A high-speed match made in silicon

Putting gallium arsenide semiconductor circuits atop a silicon base is a bit like mating a Ferrari with a Honda. The components seem incompatible, but if the match were to work, the result would be an attractive combination of high performance and economy.

With gallium arsenide and silicon, such hybrid integrated-circuit chips may now be possible. Researchers at the University of Illinois at Urbana-Champaign have discovered a way to deposit gallium arsenide layers on top of silicon wafers without spreading crystal defects that ruin the electronic properties of the materials.

Until now, silicon and gallium arsenide technologies have developed somewhat independently. Gallium arsenide is useful because electrons travel about five times faster in this semiconductor than they do in silicon. Gallium arsenide also emits light, allowing it to be used for lasers or light-emitting diodes. However, the material is brittle and difficult to grow into large, defect-free crystals.

Large silicon crystals, on the other hand, are relatively easy to produce. Silicon is a better heat conductor, and more transistors and other devices can be packed into a given surface area. The cost of producing silicon chips is also significantly lower.

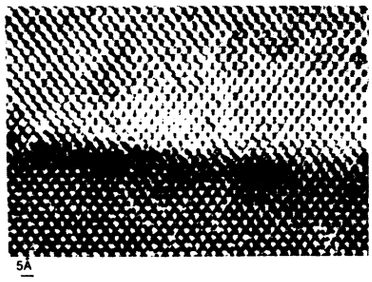
"Both technologies have a lot of things to offer," says electrical engineer Hadis Morkoç, leader of the Illinois group. "Now we don't have to choose between silicon and gallium arsenide technology because we can have the best of both on the same chip."

The trick is to find a way of aligning the silicon and gallium arsenide crystal lattices. Normally, the structures don't quite match. For a row of 25 silicon atoms, only 24 atoms from a gallium arsenide layer are needed to fill the same space. This produces a large number of defects where the two lattices meet.

The mismatch can be overcome if the silicon base is slightly tilted, says Morkoç. A gentle slope of about 4° provides, at the atomic level, tiny steps that take care of the problem. If these steps have the right orientation with respect to the silicon crystal lattice, then the inherent bumpiness of the slope doesn't produce dislocations that thread their way into the gallium arsenide layer.

"The orientation is the key," says Morkoç. For a square silicon chip with an upper surface nearly parallel to a face of the crystal lattice, the slope rises from its low point at one corner to its peak at the diagonally opposite corner. The Illinois group has applied for a patent that covers specifications for the appropriate slope orientation.

Says George W. Turner, who is doing similar work at the Massachusetts Institute of Technology, "The next important milestone, which should silence some of the skeptics who still think this is a cute idea but will never lead to anything practical, is to demonstrate a room-temperature, continuously operating laser." Using materials containing more defects than those now available at Illinois, the MIT group and another in Japan have already produced pulsed lasers.



This high-resolution image from a transmission electron microscope shows the slanting, stepped interface between gallium arsenide (top) and silicon. Despite the lattice differences, the gallium arsenide layer shows no dislocations among its atoms.

The combination of light-emitting gallium arsenide chips with complex, tightly packed silicon circuits would allow the development of "optical interconnects," says Turner. In some cases, far more power already goes into driving the wires that connect chips than in running the complicated silicon circuits themselves. With composite chips, the wires connecting one silicon device to another could be replaced by an efficient optical system, perhaps using optical fibers.

Morkoç is more interested in developing high-speed electronic devices. His team has already built several types of gallium arsenide transistors on silicon bases. Because all parts of an integrated circuit do not need to be equally fast, eventually it may be possible to deposit gallium arsenide at only the points on a silicon circuit where the chip must operate quickly. Says Morkoç, "That would make life a little easier."

The Illinois discovery will probably accelerate the pace of composite-chip research. Turner predicts that continuous lasers and optical interconnects may be developed within a year. More and more research groups are entering the field, and several small companies have been established to develop the technology.

— I. Peterson

Tumor growth: Lab imitating life

While tumors tend to thrive and multiply in the human body, they often grow abnormally, if at all, in the laboratory. A technique to grow tumors three-dimensionally may provide a way to study and manipulate them in a more lifelike environment, says its developer, Robert Hoffman of the University of California at San Diego. He is already using the technique to test cancer drugs.

Fresh tumors that eventually degrade, colonies grown from a single cell and "immortalized" cell lines that develop different characteristics from their forebears are the conventional laboratory versions of human cancers. In Hoffman's system, a piece of tumor is placed on collagen-containing gel floating in a liquid cell-culture medium.

Hoffman and his colleagues have found that the tumor cells proliferate, often growing down into the gel, and maintain their three-dimensional tissue structure, genetic makeup and other characteristics. A report on the group's work will appear in an upcoming PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES.

So far, Hoffman's laboratory has a success rate of about 75 percent from 17 types of human cancers. That number "is really quite extraordinary," says Philip Frost of the M.D. Anderson Hospital and Tumor Institute in Houston. The usual success rate for culturing tumor cells is much lower — in his lab, for example, about 1 in 23 attempts at growing renal cell cancer succeeds.

Frost's laboratory has been trying the technique for the past two months. While they are still working out the methodology, Frost has great hopes for it. "If Hoffman's right and if it's as successful as he claims, it's going to revolutionize human tumor biology," he says.

A tumor-cloning procedure in which colonies are grown from a single cell enjoyed a flurry of attention several years ago. At that time its success was low, and the process has yet to live up to its promise of providing a way to select drug regimens for individual tumors. But improvements to the procedure have brought its success rate up to 80 percent in some cases, and it is valuable for screening new drugs, says Robert Shoemaker of the National Cancer Institute's Frederick (Md.) Cancer Research Facility, who is supervising three tumor-cloning projects.

Hoffman, however, maintains that cloned tumor cells will never adequately represent the tumor itself. "Since we know almost every tumor is made of multiple cell types," he says, "to have a representative tumor you want to have the cell types in the same relationship as they were inside the person."

— J. Silberner

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