Superlattice strain in semiconductors

Layer by microscopically thin layer, scientists can now build crystal "superlattices" in which different substances intertwine to create novel, tailor-made materials. At the Sandia National Laboratories in Albuquerque, N.M., researchers have used these modern crystal-building techniques to develop a new class of semiconductors for electronics applications such as microwave generators, solar cells and solid-state lasers.

The Sandia-developed materials, called "strained-layer superlattices," consist of alternating layers of crystalline substances — for example, gallium arsenide phosphide and gallium phosphide. Normally, the atomic spacing of one layer of atoms does not match the spacing of its neighbors because the two types of crystals have repeating atomic patterns with different dimensions. However, if the crystal layers are very thin (a 5,000-layer stack barely reaches the thickness of a sheet of paper), the atoms do align themselves, either by separating or pulling together slightly. Each layer is under elastic strain, but no cracks or dislocations, like those usually found in thicker layers, appear.

The absence of imperfections is the key to the superiority of strained-layer superlattices for particular electronic uses. Electrons tend to be more mobile in these materials than in equivalent silicon-based devices. In addition, engineers can fine-tune superlattice properties by adjusting the proportion of arsenic in the layers or by altering the layer thicknesses.

Roger J. Chaffin, supervisor of Sandia's solid-state device physics division, says, "If you adjust the thickness and the type of material you use, you have theoretically an infinite number of different semiconductors you can produce. That is, technologically, an exciting prospect."

Chaffin says preliminary data show that some superlattice structures (indium gallium arsenide combined with gallium arsenide) are better than gallium arsenide by itself for high-frequency transistors used in generating microwaves. High switching speeds also make the new semiconductors potential candidates for high-speed digital logic in supercomputers. However, Chaffin admits there is some question whether this technology can be used to build integrated circuits. "That's where a lot of research has got to be done in the next few years," he says.

More promising is the gallium arsenide phosphide program, which is looking at optical electronics devices such as light emitters, solar cells and laser diodes. When blue laser light shines on these materials, they fluoresce with a vivid green color. Researchers are now investigating the possibility of using this effect to build a solid-state laser that emits green light, something that currently can't be built from existing materials. Chaffin says the addition of a laser green to the two other primary colors already available would make possible a wide variety of solid-state color displays and other devices.

So far, only simple semiconductor devices such as diodes have been built from strained-layer superlattice materials. Researchers are evaluating a superlattice transistor, but no data have been released yet. Chaffin says, "Given a material you can modify in any way you want, you can come up with several ideas for different types of new devices. We have filed patent disclosures with the Department of Energy on at least six different components, new devices or improvements on existing devices."

Although there was an attempt at this type of research more than 10 years ago, it didn't succeed because crystal-growing technology had not advanced far enough. The Sandia work began in 1980 when physicist Gordon Osbourn carried out the first theoretical study of strained-layer superlattice structures. Now, other researchers, including a group at the University of Illinois at Urbana-Champaign, are also investigating them. *—I. Peterson*

Soviets launch two Venus orbiters

The latest pair of Soviet Venus probes, Venera 15 and 16, were launched on June 2 and 7 to take up orbit around the haze-shrouded planet in early October. Neither craft carries a landing capsule, as did earlier missions that photographed and sampled the surface, but U.S. space officials and scientists with Russian contacts are virtually certain that one or both orbiters are equipped with radar to map the planet from on high.

Informed speculation is that one craft will enter a near-polar orbit to provide detailed coverage of one of the polar regions, both of which were missed by the radar aboard the U.S. Pioneer Venus orbiter. The other craft is expected to enter an equatorial orbit to search for sites for future unmanned landings, as well as to provide more information about the areas in which past Veneras have already touched down.

Some U.S. sources expect the Veneras to offer radar resolution as sharp as a few kilometers, roughly equivalent to the best earth-based radar studies of Venus and substantially better than the Pioneer radar altimeter (which provided 100-km resolution over most of the planet and up to 25 km in places). It would not, however, be as sharp as the 1-km resolution goal that some geophysicists feel is the "magic number" for identifying certain fundamental surface-altering processes, such as in distinguishing between compressional and extensional features. In the National Aeronautics and Space Administration's proposed budget for fiscal 1984 are funds to begin work on a mission called the Venus Radar Mapper, which would provide resolution as good as 300 meters.

The Soviet news agency Tass made no mention of radar or other specific investigations in announcing the two launchings, saying only that the mission would include studies of the surface and atmosphere. *—J. Eberhart*

Pioneer 10: Leaving the planets behind

There are many ways to define the edge of the solar system (SN: 4/30/83, p. 277), but June 13, 1983, will be recorded as the date on which the Pioneer 10 spacecraft became the first manmade object to leave all nine of the sun's known planets behind.

Launched in 1972, the probe was the first to travel beyond the orbit of Mars, then to penetrate the asteroid belt, and in December of 1973 to fly past Jupiter. The gravitational "slingshot" provided by Jupiter's mass sent Pioneer 10 off on a journey that would ultimately make it the first of its kind to escape the solar system on the way to the stars (though a later-launched, faster probe named Voyager 1 will pass it on the way in a few years). On April 25, it got farther from the sun than Pluto, and on June 13 it will cross the orbit of Neptune, which is at present the most distant known planet, as ceremonies at the NASA Ames Research Center in California mark the event.

There is still work for the little probe to do, however, since every mile it travels takes it farther into the unexplored reaches of space, where the effects of the sun, cosmic rays and other phenomena have been matters only of theory and conjecture. One goal, for example, is to find the location of the heliosphere — the boundary between the sun's magnetosphere and the interstellar wind — which would appear to Pioneer 10's detectors as an increased flux of cosmic rays. The heliosphere was once thought to extend perhaps to the orbit of Jupiter, but the spacecraft has now traveled six times that far from the sun without a trace of it. Ironically, another of the probe's contributions could turn out to be the discovery that it did not leave all the sun's planets behind on June 13, 1983, at all, but that there is another—a tenth planet. Long-known perturbations in the orbits of Uranus and Neptune are believed by some researchers to indicate the possible presence of a large, massive object far beyond Pluto—either a planet or a dark, stellar companion to the sun. The hope is that perturbations in the trajectories of the four spacecraft now headed out of the solar system (Pioneers 10 and 11, Voyagers 1 and 2) may reveal such a mass in ways that exhaustive searches by telescope could not.

—J. Eberhart