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## SEMICONDUCTOR

September/October 1997

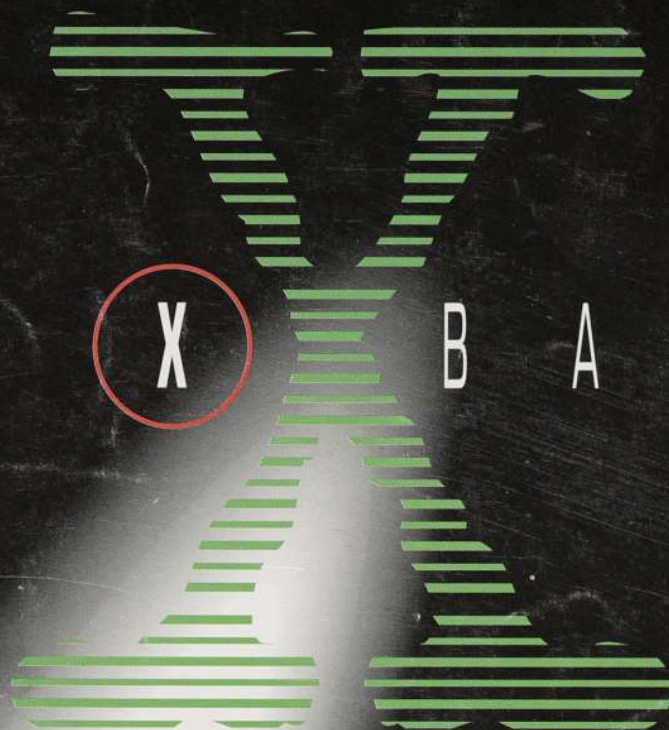
Volume 3 Number 5

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- Cree Reports CW Blue Laser
- Leaders in the DVD Laser Market
- TRW in Digital GaAs Venture
- CdZnTe Gamma Ray Detector

B E Y O N D

T H E X B A N D



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As fans of "The X-Files" TV show might say, when it comes to high frequency MMICs, the market is out there.

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#### Editor

Marie Meyer  
Franklin Publishing  
Liberty Square  
Danvers, MA 01923 USA  
TEL [1] 978 750 9739  
FAX [1] 978 750 9740  
mmeyer@compsem.com

#### Microelectronics

Robert A. Metzger  
Compound Semiconductor  
6605 Williamson Dr. NE  
Atlanta, GA 30328 USA  
Tel [1] 404 705 8475  
FAX [1] 404 255 9867  
rametzger@aol.com

#### Contributing Editors

##### Optoelectronics

Gary Wicks  
University of Rochester  
Institute of Optics  
Rochester, NY 14627 USA  
TEL [1] 716 275 4867  
FAX [1] 716 244 4936  
wicks@optics.rochester.edu

##### Materials

Colombo Bolognesi  
Simon Fraser University  
Physics Department  
Burnaby, BC V5A 1S6, Canada  
TEL [1] 604 291 5964  
FAX [1] 604 291 4951  
colombo@cs.sfu.ca



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## FACT!

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## FACT!

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# AIXTRON®



**European Headquarters**  
**Aachen, Germany**  
AIXTRON GMBH  
Kackerstraße 15-17, 52072 Aachen  
Germany  
Phone: +49 (241) 89 09 - 0  
Fax: +49 (241) 89 09 - 40  
**Customer Service Line**  
Phone: +49 (241) 89 09 - 91  
e-mail: [info@aixtron.com](mailto:info@aixtron.com)

**US Headquarters**  
**Chicago, IL**  
AIXTRON Inc.  
1569 Barclay Blvd.  
Buffalo Grove  
IL 60089, USA  
Phone: +1 (847) 215 - 73 35  
Fax: +1 (847) 215 - 73 41  
e-mail: [info@aixtron.com](mailto:info@aixtron.com)

**Sales and Service**  
**Tokyo, Japan**  
Moritani & Co., Ltd /AIXTRON  
2nd Section, 3rd Machinery Dept.  
4th Sales Division  
1-4-22 Yaesu, Chuo-Ku  
Tokyo 103, Japan  
Phone: +81 (3) 32 78 - 61 31  
Fax: +81 (3) 32 78 - 61 21  
e-mail: [KYP00751@niftyserve.or.jp](mailto:KYP00751@niftyserve.or.jp)



## HP Introduces Highest-Intensity LEDs

**Palo Alto, CA.** Hewlett-Packard has announced a line of 5-mm (T1-3/4) AlInGaP light-emitting diodes which offer "the highest intensities of any LED lamps currently in production". HP says that this "second-generation AlInGaP" product line offers reliable, weather-resistant and bright sources for use in traffic-management designs, such as traffic signals and variable-message signs and in commercial outdoor advertising, such as moving-message signs and marquees.

"LEDs are a superior light source for sign and signal applications compared to incandescent bulbs and other technologies due to their longevity, viewability and energy savings," said Milt Liebhaber, general manager of the Optoelectronics Division of HP's Components Group. "This new family widens the gap between LEDs and other light sources and will accelerate an already brisk adoption rate for LED solutions."

HP is calling the new products "precision optical performance AlInGaP II LEDs". They feature special lens structures that enable precise control of light output. This control ensures that letters and symbols in message panels appear consistently sharp and bright over the specified viewing angle. These lamps offer the same stability as HP's guaranteed-performance LEDs for traffic-signal applications due to their use of the same advanced optical-grade epoxy that greatly improves the lamps' operability in high and low temperatures and under conditions of moisture. The package's epoxy also contains ultraviolet-a and ultraviolet-b inhibitors to reduce the effects of long-term exposure to direct sunlight.

The new LEDs are available in three viewing angles, making them optimal in applications in traffic signals and road signs. They are available in three colors: amber (592 nm), reddish-orange (617 nm) and red (630 nm). At their brightest, typical intensities (@20 mA) range from 4,500 mcd for the amber, 4,000 mcd for the reddish-orange, and 3,600 mcd for the red.

Pricing is about 36 cents each in quantities of 1 million. Sample quantities of most colors and configurations are currently available from stock.

| Part Number                    | Color      | Dominant Wavelength @20 mA Typical | Intensity (mcd) @20 mA Minimum | Intensity (mcd) |
|--------------------------------|------------|------------------------------------|--------------------------------|-----------------|
| <b>15 Degree Viewing Angle</b> |            |                                    |                                |                 |
| HLMP-DL16                      | Amber      | 592                                | 4,500                          | 2,600           |
| HLMP-DH16                      | Red-orange | 617                                | 4,000                          | 2,000           |
| HLMP-DD16                      | Red        | 630                                | 3,600                          | 2,000           |
| <b>23 Degree Viewing Angle</b> |            |                                    |                                |                 |
| HLMP-DL25                      | Amber      | 592                                | 2,800                          | 1,600           |
| HLMP-DH25                      | Red-orange | 617                                | 2,100                          | 1,000           |
| HLMP-DD25                      | Red        | 630                                | 1,800                          | 1,000           |
| <b>30 Degree Viewing Angle</b> |            |                                    |                                |                 |
| HLMP-DL31                      | Amber      | 592                                | 1,700                          | 1,000           |
| HLMP-DH31                      | Red-orange | 617                                | 1,600                          | 700             |
| HLMP-DD31                      | Red        | 630                                | 1,400                          | 700             |

**Table:** Intensities of HP's new high brightness AlGaInP LEDs, which are offered in three different colors and viewing angles. HP believes these are the brightest LEDs currently in production.



*Examples of Hewlett-Packard's new high brightness AlInGaP LEDs, which are believed to be the brightest units available.*

## SDL Announces New Lasers

**San Jose, CA.** SDL has released the FA30, "the highest power commercially available fiber optic amplifier system to date". The FA30 has an optical output power in excess of +30 dBm (1 W) and operates over the 1535 nm to 1565 nm range providing over 30 dB gain, even in saturation. The +30 dBm operating point is believed to be at least two times higher in power than any other fiber amplifier system made in the US.

SDL says that this new fiber optic amplifier system "combines SDL's core competency in high power and efficient semiconductor lasers with the quality and reliability of solid state fiber optics to bring a revolutionary new amplifier technology to the telecommunications industry". The FA30 will be used as a building block for a family of amplifier products intended for both the R&D and OEM markets.

SDL also recently introduced two new visible laser diodes. The first, a 30 mW 650 nm single mode laser, is targeted at high density optical data storage applications. The 30 mW power level is sufficient for enabling both the writing and reading of data at high digital video disk storage densities.

The second new product is a 3 W fiber coupled 665 nm laser which addresses a new method of cancer treatment known as photodynamic therapy. The SDL laser delivers light through a small optical fiber, therefore allowing minimally invasive surgery.



## New GaAs Parts from CEL & NEC

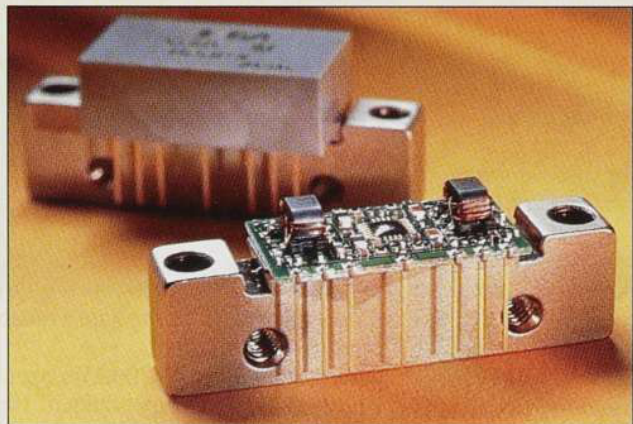
**Santa Clara, CA.** California Eastern Labs has announced the availability of several new GaAs chips produced by NEC.

First is a new family of GaAs CATV hybrid amplifiers. CEL says these push-pull and power doubler device deliver higher bandwidth, lower distortion, and higher gain than their silicon counterparts. In addition, GaAs power doublers need 10-20% less DC current. CEL also reports that the assembly and testing of NEC's GaAs hybrids is fully automated, resulting in more consistent, repeatable performance than silicon devices, which generally require some hand assembly and tuning. All of the amplifiers offer 50 - 860 MHz bandwidth, and can provide up to 22 dB gain @ 860 MHz. Their reliability is specified at <125 FITs @100°C. Pricing begins at \$32 for the push-pull amplifiers and \$42 for the power doublers in 10,000 unit quantities.

Also new from CEL and NEC is the NE72118 GaAs MES-FET. It offers excellent power gain performance - 5.5 dB@12 GHz - making it suitable for use as the oscillator stage in LNB (low noise block) applications for DBS receivers. It is housed in a miniature, 4-pin SOT-343 plastic surface mount package, and is priced at \$1.10 in 50,000 unit quantities.

For C to Ku Band low noise amplification applications, NEC is now offering the NE429M01, a new heterojunction GaAs FET. At 12 GHz, it provides a noise figure of 0.9 dB (typ.), with an associated gain of 10 dB (typ.). It is priced at \$0.89 in 10,000 quantities.

And, finally, NEC has also recently introduced a power GaAs MESFET for use in the output stage of high power Multipoint Multichannel Distribution Systems (MMDS). The NES2527B-30 delivers high output power (45.0 dBm typ), low distortion (linear gain = 13.0 dB typ) and high linear gain (PAE = 40% typ), all at a bias current of just 6.0 A. Partial matching is provided internally, and with external circuitry complete matching to 50 ohms can be achieved. Primarily developed for 2.5 - 2.7 GHz S-Band operation, 200 MHz of instantaneous bandwidth can be achieved anywhere from 2.3 to 2.7 GHz when used with modified external matching. The NES2527B-30 is a Class A device which features a 0.9 micron tungsten silicide gate structure for high reliability, silicon dioxide passivation for surface stability, and plated heat sinks for reduced thermal resistance. It is priced at \$329 in 100 piece quantities.



The new GaAs CATV amplifier from NEC and CEL.

CEL

## New EDFAs from Ortel

**Alhambra, CA.** Ortel recently announced the availability of four new erbium doped fiber amplifiers (EDFAs) for 1550 nm broadband transmission systems. The company says that these new products "demonstrate Ortel's commitment to the 1550 nm market by offering higher performance, more output power, lower noise, dual outputs and lower cost." Robert Jordan, vice president and business manager of broadband communications products, said they are a substantial addition to the company's line of 1550 nm broadband transmission products. He believes they provide the right solution for headends, cascades and distribution feeder applications, offering CATV OEMs and systems integrators the most advanced 1550 nm products.

The new EDFA products include model 9110A/B, a 16 dBm EDFA that features improved performance in noise figure; model 9112A/B, a low-power 14 dBm EDFA; model 9120A/B, which operates at 17 dBm and provides lower noise for certain applications; and model 9130A/B, a 20 dBm EDFA that offers higher output-power performance. Each of these new EDFAs features adjustable output power over a 3 dBm range from the front panel.

The 9100 Series utilizes Ortel's own 980 nm pump laser. Internal optical splitters are available to provide multiple outputs from a single EDFA. They are available either with or without optical isolators at the input. Input isolators can be omitted when connected directly to Ortel's 1550 nm transmitters, thereby improving the EDFA noise figure, resulting in links with higher carrier-to-noise ratio.



Ortel

## Small Footprint Power Amp for 1.8 - 1.9 GHz GSM from Anadigics

**Warren, NJ.** Anadigics has unveiled a new low cost single supply GaAs power amplifier which comes in a 16-pin thermally enhanced SSOP package - just half the size of the standard SSOP28 package. The AWT1902 is intended for use with PCS1900 MHz and DCS1800 applications using the GSM modulation format. It operates on 4.8 V.

The AWT1902 uses three stages, allowing operation with +7 dBm input power. The output power and efficiency are determined with a single external capacitor matching the amplifier output. Typical power added efficiency at Pout = 32 dBm is 45%. The pulse control pin also determines the output power level during the pulse, a feature which simplifies the design of the power and pulse control loop. Furthermore, the amplifier produces low noise in the receive band (less than -80 dBm in a 100 kHz band).

"The AWT1902 power amplifier enables cellular phone manufacturers to offer smaller and less expensive handsets," said Joseph DeMoura, Anadigics Design Manager. "This transmitter amplifier will offer greater power added efficiency than typical solutions in use today translating into increased talk time for the cellular subscriber." In addition to reduced space requirements, Anadigics believes that this GaAs MMIC solution provides an economic alternative to discrete and hybrid amplifiers.

The AWT1902 is manufactured using Anadigics' high volume GaAs MESFET technology. It is available at \$7.25 in quantities of 100,000.



## New GaAs ICs from Vitesse

**Camarillo, CA.** Vitesse Semiconductor has introduced the VSC7214, a multi-gigabit interconnect IC intended for high bandwidth bus, backplane and system-to-system connections.

The VSC7214 provides a serialized, duplex aggregate transfer rate of 10Gbs over four channels and is configurable to either four 8-bit channels or a single 32-bit channel. A scaleable interconnect of arbitrarily high data width or throughput is easily achieved by synchronizing multiple VSC7214 ICs in parallel.

Backplane and bus architectures must either widen or increase in clock frequency to accommodate the demands for increased bandwidth. Vitesse says that by serializing data, the VSC7214 reduces the complexity and cost of high bandwidth parallel bus and backplane architectures while reducing data skew and interference associated with parallel implementations. They report that a single VSC7214 has the same data throughput as 160 signals clocked at 50Mb/s.

## More GaAs MMICs from Fujitsu

**San Jose, CA.** Fujitsu Compound Semiconductor (FCSI) continues to introduce new GaAs MMICs for wireless handset applications. Four different models are now available, covering a broad range of cellular, personal communication, and WLL applications, including GSM, AMPS, TDMA, and CDMA.

These MMICs are manufactured by Fujitsu Quantum Devices in Kofu, Japan, using a true enhancement-mode GaAs FET process. As a result, FCSI says it has "truly eliminated the dual supply requirement of phone manufacturers using high performance GaAs products". Because fewer components are required when using these enhancement-mode products (for example, there is no need for a drain switch or negative voltage generator) the cost of manufacturing the handsets should be reduced.

Two new MMICs were introduced in July. The first, the FMM 5508ZE, is designed to meet the requirements of the DCS 1800 phones built to operate in the GSM band at 1800 MHz and the PCS (personal communications service) phones built to operate at 1900 MHz. The second, the FMM5512ZE, is designed to meet the requirements of the AMPS phones built to operate at 3.6V and high efficiency; in order to meet the continuing efforts to reduce the phone size.

These products join two other new MMICs, for 4.8V AMPS and GSM applications, which were introduced in June (see CS 3(4), p. 4). All four are available in a very low thermal resistance, ultra small plastic package (16 pin / SSOP-16 compatible).

| Part Number | Primary Application  | Vdd  | Gain @ Rated Pin     | Nadd (typ.) |
|-------------|----------------------|------|----------------------|-------------|
| FMM 5508ZE  | DCS 1800 or PCS 1900 | 4.8V | +27.5 dB<br>+27.5 dB | 37%<br>35%  |
| FMM 5512ZE  | AMPS                 | 3.6V | +23.5 dB             | 55%         |
| FMM5509ZE   | AMPS                 | 4.8V | +23.5 dB             | 55%         |
| FMM5514ZE   | GSM                  | 5.8V | +32 dB               | 45%         |

*Table: Specifications for Fujitsu Compound Semiconductor's new family of GaAs MMICs for wireless handsets.*

The VSC7214 consists of a quad 8-bit parallel-to-serial and serial-to-parallel 1.25Gb/s transceiver that can operate as either a fully synchronous 32-bit interface or as four independent 8-bit transceivers. Each channel can operate at a maximum data rate of eight 130MHz bits (1Gb/s) for an unencoded duplex aggregate data transfer rate of 8Gb/s. It includes encoding-decoding to integrate a clock signal and establish error checking, resulting in a total data channel throughput of 10Gb/s over four duplex channels.

The VSC7214 is derived from the transceiver technology implemented in Vitesse's VSC7125 Fibre Channel and VSC7135 Gigabit Ethernet transceivers. Innovative circuit techniques and the use of Vitesse's H-GaAs IV process has resulted in robust clock recovery and low jitter performance.

In the past, high speed transmitter/receiver functions were plagued by injection locking, noise and crosstalk problems. Vitesse avoided these problems by implementing both clock multiplication and clock/data recovery with a fully integrated phase lock loop (PLL), which replaces multiple PLLs common in slower and less reliable designs, Schaefer said. Integrating the PLL also eliminates the need for external filters or other components.

The VSC7214 operates off a single +3.3V supply and dissipates 4.3W. It is available in an industry standard 160 pin thermally enhanced PQFP package. Sampling is available now with pricing for 1,000 units at \$98.

## New Gigabit Ethernet Transceiver in Reduced Form Factor

Vitesse also recently advised of the availability of the VSC7135QU Gigabit Ethernet transceiver IC. Mounted in a 10mm 64-pin PQFP, this new device reduces the board space required for the transceiver and complies fully with the Gigabit Ethernet 802.3z draft specification.

The VSC7135QU is derived from Vitesse's earlier product, the VSC7135QN (14mm package) Gigabit Ethernet transceiver. Released in August, 1996, it was the industry's first Gigabit Ethernet transceiver. The VSC7135, which is a 1.25Gb/s, 10-bit serializer/deserializer with the integrated clock and data recovery and high-speed clock generation, is currently used in the majority of initial products developed for the Gigabit Ethernet industry and is suitable for network interface cards, hubs, switches, routers and test equipment.

Since then Vitesse has found that early adopter manufacturers of Gigabit Ethernet equipment have a need for a smaller transceiver that meets the 802.3z specification. "The new version of the VSC7135 allows the user to implement an 802.3z-compliant Gigabit Ethernet channel in a smaller form factor," said John Schaefer, Vitesse product marketing manager. "Since the transceiver is fully contained in a single package, designers can easily implement the high-speed physical interface to their proprietary network functions. Immediate availability allows users to get their products to market faster."

The VSC7135QU has a power dissipation of 700mW, operates from a single +3.3V supply, is delivered in an industry-standard 10mm PQFP package and requires no external components. It is available now, priced at \$19 in 10,000 unit volumes.



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## Hewlett-Packard Enters the Blue LED Market

**H**ewlett-Packard has begun shipping its first nitride-based LEDs. The current product is a InGaN-on-sapphire MQW blue LED with a 475 nm dominant wavelength and typical intensities of 1,100 mcd at a 15 degree viewing angle, and 450 mcd at a 30 degree viewing angle (at 20mA).

Company representatives revealed to *Compound Semiconductor* that HP is not fabricating the InGaN chips at this time. Instead, they are purchasing the die from an outside vendor and then packaging them at HP, using a process which is substantially the same as the one used to fabricate HP's high brightness AlInGaP LEDs. The vendor is believed to be Toyoda Gosei, although the company would not reveal any information other than the fact that it was not Nichia Chemical.

In the past HP has offered blue LEDs based on Cree Research's SiC technology, but that activity is now at an end.

### Ramping Up

HP hopes to be the dominant player in the blue LED market by the turn of the century, and they say that they will begin offering their own product - based on InGaN die produced at their facility in San Jose - later this year. Tom Flynn, Business Development Manager for Optoelectronics at HP, said "we chose this approach because it allows us to ramp up quickly. This first release of a low volume product can be used to sample product that will go into high volume production next year. The backend manufacturing - the packaging process - will be essentially the same for the present die and the die that we produce ourselves."

Flynn reported that by the end of this year HP will have capacity for around 1 million blue LEDs per month. That will be increased to 3 million per month by the second quarter of 1998, and 10 million per month in early 1999. Market leader Nichia currently has a capacity for around 10 million units per month.

The current offering is around 75% as efficient as the Nichia product, but improvements are expected in the near future. Pat Goodman, Business Manager for Electronic Signs and Signaling at HP, said "our experience over the past 25 years of working with compound semiconductors has shown us that you really have to get the high volume manufacturing process up and running before you can start improving performance parameters like brightness in LEDs. We fully expect to surpass everyone else on the market in terms of brightness by the end of the century." The company hopes to have a product with a 30° viewing angle and 1 cd of output - more than a 2x improvement over the initial release - in two to three years.

**Hewlett-Packard InGaN Blue LEDs**

| Part Number | Intensity (mcd) @ 20 mA Typical | Intensity (mcd) @ 20 mA Minimum | Viewing Angle (degrees) |
|-------------|---------------------------------|---------------------------------|-------------------------|
| HLMP-CB15   | 1,100                           | 630                             | 15                      |
| HLMP-CB30   | 450                             | 250                             | 30                      |

Specifications for HP's new line of InGaN blue LEDs. The lamps come in 5mm (T-1 3/4) package.



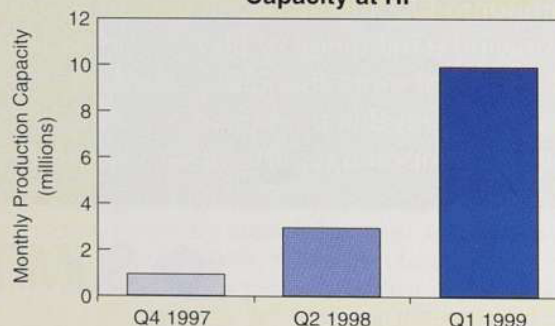
*Hewlett-Packard's first blue LED offering*

### Learning from the Quaternaries

HP is one of the world's largest producers of LEDs, and they have an especially strong position in the very high brightness AlInGaP LEDs. (See page 4.) HP will use the same process, with a few modifications, that is used for those products to fabricate the blue LEDs. Goodman notes that a few changes were necessary. For example, it is not possible to diamond scribe and cleave the sapphire substrates, so special sawing techniques were developed. Also, the InGaN die need two contacts on the top (because the sapphire substrates are insulating), so more bonding steps are needed. In addition, some modifications to the equipment were necessary because the blue LEDs are more ESD sensitive. But, on the whole, he says "we can leverage what we've already learned in the production of the AlInGaP LEDs, especially with regard to the MOCVD growth and reactor performance, which is critical." He says they will be using the same reactors for the nitrides, "only the gases are different". They have one multiwafer reactor dedicated to blue LEDs at this time, and "several more" on order.

The new LEDs will be priced, in the U.S., at \$1.80/piece in quantities of 1-99, \$1.60/piece in quantities of 100-9,999, and \$1.40/piece in quantities over 10,000. But lower prices will be introduced when production volumes increase. Goodman says that prices for blue LEDs may erode 75 - 85%, to as low as \$0.25 a piece, in three years time. As a comparison, it is interesting to note that when the AlInGaP LEDs were introduced five years ago, the introductory prices were around \$0.50 - \$0.60 per piece; but now HP is offering some models for as little as \$0.10 per piece (CS 3(4), p. 20).

**Nitride LED Production Capacity at HP**



*HP's forecast for their blue LED production ramp.*



## Future Products

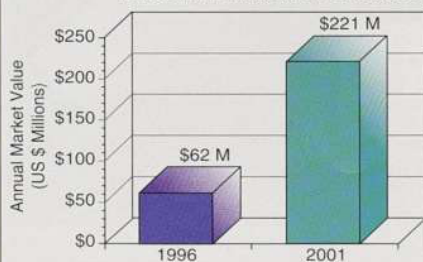
HP has plans to expand its nitride product line by offering blue-green (~500 nm) and true green (~520 - 530 nm) LEDs in the future. They are also investigating the best approach for producing a white light LED. Two possible approaches are being studied. The first is color conversion - the use of a phosphor or organic dye inside the package to convert the high power shortwavelength emission of a blue LED into white light. The second is color mixing - the integration of red, green and blue LED chips into a single package. Goodman says "At this point we are not sure which is best, and it is possible that both might have a

*"HP's use of a common manufacturing process for all of the products will be a big advantage for customers who need the full palette of colors"*

use. For simple illumination applications, the three chip approach is probably better, but if you are directly viewing the source, then color conversion might be preferred."

If, or when, HP can produce a true green LED, they will probably be the only company in the world that can offer a high brightness LED in every color. Goodman believes that HP's use of a common manufacturing process for all of the products will be a big advantage for customers who need the full palette of colors. "With our advanced process" he said, "all of our radiation patterns will match. This is important in several applications, such as large full color signs, because there will be no color mismatch, even when viewed from the side." Thus the addition of nitride capabilities should provide HP with several opportunities to expand their already extensive compound semiconductor efforts.

**Blue LED Market Forecast**



Source: Strategies Unlimited

**Forecast for the blue LED market.**  
Compound Annual Growth Rate = 30%.



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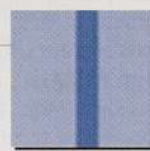
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## Cree Achieves CW Blue Laser Operation, Looks for Development Partner

On July 29 Cree Research announced that it has demonstrated continuous wave (CW) laser operation of its GaN-on-SiC blue laser diode at room temperature. Improved high reflectivity facet coatings, which lowered the threshold current for lasing, were applied to new Cree laser devices by Dr. Arto Nurmikko's group at Brown University. The CW emission lasted for more than fifteen seconds, and the device had a threshold current of 0.5 amps.

Just six weeks earlier the company had announced the first pulsed laser operation from its blue laser with lifetimes of over an hour. (CS 3(4), p. 14). This was the first ever demonstration of a laser diode on a SiC substrate. (Since then, Fujitsu has also reported a SiC laser - see page 12.) That work used a one microsecond long pulse to minimize device heating, and had a threshold current of 1.2 amps. Ten days later, the company announced it had extended the laser's operation to more than an hour.

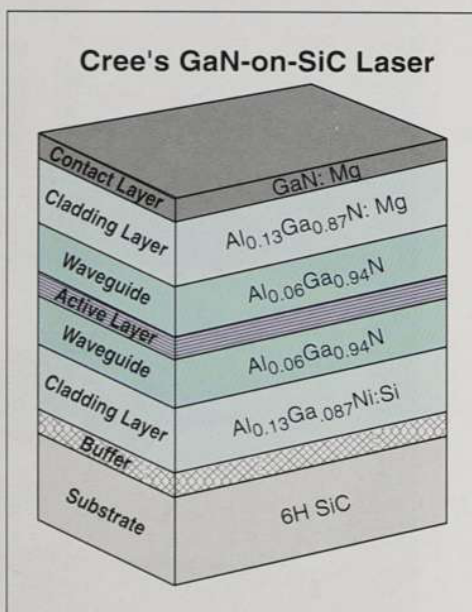
In comparison, it is interesting to note that Nichia Chemical - the only other company to achieve room temperature CW operation of a blue laser diode - required 11 months to move from their first pulsed diode to CW.

"This success really emphasizes the advantage of growing nitride laser structures on SiC. SiC is a vastly superior heat sink to sapphire or other substrates on which blue laser structures have been grown," Cree Senior Scientist, Dr. Kathy Doverspike, remarked.

Cree's John Edmond reported that the CW device is very similar to the first pulsed devices. It was grown on 6H-SiC at Cree using MOCVD. The structure is a multi-quantum well (MQW) separate confinement heterostructure (SCH) consisting of an 8-well  $\text{In}_{0.14}\text{Ga}_{0.86}\text{N}/\text{GaN}$  MQW region, with  $\text{Al}_{0.06}\text{Ga}_{0.94}\text{N}$  waveguide regions and  $\text{Al}_{0.13}\text{Ga}_{0.87}\text{N}$  cladding layers. The devices were fabricated into index-guided structures, with bars being formed by facet cleaving with a cavity length of 500 micron.

Edmond said "CW operation was achieved by reducing the threshold current to a value whereby the SiC was able to adequately remove enough heat." The device lased at 527 mA or 21 kA/cm<sup>2</sup>. The wavelength was 423 nm.

In other news, Cree is said to be searching for a development partner to invest in the further development of the laser. The Raleigh, NC "News and Observer" reports that the company is talking with two or three unidentified Asian consumer electronics companies about investing up to \$10 million. "What we want is an aggressive partner that isn't afraid to bring in new technology," said President Neal Hunter says. Cree's investment to date in blue-laser development work has totaled nearly \$8 million, most of which came from government contracts



Epitaxial structure of Cree's blue laser. The active layer is a 8-well  $\text{In}_{0.14}\text{Ga}_{0.86}\text{N}/\text{GaN}$  MQW structure

## Substrate News

### HVPE GaN-on-Sapphire Substrate

Epitronics Corporation, a subsidiary of ATMI (Danbury, CT), recently announced the availability of engineering quantities of a new type of GaN-on-sapphire substrates for blue and green LEDs and laser diodes.

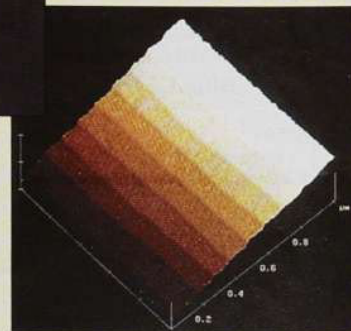
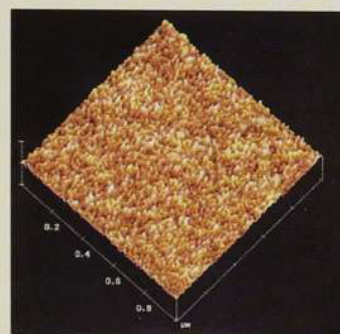
The new substrate is a thick layer of epitaxial GaN grown on sapphire by hydride vapor phase epitaxy (HVPE). The company claims that the HVPE GaN layers provide a high quality base that enable homoepitaxial GaN growth and can enhance the performance of the final light-emitting device. In particular, Epitronics reports, the HVPE GaN layers eliminate the need for the growth of a low temperature nucleation layer prior to the creation of the device structure. The samples are available in 2" diameter sizes.

High brightness LEDs with peak outputs ranging 430 to 515 nm and high quantum efficiencies have reportedly been produced using the new substrates.

According to Dr. Joan Redwing, who leads Epitronics' GaN group, tentative plans call for transitioning the HVPE GaN product for LEDs into pilot manufacturing in 1998, with full scale manufacturing in 1999.

### New Sapphire Substrate Vendor

Japanese materials manufacturer Shinkosha reports that it has implemented a technique to flatten the sapphire substrate and will start producing blue LED substrates by the end of 1997. Developed by a research group led by Professor Koinuma and Assistant Professor Yoshimoto of the Tokyo Institute of Technology, the technique heats the substrate at more than 900°C to reduce the surface unevenness to 0.3nm, down from the conventional 1-2nm.



Shinkosha says they will be capable of producing 2,000 2-inch sapphire substrates per month. The sample price is about ¥20,000 (\$175.44). Shinkosha hopes that the new product will reduce the manufacturing costs of blue LEDs.

AFM images of  $\text{Al}_2\text{O}_3$  substrate surface before (left) and after (right) surface treatment. Shinkosha says the result is a 3-6x reduction in surface roughness.

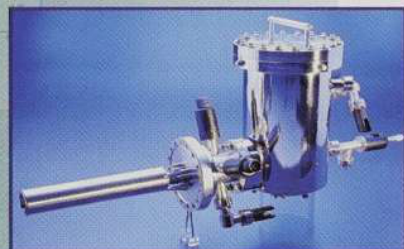




**SUMO™ Cells**  
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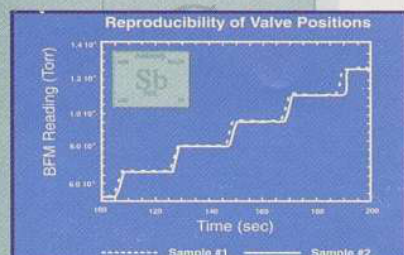
**Valved Cracker for Arsenic**



**Mark IV Valved Cracker for Phosphorus**  
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# Fujitsu Announces Second Silicon Carbide Laser

On July 24 Fujitsu Laboratories announced that a team from its Research and Development Center in Atsugi, Japan, had achieved pulsed operation of a GaN-on-SiC laser. Just 6 weeks earlier, Cree Research had announced the first ever laser grown on SiC (see page 10). Fujitsu is now the fifth group to achieve a GaN laser, behind Nichia, Meijo University, Toshiba and Cree.

The 414nm laser was operated using a 300nsec pulse width and 0.03% duty cycle. The threshold current was 800 mA, with a maximum output of 20mW.

In making their announcement, company representatives stated their belief that the Fujitsu development program will provide a technology suitable for mass production of blue laser diodes. They stressed the use of a conventional low-pressure MOVPE growth method similar to what is used for volume production of red lasers. This is the first known use of a low-pressure process to produce a working nitride-based laser. Other GaN-development efforts are using atmospheric-pressure MOVPE, which Fujitsu says requires complicated controls. Fujitsu chose to use SiC instead of sapphire (the substrate of choice for Nichia and Toshiba) for this work because the cavity mirror of laser is easily made using cleaved facets. Moreover, SiC is a conductor, whereas sapphire is an insulator; therefore, the reverse side of the GaN-on-SiC diode can serve as an n-type electrode. This may allow use of conventional methods of semiconductor laser production. SiC also has a smaller lattice mismatch to GaN than sapphire.

Fujitsu hopes to make the technology viable by about year 2000 by proceeding with research to reduce threshold current as well as voltage and to control transverse mode. The SiC substrate used now is 0.4- to 1-inch-sized wafer made by Nippon Steel.

## Substrate Debate in Montreal

The Fujitsu research group, headed by A. Kuramata, consists of just 5 scientists. One member, K. Domen, made the one of the first public presentations of their recent results at the rump session of the LEOS Summer Topical Workshop held August 14 in Montreal, Canada.

The MQW laser structure shown had a 3.5  $\mu\text{m}$  stripe width, and used a backside contact (through the substrate) and the far-field emission pattern was that characteristic of a high order transverse mode. The laser was run for more than 5 hours under pulsed conditions. "It was very beautiful" said Dr. Domen of laser's appearance. "It made me feel very cool in the hot Japanese summer".

Not surprising, a lively discussion of the merits of SiC vs. sapphire followed Domen's presentation. "I used SiC long ago" said Nichia's Shuji Nakamura. "The threshold current is very large. I would use SiC if the price was the same as sapphire." Others also expressed concern about the cost of SiC substrates. "My group would have to spend \$1000/day to use SiC" said Prof. S. DenBaars of UC Santa Barbara.

In response to a question of whether the noise performance and temperature stability of GaN lasers would be good enough for applications, Dr. Domen suggested that the stability of lasers should be good on SiC. Dr. Nakamura responded that temperature stability of lasers was fine on sapphire, and that his measurements indicated that noise is not a problem.

The other issue that generated controversy was whether the mechanism responsible for lasing in nitride quantum wells was related to quantum dots, composition fluctuations, and the like. Recent papers

have suggested that the InGaN active layers of Nichia's blue laser diodes grow as two dimensional arrays of quantum dots (or quantum dot-like structures), rather than homogeneous, continuous quantum well layers (CS 3(2), p. 24). But some controversy remains. "How could a dot-laser have such a high gain?" posed one panel member. Y. S. Park of the Office of Naval Research (ONR) cited this as a matter of central importance. ONR is responsible for significant amounts of nitride research funding in the U.S., and Park told the audience that he had 4 research proposals on this topic on his desk already - prompting some in the audience to indicate that he could expect to see more in the future.

The pace of laser commercialization is likely to accelerate towards the end of the year. Dr. Nakamura promised to present a new laser structure with much better lifetime at the International Conference on Nitride Semiconductors in Tokushima, Japan this October. The current Nichia structure has run as long as 300 hours CW. Dr. Nakamura was asked what the cause of failure is. His answer was that "after seeing our new structure, you can see what causes our short lifetime".

The evening also included a moment of historical perspective. Peter Zory of the University of Florida recalled the rump session held at the same meeting four years ago. A vote was taken to see which material system the participants thought would prevail in the marketplace - nitrides or II-VI's. They were prescient in voting for nitrides for wavelengths shorter than 450 nm, because they had just heard of the new results from Japan. But they were confident that II-VI's would nonetheless prevail for wavelengths longer than 450 nm.

The vote was not repeated at this meeting.

*special reporting by Eric Hellman,  
Bell Laboratories, Lucent Technologies, courtesy of  
"MRS Internet Journal of Nitride Semiconductor Research",  
<http://nsr.mrs.org/>*

## Nitrides at the MRS Fall Meeting

This year's MRS Fall Meeting includes a full program of GaN-related activities. In addition to Symposium D, which is dedicated to the most recent nitride research, the meeting will also include a Tutorial Session on "Industrial Applications of GaN Lasers". The presenters include Ross Bringans of Xerox, who will discuss uses for blue lasers in printing; Akito Iwamoto of the Multi-Media Laboratory of Toshiba Corporation, who will discuss applications in High Definition DVD System; and Robert Melcher of IBM, who will discuss the opportunities and requirements of blue lasers for use in displays.

Also at this year's meeting, Shuji Nakamura of Nichia Chemical is being honored with a MRS Medal for his pioneering development of GaN-based optoelectronic devices. Dr. Nakamura will give an overview of his laser diode research effort. And there will also be a banquet honoring GaN pioneer Jacques Pankove.

The MRS Fall Meeting will be held in Boston, MA on December 1-5. More information on symposium D and its related activities is available on the WWW at

<http://www.zurich.ibm.com/pub/srt/mrssympd/>



## Aixtron 1996 Results

**Aachen, Germany.** On August 29 Aixtron GmbH released a summary of their 1996 financial report. Turnover rose to DM 44.5 million (US \$24.48 million), an increase of over 70% compared to 1995. Operating profit tripled in the same period, rising from DM 1.7 million (US \$935,000) to almost DM 5.3 million (US \$2.92 million). Income before tax rose to nearly DM 6.7 million (US \$3.69 million), primarily due to an increase in income from overseas operations. Net profit was DM 3.6 million (US \$1.98 million).

Aixtron also reports that the current year is proving to be a healthy one. In the first six months of 1997, Aixtron recorded several new contracts for MOVPE systems from the US, Asia and Europe. In the U.S., Rockwell, Kopin, Epitronics and Tecstar all ordered Aixtron systems for the production of solar cells, LEDs, lasers and transistors.

In Europe the Hahn-Meitner-Institute in Berlin ordered three reactors, for research on solar cells. Orders were also received from EPFL in Lausanne, Switzerland and from the Institute for Solar Energy Systems (ISE) at the Fraunhofer Institute in Freiberg, Germany. The EPFL system will be used for blue laser research, and the ISE system will be used for solar cell research.

Aixtron is also a partner in the European RAINBOW project that commenced this year. Four companies, Thomson and Philips from France, and Epichem from Britain, along with Aixtron, are collaborating with four research institutes with the goal of development of a technology for the mass production of UHB-LEDs in various colors and also the development of blue lasers. (See CS 3(4), p. 24.)

Aixtron also reports the receipt of seven system orders from Taiwanese companies this year. Five will be used for the production of LEDs and visible laser diodes. Contracts were also received from Korea, including one for the production of LEDs from Samsung Electro Mechanics.

## Aixtron 1996 Results

|                  |                    |
|------------------|--------------------|
| Revenue          | \$24.48 M (up 70%) |
| Operating Profit | \$2.92 M (up 320%) |
| Inc. Before Tax  | \$3.69 M           |
| Net Income       | \$1.98 M           |

## \$10 Million in Contracts for VG Semicon

**Beverly, MA.** VG Semicon announced in August that it has received contracts worth in excess of \$10 million from TRW and RF Micro Devices (RFMD) for five model V100 MBE systems. TRW and RFMD are partnered in a strategic alliance aimed at developing high volume commercial applications for TRW's AlGaAs HBT technology. Two of the five systems have already been installed at TRW's Microelectronics Fabrication Center in Redondo Beach, California. Two more are scheduled to be installed by the end of 1997. The fifth system will be installed at RFMD's new fab, which is currently under construction in Greensboro, North Carolina.

Larry Kapitan, Director of Process Engineering at RFMD, said, "producers of minority carrier devices understand the serious implications of MBE design and purity on device performance. Using the well established TRW HBT growth techniques, the V100 system has provided RFMD with MMIC performance meeting or exceeding ICs from the single wafer MBE systems. We are confident in our decision and this supplier."

According to Phil Sullivan, General Manager of VG Semicon, a total of 25 V-100 systems will be in service worldwide by the end of 1997, and the company has "a very healthy backlog of orders for delivery in 1998". The TRW/RFMD systems represent the first known usage of multi-wafer MBE systems dedicated to HBT production. Sullivan says that the remaining systems are used for PHEMTs, MESFETs, and a growing number of optoelectronic applications.

"We are pleased with this repeat order from an industry leader in microelectronics. These additional systems will dramatically increase TRW's capacity to produce commercial gallium arsenide devices for wireless communications products," said David Williams, Managing Director of VG Semicon. "By focusing on product quality and innovation, VG Semicon has established itself as the premier supplier of this important semiconductor-production technology." Williams also said that company is in the advanced stages of development of a new MBE system that would provide 3-4 time more throughput. While the current generation of systems are designed for multiple 4" wafer processing, the next generation will also be capable of multiple 6" processing.



## Emcore Increases Foundry Services

**Somerset, NJ.** In August Emcore announced that it was increasing epitaxial foundry services in its E2M and Pegasus divisions. The E2M Division, which was formerly called Echelon, is Emcore's in-house epitaxial wafer foundry (E2M being shorthand for "Emcore Electronic Materials"). The Pegasus Division is described as a "package-ready device foundry". It currently fabricates InSb-based magnetoresistor sensors for General Motors.

The company says it is making this move to better meet predicted market shifts toward increased use of semiconductor foundries. The company is relying on the Taiwan Semiconductor (TSMC) foundry model, which advocates greater use of foundry expertise to provide single or second source production level fabrication of their wafer and device designs. Emcore reports increasing demand for foundry services, especially from users of Emcore's MOCVD reactors, such as General Motors, as MOCVD-based prototype devices are moved from pilot production to volume fabrication.

"Foundries have the flexibility needed to quickly ramp up production when a customer's time-to-market pressures increase," says Bill Kroll, Emcore's Executive VP of Business Development. "The bottleneck in reaching true production levels always resides in the processing, and in compound semiconductor epitaxy, the bulk of the fabrication process is accomplished in MOCVD reactors. No other foundry is able to supply Emcore's depth and breadth of MOCVD expertise especially when it comes to working with TurboDisc systems, non-stop, round the clock," says Kroll.



## EPI Reports Sales

**Saint Paul, MN.** The EPI MBE Products Group reports the recent receipt of a contract from the U.S. Army Research Laboratory in Adelphi, MD for the purchase of a dual-chamber MOD GEN II MBE System. One chamber will be used for the growth of antimonide films for microwave and millimeter wave devices. The other will be used for solid source MBE growth of lasers, modulators and quantum well IR detectors.

EPI also reports that it recently delivered a MOD GEN II System to the Device Group at the Communication Research Laboratory (CRL) of the Japanese Ministry of Posts and Telecommunications in Koganei, Tokyo.



## New Facility for Freiburger

**Freiberg, Germany.** Freiburger Compound Materials GmbH (FCM) has opened its new production facility, the largest GaAs wafer plant in Europe. During the inauguration ceremony representatives of Federmann Enterprises Ltd., an Israeli investment company that took over the firm in 1995, handed over the symbolic key for the new factory to the management.

The new facility received investments totaling DM 65 million (US \$38 million), and will provide around 120 jobs. The facility includes a 70,000-sq. ft. production and administration area that includes 20,000-sq. ft. of clean room space.

FCM, through its predecessor, Freiburger Elektronikwerkstoffe GmbH, took over the GaAs activity of Wacker Chemitronic GmbH in 1990. In January 1997, Siemens AG, one of FCM's key customers, acquired a 12.5% share of the company (CS 3(3), p. 29).

FCM reports that it is now the second largest manufacturer of semi-insulating GaAs in the world. 1996 revenues totaled DM 23.4 million (US \$13.7M), and a 20% increase, to DM 28 million (US \$16.4 million) is forecast for 1997.

## QED to Offer C-Doped HBT Wafers

**Bethlehem, Pa.** Working in close collaboration with Penn State University, Quantum Epitaxial Designs (QED) has developed high carbon-doped Heterojunction Bipolar Transistor (HBT) epiwafer material, grown by MBE, for large volume commercial and defense applications. This effort, funded by a Department of the Air Force, Rome Laboratory, Small Business Innovation Research (SBIR) contract, has developed high p-type doping ( $> 3.0 \times 10^{19}/\text{cm}^3$ ) epitaxial material that provides unity activation with very little dopant diffusion. Initial results have demonstrated a dc gain greater than 100 (with a  $5.0 \times 10^{19}/\text{cm}^3$  doped base) and low hydrogen incorporation. The hydrogen incorporation results are less than the SIMS detection limit of  $5.0 \times 10^{17}/\text{cm}^3$ , even when carbon doping is greater than  $1.0 \times 10^{20}/\text{cm}^3$ .

According to Dr. Ken Bacher, QED Research & Development Engineering Manager, "Carbon-doped HBT material grown by MBE offers the potential for improved reliability due to reduced hydrogen incorporation, and increased yields due to the inherent uniformity of MBE grown material".

QED currently offers the carbon-doped material on 3" substrates, and is planning to offer 4" samples "as market demand dictates".



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## PicoGiga First Half Results

**Les Ulis, France.** Epiwafer vendor PicoGiga reports that sales for the first half of 1997 were approximately FrF 25M (US \$5M), roughly equivalent to sales for the year-ago period. The company has been growing around 30% per year, but revenues flattened out in the past six months because of price erosion in commodity-type products, such as those used in mobile telecommunications. In addition, the company has been squeezed for production capacity - a situation that should be improved, as the company reports that it is now occupying its new, larger manufacturing facility. Operating profits for the period are said to "surpass FrF 2M" (US \$400,000).

The company has also released a description of the present geographic trends. Sales in the US are said to be up 30%. Chairman Linh T. Nuyen said "The dynamism of the big US programs in mobile communications using low orbit satellites is the driving force behind the high end GaAs technology; PicoGiga has given priority to this development trend as part of our push to remain the premier supplier in our field." At the same time, sales in Asia are down by as much as 50%, a fact that PicoGiga attributes to weak commercial activity in the region, and preferential concentration on the US market.



*Trends in Picogiga share prices since their first offering of stock in June, 1996*

## Plasma-Therm Sales

**St. Petersburg, FL.** Plasma-Therm Inc., a manufacturer of plasma process equipment, has announced the sale of three multi-chamber Versalock plasma enhanced chemical vapor deposition (PECVD) systems to "a leading supplier of high-speed gallium arsenide devices". They declined to name their customer, but said they were "quickly becoming a leading supplier for state-of-the-art radio frequency devices which leverage their unique gallium arsenide, silicon and heterojunction bipolar technologies" - suggesting that the company is RF Micro Devices.

Scott Defarrari, President of Plasma-Therm, said that this order confirms a trend toward fully automated systems which address the special process and handling needs of III-V based products. He also predicted that this order would be "one of several opportunities where Plasma-Therm will provide multi-chamber processing on the same fab line for Reactive Ion Etch (RIE), Inductively Coupled Plasma (ICP) Etch and PECVD processing".

## Kopin Shipping InGaP HBT Wafers

**Taunton, MA.** Kopin Corporation recently announced the availability of InGaP HBT epi wafers which are intended to complement the company's other offerings. Kopin is already a leading supplier of AlGaAs HBT epiwafers. The InGaP wafers are currently available in high volumes, and are said to be priced similarly to AlGaAs wafers.

Kopin's AlGaAs HBT epi wafers have been used by companies such as Rockwell and others to build millions of power amplifier circuits for cellular phone and PCS handsets. See CS 3 (3), p. 39. The availability of InGaP epiwafers is intended to give telecom circuit manufacturers greater flexibility. In comparison with AlGaAs, Kopin claims that the InGaP emitter structure delivers enhanced reliability and improved temperature stability for higher frequency, higher current applications. In addition, they can be used to simplify the formation of circuits by allowing more selective etching.

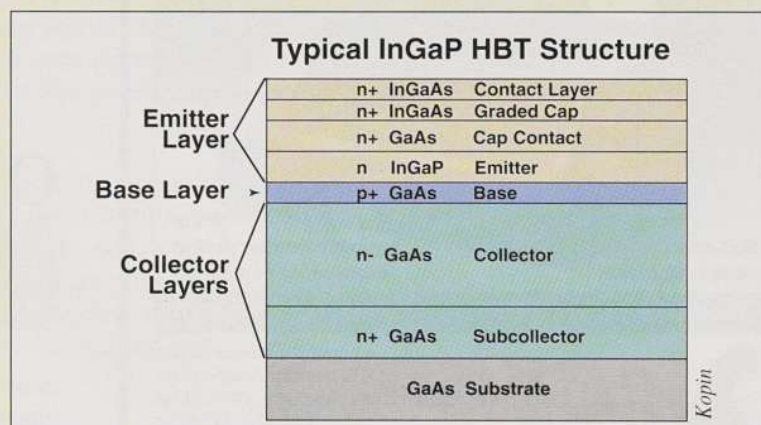
"We believe that InGaP HBTs will take HBT technology to the next level of circuit applications," said Dr. John Twynam of Sharp Corporation in Tenri, Japan. "In addition to being simpler to process, which helps improve yields, InGaP HBT devices have the potential to perform in a greater range of power and temperature conditions."

Kopin reports that InGaP HBT devices fabricated on their epi wafers have demonstrated outstanding reliability in tests performed by Sharp. Results presented at the 1997 Electronic Materials Conference showed no device degradation after 10,000 hours under rigorous accelerated test conditions (junction temperature ( $T_j$ ) = 264°C, current density ( $J_c$ ) 25,000A/cm<sup>2</sup>, operating voltage ( $V_{ce}$ ) = 2V).

"InGaP HBTs exhibit greater temperature stability and reliability due to their band gap structure, while incorporating the same clear advantages in power added efficiency and linearity as the more mature AlGaAs HBT," said Dr. Greg Stillman, Professor of Electrical Engineering at the University of Illinois. "They are highly suitable for A/D (analog-to-digital) converters, oscillators, and power amplifiers that will be used in higher frequency wireless, digital radar, collision avoidance and satellite systems."

"The performance and reliability provided by InGaP HBTs is paramount for our advanced 10 Gb/s fiber line system applications," said Dr. Robert Surridge, Manager of the Integrated Device Processing Group at Nortel Systems.

Telecom circuit providers introduced HBT-based power amplifiers to the wireless handset market in late 1995. Proponents of the technology believe HBT power amplifiers can provide superior power efficiency for longer cell phone battery life, excellent linearity for better signal characteristics, and easy design-in which lowers handset cost by eliminating excess components. HBT power amplifiers are also under development for a new generation of high-speed fiber optic driver circuits for fiber line applications.



*Schematic of a typical InGaP emitter HBT structure offered by Kopin.*



## TRW Forms Alliance to Supply GaAs ICs for Fiber Optic Networks

TRW has formed a strategic alliance with Multilink Technology Corporation (MTC, Santa Monica, CA) to supply the later with digital GaAs ICs for use in the transmission and switching equipment that links consumers and businesses with high speed fiber optic networks.

"This agreement strengthens the business relationship that TRW has been building with Multilink Technology since 1995," said Timothy Hannemann, executive vice president and general manager of TRW's Space & Electronics Group. "Our superior gallium arsenide technology coupled with Multilink's strong understanding of the commercial telecommunications and data communications markets will bring the speed of the information superhighway to more businesses and home offices than ever before."

The new alliance calls for TRW to purchase a minority interest in privately-held MTC. MTC will use TRW's GaAs HBT and HEMT technology to produce high-rate telecommunications and data communications subsystems for transmission and switching equipment used by telecommunications service providers. TRW is already engaged in a another strategic venture with RF Micro Devices, for the purpose of finding high volume applications for its HBT technology in wireless telecommunications. (CS 3(3), p 32.) That venture focuses on analog circuits at frequencies below 10 GHz.

MTC describe its products as "on-ramps" and "off-ramps" for the fiber optic information superhighway. They are used in modules that convert voice, video, or data signals to optical signals -- or vice versa -- as the information is switched between copper-wired networks that serve most homes and businesses, and high speed fiber optic networks. The chips which TRW is supplying include clock and data recovery circuits, laser drivers, and pre-amplifiers. Most are based on HBTs, but there are also some HEMT circuits involved, according to Bob Van Buskirk, who heads TRW's GaAs business.

TRW is probably more well known for analog semiconductors than mixed-signal and digital circuits. However, Van Buskirk reports, the company has been quietly exploring this field for the past two-three years. MTC's current products operate at speeds ranging from 622 Mb/s to 2.5 Gb/s; Van Buskirk says that their access to TRW's GaAs technology will allow them to extend to 10 Gb/s in the future.

"We are excited about this new alliance and look forward to expanding our line of products based on TRW's superior gallium arsenide technology," said Richard Nottenburg, president of Multilink Technology. "The agreement further strengthens our ability to improve the performance, reduce the cost and shorten the development time of communications products for our customers worldwide."

## Raytheon Quiet on Plans for Sale of TI GaAs MMIC Division

Officials at Raytheon say that progress is being made toward the sale of the former Texas Instruments' GaAs MMIC operation, but they are not able to reveal the identity of any of the potential buyers. Raytheon has until January to find a buyer under the deal struck with the U.S. Justice Department to gain their approval of Raytheon's purchase of TI's Defense Systems & Electronics Group in July.

The TI MMIC business accounted for around \$40 million in 1996 revenues, or roughly two percent of the \$1.8 billion in total TI defense revenues. After the sale Raytheon will retain its own existing MMIC capabilities and, additionally, have the right to license TI's MMIC technology for use in future product applications.

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## TriQuint Settling in At New Fab, Growing Closer to Ericsson

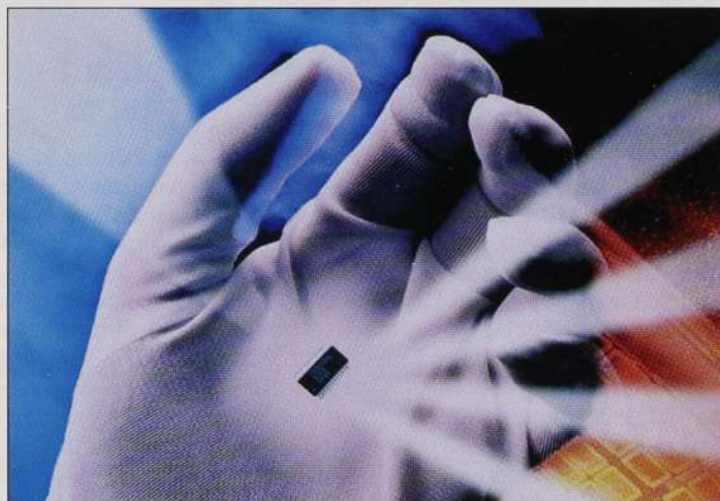
TriQuint Semiconductor has nearly completed the transition to its new fab in Hillsboro, Oregon. According to TriQuint President and CEO Steve Sharp, the process at the new fab has been preliminarily qualified, and TriQuint plans to be doing all of its production at their new location by the end of this year.

The first half of 1997 was a successful one for the company. Revenues were up 25% compared to the first half of 1996 (\$35.3 million vs. \$28.2 million), and net profits were up 45% over the year ago period (\$4 million vs. \$2.7 million). The company also recorded a record number of new design wins (see table).

In July Ericsson announced that it planned to develop 800 MHz - 2.5 GHz RFIC's using TriQuint's MESFET process. The cell phone giant plans to purchase wafers from TriQuint, but will do their own packaging. An Ericsson spokesperson said "the prime focus of this activity is to establish an Ericsson internal strategic resource of GaAs RFIC's to compliment other RFIC's products developed, based on Ericsson Components internally developed processes...the combination of technology now enables Ericsson Components to offer a full range of RF ASIC components that represent the crucial functions necessary to maintain mobile telephony global leadership."

According to Sharp, "Ericsson's design community is expanding it's use of TriQuint technology and I anticipate at least 6 power amplifier products will reach production in 1998". Sharp also said that he expects that this relationship will lead to design wins within Ericsson for TriQuint's standard products as well. He believes that TriQuint is on its way to becoming the leading supplier of GaAs chips to Ericsson.

TriQuint also recently announced that it has released to production a power amplifier/transmitter ASIC that will be used by Cellnet for wireless meter reading.



TriQuint Semiconductor has recently released a 240 page catalog featuring Wireless Communications division product offerings and GaAs foundry services. To request a copy, contact TriQuint at TEL [1] 503 615 9000, FAX [1] 503 615 8901, or E-mail: sales@tqs.com

### TriQuint Major Design Wins 1st Half 1997

| Wireless                                                                                                                                          | Telecom                                                                                                                                     | Computer                                                                                                      |
|---------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------|
| 36 New Designs                                                                                                                                    | 19 New Designs                                                                                                                              | 7 New Designs                                                                                                 |
| <ul style="list-style-type: none"> <li>• 6 Power Amp</li> <li>• 12 Receiver</li> <li>• 1 Transceiver</li> <li>• 17 Foundry &amp; Other</li> </ul> | <ul style="list-style-type: none"> <li>• 5 OC192 SONET</li> <li>• 2 OC3 Cross Connect</li> <li>• 8 ATM SONET</li> <li>• 7 Others</li> </ul> | <ul style="list-style-type: none"> <li>• 4 Gigabit Routers</li> <li>• 3 Proprietary Datacomm Links</li> </ul> |

TriQuint's tally of major design wins in the first half of 1997. Each has the potential to generate revenues over \$100,000 per year when and if it reaches production.

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## QC Laser Used in Room Temperature Sensor Application

One of last year's most significant events in the field of semiconductor laser research was the report from Bell Labs of a quantum cascade (QC) laser which operated at or above room temperature. (See CS 2(6), p. 16.) Bell Labs scientists recently demonstrated the next logical step in the evolution of this intriguing device by incorporating a QC laser into a prototype sensor that could be used for gas detection and pollution monitoring. Bell Labs says this demonstration unit is the first laser-based semiconductor sensor that operates at room temperature and has the potential for parts-per-billion sensitivity.

"This is a major accomplishment," said Alastair Glass, director of the Bell Labs Photonics Research Laboratory. "The tuning range and peak power of these prototype laser sensors are unprecedented for mid-infrared semiconductor lasers - about 10 and 100 times better, respectively, than commercial lasers of this type - all of which must be cooled."

"This work opens up an entire field of uncooled, tunable mid- and far-infrared laser sensors," said L.N. Durvasula, program manager, Defense Sciences Office, U.S. Defense Advanced Research Projects Agency (DARPA), which partly funded the work. "This is a revolutionary development for sensor applications."

The QC laser was invented at Bell Labs just three years ago. Unlike most other laser diodes, which rely on direct band-to-band, the QC lasers operate on transitions within the conduction subbands of multiple quantum wells. The newest versions can operate at or above room temperature and can be continuously tuned to operate at any of a wide range of single frequencies in the mid-infrared region. The laser's wavelength is determined by several factors. In manufacture, varying the thicknesses of the epitaxial layers of the laser sets its wavelength, and gratings can be added to make the wavelength more precise and more stable. In use, the wavelength can be tuned by adjusting the temperature or the electrical current.

The Bell Labs research team includes Jerome Faist, Claire Gmachl, Federico Capasso, Carlo Sirtori, Deborah Sivco, James Baillargeon and Alfred Cho, in collaboration with Professor Edward Whittaker of the Stevens Institute of Technology in Hoboken, N.J.

"We're happy to have moved very quickly from basic research to practical application," said Federico Capasso, head of the Quantum Phenomena and Device Research department. "The enabling technology behind all this is the marriage of optics, quantum physics, and crystal growth, in the QC laser, and we foresee a number of market opportunities for these portable, robust devices."

### Distributed Feedback QC Lasers

In a post-deadline paper at the CLEO/QELS Conference earlier this year, Gmachl presented the research team's latest experimental results. She revealed that room temperature operation has been achieved at wavelengths as long as 11.6 micron.

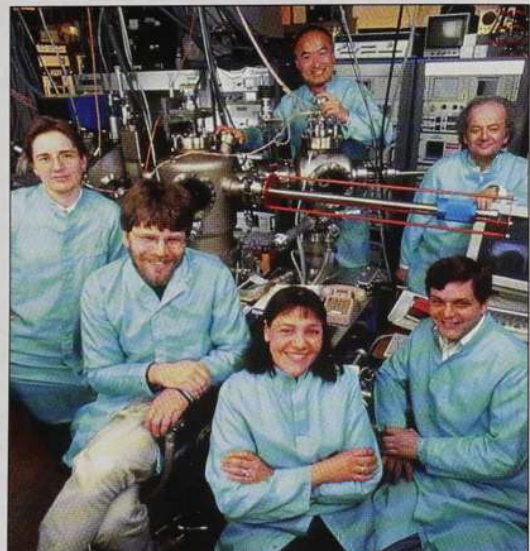
In addition, Gmachl made the first announcement of the use of a distributed feedback (DFB) QC laser. Two types of DFB gratings were examined. The first was a top-grating, fabricated by optical lithography and wet chemical etching. This approach offers the advantage of being relatively easy to fabricate. The second approach uses regrowth of an InP top cladding layer over a similarly fabricated grating located directly above the waveguide. This approach offers stronger coupling and no additional losses, and was found to allow an overall improvement in performance.

The DFB-QC laser was used in the IR sensor in order to force single mode emission in pulsed operation. The demonstration showed the ability to achieve a high single mode tuning range of  $25 \text{ cm}^{-1}$ , which is believed to be an order of magnitude greater than commercially

available lead-salt lasers, as well as high peak power of 50 mW at 300 K for a 5.35 micron unit. This allows better signal-to-noise performance and the use of uncooled detectors. In addition, the Bell Labs team reports that the laser performance is encouraging in terms of its robustness and portability.

The potential applications for a sensor such as the one currently under development are numerous. Environmental uses include pollution monitoring, automotive emission sensing and combustion diagnostics; law-enforcement possibilities include the detection of explosives or of fugitive emissions from illicit drug-manufacturing sites. In addition, there are several military applications like portable battlefield sensing of toxic gases and biological toxins; as well as industrial process control, collision-avoidance radar and medical applications.

Bell Labs estimates that the current market for mid-IR sensors is around \$2 million/year, but it is severely limited by the current state of the technology. They predict that it will be in the "tens of million dollars" range in 5 - 10 years.



*The Bell Labs QC laser development team (Clockwise from top): Al Cho, Federico Capasso, Jim Baillargeon, Deborah Sivco, and Jerome Faist, and Claire Gmachl.*

## Opto-Power Expands

Spectra-Physics has announced plans for expansion at the facilities of its subsidiary Opto Power Corp. (OPC), a manufacturer of high-power semiconductor lasers located in Tucson, AZ. OPC will be getting a new 40,000 sq ft building to increase volume capacity for semiconductor laser manufacturing.

This move is being made to meet current and anticipated market demand for high-power semiconductor lasers, semiconductor laser-pumped solid state (SLPSS) lasers and other semiconductor laser-based products:

"With the strong emergence of semiconductor lasers, we are seeing a technological paradigm shift that is comparable in impact to the evolution from vacuum tubes to ICs in the electronics industry," said Patrick L. Edsell, president of Spectra-Physics Lasers. "We intend to stay ahead of the capacity required to capitalize on this huge market opportunity. The current expansion will support the growth of our operations in areas of strategic importance and help us maintain our industry leadership."

Spectra has also leased a new 25k sq ft building at its Mountain View headquarters to expand its SLPSS laser manufacturing activities.



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## 980nm Contracts for SDL from Corning & Lucent

In July SDL announced the receipt of "a multi-million dollar contract" to supply Corning Incorporated with 980 nm fiber-coupled pump modules for use in optical fiber amplifiers modules. Optical amplifiers are used in fiber optic transmission systems to increase the optical signal power and reduce the need for electronic repeaters, and they represent a critical technology for the deployment of high bandwidth communication networks telecommunications, CATV and broadband transmission systems including dense wavelength division multiplexed (DWDM) networks.

In making the announcement, SDL said they have worked together extensively to qualify the SDL pump modules for use in several key applications served by Corning's amplifier products. The pump modules adhere to a rigorous qualification program aligned with Bellcore reliability recommendations. According to Greg Dougherty, Vice President, Communications and Information Products for SDL Inc., "...this contract highlights our philosophy of working closely with industry leaders to optimize the performance and cost combination of products we offer while maintaining the highest standards for reliability and service." Corning is a leading worldwide supplier of optical modules used in erbium doped fiber amplifiers (EDFAs) as well as other photonic components. Additionally, Corning is the world's leading manufacturer of optical fiber.

## Lucent Technologies

Earlier this year SDL reported that it had received a "significant" contract from Lucent Technologies for 980 nm fiber-coupled pump modules for use in optical fiber amplifiers.

The pump modules, to be manufactured by the SDL Optics division, will be supplied to Lucent's Network Systems Division and incorporated into optical transmission systems built at Lucent's North Andover factory. The company reports that "SDL Optics will be a major supplier of pump modules for Lucent Network Systems in 1997". At that time, this was the largest single order received by SDL for the commercial telecommunications market; however, the Corning order has now surpassed it.

SDL reports that it was one of the earliest suppliers of 980 nm pump modules for EDFAs and currently supplies devices to many of the largest and fastest growing telecommunications and CATV equipment manufacturers around the world.

## Record Order for Semiconductor Laser International

Semiconductor Laser International (SLI) recently announced that it has signed a contract with an OEM to provide \$2.2 million in laser products through the rest of 1997 and into 1998. The order more than doubled the company's backlog to a \$4 million, according to Dr. Geoffrey T. Burnham, president and chief executive officer of the company.

SLI will provide fiber coupled laser devices for use in Diode Pumped Solid State Lasers (DPSSL). The end product will be applications in the industrial sector of the laser market, including cutting, drilling and welding equipment. SLI declined to identify their customer, but said that "this manufacturer's products are used in a wide variety of applications including the industrial, aerospace/military and information

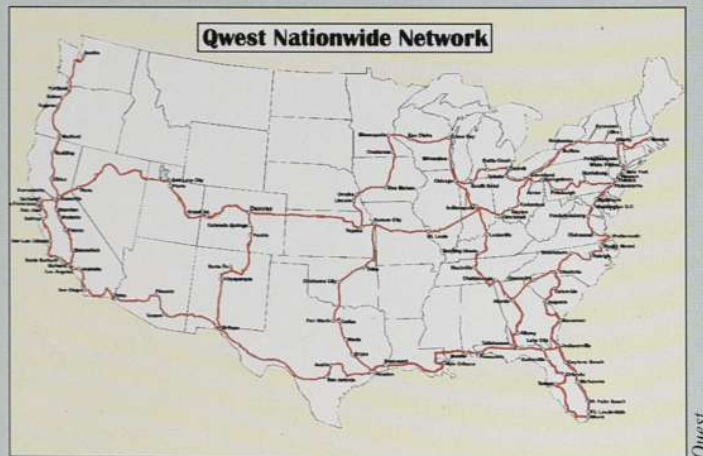
## 10 Gbps Coast-to-Coast Network for North America

Qwest Communications (Denver, CO) has concluded a number of deals this summer which will allow it to implement the first coast-to-coast 10 Gbps fiber network in North America. The network will provide high-speed bandwidth for voice and data communication to 115 cities representing 75% of the long distance traffic in the United States. It will also serve 14 major cities in Mexico, and when finished in late 1999, will extend for 16,000 miles. About 2,000 miles in the western U.S. are already operable.

This will be the first network in North America that uses 10 Gbps transmission throughout the entire network. Other networks have also implemented 10 Gbps transmission (commonly referred to as OC-192), but only for certain sections such as major trunk lines.

Qwest is building the network is largely by burying its cable under railroad rights-of-way. Nortel is their primary contractor. A Nortel spokesperson said the use of EDFAs (erbium-doped fiber amplifiers) would allow the transmission lasers to be spaced at 500 km intervals. The 1550 nm DFB transmission lasers and the 980nm pump lasers for the EDFAs are fabricated at Nortel's facility in Paignton, UK.

The cost of the entire network is believed to be approaching the \$2 billion mark. Qwest is funding the project in part by selling "dark fiber" to other companies. These deals allow companies to purchase some of the 48 to 96 fibers in the cable for their own use. In such situations the customer, not Qwest, will supply the electronics needed to "light up" the fiber.



*Qwest's plan for deploying the first coast-to-coast 10 Gbps network in the U.S.*

processing sectors. The company is a proven supplier of OEM lasers and has been a supplier of industrial material processing equipment for more than 40 years."

Commenting on the order, Burnham said, "SLI's dedication to its clients, big and small, is matched only by our goal of becoming the leading supplier of high power semiconductor diode lasers. This agreement is a significant step for SLI and its shareholders."



## Cree to Make Fake Diamonds

In a departure from their focus on semiconductors, Cree Research recently announced that it plans to develop SiC for fake diamonds for jewelry. Cree has signed development and exclusive supply agreements with C3, a company based in Morrisville, NC. Under the agreements, Cree will develop and supply C3 with near-colorless SiC crystals, which are also known by the mineral name moissanite. C3 plans to market moissanite as a superior alternative to cubic zirconia in jewelry applications.

Originally discovered in meteorites by Nobel Prize winner, Dr. Henri Moissan, moissanite is extremely rare in nature. Its collective thermal conductivity, hardness and refractive index properties are closer to diamond than any other gemstone material. C3 reports that in a recent test, 93% of jewelry store personnel surveyed mistakenly identified moissanite as diamond.

The C3/Cree tie is based in part on family connections. C3 was founded by Eric Hunter, who was also a co-founder and former CEO at Cree Research. His brother Neal Hunter now runs Cree, and another brother, Jeff Hunter, is president of C3. Jeff Hunter's wife, Paula Berardinelli, is VP of marketing at C3.

Under the development agreement, C3 will pay Cree's costs plus a profit margin to develop improved processes for manufacturing large volume crystals of the material. The five year agreement commits C3 to fund program charges of up to \$12 million, provided Cree achieves certain development milestones. Additionally, C3 has the exclusive right to purchase SiC for gemstone applications.

Cree officials noted that the development project is expected to benefit the company's continuing efforts to make larger diameter crystals. "If Cree and C3 are successful in achieving their objectives, the potential for this business is tremendous. Cree's development of SiC has resulted in the creation of yet another new product market. This opportunity plays right to our strategy of being the industry leader in developing, manufacturing and supplying high quality single crystalline SiC," commented Neal Hunter.

A product release by C3 is scheduled for the first calendar quarter of 1998. According to Mark Hahn, Chief Financial Officer of C3, "After two years' development work, we are now significantly ramping up spending at Cree in order to finalize production processes and support a major rollout in the first quarter."

## DARPA Program in Non-Lattice-Matched Crystal Growth

The U.S. Defense Advanced Research Projects Agency (DARPA) is planning a new program aimed at developing new methods of crystal growth that do not require the use of a lattice-matched substrate. The program, which will be funded for \$8 million over 3 years, is meant to include compound semiconductors as well as other electronic materials which are needed in single crystal thin film form. DARPA hopes to enable the integration of various types of device quality single crystal films - chosen for their electronic, optical, and microwave properties - to be vertically and horizontally integrated into a single package, regardless of their lattice constants.

According to the solicitation, which was published in "Commerce Business Daily" on August 15, the key will be "generalized solutions to the substrate problem". Examples of technical approaches include: projection of two dimensional electromagnetic templates (x-ray standing waves or electron interference patterns) during crystal growth using selective photodesorption/adsorption of adatoms and/or force interactions; electric field structured self-assembled monolayers for templated growth; thin film lift-off techniques; or replica techniques to template crystal growth via graphoepitaxy on amorphous substrates.

Proposals are due in mid-November. Multiple awards are expected. Interested parties are encouraged to contact Dr. William Coblenz, DARPA/DSO, 3701 North Fairfax Drive, Arlington, VA 22203-1714, FAX [1] 703 696 3999.

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## CdZnTe Gamma Ray Detector from NASA

A research team at NASA's Goddard Space Flight Center (Greenbelt, Maryland) reports that they have developed a new cadmium zinc telluride (CdZnTe or CZT) detector array capable of locating gamma ray bursts with unprecedented accuracy. They believe the new detector will have several applications in astronomy as well as commercial applications, including medical imaging, environmental monitoring, and non-destructive evaluation.

The research team was led by Dr. Carl Stahle of Orbital Sciences Corporation, (Dulles, VA) Peter Shu of Goddard's Solid State Device Development Branch and Dr. Neil Gehrels of Goddard's Gamma Ray and Cosmic Ray Astrophysics Branch.

"These detectors will not only help solve the mysteries of the universe, they may also save lives," said Stahle. He reports that NASA Goddard is collaborating with a medical imaging group the University of Arizona in Tucson on a project to use another type of CdZnTe array in a brain imaging instrument capable of mapping very small areas of activity in the brain.

"The reason for the exceptional accuracy of these detectors is the extremely fine strip electrodes attached to the front and back of each CZT chip," said Stahle. "Each strip in the electrode is separated by only 100 micrometers from its neighbor, about the width of a human hair. When a gamma ray strikes the CZT chip, it produces an electric charge in the strip electrode. Since we are able to pack so many strips into such a small area, we are able to determine very accurately where the gamma ray came from."

"The novelty of the new array is that it has many more detectors than ever packed together before," said Gehrels. "The area of the strip detector array is nearly 60 square centimeters with over 500,000 picture elements, or pixels. This is 100 times more pixels than any other array currently available. Ultimately, we want to build an array four times as large. Also, the spacing of the electrodes is finer than previously achieved. The result is that the gamma rays are located more accurately within the array. This leads to a better capability to position gamma ray emitting objects in the sky."

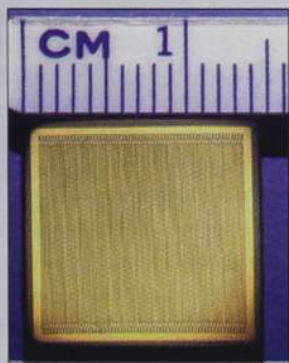
### Applications

The most obvious application of the new detector array is for studying gamma ray bursts. "Solving the gamma ray burst mystery is one of the top priorities in high energy astrophysics," said Gehrels. "Gamma ray bursts are extremely distant, staggeringly powerful explosions. In their brief lifetimes, typically a few minutes, a burst will emit the same amount of energy produced in one year by an entire galaxy consisting of some 100 billion stars. No one really understands what could release such a huge amount of energy in such a short time. The problem is that no one has been able to locate these bursts to the arc-second precision needed to study their origin. That is the key application of the new CZT detector array. The array is a prototype for a gamma ray burst mission that we have proposed called the Burst and All Sky Imaging Survey (BASIS).

Harrison Barrett, professor of Radiology

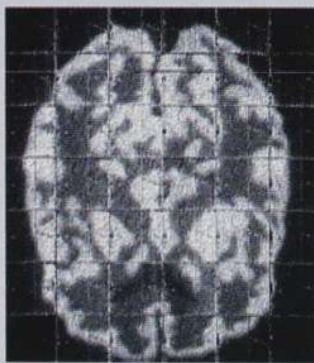
and Optical Sciences at University of Arizona, elaborated on the possibility of using a similar CdZnTe detector in a brain imaging instrument. "The instrument uses nuclear medicine techniques to identify and locate activity in the brain using gamma ray emitting material. Because the arrays are so accurate, the new instrument will allow extremely precise imaging. There are many areas of activity in the brain that are smaller than one millimeter. No instrument available today can image activity in areas this small. That is what our collaboration with Goddard is designed to do. Diagnostic applications of this instrument will allow better characterization of epilepsy and stroke," said Barrett. Better detector performance is also expected to result in an entirely new class of high resolution nuclear medicine scanners for such clinical tasks as heart imaging and for the improved detection of breast cancer.

The Goddard team believes that there are many other possible commercial applications for these arrays. "Unlike other gamma ray detectors, these arrays do not require cooling with cryogenic fluids, so they are portable. This allows them to be used wherever accurate detection of gamma rays is necessary, and it is surprising how many industrial situations require this," said Stahle. Examples include monitoring radioactive waste storage sites or to verify nuclear treaties, as well as probing the interiors of structures and equipment, looking for faults without disassembling them. "We even have a soda company that plans to use gamma rays to determine if its bottles are filled to the correct level," he reports.



NASA Goddard Space Flight Center

CZT strip electrode gamma ray detector,  $\approx 1.5$  centimeters (0.6 inches) square. The vertical lines are spaces between individual strip electrodes, which are attached to the front and back of the CZT chip. The spaces between the electrodes are 100 microns across, about the width of a human hair. When a gamma ray strikes the CZT chip, it produces an electric charge in a strip electrode.



Kevin Matherson, University of Arizona

Image taken with a prototype CZT pixel gamma ray detector approximately one inch square and containing 4096 picture elements, or pixels. The object is a model of a slice of the brain injected with radioactive technetium that emitted gamma rays at 140 KeV. White areas represent the highest intensities of gamma rays. In an actual brain, gamma ray emitting material will be injected into the bloodstream, revealing blood flow patterns.



NASA Goddard Space Flight Center

CZT detector array, with an area of nearly 60 square centimeters. It includes over 500,000 picture elements, or pixels. Readout electronics are in the lower right corner. The large number of strip electrodes packed into this small area provides unprecedented resolution. The array functions at room temperature.



## Feng to Receive David Sarnoff Award



*Milton Feng, recipient of the 1997 IEEE David Sarnoff Award.*

IEEE has announced that the 1997 David Sarnoff Technical Field Award will be conferred on Milton Feng of the University of Illinois. The award is being made to honor Feng's contributions to the theoretical and experimental understanding of the fundamental speed limitations of MESFETs and HEMTs.

Feng has been a professor of electrical and computer engineering at the University of Illinois (Urbana, IL) since 1991. He began his career at Hughes Aircraft (Torrance, CA) in 1979, researching III-V material technology

for microwave devices. In 1983 he developed ion-implanted low-noise and low-power MESFETs that lead to a demonstration of 60 GHz GaAs amplifiers. He joined Ford Microelectronics (Colorado Springs, CO) in 1984 to manage digital and microwave/millimeter-wave IC programs.

According to the IEEE citation, Feng's work has promoted understanding of the speed limitations of MESFETs and HEMTs. Since the latter's invention in 1978, they have attracted attention because of their potential application to high-speed transistors. It had generally been thought that such transistors made with high electron mobility resulting from a two-dimensional electron gas would be unusually fast. Feng showed that the crucial factor is actually high field velocity. Since 1992, he has developed ion-implanted GaAs MESFETs with noise and gain performance comparable to those of GaAs HEMTs, concluding that high field gate and drain diffusion noise dominates their noise performance. Feng has transferred this low-noise MESFET technology to several GaAs IC companies.

The holder of five patents, he has published more than 100 papers and received such honors as the Ford Aerospace Corporate Technology Outstanding Principal Investigator Award (1989) and the Beckman Research Award (1994). Feng received his B.S. from Columbia University (1973), and his M.S. (1976) and Ph.D. (1979) degrees from the University of Illinois.

## New EpiWafer Vendor

In July, Epitaxial Technologies, LLC ("ET") announced its start of operation as a manufacturer of epitaxial wafers products for the wireless and optoelectronic telecommunications market. The company operates out of the University of Maryland Baltimore County (UMBC) Technology Enterprise Center. Products will include GaAs, InP, and InSb epiwafers, offered as either standard products or custom growths.

According to ET's Leye Aina, the company was started to capitalize on opportunities for electronic and optical materials needed for wireless telecommunications, PCS handsets,

CATV, base stations and satellite telecommunications components. He said "Epitaxial Technologies' mission is to develop and manufacture high quality epitaxial compound semiconductor wafer products at a lower cost and in a more timely fashion than is available from existing suppliers of these products."

ET received a grant from the Maryland Department of Business and Economic Development's Challenge Investment Program which makes equity investments in early-stage technology companies. The company has also been awarded SBIR and STTR contracts to develop new wafer products.

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# Red Lasers Due in Time for DVD-RAM Drive Debut

## Special Report from the InterOpt '97 Conference in Japan

BY YOSHIKO HARA

**MAKUHARI, Japan** — Laser manufacturers showed off high-power red lasers at the recent InterOpt '97 here, promising that the parts—key components for the coming wave of DVD-RAM drives—will be available in volume in time for the drives' year-end market introduction.

Mitsubishi Electric Corp. plans to begin what would be the industry's first volume production of high-power red lasers. Competing vendors at the show acknowledged that Mitsubishi is ahead of the pack; most are sampling product now, with plans for volume production later this year.

The bulk of the parts feature a wavelength of around 658 nm, rather than 650 nm as specified in the DVD-RAM document. Engineers at the show said that the tolerance is a necessary margin to ensure stable emissions, and they claimed to be negotiating with drive engineers to convince them to implement the higher wavelength in their drive designs.

All of the lasers exhibited were also said to achieve less than 130 dB of relative-intensity noise (RIN). That level would meet requirements for practical use.

### Mitsubishi

Mitsubishi has been sampling its lasers at \$44 apiece since May. Output power of the 658-nm-wavelength devices is 35 mW continuous and 50 mW pulsed. The parts operate off 2.7 V and 85 mA.

The company is betting that its head start will help it grab a 50 percent share of the total market for high-power red lasers by 2000, said Masao Aiga, project manager for Mitsubishi's opto-device project. The Electronic Industries Association of Japan projected in May that the DVD market will grow to 30 million units worldwide by the turn of the century, with computer peripherals, including DVD-RAM drives, expected to account for nearly 70 percent of those units.

Mitsubishi plans to ramp production from next month's startup levels to 20,000 units per month by this September, and then

to 200,000 units per month by September 1998. "Less than 1,000 yen [around \$8.80] is our target price when the production volume reaches 200,000 units," said Aiga.

Mitsubishi attributes its ability to ramp production quickly to its adoption of 3-inch GaAs wafers—the largest available substrates now being used for the parts. "About 15,000 lasers can be cut out from the 3-inch wafer," said Aiga.

### Special Report:

### DVD Lasers



Mitsubishi's laser features a facet-with-window structure, which is claimed to prevent facet breakage. Doping zinc onto the active layer near the facet causes the crystalline structure of the end of the active layer to become transparent to laser light. The window structure is claimed to guard the facets against breakage at more than 150 mW of output power, whereas 90 mW of output will typically break a facet without the window feature.

Industry experts at the show said the technology will be essential for the volume production of lasers.

"The idea itself has existed for a long time, but implementation on a volume production line is another matter," said Aiga. Mitsubishi previously had used the technology for a 685-nm laser with a 30-mW to 60-mW output. "We have much experience with solid-phase diffusion technology, which is used to diffuse zinc in the active layer," Aiga said.

Increasing the facets' durability is claimed to give the lasers a life span of 10,000 MTTF (mean time to failure) at 60°C.

### Hitachi

Hitachi Ltd. is believed to be running second in the race to bring high-power red lasers to market. October production is planned for Hitachi's entry, which is sampling now.

The company is focusing the efforts of its various subsidiaries on DVD-product development, with plans to grow the total business to about \$9 billion (1 trillion yen) annually.

"Major components for DVD-RAM drives were developed within Hitachi groups," Osamu Numata, general manager of Hitachi's Optical Data Storage Systems Operation, said in April when the first DVD-RAM drives were announced.

High-power lasers are certainly one of those essential components. With an eye toward extending device life by minimizing operating temperatures, Hitachi engineers are focusing on lowering the operating current of the laser. So far, they've managed to bring it down to 90 mW.

Hitachi's laser is evaporated on a slanted substrate to widen the bandgap and thereby shorten the wavelength.

The tentative specifications are for a 660-nm wavelength laser in a 5.6-mm-diameter package emitting 35 mW continuously and 50 mW pulsed, over an operating temperature range of -10°C to +60°C.

Hitachi guarantees less than 1 percent failure in 1,000 hours at 60°C. "[Other] vendors would say a 10,000-hour life, but it is a simulated MTTF life, and the failure rate over time is uncontrollable," an Hitachi spokesman said.

### Toshiba

Toshiba Corp., which has spearheaded the DVD format in tandem with Matsushita Electric Industrial Co. Ltd., also plans production volumes this year for a red laser it is sampling now.

Toshiba intends to offer its laser with high-speed front automatic power control (APC). The bipolar APC detects and feeds



back the wavelength changes to stabilize the wavelength and thereby minimize noise. APC is already used in some magneto-optical drives and eliminates the bulky circuitry otherwise required for high-frequency modulation.

A Toshiba spokesman said the company's high-power red lasers will be manufactured on the same line as its 5-mW lasers to speed the production ramp once development is complete.

### Matsushita, Sharp, & Sanyo

Matsushita, meanwhile, has developed a red-laser pickup for DVD-RAM drives. That laser is a 650-nm device with 30-mW power. Sakon Nagasaki, director of the Matsushita DVD Business Planning Office, said when the device was developed in May that the company would aggressively sell the pickup on the merchant market. But no marketing plan has yet been disclosed. Consumption of the laser and pickup has so far been limited to internal customers.

Sharp Electronics Corp. came to the exhibit with a 30-mW 635-nm laser for write-once heads that's being codeveloped with Pioneer. "We are focusing on increasing the power of continuous emission. So far, no sample is available yet," said a Sharp spokesman.

The early leader in the market for shorter wavelength lasers has been Sanyo Electric Co. Ltd., which announced a 635-nm, 5-mW device in 1994. Last March, Sanyo announced another 635-nm laser, which operates up to 80°C for DVD-ROM players in automobile-navigation systems.

Sanyo entered volume production on 635-nm lasers in December and, according to a spokeswoman, is producing 200,000 units a month, largely for pointer and non-pickup applications. A 30-mW type is also included in the Sanyo portfolio, but the company is watching the market's development before making plans for the part, the spokeswoman said.

*This story appeared originally in EE Times and is reproduced here by permission.*

### Sharp Increases Semiconductor Laser Production

After the InterOpt '97 Conference (see above), Sharp Corporation announced plans to increase their semiconductor laser production capacity by 20% to 6 million units a month in the second half of 1997. The company says this move is being made in response to increasing demand for laser diodes in applications such as CD-ROM and video CD applications. The products most in demand are the 780 nm lasers, especially those with hologram glass on the emitting surface. Sharp plans to invest "billions of yen" to install additional GaAs processing lines at its Nara plant and to increase post-production capacity at its affiliate Sharp Niigata Electronics Industry. The Nara plant is the base for Sharp's production of GaAs chips and is also their sole laser diode fab.

Sharp is often considered to be the largest supplier of optical semiconductors in the world. For 1996, they supplied and estimated 12.6% of the worldwide market.

In related news, the company also detailed its plans for some of its key market segments. First, the company says it will advance into the home optical LAN market. Anticipating that demand for home optical LAN systems will increase as more fiber networks are in place between central offices and homes, the company has started shipping 680nm red semiconductor laser samples to communications equipment makers. While 1.55- and 1.3-micron lasers are used for long-distance trunk optical net-

works, Sharp regards the 680nm laser, which can be produced at low cost, as a promising option for the home LAN system. The company will develop a system for easily connecting the laser and optical fiber and seriously launch the business two to three years.

Sharp also says it will double MD (mini-disk) optical pick-up production. On the back of an increasing demand for portable MD players, the company has developed a very-small optical pick-up and will produce it at its Hiroshima plant from August, boosting its total MD pick-up production to 400,000 units per month by year end. The new pick-up comes in two models: the recording/playback model is 1/3 the size of its predecessor and weighs only 7g. The company, which predicts the world's demand for MD optical pick-ups will grow to 11 million units in fiscal 1998, will make an additional investment by summer 1998 in an attempt to expand the monthly production capacity to 500,000 units and grab over a 50% share of the global market.

And finally, Sharp says it is now ready to mass-produce DVD-RAM lasers. The company is testing a 635nm laser with an output of 30mW in order to increase heat-resistivity from 40°C to 50°C and the life cycle to 10,000 hours. The company plans to begin volume production once orders come in, and says that it will be able to produce up to 1 million units per month.

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## Other Laser News

**Sony** reports that it will **increase semiconductor laser coupler production** to 7 million units per month in fiscal 1998. The laser coupler integrates a laser and a photo detector on a single chip, reducing the number of components comprising an optical pick-up and helping increase reliability. The company, which currently produces 5 million laser couplers per month principally for music CD players and CD-ROM drives, will launch complete production at subsidiary Sony Shiroishi Semiconductor to boost output to 7 million units. Sony says it will also increase production of DVD lasers.

**Tottori Sanyo Electric** has also announced that it will **expand semiconductor laser production**. In response to the growing demand for CD-ROM and DVD-ROM lasers, the company will raise frame-type laser production to 3.5 million units a month, a 130% increase over the current level, by April 1998. Plans also call for doubling production of stem-type lasers for DVD-ROM to 1 million units a month by the end of 1998. Toward these goals, the com-

pany will invest 2 billion yen (\$17.2 million) to install additional lines at its plant and a subsidiary.

**Matsushita Electric** has developed a **semiconductor laser-based repeater unit** which is used to allow cellular phones to function in out-of-the-way places, such as large tunnels and subway stations. The unit converts 800MHz and 1.5GHz radio signals from cellular phones into optical signals with little distortions and transmits the signals over an optical fiber to a ground base station. Capable of covering 500m in radius and supporting nearly 30 channels, the unit will be priced at about 300,000 yen (\$2,632) excluding installation costs. It is possible to connect the unit with multiple ground base stations. Matsushita is aiming for commercialization in 1998.

**NEC** says it has developed a **DFB laser diode module with a non-relay data transmission over a distance of 600km**. The NDL7910P is made using NEC's unique selective MOVPE growth technique to form

a DFB laser and a modulator on a single substrate simultaneously. Designed for use in 2.5Gbps trunk optical communications applications, the 1.55-micron laser module helps extend the data transmission range fivefold to 600km without using relays. The sample price is set at ¥800,000 (\$7,080). NEC plans to produce 3,000 units per annum.

**Mitsubishi Electric** has developed small, **high-performance optical communications modules**. The transmission laser module uses a waveguide lens-integrated semiconductor laser that directly links with an optical fiber without using an optical lens. The reception module integrates a low-capacity photo diode as well as a low-noise amplifier and achieves a reception sensitivity of -36dBm, the highest of its kind. The new modules are 1/5 the size of conventional products and cost about ¥5,000 (\$43.10), half the price of other models. Shipment begins in October, and the company plans to be producing 10,000 units a month in late 1998.

## NTT Reports on Technique to Slash MMIC Costs

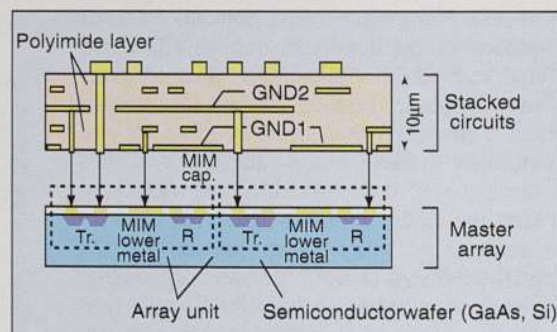
In late July NTT reported that its Masterslice 3D MMIC technology has demonstrated the potential to reduce the time and cost of developing MMICs to just 10% of their current levels. The company hopes that this approach will help to expand the applications for both GaAs and Si MMICs. The key benefit of the 3D technique is that it reduces the area required for a circuit component by 66-95%, which leads a 3-5 fold increase in the integration level. In addition, the time to develop new MMICs is greatly reduced. NTT has developed new CAD tools for 3D MMICs, and says that they will be made available to other companies in order to enhance the MMIC development environment.

### 3D Design

The 3D MMIC design allows a much higher density than existing MMICs. Its structure consists of stacked polyimide layers, each approximately 2.5  $\mu\text{m}$  thick. See Figure 1. Conductor strips and ground metals on the surface of the layers are interconnected through tiny via holes. NTT engineers report that, owing to the narrow line width and line spacing of less than 30  $\mu\text{m}$ , the 3D MMIC easily realizes integration levels as high as 3-5 times that of conventional planar MMICs, and also enables the design a parasitic-free MMIC.

The 3D MMIC approach was developed in order to reduce the size of the MMIC chips. In a conventional design, passive components may occupy as much as 80% of the chip's footprint. But the passives are stacked in the 3D MMIC design, so the area they occupy is 1/10 or less that of 2D MMICs.

Miniaturization of passive circuits also enables significant reduction in the size of active circuit components. NTT reports that it has built single-chip 3D MMIC receivers wherein the amplifiers and mixers are reactively impedance-matched, and the circuits are stacked above and below a ground metal between the polyimide layers. The overall chip size was 2 mm x 2 mm, and the area required for these amplifiers and mixers was less than 0.4 mm<sup>2</sup>, which is around 1/3 the requirement for 2D MMIC amplifiers.



**Figure 1. The basic structure of the 3D MMIC.** Many units, each of which contains transistors, resistors and the lower electrodes of MIM capacitors, are repeatedly placed (nearly 6 units/mm<sup>2</sup>) on a GaAs or Si wafer to form a master array, and the entire wafer surface is passivated. On-wafer elements not selected for microwave circuit design are covered with a ground metal, GND1. Thin polyimide layers (and an additional ground metal, GND2, as occasion demands), are stacked over the wafer and GND1 to complete the 3-D MMIC design. The upper electrodes of MIM capacitors are used for GND1 in order to maximize the space. Therefore a space for many miniature passive circuits is created over GND1. GND1 and the polyimide metal layers provide passive circuits whose performance is not affected by the substrate properties.



## Masterslice Technology

NTT's implementation of the 3D design is done through the use of a masterslice derived from the 3D MMIC structure. The masterslice is a wafer with a master array fabricated on it. The master array consists of numerous array units from which various circuit elements can be created. The ground metal (GND1) layer masks unused circuit elements within the master array. Therefore, passive circuits stacked over GND1 can be freely designed based on the master-array component locations. The GND1 layer enables the semiconductor device process to be separated from the metallization process. Furthermore, masterslice wafers can be fabricated in advance since the wafers are made by the semiconductor device process using a fixed master array. As a result, 3D MMIC chips can be developed by just the metallization process.

NTT reports that this technology can cut the turn-around time of a new chip development to less than half that of conventional technologies since only the metallization process is required. See Figure 2. Furthermore, a cost reduction is expected since the technology does not need a semiconductor process (and a corresponding mask set) for each MMIC development. This is because masterslice wafers are mass-products regardless of each MMIC structure.

## New Design Tool

NTT is embodying the Masterslice 3D MMIC design in a new Computer Aided Design (CAD) tool. The CAD software is based on the High Frequency Circuit Simulator Series IV from Hewlett-Packard. They believe that the new CAD tool will allow even greater reductions in turn-around-time than those shown in Figure 2 due to its automatic routing of transmission lines and the effective use of library circuits for the masterslice 3D MMIC. NTT says that they will make the tool available to other companies, in the hopes of stimulating industry-wide progress in MMIC design.

## Total Cost Reduction

Figure 3 shows NTT's estimate of the cost reduction possible by using the Masterslice 3D MMIC technology. The GaAs 3D MMIC technology is expected to reduce total cost up to 50% compared to that of a conventional GaAs MMIC. The GaAs Masterslice 3D MMIC raises the cost reduction to around 65%.

The 3D MMIC technology is also applicable to Si wafers. NTT has produced a 6-10 GHz band, 8-dB gain, reactive-matching amplifier with an area of 0.5 mm<sup>2</sup> by using Si bipolar transistors. The emitter size is 0.3  $\mu$ m x 120  $\mu$ m. Its maximum frequency of oscillation ( $f_{max}$ ) was 30 GHz. Other components such as VCOs and mixers also exhibited excellent performance in the C and X bands. The NTT engineers report that Si 3D MMIC operating frequency can achieve 1/3 the  $f_{max}$  of Si transistors. Furthermore, they believe that Si 3D MMIC chip-cost can be significantly reduced - by a factor of 10 or more - due to large scale inexpensive wafers and three-dimensional high-density implementation.

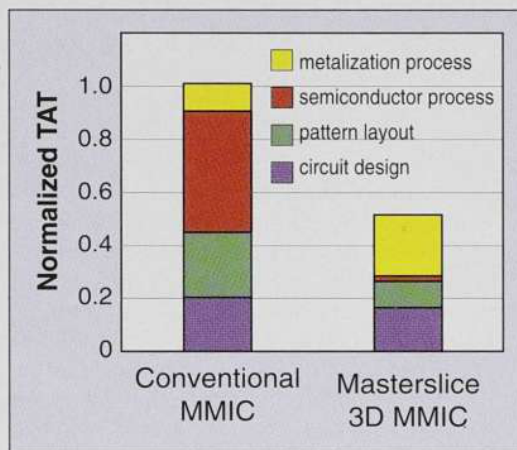


Figure 2. Estimated reduction in turnaround time (TAT) through the use of 3D Masterslice technology. Significant savings are achieved because a new semiconductor process and corresponding mask set are not required for each MMIC development. Instead, changes can be achieved by variations in the metallization alone.

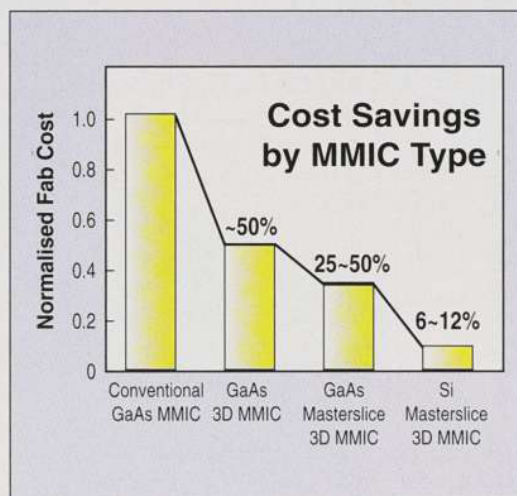


Figure 3. NTT's estimate of the cost savings possible by apply 3D MMIC and Masterslice 3D MMIC designs.

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# Beyond the X-Band

*High frequency applications will be the next growth area for analog GaAs ICs. Raytheon is ready.*

MARIE MEYER

**M**IMICs are not just for the military anymore. Demand for GaAs ICs is rising quickly in several applications at and beyond the X-band. (See Figure 1 for a refresher on band designations.)

Recent studies suggest that high frequencies represent the fastest growing segment of the analog GaAs market. According to Strategies Unlimited,<sup>1</sup> applications above 15 GHz will grow to 21% of the total market, or nearly \$300 million, by 2000. See Figure 2. Uses will include satellite communications, millimeter-wave radar sensors for military and consumer automotive, and newly emerging communications at 28 GHz and 38 GHz. Of course the lower frequencies will still encompass the highest volume applications for GaAs, but it appears that there will be good opportunities for several companies to leverage their GaAs expertise for systems beyond the X-band.

<sup>1</sup> "GaAs IC and FET Market Review and Forecast 1996 - 2000", Strategies Unlimited, (1997) \$3,950.

| Microwave & Millimeter-Wave Band Designations (up to 110 GHz) |          |            |
|---------------------------------------------------------------|----------|------------|
|                                                               | Band     | Frequency  |
| Microwave                                                     | L-band   | 1-2 GHz    |
|                                                               | S-band   | 2-4 GHz    |
|                                                               | C-band   | 4-8 GHz    |
|                                                               | X-band   | 8-12 GHz   |
|                                                               | Ku-band  | 12-18 GHz  |
|                                                               | K-band   | 18-26 GHz  |
|                                                               | Ka-band* | 26-40 GHz  |
| Millimeter                                                    | U-band*  | 40-60 GHz  |
|                                                               | V-band   | 50-75 GHz  |
|                                                               | E-band   | 60-90 GHz  |
|                                                               | W-band   | 75-110 GHz |

\*There is also an overlapping Q-band designation from 33-50 GHz

Figure 1. Band designations for microwave and millimeter-wave frequencies up to 110 GHz.

Raytheon is a major supplier of RF GaAs ICs for cellular and PCS applications. But they are also one of the top contenders for leadership in the high frequency field. Their III-V activity is based at the Advanced Device Center, which is the wafer fabrication, design and production operation of the Raytheon Microelectronics Division. Both are located in Andover, MA. (Silicon chips, such as DC-DC converters and multimedia video circuits, are produced by the Raytheon Semiconductor Division in Mountain View and San Diego, CA.)

The wafer fab in Andover includes both R&D (on 3" wafers) and production (done entirely on 4" wafers since early 1995). In addition to the 80 people working in R&D, Raytheon has over 115 in MMIC and module design and approximately 225 in the production areas. The technologies that are currently in production include 0.5-micron low noise and power MESFETs; 0.25-micron power and low noise PHEMTs; and 0.15-micron power PHEMTs. HBT and InP circuits are said to be under development.

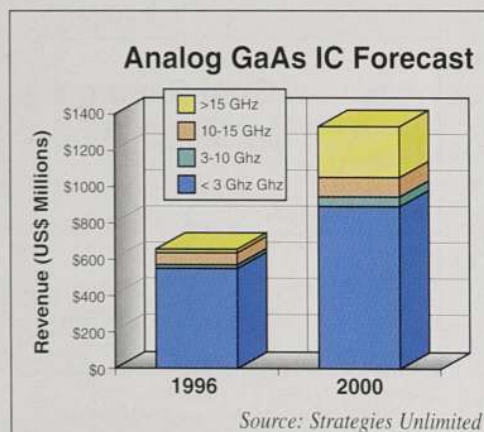


Figure 2. The forecast for the analog GaAs IC Market. The fastest growing segment is frequencies at 15GHz and above, which will expand from just 3% of the total market in 1996 (\$20 million) to 21% in 2000 (\$280 million).



GaAs MMIC Wafers from Raytheon Microelectronics.

PHEMTs currently account for approximately one-third of Raytheon's current production. See Figure Three. According to Jim DiLorenzo, who heads the Microelectronics Division, production of PHEMTs will increase by a factor of 4-5 by the year 2000. MESFET production is booming, too, and the GaAs fab, currently working 7 days a week, 24 hours a day, is nearing full capacity.

In January of this year, Raytheon agreed to spend more than \$12 billion to acquire the defense electronics businesses of both Texas Instruments and Hughes Electronics. As originally planned, these deals would have roughly doubled Raytheon's GaAs capacity. However, the U.S. Justice Department is forcing Raytheon to divest the TI GaAs fab, due to anti-trust concerns (see page 16). The company will have to rely instead on internal expansion and the yet-to-be-completed Hughes merger to relieve the current crunch. The internal expansion will likely include both the additions of new processing lines as well as transition to 6" wafers (for both MESFETs and PHEMTs) in the very near future.

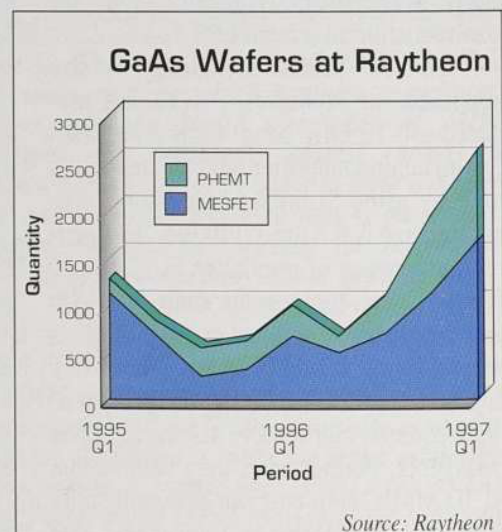


Figure 3. GaAs wafer production at Raytheon by device type.



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## DBS Receivers

The most familiar commercial application for high frequency GaAs is Direct Broadcast Satellite (DBS) TV receivers which operate at 10 - 13 GHz. Raytheon has been active in DBS since 1991, and has shipped almost 6 million GaAs circuits for this application to date. See Figure 4. Most of these are MMIC downconverters based on a 0.5 micron MESFET process, offering typical noise figures around 6.5 dB, with 35 dB conversion gain. In the near future Raytheon will introduce a PHEMT-based LNA MMIC for use in the front end of the DBS receiver low noise block (LNB).

Raytheon has enjoyed impressive growth in their DBS business (see Figure 4), but they acknowledge that it will be difficult to keep up this pace. "New services like DirecTV and PrimeStar have helped boost the U.S. market for receivers" said Dave Laks, Raytheon's Wireless Component Product Line Manager, "but overall the market is slowing down due to saturation in other countries that adopted DBS at an earlier date". He reports that much of Raytheon's recent growth has come by expanding their market share at the expense of other MMIC vendors and suppliers of discrete solutions.

## Satellite Hardware

As growth in the DBS area is slowing down, the expansion of the space hardware area is speeding up. The number of satellites being launched each year continues to grow (see Figure 5), and each one may carry up to 3,000 GaAs MMICs in their antennae.

"Right now, satellites represent the best commercial area for high frequency GaAs," says Bart Van Rees, who manages Raytheon's Space Communications Products. Raytheon has become a major player in this field. For

example, they are supplying the main mission antenna transceiver systems for the 66 satellites in Motorola's high-profile IRIDIUM® project. They are also provisioning the 56-satellite Globalstar™ project, which is sponsored by Loral and Qualcomm.

George Bechtel of Strategies Unlimited agrees that the satellite hardware business is an exciting place to be. "Much of the forecasted increase in GaAs consumption at 15 GHz and higher is due to deployment of satellite networks", he says. Van Rees calculates that the worldwide demand for GaAs chips for space hardware will equate to 40,000 4" wafers a year for the next several years.

Raytheon reports that they will be supplying "tens of thousands" of Ka-band amplifiers as well as L-band and S-band LNA and power modules for the Iridium and Globalstar projects, using GaAs MMICs produced by the Microelectronics division. The company is also actively bidding on several other projects, many of which involve K-band or Ka-band communications links. Most of Raytheon's solutions are PHEMT-based. "Satellites need linearity, efficiency and low noise performance" said Van Rees, "and MESFETs aren't as good for the job." Typical specifications include minimum 45% efficiency for a multistage output 0.5-Watt module at 20 GHz with <2 dB noise. Since most of the projects under discussion will use low earth orbits (LEOs), special rad-hard conditioning is not required, although space-qualified packaging is, of course a necessity.

## Ground Stations

The only problem with the satellite business, it seems, is that eventually it will come to an end. Once Iridium, Globalstar and the dozens of other satellite networks that are currently in development have been deployed, there will be a precipitous decline in the num-

ber of new "birds" that are needed every year. Fortunately, there will still be demand for high frequency MMICs for use in ground stations that link to the satellites. These MMICs will be essentially the same as those used in orbit, although less expensive packaging materials can be used.

In a recent report<sup>2</sup> Frost & Sullivan forecast that spending on ground station antennae and amplifiers (the areas where GaAs is most likely to be used) will have a CAGR of 10% and 5% respectively from 1993 - 2003. See Figure 6. These two areas will have a combined value of nearly \$1.7 billion by 2003.

Van Rees thinks that the ground station market will ultimately be even larger than the space hardware business itself. He says the current satellite business "is analogous to building up a highway system, and the ground stations are like cars. Once you've finished the first part, you've enabled the second part to become a large market." He believes that even after the satellite business begins to slow down - probably around 2003 - the ground station market will fuel continued growth in the demand for GaAs MMICs in the 20 - 30 GHz range.

## WideBand Communications

Not all of Raytheon's commercial high frequency GaAs business is based in space. Doug Maki, manager of the millimeter-wave product line, reports that in addition to the satellite business, Raytheon is also pursuing applications in millimeter-wave radio, LMDS, and automotive radar.

LMDS (Local Multipoint Distribution Service) is a wireless technology with an architecture similar to that used in cellular telephony - except that LMDS operates in the

<sup>2</sup> "World Satellite Ground Segment Equipment Markets", Frost & Sullivan Report #5639-60 (June 1997) \$3,990.

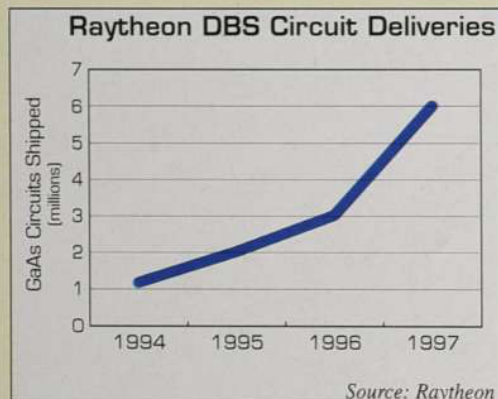


Figure 4. Raytheon's deliveries of DBS Circuits from 1994 - 1997 (cumulative).

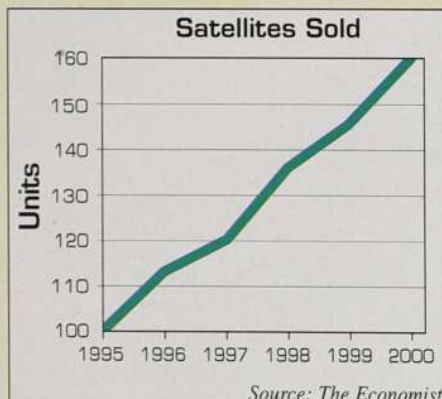


Figure 5. Forecast for commercial satellite sales, 1995 - 2000.

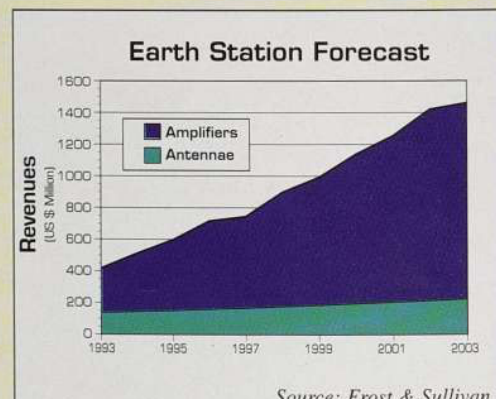


Figure 6. Forecast for sales of amplifier and antenna equipment for satellite earth stations, 1993 - 2003.



Ka-band at 28 GHz. The extra bandwidth available at this frequency makes it suitable for delivering video services. Therefore, it is under consideration as an alternative to cable television or DBS.<sup>3</sup>

"LMDS is an exciting area, because it is consumer-oriented, and because it is possible to make 'one-on-every-rooftop' forecasts. But it is still too early to make many predictions" says Maki. While the technology required to implement LMDS is fairly straightforward, there are some significant uncertainties about its regulatory status, which will likely slow down its deployment.

The mainstay of the current business in Maki's area is millimeter-wave radio. He reports "there is a very steady business in this area - over a hundred thousand radios a year." And the field is growing, due to applications like PCS backhaul, where communications between base stations is done in the Ka-band at 38 GHz.

Another application for the future is automotive radar. As we reported in a previous issue, this application has the potential to create demand for several million millimeter-wave circuits every year (see CS 3(1), p. 30).

<sup>3</sup> We will provide more coverage of LMDS in the "New Applications" feature in our next issue.

But at present, only prototypes are available. According to Maki, "we are all sure it will happen, the question is when it happen. Our best guess is that volume usage will begin in 2002, or perhaps one or two years later." He reports that Raytheon is sampling products in the V-band at 60 GHz for Japan, and in the W-band 77 GHz for the rest of the world.

### Military Radar

Once the TI and Hughes deals are completed, Raytheon's books will show annual sales in excess of \$21 billion, more than \$13 billion of which will be in defense electronics. Therefore it is not surprising to find that Raytheon maintains an active interest in military MMICs - despite the fact that commercial applications now represent the majority of Raytheon's GaAs business.

The biggest military application for MMICs is in transmit/receive (T/R) modules for radar. Defense contractors anticipate that the U.S. government alone will purchase more than 7,000 radars over the next 15 - 20 years. Each radar can contain 2,000 - 10,000 T/R modules. Altogether, the radar contracts are estimated to have a market value in excess of \$30 billion, and of this amount, the MMICs and modules are valued at more than \$5 billion. A variety of frequencies may be used,

but the large majority will be in X-band.

Raytheon was recently awarded a \$4.5 million contract from the Naval Air Warfare Center aimed at reducing the cost of military radars. The official title is "Manufacturing Research and Development of X-band Active Electronically Scanned Array Transmit/Receive Modules", but Raytheon simply calls it the "\$300 Module Program", because that is their target price.

Historically, T/R modules have cost around \$10,000 each in small volumes, and even in large quantities (tens or even hundreds of thousands), the price was still around \$1,000. Those high costs have meant that, in this era of shrinking military budgets, the radar module market has stalled at a few hundred thousand modules a year. Raytheon's mandate from the Navy is to develop modules that cost just \$300 dollars in 20,000 unit quantities.

If Raytheon can reach that goal, it may revolutionize the military radar business. George Jerinc, who oversees the project for Raytheon, says, "we anticipate demand for hundreds of thousands of T/R modules if we can meet this price. All branches of the military have indicated great interest in new uses for radar if we can lower the cost by 2 - 5 times."

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The military market is in a situation similar to where the commercial GaAs manufacturers were a few years ago: under pressure to drastically reduce costs so as to enable high volume markets. But according to Jerinc, "the cost-reduction techniques that were available to the commercial manufacturers, like sending assembly work off-shore to take advantage of cheaper labor, can't be done with military components. Therefore we have to emphasize the use of robotics, lower cost materials, and better engineering that will reduce the size and weight of the part, while increasing its functionality." He says that areas receiving current emphasis include transitioning to 6" GaAs wafers, implementing higher density packaging, and increasing design automation.

"Moving to 6" wafers comes first", says Jerinc, "because that is where we will get the biggest payoff, especially at a place like Raytheon where our commercial business can keep the fab busy all the time." Automated design is also receiving a lot of attention in the \$300 Module Program. "It is much more difficult in microwave frequencies than others, because microwave circuits are more space sensitive" reports Jerinc. And as for packaging, Jerinc says "for today's needs, we can meet the cost and performance expectations with the traditional metal box with a lid on it. Even for the \$300 Module Program, we think that with bigger wafers and better designs, we can meet the goal with today's packages. But there is a need for experimenting with new things - plastic, ceramic, etc. - for the future. (For more on packaging, see box.)

Today's military GaAs business is much different now than it was in the days of the MIMIC program. As Jerinc explains, "in the mid-80's the issues were whether or not the technology could perform, so the military funded programs to prove feasibility, to demonstrate that you could build a MMIC T/R module. Now we know we can build anything that the government wants - for example, very high performance units, such as an X-band unit delivering tens of Watts per channel with efficiencies well over 25% and noise figures in the 3-5 dB range. So now the emphasis isn't on what we can make, it is on how cheaply we can make it."

The emphasis on making things cheaply has served GaAs fabs working at frequencies below 2 GHz very well. As this culture takes hold in the minds of those working at higher frequencies as well, it has the potential to fuel exciting developments in high volume applications for GaAs beyond the X-band.

## MMIC Packages: The Next Generation

As mentioned in the preceding discussion, new packaging techniques will be needed for future generations of microwave modules. Reports from the recent MTT-S International Microwave Symposium illustrate two possibilities.

Researchers at Hughes are working on the development of flip-chip technology that can be used with PHEMT devices<sup>1</sup>. The MMICs are fabricated using all the conventional frontside steps. But whereas the "face-up" wafer requires backside processing (including thinning, via etch, and backside plating), the flip-chip wafer requires just the formation of IO interconnection and thermal shunts which are accomplished simultaneously by depositing 0.004" x 0.006" silver "bumps" by a dry film lamination process.

The biggest technical advantage of the flip-chip is its thermal properties. For conventional power amp, the heat generated in the gate region must travel through the GaAs substrate, which has a high thermal resistance. But in the flip-chip, the heat travels straight from the gate region to a source pad where it is conducted away by a thermal bump. The Hughes team estimates that that the flip-chip provides 40% less thermal resistance than the conventional configuration.

The flip-chip also reportedly provides significant cost savings. The table below presents Hughes' cost model for an X-band high power amplifier with 35% PAE and five watts of output power. Backside processing, which accounts for around 25% of the wafer cost, is eliminated, and assembly costs are reduced, because die attach & wirebond are now accomplished simultaneously. In addition, Hughes says its flip-chip technology provides ~40% higher yield. Overall, they reported a 40% reduction in chip cost.

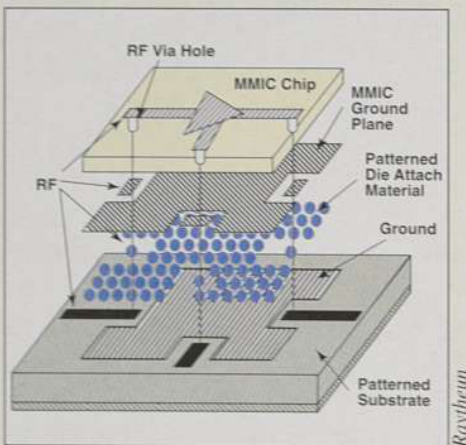
| Face-Up Process |       |         | Flip-Chip Process |       |         |
|-----------------|-------|---------|-------------------|-------|---------|
| Process Step    | Yield | Cost    | Process Step      | Yield | Cost    |
| Frontside       | 80%   | \$3,000 | Frontside         | 80%   | \$3,000 |
| Backside        | 90%   | \$1,200 | Bump              | 95%   | \$400   |
| Wafer Test      | 75%   | \$360   | Wafer Test        | 95%   | \$380   |
| Module Assy     | 95%   | \$1,320 | Module Assy       | 99%   | \$615   |
| Total           | 51%   | \$5,880 | Total             | 71%   | \$4,395 |
| Chip Cost       |       | \$23.44 | Chip Cost         |       | \$14.50 |

Hughes

*Hughes' cost model showing that the lower overall cost and higher yield of the flip-chip process results 40% reduction in the cost of the chip*

Researchers at Raytheon are working an alternative approach to MMIC interconnects<sup>2</sup>. They see a key drawback in flip-chip packaging, in that it requires coplanar or lumped element circuit topologies. As a result, the circuits must be larger, which conflicts with Raytheon's goals of shrinking die size as much as possible. Flip-chips are also incompatible with microstrip layouts.

As an alternative, Raytheon has developed its own experimental bond-wire-free approach, called DBIT: Direct Backside Interconnect Technology. As illustrated at left, all RF, DC and control signals are brought to the backside of the thinned MMIC chip through via holes. The chip is then directly mounted onto a patterned substrate such that these control lines and the ground plane mate with the respective features on the substrate. All chip connections are made in a single step.



*Schematic of the DBIT approach highlighting the interconnect via holes, patterned MMIC backside, patterned substrate and interconnect/die attach material.*

Raytheon

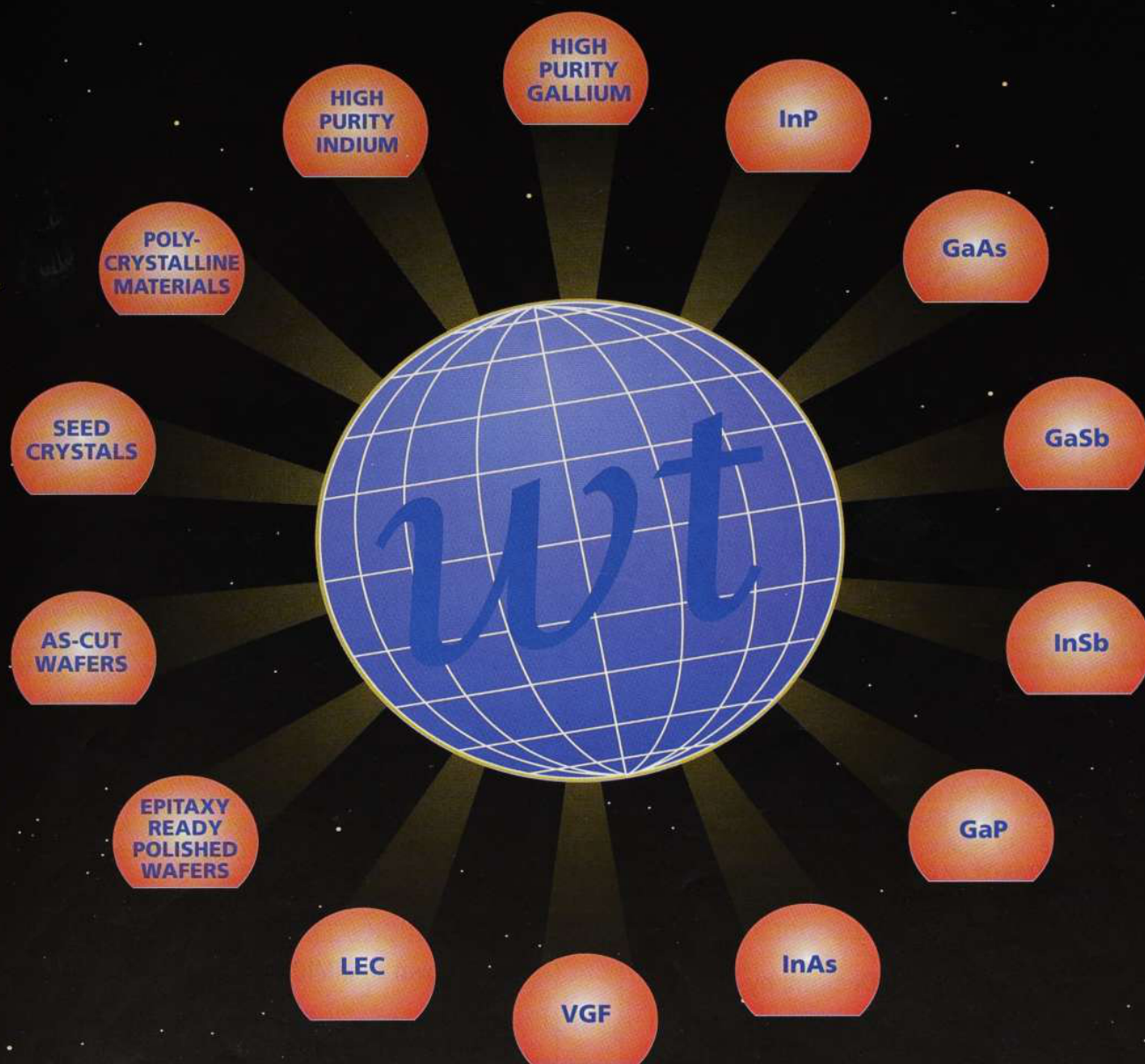
Raytheon researchers report that the parasitic reactance and conductor loss associated with the DBIT RF interconnects are dominated by the impedance of the via hole and are predictable and highly repeatable. The approach has been shown to work with conventional thinned 4 mil thick GaAs wafers, which allows use of conventional microstrip circuit topology. So far, RF interconnects have been characterized up to 40 GHz, and it is expected that the DBIT method can be extended into the millimeter wave region.

<sup>1</sup> P. Cameron, et al, 1997 IEEE MTT-S Int'l Microwave Symp (Denver, CO June 8 - 13, 1997), paper WE3F-36.

<sup>2</sup> T.E. Kazior, et al, 1997 IEEE MTT-S Int'l Microwave Symp (Denver, CO June 8 - 13, 1997), paper WE3E-1.



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# First Release of the MAFET Design Environment

Some of the first results of the MAFET (Microwave and Analog Front End Technology) Program are now available. DARPA has announced the completion of the MAFET Design Environment Release 1.0. A DARPA spokesperson said this is a major step toward realizing the primary goal of the MAFET program: a 3x reduction in cost and cycle-time for MMICs and high frequency multi-chip assemblies.

MAFET is often thought of as the follow-up to the MIMIC program. That project, which was also directed by DARPA, poured more than \$500 million into GaAs programs in the U.S. from 1987 to 1995, and it had a major influence on the development of the American GaAs industry. This time around, DARPA will have to make do with less money. So far, just slightly more than \$100 million in funding has been made available.

## The MAFET Design Environment Consortium

The MAFET Design Environment (MDE) Project is one of the most important parts of the MAFET Program. Its purpose is to develop improved computer tools for MMIC and microwave module design. The participants, known as the MDE Consortium, consist of three computer aided engineering (CAE) companies and four MMIC/module fabs. The CAE companies are Ansoft/Compact Division, Cadence Design Systems, and HP EEsof. The four fabs are Hughes, Raytheon, Texas Instruments, and TRW. These seven are sharing the cost of the \$59 million, three-year MDE project with DARPA. There are also nine subcontractors.

Design tools resulting from the program will be available to the entire industry through the Ansoft, Cadence, HP EEsof and Sonnet Software. According to DARPA, some of the initial developments have already been commercialized.

DARPA defines "design environment" as including integrated design capture tools, interchange formats for design databases and models, and a definition of the data typically interchanged between microwave/millimeter-wave design houses and foundries for MMICs and multi-chip assemblies.

The completion of MDE Release 1.0 marks the release of beta-site software to the MMIC/module fabs. The next steps, which are already underway, include benchmarking by the fabs, to determine how well the release meets the program goals and expectations. A second release, incorporating their feedback, is expected next spring.

According to Donnie Barton, who heads TI's participation in the MDE Consortium, the full fruits of the program should be available to the rest of the industry, in the form of standard products from the CAE companies, in 1998 or 1999.

## Virtual Prototyping

In addition to 3x faster and less expensive design cycles, Barton says that the MDE Consortium also hopes to enable higher quality, higher yielding designs. The key is use of virtual prototyping, which has had limited use in microwave and millimeter-wave designs thus far, because of the complex interaction among components, devices, and packages when operating frequencies exceed 10 GHz.

The MDE Consortium hopes to develop the tools that will suit the future of the market. Among the tasks being addressed are enhancing support for multi-function and mixed-mode MMICs, which are predicted to become increasingly important within the next few years. See Figure 1. Also under consideration is the changing nature of the semiconductor technology used in MMIC fabrication; the Consortium is predicting a general trend toward PHEMTs and HBTs (see Figure 2), and is working on improving non-linear region modeling in response.

Each of the semiconductor companies involved is concentrating on its primary device technology modeling area of expertise. Raytheon's focus is on the large-signal PHEMT area to achieve improved parameter extraction and data collection, and is also defining a statistical modeling methodology for PHEMT and FET devices. Hughes is working both on modeling of large power-generating PHEMT and MESFET devices and on modeling of co-planar waveguide and flip-chip structures. TI is working on FET and HBT device modeling, and TRW's modeling work involves validating models and the model generation tools at MMW frequencies, developing automated mechanisms to support model development, and improving probing techniques for device measurement.

The current phase of the MDE Project is scheduled to terminate in 1998. The consortium hosts an annual industry workshop to showcase the current results of tool development. The next meeting will be held in the Washington, DC area in October of this year.

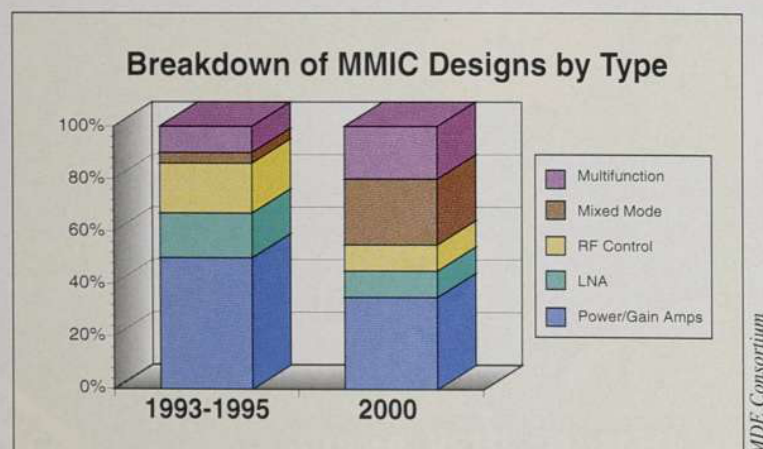


Figure 1. The MDE Consortium's view of the trend toward multi-function and mixed-mode MMICs. The design tools being developed are structured to facilitate this shift.

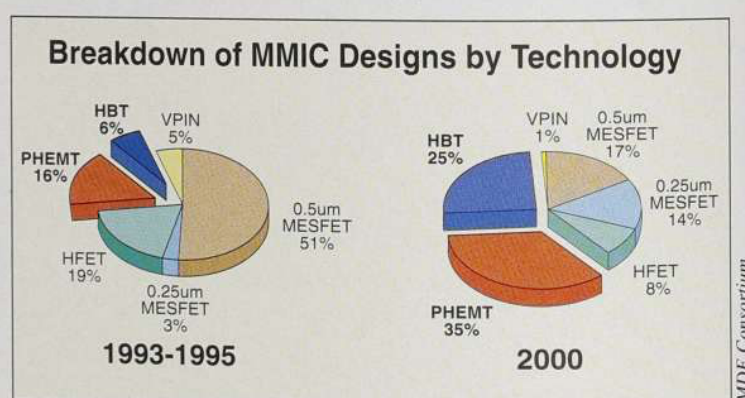
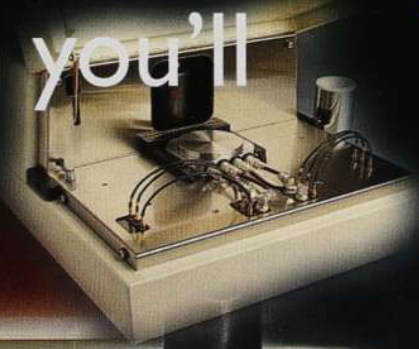


Figure 2. The MDE Consortium's view of the increasing usage of PHEMT and HBT circuits in MMICs, indicating that they will likely dominate the field by the year 2000. In response, the MDE project is focusing on improving microwave and millimeter-wave non-linear region modeling.



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# Patterned Substrates: Making Light Work

DR. CARL E. NORMAN  
TOSHIBA CAMBRIDGE RESEARCH CENTER  
260 CAMBRIDGE SCIENCE PARK  
MILTON ROAD  
CAMBRIDGE CB4 4WE  
UNITED KINGDOM

Recent years have witnessed a dramatic increase in research into semiconductor growth on pre-patterned substrates. The driving force has been two-fold: the push for ever smaller structures demonstrating quantum confinement in 2 or 3 dimensions, and the integration of optoelectronic devices such as lasers, modulators and waveguides. The limits of optical lithography have been reached at the micrometre level, and electron beam lithography and subsequent etching are not yet mature enough to produce damage-free structures on the scale of a few nanometres. Crystal growers have therefore turned to self-organising growth as a possible solution, in both MBE and MOVPE. Structures can be patterned with fairly coarse (if one considers a 1 to 2  $\mu\text{m}$  scale coarse!) features, such as mesas, ridges or grooves, and the subsequent shrinkage of these features during overgrowth is used to form the low-dimensional structures. Where patterns are etched to expose different crystal facets, the differences in growth rates on such facets, or differences in their adatom incorporation behaviour, may be used to engineer the band gap in selected areas across the wafer. Electrons and holes can be confined in selected regions by increasing the band gap in surrounding areas, or by using amphoteric dopants to change the electrical characteristics from n-type to p-type across different crystal facets.

## Characterization

As the features of interest continue to shrink, the techniques used to characterize them require ever higher spatial resolution. Since many present and future devices rely on close control of optical as well as electronic properties in the epitaxial structures, techniques with sub-micron resolution of electro-optical properties are becoming of paramount importance. One such technique is cathodoluminescence (CL) in the scanning electron microscope (SEM), particularly when performed at cryogenic temperatures. In the CL technique, a finely focused beam of electrons generates electron-hole pairs in a very small volume below the surface of a semiconductor. The electron beam is a very amenable probe, and can easily be positioned with nanometric accuracy in a properly calibrated SEM. These electron-hole pairs subsequently recombine, some generating photons of light which can be collected and analysed. Their energy is characteristic of the electronic transitions in the material or heterostructure under investigation.

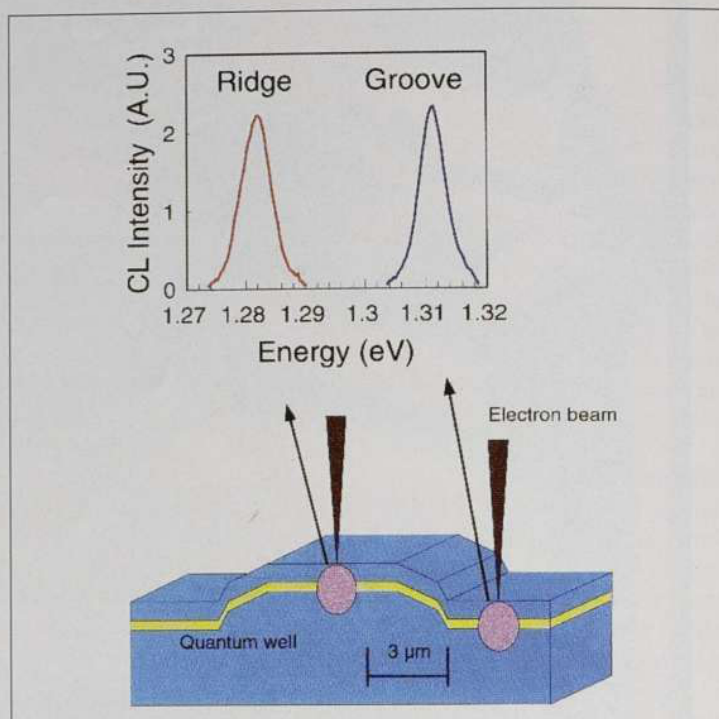


Figure 1. CL probing of two different regions of a ridge structure with a strained InGaAs/GaAs SQW grown on it. Locally increased indium concentration in the SQW grown on the ridge top is manifested as a shift to lower energies of the CL peak.

## CL Hardware

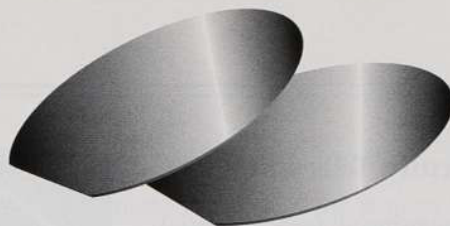
The equipment required for cryogenic CL investigations of low-dimensional semiconductor structures must fulfil certain criteria. The SEM must be capable of obtaining good quality images over a range of beam currents from pA to nA, at a working distance of 12mm or so, in order to accommodate the CL collecting mirror between the polepiece and the specimen. The luminescence collection and detection system must be as efficient as possible, since CL signals tend to be weak and arise from a very small volume of material. A cryostat is essential to maximise the radiative recombination of electron-hole pairs by cooling the sample, and this must be physically stable when at low temperature, to enable long (possibly tens of minutes) image acquisition times to be used, without catastrophic thermal specimen drift. The prolonged use of cryogenic temperatures (e.g. 4.2K) also necessitates a better than average vacuum system in the SEM, to avoid excessive contamination of the sample by hydrocarbons, water, or condensed gases. The results summarised in this article were obtained using the Oxford Instruments MonoCL system and CF302TC liquid helium cryostat, attached to a LEO S440 SEM with upgraded vacuum system.

## Spectra Point the Way

Figure 1 shows CL being used to probe two different regions of a ridge structure with a strained InGaAs/GaAs SQW structure grown on it using MBE. Indium has migrated off the A-type (gallium terminated) sidewalls during the growth of the SQW, and has locally increased the indium concentration of the SQW grown on the ridge top, with respect to the SQW off the ridge. This is manifested as a shift to lower energies of the CL peak from the ridge top.



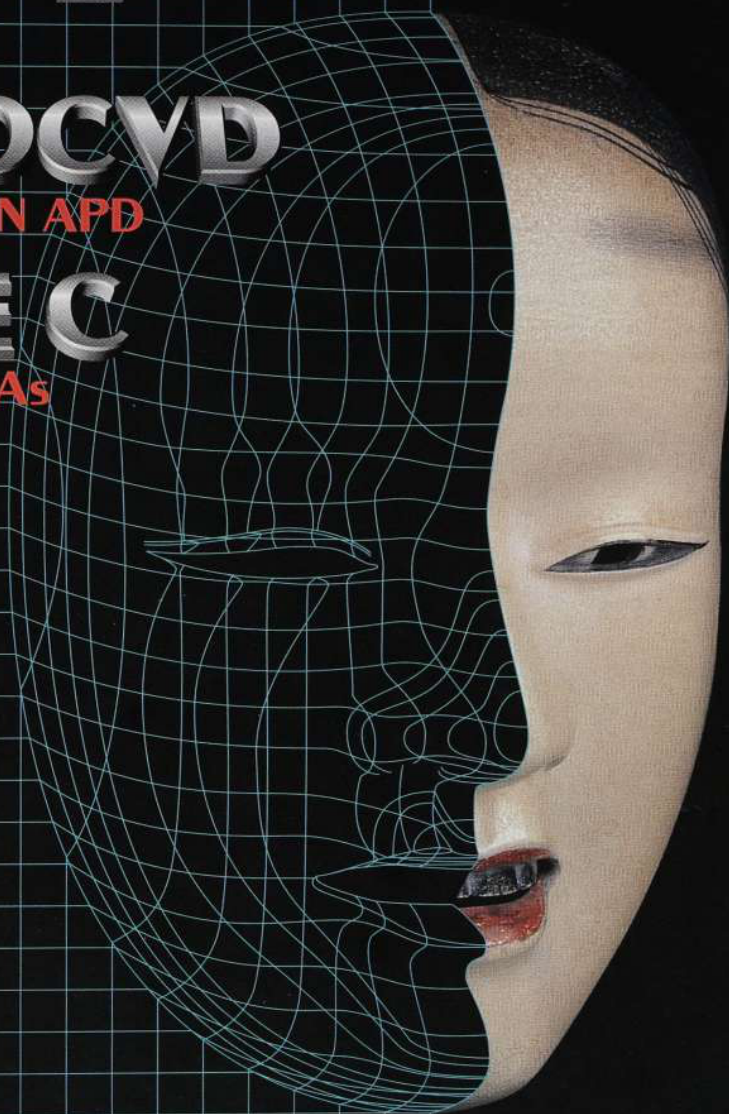
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## Every Picture Tells a Story

Imaging using all (panchromatic), or only one selected wavelength (monochromatic) of the emitted CL is a useful way to identify which areas of the specimen are luminescing, and how strongly. Figure 2 shows an example in which monochromatic CL imaging is used to reveal which regions of three ridge structures (similar to that in figure 1, but this time in the form of a ring) contain the highest concentration of indium in the SQW. In these specimens, excess indium has arrived on the top of the ring only from the sidewalls which run vertically in the image. It is clear that whilst plenty of excess indium still arrives as the MBE growth temperature is lowered, it does not have sufficient mobility on the (100) surface to distribute itself so evenly around the ridge top.

## How Low Can You Go?

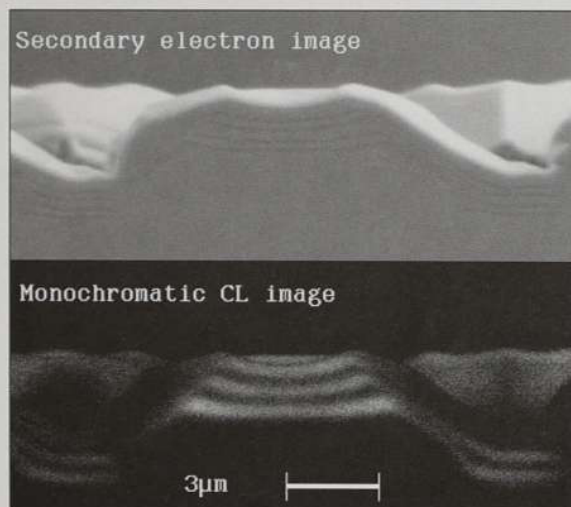
The spatial resolution possible in the CL mode depends on the beam conditions. As the accelerating potential of the electron beam is reduced, the size of the volume from which light is emitted is also reduced, but at the cost of a lower CL signal. Accelerating potentials of as low as 1 to 3kV can give lateral resolutions of tens to hundreds of nanometres in most semiconductors, with surface recombination acting to limit the effective diffusion lengths of electrons and holes.

The choice of beam parameters will be governed to a large extent by the sample geometry. As an example; if a beam has to penetrate 1 $\mu$ m through a specimen to reach a QW, an accelerating potential of 10 to 15 kV will be required and the spatial resolution limited to worse than

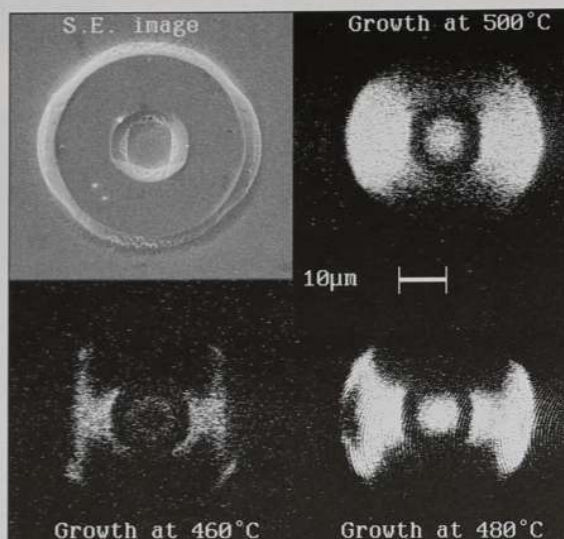
1 $\mu$ m, probably nearer 2 or 3 $\mu$ m when electron and hole diffusion is considered. If the same specimen is cleaved and examined in cross-section, it is possible to inject electron-hole pairs directly into the QW using a much lower

accelerating potential and obtain a much higher resolution. Figure 3 shows such a cross-section through a pattern feature which has had three InGaAs/GaAs QWs grown on it, each with two AlAs cladding layers. Just as the three QWs can be resolved in the monochromatic image, it is possible to probe each one individually with the electron beam, to establish whether

all three are truly identical. The sloping sidewalls of the feature emit at a different wavelength, and so do not appear very bright in this image.



**Figure 3.** A cross-section through a pattern feature which has had three InGaAs/GaAs QWs grown on it, each with two AlAs cladding layers. It is possible to probe each one individually with the electron beam, to establish whether all three are truly identical.

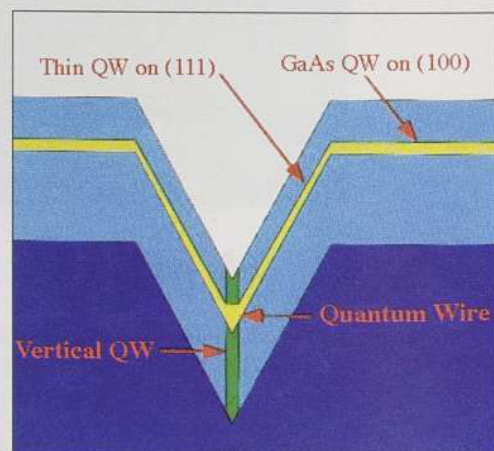


**Figure 2.** Monochromatic CL imaging used to reveal which regions of three ring-shaped ridge structures grown at different temperatures contain the highest concentration of indium in the SQW. The secondary electron (S.E.) image of one sample is shown for reference.

## In the Groove

One of the most promising structures for the self-organised growth of quantum wires is the V-groove, shown schematically in figure 4. Sharp "V"s are chemically etched into the substrate, and during subsequent MOVPE overgrowth of a GaAs/AlGaAs QW structure the QW thickness becomes modulated over the pattern: the QW on the (e.g. (111) orientated) sidewalls is much thinner than on the unetched (100) material, and a locally thick region of the QW develops at the point of the "V", which serves to confine carriers in all directions except along the bottom of the V-shaped groove, hence, a quantum wire. Depending on the precursors and growth conditions used, a gallium-rich region may be incorporated leading up from the bottom of the etched "V", along the line where the growth fronts from both sidewalls intercept, forming a so-called vertical quantum well (VQW).

Figure 5(a) shows a cleaved cross-section of such a V-groove quantum wire structure, and figures 5(b)-(d) are very high resolution cryogenic CL images of the same specimen. It is worth pointing out that these particular structures are in no way ideal for high resolution CL examination, since they were intended for electrical transport measurements and were thus grown on semi-insulating substrates. In panchromatic mode (fig. 5(b)) the "V" appears as a "Y" due to additional emission from the VQW below the quantum wire. No signal is seen from the (100) regions between the grooves due to a layer of SiO<sub>2</sub> which is present to inhibit growth. The individual signals from the quantum wire, the sidewall QWs and the VQW can be identified by point spectra, and illustrated by monochromatic imaging. The wire emits at 812nm (not shown in figure 5) whereas the sidewall QWs emit at 796nm



**Figure 4.** A schematic representation of a V-groove wire structure.



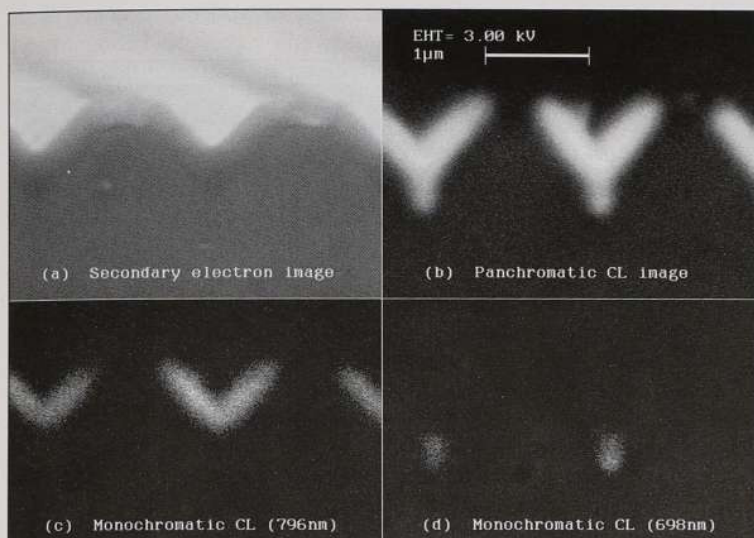


Figure 5(a). A cleaved cross-section of a V-groove quantum wire structure; Figures 5(b)-(d). Very high resolution cryogenic CL images of the same specimen.

(fig 5(c)). The VQW emits at a much lower wavelength and can be seen in figure 5(d) with an exceptionally good spatial resolution of better than 230nm, amply demonstrating the power of the CL technique applied to semiconductor growth on patterned substrates.

## Acknowledgements

The author thanks all those involved in the projects from which these results and images are drawn: Robin Williams (NRC, Ottawa, Canada) and Andrew Pratt (OKI, Japan), both formerly of the Physics Department at Imperial College, Christel Dieker and Arno Hartmann of ISI-KFA Jülich, Germany, and numerous colleagues at the Semiconductor IRC.

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# III-V Oxides, and Their Uses in Optoelectronic Integration

*A smart pixel development project provides another illustration of the tremendous potential of III-V oxides*

C. B. Wheeler

Intelligent Automation, Inc  
2 Research Place, Suite 202  
Rockville, MD 20850

Y. H. Zhang

Arizona State University  
Ctr for Solid State Electronics Research  
Tempe, AZ 85287-5706

Excellent progress is being made toward realizing the potential of III-V oxides. Yet this is a relatively new field of study. It was only in 1990 that Holonyak and co-workers at the University of Illinois discovered the keys to forming insulating aluminum oxide compounds in AlAs and high-aluminum-content AlGaAs layers [1].

Since this breakthrough was reported, III-V oxides have been used to form current apertures in VCSELs - work which has yielded remarkably high quality lasers. Record low threshold currents of 8.7  $\mu\text{A}$  [2], record high wall plug efficiencies up to 50% (78% slope efficiency) [3] and modulation bandwidths surpassing 20 GHz [4] have been reported. Other applications of for III-V oxides are also being explored. GaAs MOSFET devices that use a thermal oxide as a gate dielectric [5], MESFETs with oxide buffer layers to reduce backgating and noise effects [6], and optical wave guides [7] are a just a few examples of these new applications.

## Oxides at ASU

Research at Arizona State University has yielded yet another use - a method to monolithically integrate optoelectronic components using a thermal oxide isolation (TOI) layer [8]. The goal is to use the TOI technology to develop "smart pixels", which are optoelectronic devices that combine optical inputs and/or outputs with electronic processing circuitry. Initial efforts have been primarily focused on developing a method to monolithically integrate the basic component devices (detectors, transistors and VCSELs) that will later be combined to form smart pixel circuits.

The underlying principle behind TOI is to selectively form insulating regions within each device to serve as a current guiding mechanism. This simple concept enables some inter-

esting optoelectronic device structures and combinations of integrated devices that are normally difficult (or not possible) to implement. The extremely fast oxidation rate of AlAs is used to selectively form an insulating layer under in-plane current devices, while leaving the bulk devices conductive to vertical current flow (through an oxidized aperture). This scenario is accomplished by exposing an AlAs layer at the periphery of an etched mesas to an steam ambient at about 450°C. The oxidation proceeds laterally into the mesa at a rate that is strongly dependent on the Al mole fraction of the exposed layers [1]. Mesas containing the vertical current-flow devices (VCSELs and RC-PDs) are simply made to have a larger cross-section than the transistor mesas and the oxidation stopped before the larger mesa is fully oxidized. Figure 1 is a photograph of a group of oxidized mesas viewed from the top (through a 700Å GaAs cap layer). The square (VCSEL) mesas are seen to contain a central unoxidized current aperture, whereas the rectangular (MESFET) mesas contain a fully oxidized AlGaAs layer.

## Integrated VCSELs, MESFETs & Detectors

The work at ASU thus far has encompassed discrete MESFETs isolated with a buried oxide layer, a single MESFET monolithically integrated with a single VCSEL, a novel 2-D array configuration of FET/VCSELs and monolithically compatible

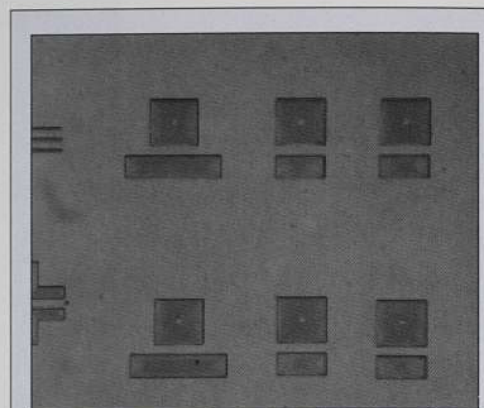


Figure One. Oxidized mesas, seen from above. The square mesas measure  $75\text{ }\mu\text{m} \times 75\text{ }\mu\text{m}$  and contain a central unoxidized current aperture. The rectangular mesas are fully isolated from the underlying substrate by a continuous buried oxide layer.

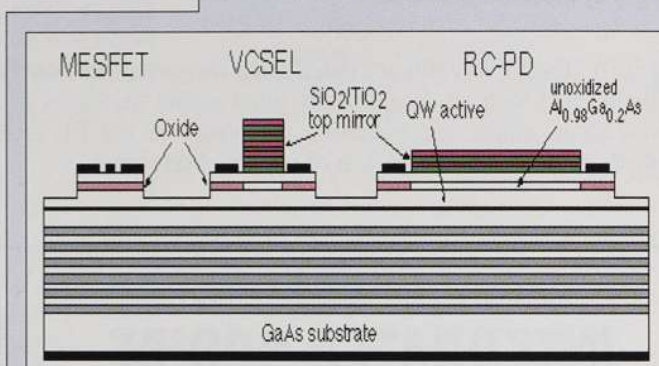


Figure Two. Simplified cross-section showing how the TOI process can be used to simultaneously form the device components needed for practical OEIC applications. The VCSEL is shown with more top dielectric mirror periods than the RC-PD because the laser requires a much higher finesse than the detector.

resonant-cavity photodetectors (RC-PDs).

A simple smart pixel element might comprise an emitter, a detector, and a processing circuit. Figure 2 shows a simplified representation of how TOI can be used to simultaneously fabricate VCSELs (emitters), RC-PDs (detectors), and MESFETs (processing circuits) on a common substrate. MSM photodetectors could be used instead of the RC-PDs, with some modifications to the structure.

The most convenient wavelength to work with from the standpoint of the VCSEL/MESFET device combination is 980 nm (using InGaAs quantum well VCSELs). GaAs is transparent to photons with energy corresponding to 980 nm, so the transistor active channel and the VCSEL top mirror period (cathode ohmic contact layer) can share the same epitaxial layer. Shorter wavelengths can be used, but the fabrication becomes more complex.

At 980 nm, the problem then becomes how to incorporate a satisfactory photodetector without having to grow additional absorber-



ing layers and somehow incorporate them into the integrated devices. The resonant cavity enhancement effect characteristic of RC-PDs appears to solve this problem [9]. It is somewhat surprising that the same active region used to generate the 980 nm radiation in the VCSEL ( $3 \times 80 \text{ \AA}$   $\text{In}_{0.2}\text{Ga}_{0.8}\text{As}$  QWs) can then be used as the absorbing region in a photodetector on the same chip. Theoretical calculations go on to predict that even though neither the incident photon energy (absorption coefficient) nor the absorbing region thickness are all that favorable, the overall quantum efficiency of the detector can still be very satisfactory. Moreover, because the VCSEL and the RC-PD are fabricated monolithically from the same epitaxial layers, the resonant wavelengths of the two devices should be exactly matched. Chips fabricated from the same wafer should, in principle, all be compatible on a system level.

This self-tuning effect is demonstrated in Figure 3. The top plot is a measured reflectance spectra of an as-grown wafer. As is the case of all VCSEL wafers, the Fabry-

Perot resonance determines the lasing wavelength. The corresponding VCSEL emission spectra and photodetector photoresponse are shown in the second and third plots, respectively. The cavity resonant frequency of 981 nm is clearly evident from these three different measurements.

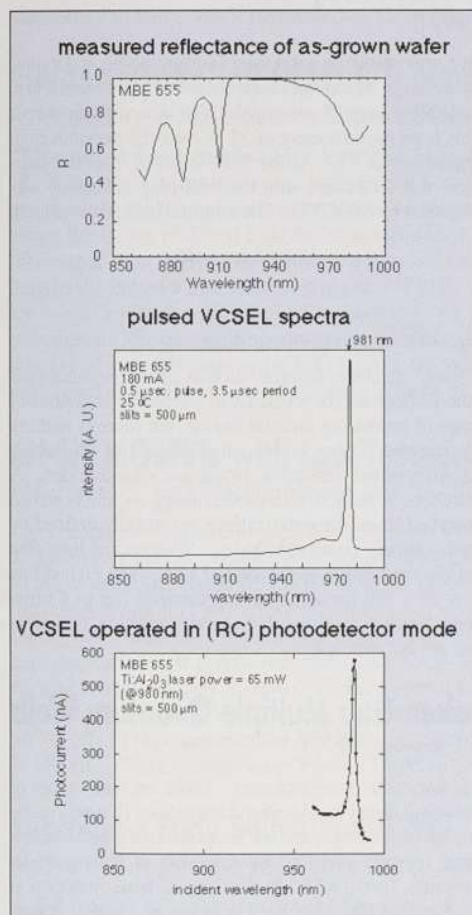
Monolithic integration of optoelectronic circuits is a difficult undertaking regardless of how it is approached. Unlike silicon CMOS technology, most OEICs produced in this way generally require significant custom development efforts. In fact, several research efforts are under way to develop an alternative hybrid integration method that combines III-V optoelectronic devices with silicon circuitry.

Thus far, we see that the TOI method provides solutions to important technological issues. Conventional III-V epitaxial methods are not capable of producing high quality (thin) insulating buffer layers to isolate different devices in the growth direction. The buried oxide layers formed by TOI post-processing of the epi films provides this type of barrier. One device can literally be stacked on top of another, and doping polarities and concentrations arbitrarily changed. The fabrication sequence itself is fairly compact but still capable of producing a variety of different device types simultaneously. The resulting surface topology can be near-planar, prior to the top dielectric mirror deposition, which is beneficial for resolving small device features and tends to eliminate the need for additional planarization, such as polyimide.

By using TOI technology, it is hoped that a manufacturable monolithic process can be developed. Circuit speed enhancements and cost reduction are the potential rewards for doing so.

### References

1. An excellent general review of the oxidation of AlGaAs can be found in R. D. Dupuis, "III-V Compound semiconductor native oxides - the newest of the semiconductor device materials", *Compound Semiconductor*, Vol 3, No. 1, pp. 32-34 (1997).
2. G. M. Yang, et al, *Electronics Lett.*, 31(11), 886 (1995).
3. K. L. Lear et al, *Electronics Lett.* 31(3), 208 (1995).
4. K. L. Lear et al CLEO '97, Baltimore, MD paper CWA2.
5. E. I. Chen et al *Appl. Phys. Lett.* 66(20) 2688 (1995).
6. P. A. Parikh et al, *IEEE Electron Device Lett.*, (1996).
7. A. Fiore et al *Appl. Phys. Lett.* 68, 1320 (1996).
8. C. Wheeler et al, *IEEE Photonics Technology Lett.*, Feb. 1997.
9. K. Kishino et al, *IEEE J. Quantum Electronics*, 27 (8), 2025 (1991).



**Figure Three.** Three different measurements made on the same wafer demonstrate the interrelation between the Fabry-Perot mode of the as-grown wafer and the resonant wavelengths of the resulting monolithic devices. The VCSEL and RC-PD are essentially 'self-tuned' to a single wavelength determined by the FP mode.

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## Toward Monolithic 1.3 - 1.55 $\mu\text{m}$ VCSEL's

Vertical cavity semiconductor lasers (VCSELs) that operate in the 0.8 - 1.1  $\mu\text{m}$  range are highly successful and have made the transition from research to production. VCSELs which emit at the technologically important range of 1.3 - 1.55  $\mu\text{m}$ , lag far behind their shorter wavelength cousins.

There are two main materials requirements for VCSELs: a materials pair with a large refractive index difference for high reflectivity mirrors, and a material that emits the desired wavelength for the active layer. For 0.8 - 1.1  $\mu\text{m}$  VCSELs both of these materials requirements are met with standard GaAs-based materials. For the longer wavelength range, however, the standard materials for the active region would be InP-based, but InP-based materials don't make good mirrors. At present the only viable approaches to 1.3 - 1.55  $\mu\text{m}$  VCSELs involve hybrid technologies, such as substrate etch-back followed by the deposition of dielectric mirrors or the use of wafer bonding. These hybrid approaches work, but involve significantly more complicated fabrication than that used in the monolithic shorter wavelength VCSELs.

If monolithic 1.3 - 1.55  $\mu\text{m}$  VCSELs are to be made, either good mirrors will have to be made on InP or longer wavelength emitting materials will have to be made on GaAs. Research is proceeding along both lines. A group led by Université de Montpellier II scientists has obtained good mirrors at 1.3  $\mu\text{m}$  with AlGaAsSb/AlAsSb lattice matched to InP. With 15.5 periods, a reflectivity of 98% was obtained. Combining these mirrors with an InP-based active layer material of GaInAs(P) is the obvious extension of this work. There are a few approaches for extending GaAs-based emission wavelengths out to the 1.3 - 1.55  $\mu\text{m}$  range. Using InGaAs quantum dots researchers from University of Texas at Austin have made photodiodes on GaAs substrates that operate at 1.27  $\mu\text{m}$ . When forward biased, these same devices function as LED's, emitting wavelengths near 1.3  $\mu\text{m}$ . This result creates some optimism that similar materials could also be used for lasers. In Japan, Ricoh researchers have been working with a new GaAs-based material for emitters, GaInNAs. They recently reported a 1.3  $\mu\text{m}$  edge-emitting laser operating under pulsed conditions at room temperature. Either GaInAs quantum dots or GaInNAs layers might be able to be combined with the standard GaAs/AlAs mirror materials to make a monolithic longer wavelength VCSEL on GaAs.

See G. Almuneau et al, Electronics Lett. 33 (14), 1227 [3 July, 1997]; J.C. Campbell et al, Electronics Lett. 33 (15), 1337 [17 July, 1997]; S. Sato et al, Electronics Lett. 33 (16), 1386 [31 July, 1997].

# Research Review

*The following is a sampling of recent papers in the compound semiconductor field, compiled by the staff of Compound Semiconductor from a variety of international journals.*

## Optoelectronic Devices

### New Material for 1.3 - 1.55 $\mu\text{m}$ Lasers

W. G. Bi et al, IEEE Photonics Lett. 9 (8), 1072 [August, 1997].

A new III-V semiconductor, InNAsP, was recently used as the active region in a 1.3  $\mu\text{m}$  laser. The InNAsP quantum well used GaInAsP barriers that were lattice matched to an InP substrate. InNAsP can be visualized as InP with some As and N added. The addition of As and N have opposite effects on the lattice constant, but both lower the bandgap and raise the conduction band offset with GaInAsP. The conduction band offset is an especially important characteristic since it determines the temperature stability of the laser's threshold, as expressed by the parameter  $T_0$ . In comparison with the conventional GaInAs or GaInAsP active layers, InNAsP is expected to have a larger conduction band offset. This expectation is corroborated by the recent result that shows better high temperature laser performance with the new material. The results were obtained in a collaboration between University of California at San Diego and Northwestern University. The test lasers for these experiments were optically pumped quantum well microdisk lasers, one with an InNAsP active region and one using GaInAs instead. The InNAsP device lased at temperatures up to 340 K, while the GaInAs laser only reached 220 K.

### 155 Watts of CW Power from a Laser Diode Array

X. He et al, Electronics Lett. 33 (14), 1221 [3 July, 1997].

High power continuous-wave (cw) laser diode sources have importance in solid state laser pumping and manufacturing applications such as soldering and materials processing. Recently, researchers at Opto Power Corp. (Tucson, Arizona) reported record cw output powers for monolithic laser diode arrays. A device with an output aperture of 4.8 mm produced 155 W of cw output power. This is an improvement of 35 W over the previous high power record. The device was water cooled with a water temperature of 3°C. At the 155 W output level the junction temperature was estimated to be 110°C, the drive current was 210 amps, and the wall plug efficiency was 40 %. The laser was fabricated in AlGaAs/InGaAs materials grown by MOCVD. The nominal lasing wavelength was 915 nm.

### Polarization Control of VCSEL's

P. Dowd et al, Electronics Lett. 33 (15), 1316 [17 July, 1997].

Vertical Cavity Surface Emitting Lasers (VCSELs) have many attractive features such as ultra-low thresholds and easy processing enabling on-chip testing. One of the difficulties for VCSELs to overcome is control of polarization. The circular VCSEL geometry has the advantage of producing circular beams, but there is nothing in the symmetry of the structure to select any specific polarization. There have been a number of interesting approaches to controlling the polarization, such as the use of misoriented substrates, strain, and quantum dots. A new approach, examined by University of Bristol (UK) researchers, is attractive in its simplicity. A line is etched next to (within a  $\mu\text{m}$  or so) a gain guided VCSEL. Without etched lines, the polarizations are usually defined by the crystal axes with higher order modes co-existing with orthogonally polarized modes. With etched lines, the polarizations are normal to the etch direction, irrespective of the orientation to the crystal axes. The etched line maintains the polarization ratio of the VCSEL in the range of 50 - 100 for all currents examined (up to 4 times threshold). The line does not reach down to the active layer nor does it cross through the cavity aperture, thus electrical performance and the high spectral quality circular beam are not degraded.

### Room Temperature Lasing in Type II Broken Gap Multiple Quantum Wells

A. N. Baranov et al, Appl. Phys. Lett. 71 (6), 735 [11 August, 1997].

Semiconductor lasing in the 2 - 12  $\mu\text{m}$  range has become a very active research area. There are many types of optical transitions being investigated, including the conventional direct band-to-band transitions in type I quantum wells, type II band-to-band transitions in multiple quantum wells, and quantum cascades using either intersubband transitions or type II transitions. A new approach, recently reported by scientists at Université de Montpellier II (France), uses the type II broken gap heterojunction, InAs/GaSb. In this type of heterojunction, if the layers are thick, the bandgap is negative, i.e. the valence band maximum of the GaSb lies at a higher energy than the conduction band minimum of the InAs. In the present work, however, the InAs layers were thin, ranging from 6 to 24 Å. The quantum size effect pushes the ground state of the InAs conduction band electrons to energies above the valence band maximum of the GaSb. Holes in the GaSb valence band are pulled up against the interface by their attraction to electrons in the InAs conduction band quantum well, producing a triangular quantum well in the GaSb valence band. Room temperature lasing was observed at 1.98 and 2.32  $\mu\text{m}$  for structures with 6 and 12 Å thick InAs QWs, respectively. Strong electroluminescence was observed at wavelengths out to 3.4  $\mu\text{m}$  in structures with wider InAs wells.



# Electronic Circuits and Devices

## 2-V Power HEMTs for Personal Handy Phone

Yeong-Lin Lai et al, IEEE Microwave and Guided Wave Letters, 7(8), 219 [August 1997].

Lower operating voltages, higher power densities, and increased power-added efficiencies, are critical factors for weight reduction and increased battery lifetime in wireless phones applications. Operating at 1.9 GHz, a delta-doped AlGaAs/InGaAs HEMT has been utilized in a Japanese Personal Handy Phone (PHS). Grown by MBE, the AlGaAs/InGaAs power HEMT uses delta-doping donor layers both above and below a  $\text{In}_{0.2}\text{Ga}_{0.8}\text{As}$  channel, resulting in a device which exhibited an  $I_{\text{max}}$  of 485 mA/mm (at a gate voltage of +0.5 V) and a transconductance of 310 mS/mm. Under 2.0 V operation, a HEMT with a 1 mm wide gate delivered a power density of 105 mW/mm with a 45.3% PAE. This power density is the highest ever reported for power transistors operating in a PHS system. Work performed at the National Chiao Tung University [Hsinchu, Taiwan, ROC] and Hexawave [Hsinchu, Taiwan, ROC].

## An InP W-Band HEMT/HBT Monolithically Integrated Amplifier

K.W. Kobayashi et al, IEEE Microwave and Guided Wave Letters, 7(8), 222 [August 1997].

Because each device type (HEMTs, HBTs, MESFETs) has unique strengths and weaknesses for a given application, circuit performance utilizing only one device type is often limited due to some intrinsic performance limitation of the device. By mixing device types within a given circuit, further performance enhancements should be achievable over the single device type approach. By using a merged InP-based HEMT/HBT MBE growth process, a single-stage HBT op-amp current regulator has been integrated with a single-stage HEMT amplifier in order to regulate and self-bias the HEMT device over process, temperature and age variations, for W-band operation. The resulting HEMT W-band amplifier achieved a gain of 5.9 dB at 94 GHz. This represents the highest MMIC frequency performance demonstrated for any HEMT-HBT monolithically integrated device technology to date. Work performed at TRW [Redondo Beach, CA].

## InAlAs/InGaAs/InP HEMT E/D Mode Ring Oscillator

A. Mahajan et al, IEEE Electron Device Letters, 18(8), 391 [August 1997].

The use of direct coupled FET logic (DCFL), which requires both enhancement and depletion-mode FETs, offers many advantages over buffered FET logic (BFL), which requires only depletion mode devices. DCFL can result in substantial savings in power, chip area, and can be implemented in single power supply operation. Using the lattice matched InAlAs/InGaAs/InGaAs material system, 0.5  $\mu\text{m}$  gate length E/D-mode HEMTs were fabricated. The D-HEMTs exhibited a threshold voltage of -365 mV, while E-mode HEMTs with identical gate lengths displayed a threshold voltage of 195 mV. The  $f_t$  of both devices was 70 GHz. An 11-stage ring oscillator was fabricated with this E/D technology. At a supply voltage of 0.4 V, a propagation delay time of 22.4 ps/stage and a corresponding power dissipation of 120  $\mu\text{W}$ /stage was achieved, this representing the first demonstration of a circuit employing E/D HEMT technology in the lattice matched InP-based material system. Work performed at the University of Illinois [Urbana, IL].

## 6H-SiC MOSFETs with Low Temperature S/D Implant Activation Anneal

J.N. Pan et al, IEEE Electron Device Letters, 18(7), 349 [July 1997].

A critical element of Si-based IC technology is the use of the self-aligned (SA) MOSFET in which a polysilicon gate acts as a mask for the source drain implants. These implants are then activated by a thermal anneal. In the case of SiC-based MOSFET devices, in which nitrogen is implanted, the high temperatures required for implant activation (1200° - 1500°C), produce a significant increase in surface state and fixed charge densities at the  $\text{SiO}_2/\text{SiC}$  interface, resulting in large negative threshold voltages which make the devices unsuitable for circuit applications. It is now reported that a SA process in 6H-SiC with 25-nm gate oxides has been demonstrated which requires only a 1050 C furnace anneal for implant activation, resulting in a MOSFET with a positive threshold voltage of 1 V, and a peak transconductance of 3.6 mS/mm - values comparable to non-self aligned SiC MOSFETs. This represents the first demonstration of a low temperature anneal process suitable of SA MOSFETs in 6H-SiC. Work performed at Purdue University [West Lafayette, IN].

## Submicron Fully Self-Aligned HBT

Madjid Hafizi, IEEE Electron Device Letters, 18(7), 358 [July 1997]

HBT-based ICs have reached the LSI level of complexity, and are poised to reach even higher levels of integration. Because HBTs often operate at current densities of  $10^4$  to  $10^5$  A/cm<sup>2</sup>, in order to implement higher levels of integration, smaller junction areas are required in order to minimize the power dissipation, thermal management issues, and reliability problems associated with a large number of devices operating at high current densities. AlInAs/GaInAs HBTs grown by MBE have been utilized in the fabrication of fully self aligned devices with emitter geometries as small as 0.3  $\mu\text{m}^2$ . In this process, the emitter, base, and collector ohmic contacts are all self-aligned to the emitter mesa, as well as being deposited in a single metalization step. These devices exhibit an  $f_t$  and  $f_{\text{max}}$  of 120 and 130 GHz, respectively, and represent the smallest HBTs ever reported. Work performed at the Hughes Research Laboratories [Malibu, CA].

## HBT 16x16 Crosspoint Switch

Crosspoint switches, which are key elements in ATM switch cores and wavelength division multiplexing networks, provide a programmable interconnection between high speed data sources and high speed data receivers. At present, 16x16 crosspoint switches with up to 2.5 Gb/s/channel are commercially available, while switches operating up to 5 Gb/s/channel have been demonstrated. Using a 2  $\mu\text{m}$  GaAs HBT process, researchers at Nortel Technology [Ottawa, ON, Canada] have demonstrated a 16x16 crosspoint switch which exhibits a 10 Gb/s/channel capacity, delivering an aggregate rate of 160 Gb/s - the highest reported to date for a 16x16 switch.

The profile utilized in these HBTs consists of a 350 nm GaAs collector Si doped at  $5 \times 10^{16} \text{ cm}^{-3}$ , a 60 nm AlGaAs base region C doped at  $5 \times 10^{19} \text{ cm}^{-3}$  in which the Al content increases from 0 to 5% in the region from the collector to emitter, followed by a 15 nm base-emitter graded region in which the Al content is increased to 30%, and then a 30 nm AlGaAs emitter Si doped at  $5 \times 10^{17}$ . Utilizing 2.0  $\mu\text{m}$  emitter geometries, this HBT exhibits an  $f_t$  and  $f_{\text{max}}$  of 80 GHz and a current gain of 100. These devices have been grown by CBE, MOCVD, and MBE (where in this case Be is used as the p-type base dopant). It is reported that HBTs fabricated with CBE grown material typically exhibited the highest current gain.

In order to fabricate the HBTs, definition of device active areas were formed by implant isolation using 190 keV He<sup>+</sup> ions implanted to a dose of  $1.3 \times 10^{15} \text{ cm}^{-2}$ , followed by a 20 second anneal at 600°C. An Ar/Cl<sub>2</sub>/CF<sub>4</sub> RIE etch is used to selectively etch off the GaAs emitter cap, and the etch is terminated within the emitter region prior to base metallization. A Pd-Zn-Pt-Au-Pd metallization layer is used to make p-type ohmic contact to the base by alloying through a region of the AlGaAs emitter and into the p<sup>+</sup> base. The penetration depth during alloying can be controlled by the thickness of the Pd below the Pt barrier (typically 20 nm). Etching to the subcollector is carried out in a BCl<sub>3</sub>/Cl<sub>2</sub> RIE etch, and both the emitter and subcollector are metallized by Ni-Ge-Au.

The crosspoint switch employs a broadcast-and-select architecture that consists of 16 independent selector slices and a 4:16 b output address decoder. Overall, the crosspoint die is 7.10 x 6.35 mm<sup>2</sup> in size and contains 3973 HBTs and 1840 resistors. Using a logic cell supply voltage of -6 V and a Data I/O cell supply voltage of -5 V, the total power dissipation of the crosspoint averaged 10.5 W. See, Kerry S. Lowe, IEEE Journal of Solid-State Circuits, 32(8), 1263 [August 1997].



## Gallium Nitride Growth on LiGaO<sub>2</sub> Substrates

GaN single crystal substrates are difficult to obtain because of the high equilibrium nitrogen partial pressure at the required growth temperatures. Traditionally, GaN epitaxial films have therefore been grown on sapphire (Al<sub>2</sub>O<sub>3</sub>) substrates despite a large lattice mismatch of approximately 14%. Still, the large lattice mismatch between GaN and sapphire results in a high dislocation density of  $10^8 - 10^{10} \text{ cm}^{-2}$ .

Recently, encouraging results have also been achieved by growth on SiC substrates because of their reduced lattice mismatch with respect to GaN and LiGaO<sub>2</sub> is also beginning to receive attention because it has an average lattice mismatch of just 0.9% with respect to hexagonal GaN. A significant breakthrough has come with the work of a group of researchers from NTT.

Previous attempts to grow GaN films on LiGaO<sub>2</sub> substrates resulted in layers that peeled off the substrates as soon as they were exposed to air. It is reported that (001) LiGaO<sub>2</sub> grown by Czochralski pulling consists of {110}-aligned multiple polar domains ("A" and "B") that may be due to a polarity inversion and which can be revealed by chemical etching in an aqueous solution of nitric acid. The domains can be differentiated by their etch rate as well as by the geometrical shape of etch patterns delineated on the etched surfaces. "A" and "B" domain substrates were prepared by cleaving (001) wafers containing both domain types.

GaN epilayers with a thickness of 0.4  $\mu\text{m}$  were grown by MBE on both types of substrates: layers grown on "A" domain substrates were found to peel off and were characterized by an XRD FWHM of 1840 arcsecs, whereas epitaxial layers grown on "B" domain substrates were smooth and showed an XRD FWHM of 260 arcsecs only (roughly 7 times smaller than for GaN films grown on {0001} sapphire substrates). The previous reports of poor adhesion of GaN films grown on LiGaO<sub>2</sub> substrates probably arose from the polar multi-domain structure of the (001) LiGaO<sub>2</sub> surface. The authors state that they have also succeeded in growing single-domain LiGaO<sub>2</sub> crystals by Czochralski pulling. These new substrates may eventually prove to be a viable alternative to both sapphire and SiC substrates for GaN-based thin films.

Work done at the NTT System Electronics Laboratories, Japan. See Y. Tazoh et al, *Jpn. J. Appl. Phys.* 36 (Part 2, 6B) L746 [1997].

# Compound Semiconductor Materials

## Improved GaInP/AlGaInP Laser Thresholds by RTA Annealing

M. Jalonen et al, *Appl. Phys. Lett.* 71 (4), 479 [1997].

When MBE-grown GaInP/AlGaInP laser structures are RTA annealed, the laser threshold current densities are significantly decreased. This improvement in lasing performance was assigned to a possible removal of nonradiative recombination centers from the quantum wells. The laser emission wavelength, differential quantum efficiency, and characteristic temperature were not affected to any significant degree, indicating that the interdiffusion of group-III elements during the RTA step did not damage the structures. Work done at Tampere University of Technology (Semilab), Finland.

## PL Enhancements in GaAs Passivated by Postgrowth Phosphidization

D. A. Harrison et al, *Appl. Phys. Lett.* 70 (24), 3275 [1997].

Dramatic enhancements by factors of over 300 in the room temperature photoluminescence signal obtained from high purity GaAs epitaxial layers were recorded after a brief postgrowth heat treatment in tertiarybutylphosphine (TBP) vapor. Low temperature photoluminescence spectra indicate that, unlike other passivation techniques, the surface layer formed during this simple treatment does not induce any appreciable strain on the underlying epilayer. The increases in photoluminescence intensity are indicative of a reduction in surface recombination brought about by the formation of a very thin GaP layer that protects against surface oxidation. Work done at Simon Fraser University (Burnaby, BC, Canada), and Nortel Technology (Ottawa, ON, Canada).

## SiC Growth and Devices

A. Itoh et al, *CRC Critical Reviews in Solid State* 22 (2), 111 [1997].

Single crystal bulk and homoepitaxial growth of SiC and its application to power electronic devices are reviewed in detail. The electrical properties of SiC grown by step-controlled epitaxy are reported: a high electron mobility of  $720 \text{ cm}^2/\text{Vs}$  is achieved at 300 K. Breakdown fields of 1-5 MV/cm are found in 4H- and 6H-SiC, and a saturation velocity of  $1.6 \times 10^7 \text{ cm/s}$  is measured at a field of 86 kV/cm. At higher fields the velocity was observed to decrease with increasing electric field. Work done at the Tokyo Institute of Technology, and Kyoto University, Japan.

## NDC by Phonon Emission in SiGe Dots

S. J. Koester et al, *Appl. Phys. Lett.* 70 (18), 2422 [1997].

The operation of a laterally patterned negative differential conductance device based on hot-electron effects in strained Si/SiGe quantum wells is demonstrated. The device consists of a small, etch-defined dot region connected to narrow leads on either side via point-contact tunnel barriers. At  $T = 0.4 \text{ K}$  ( $T = 1.3 \text{ K}$ ), the drain characteristic of this device shows a pronounced NDC region with a peak-to-valley ratio greater than 600 (100). The NDC is attributed to phonon emission by hot electrons injected into the dot region, and is observable up to roughly 30 K. Work done at the IBM Thomas J. Watson Research Center, Yorktown Heights, NY.

## InAs/AlGaSb Superconducting HFETs

T. Maemoto et al, *Appl. Surf. Sci.* 117/118, 714 [1997].

Submicron scale superconducting weak links were fabricated with Pb-alloy superconducting source and drain contacts deposited on an InAs/AlGaSb MBE-grown quantum well. Because the superconducting electrons in the Pb-alloy contacts maintain their character over a given coherence length (primarily determined by the electron concentration in the "normal" QW material), superconducting wavefunctions can tunnel between the source and drain electrodes through the InAs quantum well: a superconducting current flows through the InAs QW. Multiple ("Andreev") reflections of the superconducting quasi-particles between the superconductor/semiconductor interfaces lead to sharp dips in differential resistance measurements at cryogenic temperatures. When a gate is placed between the source and drain, negative gate voltages quench the differential resistance dips by gradually decreasing electron density and the associated superconducting coherence length in the InAs quantum well. Work done at the Osaka Institute of Technology, Japan.



## The 1.6 Billion Dollar GaAs IC Company

*Vitesse rides the Bull Market to a record valuation - plus a round-up of first half results.*

MARIE MEYER

**B**oosted by record revenues and income for the second quarter of this year, Vitesse Semiconductor's share prices have continued their strong upward trend, closing at \$46 on August 30. As a result, the

company now has a rather astonishing market capitalization (determined by multiplying the number of shares outstanding by the share prices) of more than \$1.6 billion, more than double its value 12 months ago. See chart.

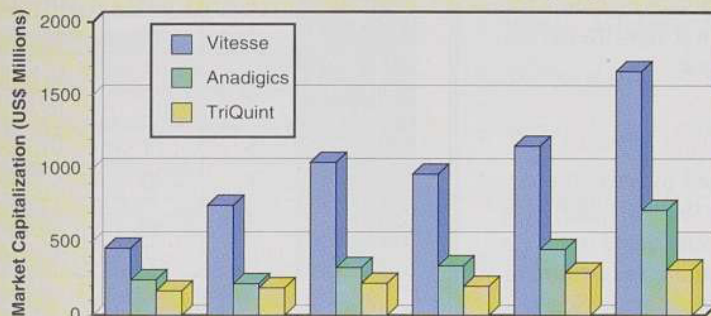
Vitesse's revenues for the quarter which ended June 30, 1997 were \$27.6 million, an increase of 12% over the previous quarter and an increase of 60% over the \$17.3 million reported a year ago. Net income was \$9.0 million, or 23 cents per share,

compared with \$7.8 million, or 20 cents per share, for the previous quarter and \$3.8 million, or 12 cents per share, for the year ago period. Both the revenue and profit figures were records for the company. Vitesse's \$1.6 billion valuation is more than twice that of Anadigics, which is the next highest company in our Portfolio. Their August 30 closing price of \$51 1/4 gives them a market capitalization of \$717 million. Like Vitesse, Anadigics' share prices were buoyed by record results for the June quarter. Net sales increased 57% to a record \$25.0 million, compared to \$15.9 million in 1996. Net income rose 75% to \$3.6 million. The company reported that its gross profit margin increased to 47.3%, compared to 46.1% for the previous quarter. This was attributed to the conversion to 4" wafers that began in late 1996 and improvements in product yields.

Anadigics reported that their sales of GaAs ICs for cellular and PCS applications grew 229% to \$12.9 million. The company believes that it is now the leading supplier of GaAs power amplifiers.

TriQuint, which is third in our market capitalization rankings at \$310 million, also turned in a good second quarter report. Revenues were a record \$18.5 million, a 23% increase over the \$15.1 million reported in the comparable period of 1996. Net income was \$2.3 million, a 22% increase over the \$1.9

The \$1.6 Billion GaAs IC Company



| Company          | Symbol | Exchange | Last 52 Weeks |        | Closing Price |          |        | Average Daily Volume | P/E Ratio | Market Cap (\$M) | % Held by Institutions |
|------------------|--------|----------|---------------|--------|---------------|----------|--------|----------------------|-----------|------------------|------------------------|
|                  |        |          | Hi            | Lo     | Aug 30        | Jan 2    | Change |                      |           |                  |                        |
| Alpha            | AHA    | AMEX     | 16            | 5 1/2  | 14 3/4        | 8        | +84%   | 49,000               | ◆         | 146              | 41                     |
| Anadigics        | ANAD   | NASDAQ   | 54 1/5        | 14     | 51 1/4        | 25 1/3   | +102%  | 259,000              | 47        | 717              | 57                     |
| APA Optics       | APAT   | NASDAQ   | 6.5           | 4 1/4  | 6             | 4 1/2    | +33%   | 4,000                | ◆         | 52               | 2                      |
| ATMI             | ATMI   | NASDAQ   | 32 1/2        | 10 7/8 | 27 3/4        | 16 7/8   | +64%   | 68,000               | 57        | 38               | 38                     |
| Celeritek        | CLTK   | NASDAQ   | 16 1/2        | 9 3/16 | 14            | 10 5/8   | +32%   | 28,000               | 27        | 45               | 45                     |
| Cree Research    | CREE   | NASDAQ   | 20 1/2        | 8 7/8  | 16 5/8        | 10 5/8   | +56%   | 169,000              | 59        | 27               | 27                     |
| Emcore           | EMKR   | NASDAQ   | 25 1/4        | 9 1/4  | 23 3/4        | 10 5/16* | +130%  | 31,000               | ◆         | 16               | 16                     |
| Int'l Semi Corp  | ISSM   | OTC      | 2             | 1/32   | 1/16          | 9/16     | -89%   | 119,000              | ◆         | 0.6              | na                     |
| Kopin            | KOPN   | NASDAQ   | 20 1/2        | 7 1/4  | 20 1/4        | 11 5/8   | +74%   | 65,000               | ◆         | 232              | 14                     |
| Ortel            | ORTL   | NASDAQ   | 26 1/4        | 10 7/8 | 23            | 22       | +5%    | 118,000              | 34        | 273              | 28                     |
| Power Spectra    | PWSP   | OTC      | 1 5/8         | 3/8    | 7/16          | 11/16    | -38%   | 16,000               | ◆         | 9                | na                     |
| RF Micro Devices | RFMD   | NASDAQ   | 23 3/4        | 14 1/2 | 19 1/8        | 15 5/16* | +25%   | 126,000              | ◆         | 299              | 6                      |
| SDL              | SDLI   | NASDAQ   | 29            | 8      | 18            | 24 5/8   | -27%   | 102,000              | ◆         | 240              | 80                     |
| SLI              | SLIC   | NASDAQ   | 9 3/4         | 4      | 4 5/8         | 7        | -34%   | 26,000               | ◆         | 17               | 0                      |
| Spire            | SPIR   | NASDAQ   | 13 1/2        | 2 1/4  | 12 1/4        | 2 3/8    | +416%  | 28,000               | 83        | 38               | 9                      |
| TriQuint         | TQNT   | NASDAQ   | 45 1/2        | 16 7/8 | 37 1/8        | 27 3/8   | +36%   | 218,000              | 44        | 310              | 57                     |
| Vitesse          | VTSS   | NASDAQ   | 51 3/4        | 19 3/4 | 46            | 28 1/8   | +64%   | 582,000              | 62        | 1,665            | 78                     |

\* Closing price on first day of trading: 3/6/97 for EMKR; 6/3/97 for RFMD

◆ = Loss in most recent 4 quarters.



million reported for 1996. But the company is offering cautious predictions for the second half of 1997, saying that growth would be slower than previously expected. In a conference call with analysts, company officials said bookings looked sluggish because some of its customers were having delays in introducing new wireless telephone handsets. The company also said it plans to issue an equity offering, which raised investors' concerns about dilution.

## First Half Results

In our previous issue (CS 3(4), p.46), we reviewed the share price performance for our 17 Portfolio companies in the first half of 1997. Quarterly reports filed since then make it possible to analyze the profit & loss picture for most of the Portfolio companies in the first six months of 1997. As of this writing, complete data was available from all but two - Ortel and International Semiconductor.

As you might expect from the preceding discussion of valuations, the three GaAs IC companies - Vitesse, Anadigics and TriQuint - enjoyed the top three spots in terms of income and revenue for the period. If they continue on their current trajectory, it looks as if Vitesse and Anadigics will both break the \$100 million/year barrier in 1997.

## Profits

Eight companies reported a profit for the first half of 1997: Anadigics, ATMI, Celeritek, Cree, RFMD, Spire, TriQuint and

Vitesse. See table, below.

For three of the companies - Cree, RFMD, and Spire - this represents a turnaround of sorts, as they all posted losses in the first half of 1996. Shares in Cree hit a new 52 week high on the news that they would begin making materials for fake diamonds (see page 19). And interest in RFMD continues to be strong. Their shares are up 25% since the company's IPO in June.

Vitesse posted the largest increase in income (164%), followed by ATMI (121%), Anadigics (77%), and TriQuint (45%).

## Revenues

The biggest revenue gainer for the first six months of 1997 was Emcore, which nearly doubled its sales figures from the first half of 1996. However, the company showed a net loss of \$2,320,000 on its \$27,035,000 in sales.

Other big revenue gainers include Cree (89%), RFMD (88%), Power Spectra (64%), Anadigics (62%) and Vitesse.

## Losses

Net losses were posted by several companies. The biggest loss (\$28,964,999) was reported by SDL, which was forced to take a one-time charge of \$30.9 million as a result of the settlement of its lawsuit with Spectra-Physics. Alpha was also in the red for the first half, with a net loss of \$4,235,000, due in large part to restructuring. The company is forecasting profitability for the second half of the year. Significant losses were also report-

## Analyst Round-Up

Data supplied by Zacks Investment Research indicates that several of the companies in our portfolio are receiving "buy" recommendations from stock analysts. Here is a summary of their opinions as of August 29. Note that several of the companies in the Portfolio do not attract professional coverage, and therefore are not listed here.

|      | Buy | Hold | Sell |
|------|-----|------|------|
| AHA  | 3   | 2    | 0    |
| ANAD | 8   | 1    | 0    |
| ATMI | 4   | 1    | 1    |
| CLTK | 1   | 1    | 0    |
| CREE | 2   | 0    | 0    |
| EMKR | 2   | 0    | 1    |
| KOPN | 2   | 1    | 0    |
| ORTL | 4   | 5    | 0    |
| RFMD | 3   | 1    | 0    |
| SDLI | 1   | 0    | 1    |
| TQNT | 8   | 4    | 0    |
| VTSS | 8   | 2    | 1    |

Source: Zacks Investment Research

ed by Kopin (\$3,791,000), SLI (\$3,382,000), Power Spectra (\$1,041,000) and, as mentioned previously, Emcore.

### 1<sup>st</sup> Half Profits

|           |        | 2 <sup>nd</sup> Quarter 1997 |                       | 1 <sup>st</sup> Half 1997 |                         |
|-----------|--------|------------------------------|-----------------------|---------------------------|-------------------------|
|           |        | Revenue                      | Income                | Revenue                   | Income                  |
| Anadigics | 1997   | \$24,969                     | \$3,612               | \$47,829                  | \$6,783                 |
|           | Change | Up 57%                       | Up 75%                | Up 62%                    | Up 77%                  |
| ATMI      | 1997   | \$13,632                     | \$1,340               | \$26,098                  | \$2,447                 |
|           | Change | Up 10%                       | Up 109%               | Up 16%                    | Up 121%                 |
| Celeritek | 1997   | \$12,595                     | \$956                 | \$24,201                  | \$1,969                 |
|           | Change | Up 9%                        | Up 6%                 | Up 8%                     | Same                    |
| Cree      | 1997   | \$8,479                      | \$724                 | \$15,445                  | \$1,278                 |
|           | Change | Up 86%                       | Up from loss of \$978 | Up 89%                    | Up from loss of \$774   |
| RFMD      | 1997   | \$10,235                     | \$1,175               | \$19,383                  | \$2,039                 |
|           | Change | Up 55%                       | Up from loss of \$988 | Up 88%                    | Up from loss of \$3,146 |
| Spire     | 1997   | \$6,433                      | \$702                 | \$10,884                  | \$852                   |
|           | Change | Up 43%                       | Up 2,027%             | Up 31%                    | Up from loss of \$233   |
| TriQuint  | 1997   | \$18,544                     | \$2,266               | \$35,344                  | \$4,033                 |
|           | Change | Up 23%                       | Up 22%                | Up 25%                    | Up 45%                  |
| Vitesse   | 1997   | \$27,607                     | \$8,955               | \$52,169                  | \$16,737                |
|           | Change | Up 60%                       | Up 136%               | Up 59%                    | Up 164%                 |

### 1<sup>st</sup> Half Losses

|            |        | 2 <sup>nd</sup> Quarter 1997 |                                  | 1 <sup>st</sup> Half 1997 |                                    |
|------------|--------|------------------------------|----------------------------------|---------------------------|------------------------------------|
|            |        | Revenue                      | Income                           | Revenue                   | Income                             |
| Alpha      | 1997   | \$25,705                     | \$1,110                          | \$48,468                  | -\$4,235                           |
|            | Change | Up 28%                       | Up from loss of \$3,424          | Up 6%                     | Increase 30% over loss of \$3,262  |
| APA Optics | 1997   | \$662                        | -\$29                            | \$1,554                   | -\$18                              |
|            | Change | Up 23%                       | Up from loss of \$64             | Up 34%                    | Up from loss of \$156              |
| Emcore     | 1997   | \$14,106                     | \$830                            | \$27,035                  | -\$2,320                           |
|            | Change | Up 83%                       | Up from loss of \$1,482          | Up 97%                    | Same                               |
| Kopin      | 1997   | \$4,267                      | -\$1,689                         | \$8,296                   | -\$3,791                           |
|            | Change | Down 10%                     | Up from loss of \$3,893          | Down 18%                  | Up from loss of \$12,614           |
| PwrSpectra | 1997   | \$230                        | -\$609                           | \$587                     | -\$1,041                           |
|            | Change | Up 24%                       | Up from loss of \$1,049          | Up 64%                    | Up from loss of \$1,898            |
| SDL        | 1997   | \$21,570                     | -\$29,471                        | \$42,586                  | -\$28,964                          |
|            | Change | Same                         | Down from profit of \$2,429      | Same                      | Down from profit of \$4,588        |
| SLI        | 1997   | \$178                        | -\$1,359                         | \$178                     | -\$2,382                           |
|            | Change | Up from zero                 | Increase 284% over loss of \$354 | Up from zero              | Increase 131% over loss of \$1,029 |



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## Electronic Devices

**P 05646573 / 1997 07 08 / Anadigics  
Bayruns, R & Laverick, T**

**Automatic Gain-Control Transimpedance Amplifier.** The transimpedance amplifiers includes an operational amplifier and a variable feedback resistance means connected between the input and the output of the amplifier. The variable feedback resistance means may include a single feedback PIN diode, two serially connected feedback PIN diodes, a PIN diode connected to a feedback resistor in parallel, or two serially connected PIN diodes connected to a feedback resistor in parallel. Ultra-high linearity is achieved because the dynamic resistance of the PIN diode under forward bias is substantially linearly dependent on the inverse of the current that passes the diode.

**05643811 / 1997 07 01 / Fujitsu  
Hasegawa, Yuuichi**

**High-Frequency FET.** The present invention relates to a field effect transistor such as MES-FET, HEMT, MISFET or MOSFET. It describes a FET including a gate electrode divided into a plurality of parts in the gate-length direction. The gate electrode makes Schottky-contacts with a semiconductor layer or is formed on the semiconductor layer through a gate insulating film.

**05656514 / 1997 08 12 / IBM  
Ahlgren, David et al**

**HBT.** With Self-Aligned Retrograde Emitter Profile. A high gain, high frequency transistor is formed having a combination of a moderately doped retrograde emitter and a collector which is formed by self-aligned implantation through an emitter opening window. Cut-off frequencies on the order of 100 GHz can be obtained in the performance of a transistor with a 30 nm base width in a SiGe device.

**05646570 / 1997 07 08 / Lucent  
Blodgett, James Russell**

**Biasing A Field Effect Transistor with a Single Voltage Supply.** Embodiments of the present invention bias a field effect transistor with only a single voltage source and generally do not have the disadvantages of traditional "floated source" bias techniques. Furthermore, some embodiments of the present invention are capable of automatically compensating for the normal manufacturing variations that often result in the physical characteristics of individual FETs.

**05656515 / 1997 08 12 / Lucent  
Chandrasekhar, S. et al**

**High Speed DHBTS.** The lateral base resistance of a double HBT device is reduced and its high-speed operating characteristics thereby

improved by forming a structure that initially includes a relatively thick extrinsic base layer overlying a relatively thin intrinsic base layer. High-performance devices are thereby realized in a relatively simple process that has advantageous self-alignment features.

**05650335 / 1997 07 22 / Mitsubishi  
Terazono, Shinichi**

**Method Of Adjusting FET Characteristics.** The present invention relates to a fabricating method of a semiconductor device including a process of adjusting characteristics of an FET after forming the FET constituting the semiconductor device so that a device including a GaAs based epitaxial substrate can be fabricated with a stable yield.

**05659267 / 1997 08 19 / Motorola  
Buer, K & Corman, D**

**High Gain K-Band power Amplifier.** This invention relates in general to the field of power amplifiers, in particular to K-band microwave power amplifiers and more particularly MMICs that use FETs in power amplifiers. The FET cells are designed to be unconditionally stable without the use of an external series gate resistance. The FET cells are combined to provide total device periphery suitable for output power levels exceeding 0.8 watt at frequencies ranging from 19 to 23.5 GHz.

**05652440 / 1997 07 29 / National Science  
Council (Taiwan)  
Chang, Chun-Yen**

**GaAs-InGaAs HEMT.** The present invention relates generally to a GaAs-InGaAs high electron mobility transistor, and more particularly to a delta-doped GaAs/InGaAs/GaAs PHEMT.

**05648280 / 1997 07 15 / NEC  
Kato, Hiroshi**

**HBT with Low Resistance Base Layer.** A base region structure involved in a bipolar transistor, wherein the base region comprises a compound semiconductor epitaxial layer formed in a recessed portion provided by etching in an upper region of the semiconductor substrate and the recessed portion has a depth corresponding to a thickness of the compound semiconductor epitaxial layer so that the base region has a top surface positioned at the same level as a top surface of the semiconductor substrate.

**05661318 / 1997 08 26 / NEC  
Nashimoto, Yasunobu**

**JFET.** A junction type field-effect transistor in accordance with the invention makes it possible to achieve a gate length shorter than a mini-

mum length achievable by lithography technique.

**05648294 / 1997 07 15 / TI  
Bayraktaroglu, Burhan**

**HBT with InGaAs Etch Stop.** Heterojunction bipolar transistors with bases including an etch stop element are disclosed. The preferred embodiment devices have AlGaAs emitters and GaAs collectors and bases with InGaAs added to the bases to stop chloride plasma etches.

**05648278 / 1997 07 15 / TI  
Bayraktaroglu, Burhan**

**Microwave Heterojunction Bipolar Transistors Suitable For Low-Power, Low-Noise And High-Power Applications.** A microwave heterojunction bipolar transistor suitable for low-power, low-noise and high-power applications is disclosed, wherein the base is composed of one or more islands of semiconductor material.

**05654558 / 1997 08 05 / U.S. Navy  
Meyer, J; Hoffman, C; Bartoli, F**

**Interband Lateral Resonant Tunneling Transistor.** This invention describes a nanometer scale interband lateral resonant tunneling transistor, and the method for producing the same, with lateral geometry, good fanout properties and suitable for incorporation into large-scale integrated circuits. The transistor is of a single gate design and operation is based on resonant tunneling processes in narrow-gap nanostructures which are highly responsive to quantum phenomena. Such quantum-effect devices can have very high density, operate at much higher temperatures and are capable of driving other devices.

**05643807 / 1997 07 01 / U.S. Philips  
Frijlink, P. M.; Iost, M.**

**Buried Channel FET.** A method of manufacturing a semiconductor device comprising a buried channel field effect transistor, applied in particular to the realization of integrated semiconductor devices comprising high electron mobility transistors (HEMTs).

**05654214 / 1997 08 05 / U.S. Philips  
Frijlink, P Bellaiche, J**

**FETS with Different Pinch-Off Voltages.** The invention applies in particular to the realization of integrated semiconductor devices including high electron mobility transistors (HEMT) of which the the enhancement-type transistor (E) and the depletion-type transistor(D) are present on one and the same semiconductor substrate and are to be manufactured in the course of the same process.



## Semiconductor Lasers

05648978 / 1997 07 15 / Cannon  
Sakata, Hajime

**Oscillation Polarization Mode Selective Semiconductor Laser.** A semiconductor laser structure is designed such that light in both of two polarization modes can be excited therein.

05651016 / 1997 07 22 / Conductus  
Yu, R-C; Whiteley, S R; Whalen, B H

**Ultrahigh Speed Laser.** An apparatus and method for obtaining ultra-high speed operation of a semiconductor laser diode is presented. The invention utilizes any of a variety of conventional laser diodes in combination with cooling means for operation of the laser at temperatures below 120 K.

05661076 / 1997 08 26 / ETRI (Korea)  
Yoo, Byeung-Su et al

**Method for fabricating VCSELs.** The present invention relates to a method for fabricating a vertical-cavity surface-emitting laser diode, more particularly to a method for making the laser device with an amorphous GaAs layer, which is around active layers, and an etched cavity for a single fundamental transverse mode emission, deposited in a low temperature.

05657339 / 1997 08 12 / Fuji Photo Film  
Fukunaga, Toshiaki

**Integrated Optics Semiconductor Laser Device.** This invention relates to an integrated optics semiconductor laser device wherein adverse effects of an optical wave returning from an end face of the optical amplifier are kept small.

05648295 / 1997 07 15 / Fuji Xerox Co  
Otoma, Hiromi et al

**Method of Making A Semiconductor Laser.** The present invention relates to a visible buried semiconductor laser device manufactured by the mixed-crystal forming technique based on the diffusion of an impurity such as Zn and Si into the superlattice, which consists of extremely thin semiconductor layers, several to several tens nm thick, of different compositions such as AlGaAs/GaAs,

05646953 / 1997 07 08 / Matsushita  
Naito, H & Kume, M

**Semiconductor Laser Device.** The present invention relates to a high-yield semiconductor laser device of real refractive index-guided structure operating at low current value, which is highly suitable for a light source for use in optical information processing and the like, and a method of the production thereof.

05652762 / 1997 07 29 / Matsushita  
Otsuka, Nobuyuki et al

**Strained Quantum Well Semiconductor Laser.** The semiconductor laser device of the invention includes: a strained quantum well structure including a well layer and a barrier layer, and a semiconductor substrate for sup-

porting the strained quantum well structure. In the semiconductor laser device, at least one of the well layer and the barrier layer is composed of a mixed crystal where an atomic ordering is generated.

05644587 / 1997 07 01 / Mitsubishi  
Kaneno, N & Karakida, S

**Semiconductor Laser Device.** The present invention relates to an increase in the reliability (lifetime) and a reduction in the threshold current of a semiconductor laser device by applying a tensile strain to the well layer.

05644586 / 1997 07 01 / Mitsubishi  
Kawano, M & Sakano, G

**Laser Stack.** The present invention relates to a semiconductor laser device comprising a stack of semiconductor laser chips that is used as a high-power output semiconductor laser device. Two adjacent chips in the stack are connected such that the lower electrode of an upper chip is bonded to the upper electrode of a lower chip with solder. Since the upper electrode (lower electrode) is disposed on a portion of the upper surface (lower surface) of each laser chip, the solder hardly flows over the side surface of the chip, so that unwanted short-circuiting between the upper electrode and the lower electrode of the laser chip is avoided.

05656539 / 1997 08 12 / Mitsubishi  
Motoda, T & Kato, M

**Method of Fabricating A Semiconductor Laser.** The present invention relates to a semiconductor laser including a ridge structure and a method of fabricating the semiconductor laser.

05659562 / 1997 08 19 / Mitsubishi  
Hisa, Yoshihiro

**Semiconductor Laser Including Embedded Diffraction Grating.** A semiconductor laser has a semiconductor substrate, an active layer disposed indirectly on the semiconductor substrate, a barrier layer disposed on the active layer having a larger band gap energy than the active layer, and an embedded diffraction grating of stripes of a semiconductor material, the stripes having a width in a resonator length direction, a length perpendicular to the resonator length direction, and a thickness, and are embedded in the barrier layer.

05661743 / 1997 08 26 / Mitsubishi  
Nagai, Yutaka

**Fiber Pump Laser.** The present invention relates to a semiconductor laser and a fabricating method thereof and, more particularly, to a semiconductor laser for exciting a fiber amplifier doped with Er (erbium) or Pr (praseodymium) and a fabricating method thereof. A Si-doped AlGaAs current blocking layer is used so as to promote the absorption of light having a wavelength of 0.9 ~ 1.2 micron, which results in the suppression of higher-order modes, and therefore laser light having a fundamental mode is stably produced.

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## Semiconductor Lasers, con't

**05657338 / 1997 08 12 / NEC  
Kitamura, Mitsuhiro**

**Tapered Thickness Waveguide Integrated Semiconductor Laser.** This invention relates to a tapered thickness waveguide integrated semiconductor laser in which the coupling to a singlemode optical fiber is facilitated.

**05658823 / 1997 08 19 / Samsung  
Yang, Seung-kee**

**Ridge Type Laser Diode.** The present invention relates to a semiconductor laser diode and manufacturing method therefor, and more particularly, to a ridge-type laser diode having an improved ohmic contact surface and a manufacturing method therefor.

**05644584 / 1997 07 01 / SDL  
Nam, D., et al**

**Tunable Blue Laser Diode.** A harmonic generator laser system which features a distributed Bragg reflector (DBR) or distributed feedback (DFB) tunable diode laser coupled to a quasi-phasematched (QPM) waveguide of optically nonlinear material. Tuning of the DBR laser may be achieved either thermally or via current injection, or both, halving the wavelength of a red laser into the visible blue spectral band.

**05651018 / 1997 07 22 / SDL  
Mehuys, D et al**

**Wavelength-Stabilized, High Power Semiconductor Laser.** The present invention relates to external-cavity semiconductor lasers, especially to those lasers that include a wavelength-selective element for wavelength stabilized and narrow linewidth light emission. The invention also relates to lasers with single spatial mode, diffraction-limited emission, and to light amplifying diode heterostructures with flared gain regions.

**05657337 / 1997 08 12 / Sharp  
Okumura, Toshiyuki**

**Semiconductor Laser Device Having A Resonator.** The present invention relates to semiconductor lasers having a quantum well structure which can be used for fiber optic communication, information processing utilizing light, and the like. The quantum well structure serves as a resonator of the device and includes at least one quantum well layer and at least one barrier layer. The resonator is of a particular length for reducing threshold current density.

**05658824 / 1997 08 19 / Sharp  
Itoh, S & Okumura, T**

**II-VI Laser Diode.** A laser diode structure includes a II-VI compound semiconductor active layer interposed between the lower cladding layer and the upper cladding layer; and a burying blocking layer made of an aromatic polyamide resin formed on a bottom of the upper cladding layer so as to be in contact with sides of the stripe-shaped ridge portion. The laser provides the advantages of providing blue or blue-green light with a low oscillation threshold current and stable high output operation, which is capable of preventing the current from leaking into a region other than the oscillation region and controlling a fundamental lateral mode oscillation.

## Other Optoelectronics

**05661742 / 1997 08 26 / (Not Assigned)  
Huang, Kuo-Hsin & Chen, Tzer-Perng**

**MQW LED.** This invention relates to the structure of a semiconductor light emitting diode, and more specifically to a light emitting diode structure comprising multiple quantum wells or strained multiple quantum wells.

**05661590 / 1997 08 26 / CalTech  
Almogy, G.; Yariv, A; Xu, Y**

**QW IR Photo Detector And Monolithic Chopper.** A quantum well infrared photodetector and modulator are monolithically integrated to one another. They both use the same kinds of materials, preferably GaAs and AlGaAs, so they essentially become a single unit, obtaining better noise and operating characteristics from the combination.

**05647029 / 1997 07 08 / Lucent  
Mihailidi, M & Zucker, J**

**Traveling Wave Quantum Well Waveguide Modulators.** The invention includes an n-i-n structure with lower optical propagation loss than in known p-i-n structures. It also includes quantum well structures that allow much lower voltage operation, such as about 2 V operating voltages, as opposed to, for example, 8 V used in known modulators.

**05661741 / 1997 08 26 / Mitsubishi  
Kakimoto, Syoichi**

**Semiconductor Light Emitting Device.** The present invention relates to a semiconductor light emitting device, a laser amplifier, and an integrated light amplifier and variable wavelength filter employed in highly sensitive optical communication systems and optical switching systems.

**05654578 / 1997 08 05 / NEC  
Watanabe, Isao**

**Superlattice Avalanche Photodiode With Mesa Structure.** The present invention relates to a superlattice avalanche photodiode and more particularly, to a superlattice photodiode with the mesa structure which has a semiconductor superlattice carrier multiplication layer and semiconductor electric-field buffer layers disposed at each side of the carrier multiplication layer.

**05656831 / 1997 08 12 / NEC  
Kusakabe, Atsuhiko**

**Semiconductor Photo Detector.** A semiconductor photo detector has its construction such that on a substrate made of InP

are formed light absorption layer having a superlattice structure made of n-type InGaAsP and InAsP, an intermediate layer made of n-type InGaAs, a multiplication layer made of n-type InP and a layer made of p-type layer. The light having a wavelength 1.65 micron being made incident into the detector from the p-type InP layer is absorbed in the superlattice structure light absorption layer of n-type InGaAs/InAsP and changed into carriers, which flowed out an external circuit.

**05656829 / 1997 08 12 / Showa Denko  
Sakaguchi, Yasuyuki et al**

**Yellow - Orange LED.** This invention relates to a semiconductor light emitting diode, more particularly to a LED having an AlGaInP double-hetero structure which emits yellow to orange light with high emission efficiency. The LED includes a compound semiconductor substrate and a double-hetero structure of AlGaInP as an active layer, and an upper clad layer of the double-hetero structure has a larger band gap energy than the band gap energy of the active layer and has a thickness of 3-50 micron.

**05657336 / 1997 08 12 / Sony  
Okuyama, H et al**

**II-VI Light Emitter.** A II-VI group compound semiconductor light-emitting device can emit light of a short wavelength at room temperature. Operation characteristics, such as current-voltage characteristics and current-light output characteristics can be stabilized and a life of this semiconductor light-emitting device can be extended. The semiconductor light-emitting device comprises a substrate, at least a first cladding layer of a first conductivity type, an active layer and a second cladding layer of a second conductivity type, wherein at least the active layer is made of a II-VI group compound semiconductor and the active layer is doped by either or both of n-type and p-type dopants.

**05652435 / 1997 07 29 / U.S. Air Force  
Martin, E; Vaccaro, K; & Spaziana, S**

**Vertical Structure Schottky Diode Optical Detector.** A vertical structure Schottky contact photodiode has a narrow bandgap InGaAs light absorbing layer cladded front and back with InAlAs current blocking layers having metal contacts formed thereon. As compared to single-side MSM photodiodes, with interdigitated electrodes lying in a single plane, response time is improved due to reduced spacing between the electrodes. Response time is also improved since capacitance is reduced due to inherently low doping levels in the semiconductor material.

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## Wide BandGap Materials

**05652437 / 1997 07 29 / ABB Research Harris, Christopher**

**Low Resistance Ohmic Contact Between Metal & SiC.** The present invention is a semiconductor device comprising a semiconductor layer of SiC, a metal layer adapted to form a low resistance ohmic contact with the SiC-layer and a thin layer of a material having a smaller bandgap than the SiC of the SiC-layer and is placed between the SiC-layer and the metal layer. The SiC-layer is highly doped at least in the region next to the thin layer, and the material of the thin layer is a Group 3B-nitride including indium and at least another Group 3B-element.

**05654208 / 1997 08 05 / ABB Research Ltd. Harris, C; Konstantinov, A; Janzen, E**

**SiC Semiconductor.** The present invention relates to a method for producing a semiconductor device having a semiconductor layer of SiC, the method comprising at least the steps of a) application of a mask on at least a portion of said SiC layer and b) heat treatment of the SiC layer.

**05661074 / 1997 08 26 / ATMI Tischler, Michael A.**

**High Brightness Electroluminescent Device Emitting In The Green To Ultraviolet Spectrum.** A green-blue to ultraviolet light-emitting optical device, e.g. a green-blue to ultraviolet emitting laser or a green-blue to ultraviolet emitting diode, comprising a green-blue to ultraviolet light emitting gallium nitride material on a base structure including a silicon carbide substrate, which preferably consists of 2H SiC, 4H SiC, or a-axis oriented 6H SiC. The carrier mobility and the transparency of the silicon carbide substrate are optimized by the selection of orientation and polytype, thus enhancing device performance.

**05652434 / 1997 07 29 / Nichia Chemical Nakamura, Shuji et al**

**Gallium Nitride III-V Semiconductor.** A gallium nitride-based III-V Group compound semiconductor device has a gallium nitride-based III-V Group compound semiconductor layer provided over a substrate, and an ohmic electrode provided in contact with the semiconductor layer. The ohmic electrode is formed of a metallic material, and has been annealed.

**05653798 / 1997 08 05 / Oregon Grad. Inst. Parsons, James D**

**3C-Silicon Carbide Substrates.** A substrate for the growth of monocrystalline 3C-silicon carbide is formed by growing a body of monocrystalline cubic material for example TiC, ZrC, HfC, or TiN.

**05658834 / 1997 08 19 / Syracuse Univ. Dowben, Peter A.**

**Forming Boron Carbide by CVD.** This invention relates to the process of deposition of

boron carbide semiconductor material, and also to semiconductor devices formed by deposition of a boron carbide film.

**05650641 / 1997 07 22 / Toyoda Gosei Sassa, Michinari**

**Group III Nitride Compound and Flat Display Comprising Same.** The present invention relates to a light emitting semiconductor device that uses a Group III nitride compound. Specifically, the invention relates to a LED and to flat or panel-type display utilizing light-emitting semiconductor elements that are formed on a substrate and selectively enabled to emit light of a single color or one of the three primary colors at a time.

**05652438 / 1997 07 29 / Toyoda Gosei Sassa, Michinari et al**

**Light-Emitting Device Using Group III Nitride Compound.** The present invention relates to a light-emitting semiconductor device that emits blue light and uses a Group III nitride compound. Specifically, the invention relates to reducing the surface areas occupied by electrodes or bonding pads on a surface layer of the device to increase the quantity of light emitted from the device.

**05650198 / 1997 07 22 / University of Calif. Denbaars, S & Speck, J**

**Defect Reduction in the Growth of Group III Nitrides.** The present invention relates to an improved method to produce Group III nitride semiconductor, achieved when the thin layer is first formed at low pressure, then alternating use of low pressure and high pressure as needed. The method comprises:

(a) combining under metalorganic chemical vapor deposition (MOCVD) conditions at least one Group III metalorganic compound with ammonia, hydrazine, nitrogen-hydrogen, or combinations thereof in a molar ratio of between about 1/10000 and 2/1 of metalorganic to the ammonia, hydrazine, nitrogen-hydrogen, or combinations thereof, at a low pressure of about 100 torr or less, to produce a first nitride layer;

(b) combining under metalorganic chemical vapor deposition conditions at least one Group III metalorganic compound with ammonia, hydrazine, nitrogen-hydrogen, or combinations thereof in a molar ratio of between about 1/10000 and 2/1 of metalorganic to the ammonia, hydrazine, nitrogen-hydrogen, or combinations thereof, at a high pressure of about 700 to 760 torr or greater for between about 5 and 60 min to produce a nitride layer having a reduced defect density and;

(c) repeating steps (a) and (b) to produce a Group III metal nitride having a reduced defect density of less than half of the defects observed wherein high and low pressure cycling is not used.

**05657335 / 1997 08 12 / Univ. of Calif. Rubin, M et al**

**P-type Gallium Nitride.** Molecular beam epitaxy on substrates held at the proper temperatures, assisted by a nitrogen beam of the proper energy produced several types of p-type GaN with hole concentrations of about  $5 \times 10^{11} \text{ cm}^{-3}$  and hole mobilities of about  $500 \text{ cm}^2/\text{V-sec}$ , measured at 250 K. P-type GaN can be formed of unintentionally-doped material or can be doped with magnesium by diffusion, ion implantation, or co-evaporation. When applicable, the nitrogen can be substituted with other group III elements such as Al.

## Other Materials

**05659184 / 1997 08 19 / Cannon Tokunaga, H; Kawasaki, H**

**III-V Device with A Polycrystalline Structure.** The present invention relates to a method for forming polycrystals of III-V compound semiconductive material, a semiconductor device utilizing said compound semiconductive material, and a printer and a display device utilizing said semiconductor device. Another object of the present invention is to provide a III-V compound semiconductor device formed in self-aligned and isolated manner on arbitrary substrates including insulating ones, and a method for producing such semiconductor device.

**05656076 / 1997 08 12 / Fujitsu Kikkawa, Toshihide**

**Si-Doped III-V Crystal.** In a method for growing a III-V group compound semiconductor crystal, as a Si dopant, a compound including a Si atom bonded to an alkyl group and a hydrogen atom is used. Si can be doped evenly at a high concentration at a low temperature with a safe operation by the invention.

**05661316 / 1997 08 26 / Hewlett-Packard Kish, Jr., F & Vanderwater, D**

**Bonding Compound Semiconductor Wafers To Create an Ohmic Interface.** A method for forming an ohmic interface between unipolar (isotype) compound semiconductor wafers without a metallic interlayer and the semiconductor devices formed with these ohmic interfaces are disclosed. The ohmic interface is formed by simultaneously matching the crystallographic orientation of the wafer surfaces and the rotational alignment within the surfaces of the two wafers and then subjecting them to applied uniaxial pressure under high temperatures to form the bonded ohmic interface. Such an ohmic interface is required for the practical implementation of devices wherein electrical current is passed from one bonded wafer to another.



**05646425 / 1997 07 08 / IBM  
Beach, David Bruce**

**Rare Earth Doped Semiconductor Layers.**

The invention relates to a CVD process for producing supersaturated rare earth-doped semiconductors. The process may be used to produce optoelectronic devices comprising a silicon substrate and an erbium-doped epitaxial silicon film.

**05660628 / 1997 08 26 / Mitsubishi  
Sato, T & Takahashi, H**

**Method Of Manufacturing Semiconductor Epitaxial Wafer.**

There is provided a method for suppressing generation of cracks or damages on a compound semiconductor epitaxial wafer during an epitaxial growth due to growth of an epitaxial layer on the rear surface at the edge of the epitaxial layer which is located at the upstream side of the flow of the source gas. In manufacturing a semiconductor wafer by growing a single crystal semiconductor epitaxial layer having a zinc blend structure on a single crystal semiconductor substrate having a zinc blend structure, the surface of the single crystal semiconductor substrate has (100) surface orientation having an off angle and a source gas is supplied in the direction of the off angle or in a direction at 30 degree or less to the direction at 180 degree thereto.

**05650635 / 1997 07 22 / Northwestern Univ.  
Razeghi, M & Piotrowski, J**

**Multiple Stacked Sb Heterostructures.** This invention relates to Sb-based semiconductor heterostructures for use in photodetectors and more particularly series connected Sb-based semiconductor heterostructures with reduced dark current and increased resistance for use at room temperature.

**05658825 / 1997 08 19 / Northwestern Univ.  
Razeghi, Manijeh**

**Method of Making an InAsSb/InAsSbP**

**Diode Lasers.** InAsSb/InAsSbP/InAs Double Hetero-structures (DH) and Separate Confinement Hetero-structure Multiple Quantum Well (SCH-MQW) structures are taught wherein the ability to tune to a specific wavelength within 3 micron to 5 micron is possible by varying the ratio of As:Sb in the active layer.

**05656540 / 1997 08 12 / OTR (Japan)  
Nomura, Y; Goto, S; Morishita, Y**

**Semiconductor Crystal Growing Method.**

This invention relates to a method of carrying out crystal growth of a compound semiconductor and, in particular, to a method of controlling selective crystal growth.

**05645638 / 1997 07 08 / Rikagaku  
Kenkyusho Kumagai, Hiroshi**

**Crystalline Thin-Films For Solid-State**

**Lasers.** The present invention relates to a method and an apparatus for preparing crystalline thin-films for solid-state lasers which can be used for the development of micro-cavity and the like, and allowed solid-state laser to directly grow on a semiconductor laser can be prepared.

**05643827 / 1997 07 01 / Shin-Etsu  
Handotai Ootaki, T. et al.**

**GaP Light Emitting Substrate.** This invention relates to a GaP substrate used when manufacturing green-light GaP LEDs. The object is to provide a GaP wafer which contains a nitrogen-doped n-type GaP layer with a sufficiently low concentration of sulfur as an n-type dopant, and produces a high light emission output, as well as a method of manufacturing it.

**05643828 / 1997 07 01 / Sony  
Ugajin, R; Hase, I; Nomoto, K**

**Quantum Device Manufacturing Method.**

A method of manufacturing a quantum device such as a coupled quantum boxes device are disclosed.

**05647917 / 1997 07 15 / Sumitomo Electric  
Oida, K & Nakai, R**

**InP Substrate For Epitaxial Growth.** This invention relates to an epitaxial method for suppressing the occurrence of hillocks which are likely to appear on an epitaxially grown compound semiconductor. When compound semiconductor films are grown on an InP wafer having a surface near a (100) orientation hillocks tend to arise on the films. Off-angle wafers have been adopted for substrates in order to suppress the occurrence of hillocks. The off-angle, however, is not the sole factor for determining whether hillocks will be formed on the film. There is a concealed parameter which determines the generation of hillocks - namely, the defects on the substrate itself. No hillocks originate on portions of the film that correspond to the portions of the InP wafer without dislocations. The role of the off-angle of the substrate is preventing the influence of the dislocations from transmitting to the films.

A smaller density of the defects on the substrate allows a smaller off-angle for suppressing the hillocks from arising. A larger density of the defects demands a larger off-angle for the substrate so as to prevent the hillocks from originating.

**05656077 / 1997 08 12 / Sumitomo Electric  
Kawase, Tomohiro**

**Crucible For Preparing Compound Semiconductor Crystal.**

A method of preparing a compound semiconductor crystal in a crucible which makes it is possible to prevent a raw material melt from wetting the crucible interior surface and thus to suppress polycrystallization, thereby preparing a compound semiconductor single crystal with an excellent yield.

**05656538 / 1997 08 12 / Univ. of Illinois  
Gardner, N et al**

**Halide Dopant for S.I. III-V's.** The present invention relates generally to the production of semi-insulating layers of indium phosphide (InP) or other Group III-V compounds in semiconductor devices using gas phase growth techniques using halide dopant sources, such as carbon tetrachloride and carbon tetrabromide at low growth temperatures. The halide dopant technique of the present invention results in high resistivity and is more easily implemented than typically utilized iron doping techniques for producing semi-insulating InP.

**05653801 / 1997 08 05 / Univ. of Maryland  
Chen, J-C & Huang, Z**

**Se Doping of III-V Layers.** Contamination of aluminum-containing compound semiconductors is greatly reduced by an improved method for manufacturing the semiconductors, wherein the growing semiconductor crystal is doped with a predetermined concentration of selenium. The method of the present invention can be used to reduce contaminants in both p-type and n-type semiconductors.

**05650337 / 1997 07 22 / Yeda R&D  
Co Cahen, D; Chernyak, L; Jakubowicz, A**

**Monolithic Optoelectronic and Electronic Structures.** The invention related to a process for the production of a monolithic electronic and/or optoelectronic single-element or multi-element structure from a semionic material selected from the group of semionic materials comprising doped elemental semiconductors and doped binary, ternary or multinary chalcogenide or pnictide semiconductors.

*The full text of any of these patents can be obtained by e-mail  
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*See <http://www.micropat.com>  
and select the "PatentWEB™" option.*



## CALL FOR PAPERS

### 1997 Lasers and Electro-Optics Society Annual Meeting

LEOS '97 will be held Nov. 10 - Nov. 13, 1997 at the Crown Plaza Parc Fifty Five Hotel, San Francisco, CA.  
Contact: Ms. Melissa K. Estrin  
IEEE/LEOS  
445 Hoes Ln  
TEL [1] 908 562-3896  
FAX [1] 908 562-8434  
Net or Web: m.estrin@ieee.org  
<http://www.ieee.org/leos/meet.htm>

### The Market and Business Outlook for Gallium Arsenide & Other Compound Semiconductors

A business development conference and industry forum on "The Market and Business Outlook for Gallium Arsenide & Other Compound Semiconductors" will be held November 12 - 14, 1997 at the Doubletree Hotel Mission Valley in San Diego, California.  
Contact: Intertech Corporation  
411 US Route One  
Portland, ME 04105 USA  
TEL [1] 207 781 9800  
FAX [1] 207 781 2850

### Materials Research Society Fall Meeting

The Fall '97 MRS Meeting will be held December 1-5, 1997 in Boston, MA. Symposia for this year's meeting include: Self-Organized Nanostructures; Nitride Semiconductor Materials; Power Semiconductor Materials and Devices; Infrared

Applications of Semiconductors; Thin-Film Structures for Photovoltaics; Materials and Devices for Si-Based Optoelectronics; Semiconductors for Room-Temperature Radiation Detector Applications; and Electrical, Optical and Magnetic Properties of Organic Solid State Materials

Contact: MRS  
9800 McKnight Road  
Pittsburgh, PA 15237-6006  
TEL [1] 412 367-3003  
FAX [1] 412 367-4373  
Net or Web: info@mrs.org  
<http://www.mrs.org>

### 1997 International Electron Devices Meeting

IEDM '97 will be held December 7 - 10, 1997 in Washington, DC. A special emphasis on RF devices is planned for this year's meeting.

Contact: Phyllis Mahoney  
IEDM Conference Office  
101 Lakeforest Boulevard  
Suite 270  
Gaithersburg, MD 20877 USA  
TEL: [1] 301 527 0900  
FAX [1] 301 527 0994  
Net or Web: pwmahoney@aol.com  
<http://www.ieee.org/conference/iedm>

### 1997 International Semiconductor Device Research Symposium

ISDRS '97 will be held December 11, 12, 13, 1997 in Charlottesville, VA (following IEDM in Washington, D. C.). The Symposium will emphasize fundamental concepts in novel devices and

advanced processing technologies.

Contact: William C. B. Peatman, Program Chair  
Department of Electrical Engineering  
Thornton Hall  
University of Virginia  
Charlottesville, VA 22903-2442 USA  
TEL: (804) 979-4103  
FAX: (804) 979-2653  
Net: wcp4b@virginia.edu  
Web:  
<http://www.ee.virginia.edu/AEPL/isdrs.html>

### 1998 IEEE Int'l Solid-State Circuits Conference

ISSCC '98 will be held February 5-7, 1998 in San Francisco, CA. The theme of this year's meeting is "Global Communications". Original papers are solicited in subject areas including but not limited to the following: analog, communications, digital and memory circuits; sensors, imagers & displays; signal processing; and technology directions. Abstract Submission Deadline: September 5, 1997

Contact: ISSCC '98  
Diane Suiters  
Courtesy Associates  
2000 L Street N.W. Suite #710  
Washington, DC 20036 USA  
TEL [1] 202 973 8667  
FAX [1] 202 331 0111  
NET isscc@courtesyassoc.com

### 1998 Conference on Optical Fiber Communication

OFC '98 will be held Feb. 22 - Feb. 27, 1998 at the San Jose Convention Center in San Jose, CA.  
Contact: Ms. Lisa Myers

OSA Conference Services  
2010 Massachusetts Ave., NW  
Washington, DC 20036-1023  
TEL [1] 202 416-1980  
FAX [1] 202 416-6100  
Net or Web: ofc.info@osa.org  
<http://www.osa.org>

### Integrated Photonics Research Topical Meeting

IPR '98 will be held March 30 - April 3, 1998 in Victoria, British Columbia, Canada. It will consist of a technical meeting and a tabletop exhibition. Abstract Submission Deadline: December 1, 1997

Contact: OSA  
2010 Massachusetts Ave.  
Washington, DC 20036-1023  
TEL [1] 202 416 1985  
FAX [1] 202 416 6100  
Net or Web: ofc.info@osa.org  
<http://www.osa.org>

If you would like your conference to be included in future issues, send the appropriate information by E mail to [calendar@compsem.com](mailto:calendar@compsem.com), or by FAX to [1] 508 750 9740, attention "Calendar"

Contributions must be received by October 24 to appear in our next issue.

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# 1998 Conference on Lasers & Electro-Optics & The International Quantum Electronics Conference

CLEO/IQEC '98 will be held May 3-8, 1998 at The Moscone Center in San Francisco, CA.

Contact: Ms. Amy Hutto  
OSA Conference Services  
2010 Massachusetts Ave., NW  
Washington, DC 20036-1023  
TEL [1] 202 416-1980  
FAX [1] 202 416-6100  
Net or Web: cleo.info@osa.org  
http://www.osa.org

# 193rd Meeting of the Electrochemical Society

The 193rd ECS Meeting will be held May 3-8, 1998 at the Sheraton San Diego Hotel & Marina in San Diego, California. Symposia include: E1 - Third International Symposium On Low And High Dielectric Constant Materials (covering all aspects of low and high dielectric materials in silicon and compound semiconductor); F3 - First International Symposium On Environmental Issues With Materials And Processes For The Electronics And Semiconductor Industries (including III/V semiconductor materials and processes); I2 - State-Of-The-Art-Program On Compound Semiconductors (SOTAPOCS XXVII); K1 - Light Emitting Devices For Optoelectronic Applications Abstracts Submission Deadline: January 2, 1998

Contact: The Electrochemical Society  
10 South Main Street  
Pennington, NJ 08534-2896 USA  
TEL [1] 609 737 1902  
FAX [1] 609 737 2743  
NET or WEB:  
ecs@electrochem.org or  
http://www.electrochem.org

# 10th Int'l Conf. On InP and Related Materials

IPRM '98 will be held May 11-15, 1998 in Tsukuba, Japan. The scope of the conference will include optoelectronics, electron devices, processing, epitaxy, bulk growth and characterization, and new materials and nanostructures. Abstract Submission Deadline: November 25, 1997

Contact: IPRM '98  
IEEE/LEOS  
445 Hoes Lane  
Piscataway, NJ 08854 USA  
TEL [1] 908 562 3896  
FAX [1] 908 562 8434  
NET msarcone@calypso.ieee.org

# 22nd Workshop on Compound Semiconductor Devices and Integrated Circuits

WOCSDICE 98 will be held May 24-27, 1998 at the Pannonia Hotel in Zeuthen, Germany. The European Workshop on Compound Semiconductor Devices and Integrated Circuits aims to bring together scientists and engineers working in the area of III/V compound semiconductor devices and integrated circuits for microwave, mm-wave and optoelectronic applications. To encourage interaction between participants and to permit sufficient discussion, presentations are kept short and focused on the main results and new ideas presented by the participants. The Workshop is open to European and world wide participation. Abstract Submission Deadline: February 16

Contact: Joachim W. rll  
Ferdinand-Braun-Institut  
für Hochfrequenztechnik  
Rudower Chaussee 5  
D-12489 Berlin Germany  
TEL [49] 30 6392 2690  
FAX [49] 30 6392 2685  
NET or WEB:  
wocsdice@fbh-berlin.de or  
http://www.fbh-berlin.de

# 1998 Electronic Components & Technology Conference on Optoelectronics

The 48th ECTC Optoelectronics Conference will be held May 25-28, 1998 in Seattle, WA. Papers are solicited on all topics pertaining to the design, development, and technology of packaging active/passive hybrid and integrated photonic components, devices, circuitry and systems. Abstract Submission Deadline: October 15, 1997

Contact: Mark W. Beranek  
The Boeing Company  
PO Box 3999, M/S 2W-51  
Seattle, WA 98124-2499  
TEL [1] 253 657 5748  
FAX [1] 253 657 8903

# 9th Int'l Conf. On Metal Organic Vapor Phase Epitaxy

ICMOVPE IX will be held May 30 - June 4, 1998 at the Sheraton Grande Torrey Pines in LaJolla, CA. Topics of interest include precursors, process design/communication issues; developing application of MO compounds; growth technologies; advances in devices by MOVPE, and characterization. Abstract Submission Deadline: January 15, 1998

Contact: Barbara Laitwood  
TMS  
420 Commonwealth Drive  
Warrendale, PA 15086 USA  
TEL [1] 412 776 9000 x234  
FAX [1] 412 776 3770  
NET kamperman@tms.org

# 1998 MTT-S International Microwave Symposium

MTT '98 will be held June 7-12, 1998 at the Baltimore Convention Center in Baltimore, MD.

Contact: Mr. Steven Stitzer  
Westinghouse Electric Corp.  
P.O. Box 1521, MS 3T15  
Baltimore, MD 21203  
TEL [1] 410 765-7348  
FAX [1] 410 993-7747

# 1998 IEEE Radio Frequency Integrated Circuits Symposium

RFIC '98 will be held Jun. 07, 1998 - Jun. 12, 1998 at the Baltimore Convention Center in Baltimore, MD (in conjunction with MTT '98).

Contact: Dr. Vijay Nair  
Motorola Inc.  
2100 E. Elliot Rd., EL508  
Tempe, AZ 85234  
TEL [1] 602 413-5922  
FAX [1] 602 413-5934

# 4th International Workshop on Expert Evaluation and Control of Compound Semiconductor Materials and Technologies

EXMATEC 98 will be held June 22-24, 1998 in Cardiff, Wales, UK. Central issues to be addressed are the improvement of yield, reliability, performance, lifetime and reproducibility of electronic and optoelectronic devices and circuits through characterisation, optimisation, and control of materials and processes. Papers on investigations ranging from perfection of crystal growth and improvement of intermediate processing steps to device lifetime testing are solicited. Material systems to be discussed include wide band gap (GaN, ZnSe, SiC), intermediate band gap (GaAs, InP, SiGe), and narrow band gap (HgCdTe) compound semiconductors.

Abstract Submission Deadline: December 1, 1997  
Contact: Cherrie Summers  
Cardiff School of Engineering  
PO Box 917, Newport Road  
Cardiff, Wales CF2 1XH UK  
TEL [44] 1222 874000  
FAX [44] 1222 874421  
NET or WEB: summersc@cardiff.ac.uk

# 1998 Electronic Materials Conference

The 40th EMC will be held at the University of Virginia in Charlottesville, VA on June 24-26, 1997. This conference provides a forum for topics of current interest and significance in the areas of preparation and characterization of electronics materials. Individuals actively engaged or interested in electronic materials research and development are encouraged to attend this meeting, and papers in this general subject area are solicited. Abstract Submission Deadline: February 6, 1998

Contact: Barbara Laitwood  
TMS  
420 Commonwealth Drive  
Warrendale, PA 15086 USA  
TEL [1] 412 776 9000 x234  
FAX [1] 412 776 3770  
NET: kamperman@tms.org

# ICCG-12 & ICVGE-10

The Twelfth International Conference on Crystal Growth in conjunction with The Tenth International Conference on Vapor Growth and Epitaxy will be held July 26 - 31, 1998 at the Renaissance Jerusalem Hotel in Jerusalem, Israel Abstract Submission Deadline: November 1, 1997

Contact: Conference Secretariat  
ICCG-12 / ICVGE-10  
International Travel and Congresses Ltd.  
P.O. Box 29313, 9 Rothschild Blvd.  
Tel Aviv 61292 ISRAEL  
TEL [972] 3 5102538  
FAX [972] 3 5160604  
NET or WEB:  
100264.2432@compuserve.com or  
http://www.technion.ac.il/~iccg12

# 10th Int'l Conference on Molecular Beam Epitaxy

MBE-X will be held August 31 - September 4, 1998 in Cannes, France. This conference will cover the full spectrum of MBE-related topics, in the pleasant surroundings of the south of France. Abstract Submission Deadline: TBA

Contact: Prof. Jean-Pierre Faurie  
CRHEA-CNRS Sophia Antipolis  
Rue Bernard Gregory  
F 06560 Valbonne France  
TEL [33] 4 9395 4220  
FAX [33] 4 9395 4142  
NET or WEB: MBE-X@crhea1.unice.fr  
http://www.crhea.unice.fr/

# 1998 Conference on Lasers & Electro-Optics Europe & The 6th European Quantum Electronics Convention

CLEO EUROPE/EQEC will be held Sep. 13 - Sep. 18, 1998 at the Scottish Exhibition & Conference Center in Glasgow, Scotland.

Contact: Ms. Melissa K. Estrin  
IEEE/LEOS  
445 Hoes Lane  
P.O. Box 1331  
Piscataway, NJ 08855-1331  
TEL [1] 908 562-3896  
FAX [1] 908 562-8434  
Net or Web: m.estrin@ieee.org  
http://www.ieee.org/leos/meet.htm

# 1998 IEEE Bipolar/BiCMOS

Circuits and Technology Meeting BBCTM '98 will be held September 27-29, 1998 in Minneapolis, MN.

Contact: Ms. Janice V. Jopke  
CCS Associates  
6611 Countryside Dr.  
Eden Prairie, MN 55346  
TEL [1] 612 934-5082  
FAX [1] 612 934-6741  
Net or Web: jjopke@aol.com

# 1998 IEEE/LEOS Semiconductor Laser Conference

The 1998 IEEE/LEOS Semiconductor Laser Conference will be held October 5-10, 1998 at the Nara Public Hall in Nara, Japan.

Contact: Ms. Elsie L. Vega  
IEEE/LEOS  
445 Hoes Lane  
P.O. Box 1331  
Piscataway, NJ 08855-1331  
TEL [1] 732 562-3897  
FAX [1] 732 562-8434  
Net or Web: e.vega@ieee.org  
http://www.ieee.org/leos/lsc.htm

# 1998 IEEE GaAs IC Symposium

The 1998 IEEE GaAs IC Symposium will be held Nov. 01 - Nov. 04, 1998 at the Westin Peachtree Plaza in Atlanta, GA.

Contact: Dr. William Stanchina  
Hughes Research Labs., RL61  
Plasma Physics Lab.  
3011 Malibu Canyon Rd.  
Malibu, CA 90265  
TEL [1] 310 317-5089  
FAX [1] 310 317-5483

# 194rd Meeting of the Electrochemical Society

The 194rd ECS Meeting will be held November 1-6, 1998 at the Sheraton Boston Hotel & Tower in Boston, Massachusetts. Symposia include: G1 - Dielectric Science And Technology/Electronics Joint General Session; H1 - Interconnect And Contact Metallization: Materials, Processes And Reliability; I1 - III-V Nitride Materials And Processes; J1 - Fifth International Symposium On Quantum Confinement: Nanostructures; N1 - Compound Semiconductor Power Transistors; N3 - Sixth International Symposium On Long Wavelength Infrared Detectors And Arrays: Physics And Applications; N4 - State-Of-The-Art Program On Compound Semiconductors (SOTAPOCS XXVIII); P1 - Photovoltaics For The 21st Century Abstracts Submission Deadline: June 1, 1998

Contact: The Electrochemical Society  
10 South Main Street  
Pennington, NJ 08534-2896 USA  
TEL [1] 609 737 1902  
FAX [1] 609 737 2743  
NET or WEB: ecs@electrochem.org or  
http://www.electrochem.org

# 45th National AVS Symposium

The 1998 AVS National Symposium will be held November 2-6, 1998 at the Baltimore Convention Center in Baltimore, MD. AVS Technical Divisions include: applied surface science; nanometer-scale science and technology; surface science; vacuum metallurgy; electronic materials and processing; plasma science and technology; thin film; and vacuum technology. Abstract Submission Deadline: May 1, 1998

Contact: Marion Churchill  
AVS  
120 Wall Street  
New York, NY 10005 USA  
TEL [1] 212 248 0200  
FAX [1] 212 248 0245  
Net: marion@vacuum.org  
Web: http://www.vacuum.org

# 1998 IEEE International Electron Devices Meeting

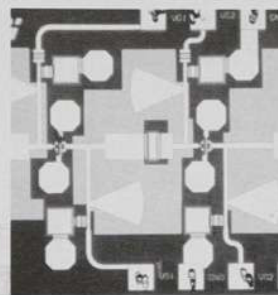
The 1998 IEDM will be held December 6-9, 1998 in San Francisco, CA.

Contact: Ms. Phyllis Mahoney  
Widerkehr & Associates  
101 Lakeforest Blvd.  
Suite 270  
Gaithersburg, MD 20877  
TEL [1] 301 527-0900  
FAX [1] 301 527-0994  
Net or Web: pwmahoney@aol.com

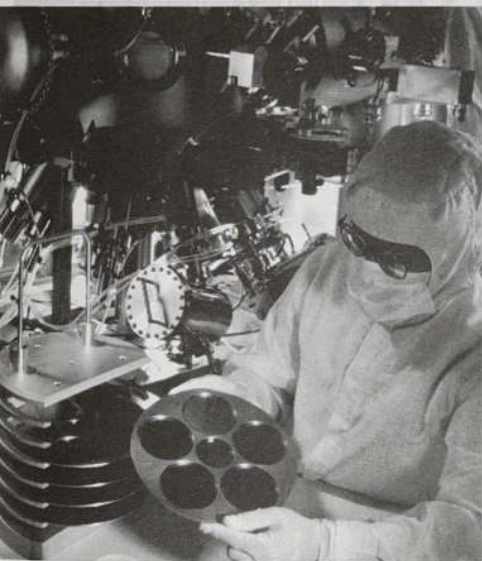


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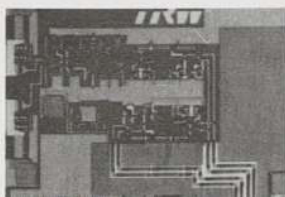
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**Marie Meyer**  
Editor  
*Compound Semiconductor Magazine*  
Liberty Square  
Danvers, MA 01923 USA  
TEL [1] 978 750 9739  
FAX [1] 978 750 9740  
e-mail: mmeyer@compsem.com

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Picogiga, Inc.  
4773 Sonoma Hwy. #62  
Santa Rosa, CA 95409  
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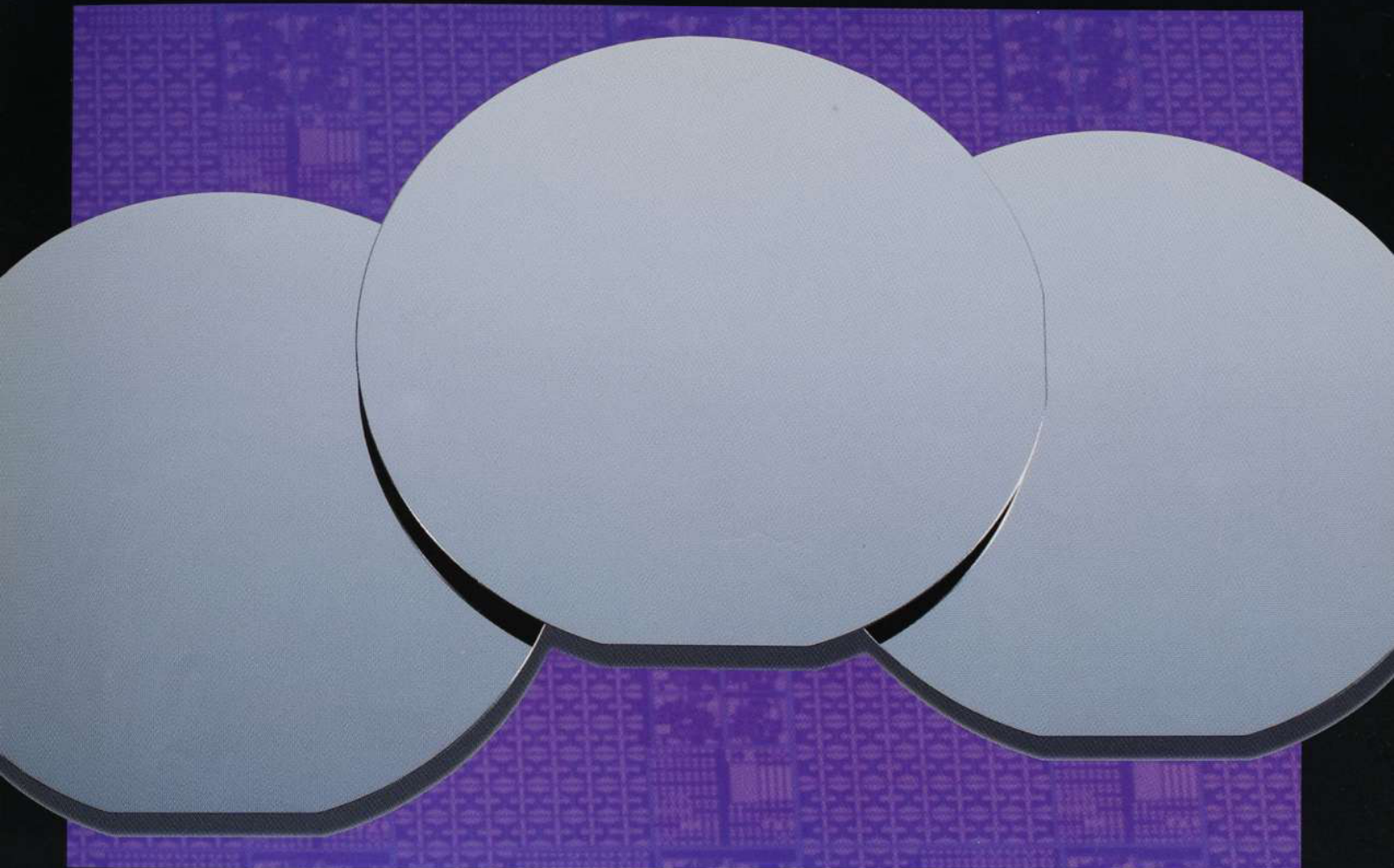
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