

## Fact Sheet

### THE DISCOVERY

#### MOTOROLA LABS SOLVES A 30-YEAR SEMICONDUCTOR INDUSTRY PUZZLE

Motorola has a legacy of innovation in communications, semiconductors and semiconductor materials, including copper interconnect, MRAM and silicon germanium process technology. On September 4, 2001, Motorola unveiled a significant new innovation in material science with the announcement that its scientists had discovered the long-sought key to creating a new class of high-performance semiconductor wafers and devices. The technology has enabled Motorola to create wafers that combine the best properties of silicon (robustness and cost efficiency) with the best properties of group III-V compound semiconductors (optical capabilities and high speed). The semiconductor industry has been searching for that key for nearly 30 years.

Since the initial discovery, Motorola Labs has demonstrated the science by successfully developing gallium arsenide (GaAs) on silicon wafers, and by creating power amplifiers (PAs) from those wafers and then demonstrating those working PAs in cell phones. In conjunction with commercialization partner IQE, Plc., the team fabricated GaAs on silicon wafers up to 12 inches in diameter.



*Dr. Jamal Ramdani and  
Dr. Ravi Droopad display  
the world's first 12-inch  
GaAs on silicon wafer.*



### INDUSTRY IMPACT

The technology is expected to fundamentally change the semiconductor industry, enabling smarter, better products and new classes of semiconductor devices. Motorola believes the technology will prove to be a cost-effective, disruptive technology that will enable an industry shift, similar to the transition from discrete to integrated circuits.

By eliminating the current cost barriers holding back many advanced applications, the discovery opens the door to significantly less expensive optical communications, high-frequency radio devices and high-speed microprocessor-based subsystems.

For consumers, the technology should result in smarter electronic products that cost less, perform better and enable exciting new features.

### TECHNOLOGY BACKGROUND

The technological boom of the late 20th century was built upon silicon, a group IV semiconductor material with robust physical and electrical characteristics, and upon the premise of Moore's Law.

The basic principle behind Moore's Law, that the number of transistors per unit area of silicon will double every 18 months, has driven several decades of phenomenal technological and economic growth. In turn, this has enabled Motorola and other electronics manufacturers to introduce smarter, better products in smaller packages, year after year.

It has been known for some time that this ability to continue scaling silicon will grow more costly and eventually may end altogether due to issues with silicon's basic properties. Through monumental engineering efforts and inventive technology, the industry has continued to push back the point at which it is no longer economical to scale silicon.

## SEMICONDUCTOR MATERIALS

While silicon has served as the workhorse for the electronics industry, its ability to emit light is limited, and so it does not work well for light-emitting diode (LED), laser or fiber optic applications. It also has limited ability to deliver the high speeds new applications demand.

Many other semiconductor materials exist, and mixtures of elements from the group III and group V elements (referencing the third and fifth columns of the Periodic Table of Elements) have always shown tremendous promise due to their superior electrical and optical characteristics, power efficiency and high switching speeds. Some of these materials are also better able to endure high levels of radiation, which is important to space applications.

The success of III-V materials has been limited by their shortcomings (e.g., small wafer size, brittleness and other processing challenges), which are reflected in the high cost of III-V wafers and devices. Overcoming those shortcomings would set the stage for another round of broad improvements in the performance and cost of integrated circuits.

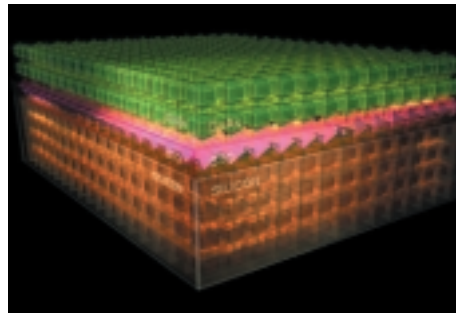
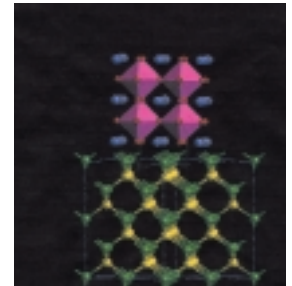
Motorola Labs' discovery enables the epitaxial growth of III-V semiconductor compounds on a silicon substrate. Motorola successfully created this new class of wafers by solving fundamental materials issues.

One key issue was that silicon and the III-V materials are crystalline structures, and it is impossible to grow a robust structure of one crystalline material on top of another unless they have very similar lattice constants (the distance between the atoms in the structure). If the two materials have less than a 2% mismatch, then very thin layers of one material can be grown on the other material. However, the strain caused by the mismatch becomes too great when thicker layers are grown or when the lattice constant exceeds 2%, causing dislocations or "cracks" in the material.

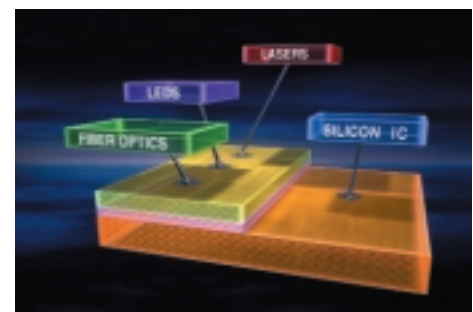
The key to solving this problem grew out of Motorola Labs' research on a class of perovskite materials. In 1999, Motorola Labs demonstrated the world's thinnest functional transistor by growing a strontium titanate (STO) crystalline material on a silicon substrate. The STO worked, but under certain conditions, oxygen molecules diffused through the layer and began to bond with the silicon below, creating an amorphous interface layer between the silicon and the STO.

Motorola Labs' scientists discovered that the amorphous layer allowed the STO to completely relax to its own natural lattice constant and acts as a compliant buffer relieving strain between materials with different thermal expansion rates. This is the first time a high-quality single-crystal layer was demonstrated with a different lattice constant than the substrate.

Since that early work, Motorola Labs has been proving, perfecting and patenting the technology and processes. The early work establishes a baseline technology that can be extended to other materials systems. Motorola Labs has begun simulations on a variety of other materials, including indium phosphide (InP).



*Above: Computer simulation demonstrates the structural mismatch of the crystalline materials. Left: The key to resolving problems caused by the structural mismatch was introducing an intermediate layer of material between the silicon and the III-V material. This artist's rendition illustrates gallium arsenide (GaAs) on strontium titanate (STO) on silicon. Below: The discovery is expected to enable a higher level of integration than has ever been possible, and this artist's rendition demonstrates potential integrated devices.*



## MARKET APPLICATIONS

The use of compound semiconductors is growing in all market segments, and this technology's ability to integrate light-emitting capabilities with silicon offers enormous potential to further accelerate that trend, particularly for wireless communications, optical and networking markets as well as for telecom lasers and detectors.

### SEMICONDUCTOR WAFER MARKET

The technology offers significant potential for businesses along the semiconductor value chain. Motorola expects the initial value will be realized first in wafer and device development, and then in a new category of integrated semiconductor circuits (ISCs).

The fundamental value to the wafer industry lies in its ability to reduce the substrate cost, increase the substrate size and reduce processing costs. Currently, there is no commercially viable way to produce GaAs wafers larger than 6 inches or InP wafers larger than 4 inches. However, this technology has already enabled 8-inch and 12-inch GaAs on silicon wafers.

### SEMICONDUCTOR DEVICE MARKET

III-V compound semiconductor devices are used for such high-performance applications as power amplifiers in cellular phones, infrastructure equipment, network switches and for optical applications such as lasers and LEDs.

The advantages of the new technology include lower-cost processing, improved process yields, the ability to produce larger GaAs, InP and GaN wafers than are currently commercially possible, and improved heat transfer performance in devices because silicon substrates conduct heat more readily than GaAs. This technology will in effect extend the life of silicon and existing capital investments.

### A NEW INTEGRATED SEMICONDUCTOR CIRCUIT MARKET

In the future, this technology will offer semiconductor manufacturers the exciting possibility of creating an entirely new class of devices with much higher integration. Many currently available compound semiconductor products will eventually incorporate silicon CMOS logic components to provide high-frequency RF devices, optical I/O for networking processing devices and high-speed processor subsystems. Manufacturers will be able to use the silicon substrate to produce standard silicon CMOS logic circuitry and then interconnect that circuitry with III-V circuitry epitaxially grown on the same silicon substrate.

### COMMUNICATIONS INDUSTRY

The need for high-frequency communications is growing rapidly as consumers begin to demand wireless data access from the Internet, digital audio- and video-on-demand and small dish satellite TV. The communications industry also needs smarter systems that can implement more complex functions and smaller-sized, steerable antennas for fixed access wireless systems. This technology has the potential to deliver improved devices to meet these needs and at the same time reduce energy consumption, system size and overall costs through the elimination of components.

### OPTICAL INDUSTRY

Until now the optical industry has been dependent on costly GaAs and InP wafers. In optical markets, the new technology from Motorola Labs has the potential to substantially reduce costs and improve system integration for networking systems, including fiber transport and physical interface mechanisms, switching and control processors, and optical interconnects.

### ADDITIONAL MARKET OPPORTUNITIES

The full potential of the technology will continue to grow as it becomes widely deployed, but other potential market applications include lighting, solar cell/photovoltaics, data storage, consumer lasers, medical applications and automotive radar for crash avoidance systems.

*"This is beyond fascinating research. The company has already demonstrated in its internal research that chips made with the process work in cell phones and has gotten well down the path of developing the data needed for mass manufacturing."*

JEREMY DONOVAN,  
GARTNER GROUP/  
DATAQUEST

**MOTOROLA PATENTS**

Motorola has more than 300 patent applications on file with the U.S. Patent and Trademark Office covering various aspects of the technology and its applications. Motorola is pursuing an aggressive program of world-wide patenting involving this technology. Motorola is building a valuable portfolio of patents for licensing through a wholly owned subsidiary, Thoughtbeam, Inc.

Motorola has already received indications from the U.S. Patent and Trademark Office that certain of our patent claims are allowable.

**CONTACT INFORMATION**

Licensing:  
Michael Haight  
Thoughtbeam, Inc., a Motorola company  
512-996-4883  
michael.haight@motorola.com

Media Contact:  
Anne Stuessy  
847-538-6192  
anne.stuessy@motorola.com

Motorola, Inc. (NYSE:MOT) is a global leader in providing integrated communications and embedded electronic solutions. Motorola Labs is the research arm of Motorola, Inc., with a strong, global team of scientists and engineers focused on discovering and developing new materials, technologies, architectures, algorithms and processes for future products and product enhancements. Motorola actively licenses technologies developed in the Labs.

Business Risks: Statements about the impact of this new technology are forward-looking and are based on current expectations that involve risk and uncertainties. Factors that could cause actual results to differ materially from those in the forward-looking statements include: market acceptance of the technology; unanticipated technological delays; competing technologies; the cost of manufacturing the technology; and other factors found in Motorola's filings with the Securities and Exchange Commission.

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