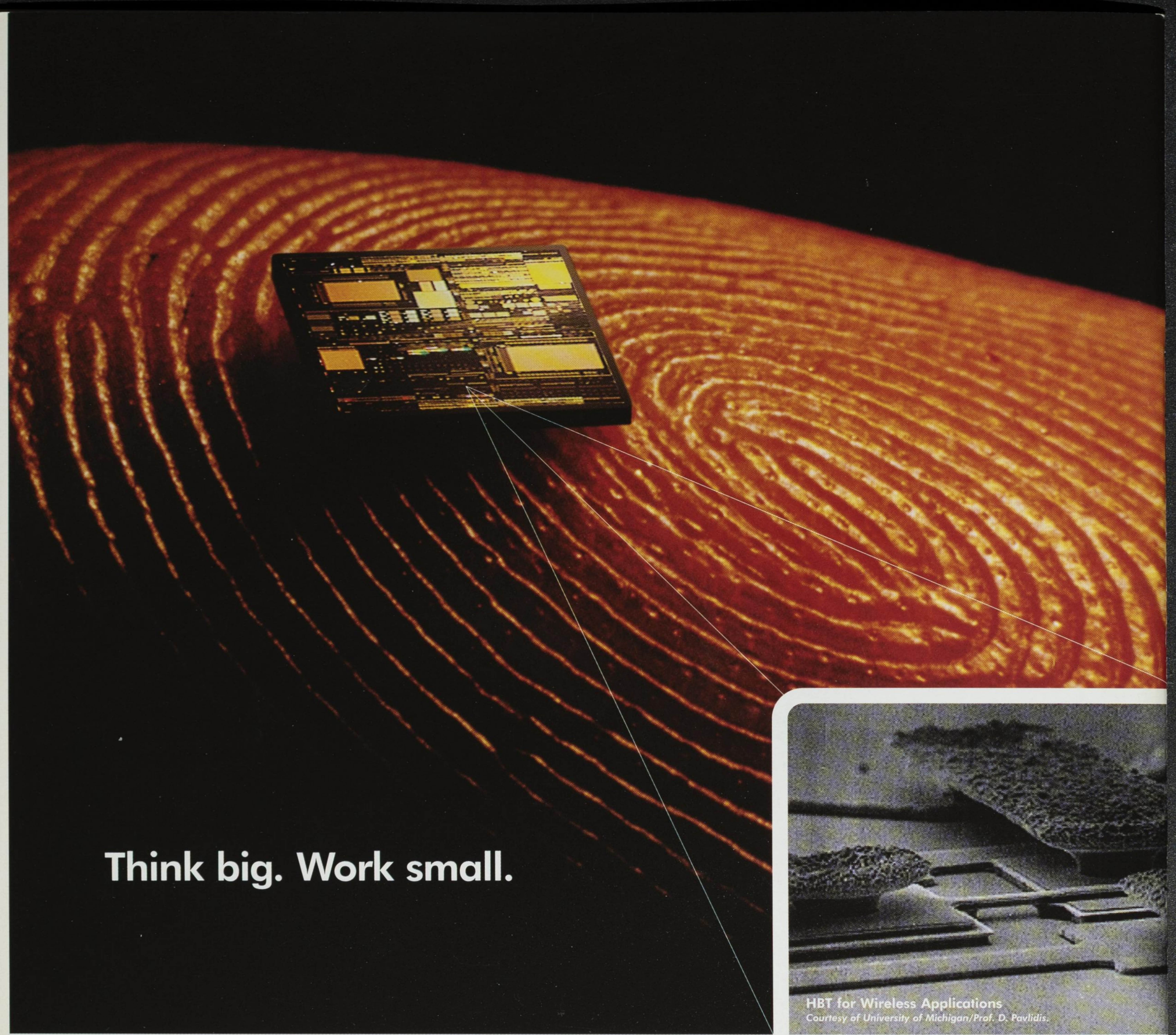
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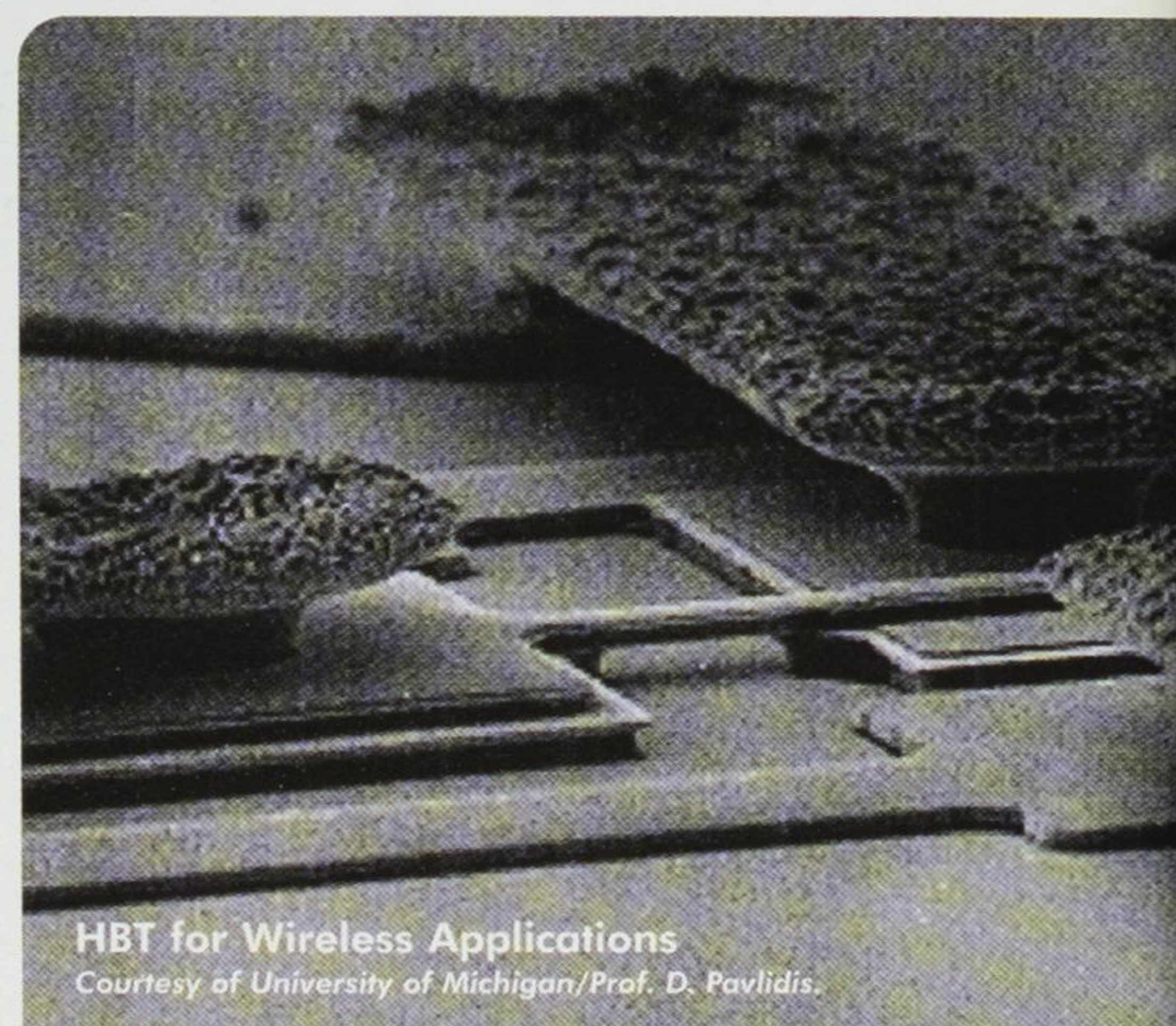
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