WAYNE SORCE

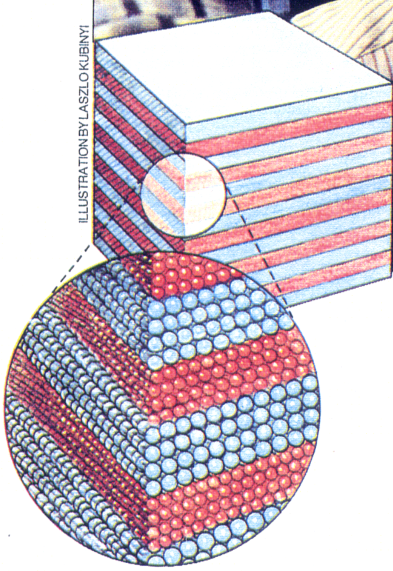

ILLUSTRATION BY LASZLO KUBINYI

Architects in the Laboratory

Man-made crystals called superlattices may lead to a new breed of electronic devices

Physicist Ivan Schuller designs structures and is, in a way, an architect. But in place of steel and concrete, he uses atoms. And instead of skyscrapers, he creates crystalline structures that rise to such dizzying heights as 100 millionths of an inch. In his way, Schuller is giving nature a bit of competition.

Nature's talent for atomic design is apparent in the precise cubic shape of a grain of salt or the delicate filigree of a snowflake. These forms are outward expressions of atomic structure—clear evidence that the atoms within are arranged in regular three-dimensional geometric patterns, called lattices. Schuller, who works at the Argonne National Laboratory in Illinois, and other atomic architects are interweaving two different substances—one atom-thick layer at a time—to produce materials that have never before existed. Because these man-made crystals are more complex than the usual crystalline structures found in nature, they have been given an appropriate name: superlattices.

The new superlattice technology is impor-

Charles Falco and Ivan Schuller producing a metal superlattice. Inset shows its layers of atoms

tant because it gives scientists a way to tailor-make materials for specific electronic, magnetic, and optical properties. Says a Bell Laboratories spokesman, "In a way, superlattices are to physics what recombinant DNA, or gene splicing, is to biology."

Several "atom splicing" techniques are used in building superlattices. In one, the materials to be layered are heated in separate ovens within a vacuum chamber until their atoms begin to boil off. A computer-controlled shutter then opens and closes at precisely timed intervals, releasing the proper quantity of atoms, first of one material then the other, from each furnace. Like droplets from a spray-paint can, these atoms strike and adhere to a base plate, forming alternate layers.

One of Schuller's recipes calls for alternating four layers of copper atoms with four of niobium (a metal used in making stainless steel) until there are about a thousand layers in all. They form what looks like a thin piece of metallic foil. "What happens is so surprising," says Schuller. "Copper and niobium look as if they wouldn't fit together, because of their different atomic structures. But they do fit." Besides copper and niobium, Schuller and his colleague Charles Falco are working on a dozen other combinations. By trial and error, they have learned that nickel and copper, for example, layer nicely, lead and silver do not.

Metals are not the only raw material for superlattices. At IBM and Bell Labs, where most of the pioneering work has been done, scientists are stacking semiconductors—substances that are somewhere between a conductor and an insulator in electrical conductivity. Their goal: to uncover the physical laws that govern these man-made crystals. Whatever the materials used, researchers are finding that a superlattice is totally different from either of its two constituents. The copper-niobium superlattice, for example, is like neither copper nor niobium. It is an entirely new substance. This comes as no surprise to one superlattice pioneer; IBM's Leo Esaki, a 1973 Nobel laureate in physics,* suggested a decade ago that the phenomenon would occur.

Bell Labs has demonstrated the promise of superlattices by building one (made of gallium arsenide and aluminum arsenide) for use as a laser only a quarter of a millimeter long. "This was a modification of a laser used in light-wave communications," says Morton Panish, head of the material science research department. "We already see some advantages." Even so, he admits, "the practical use of superlattices is still far in the future."

But the potential for fashioning atomic structures to order seems endless. Schuller envisions metal superlattices made into tiny but powerful magnets for use in computer memories or in miniature motors for medical devices, such as implantable pumps and valves. They could even be embedded in the mouth to keep false teeth from slipping. Semiconductor superlattices could be formed into computer components that transmit signals faster than conventional parts and use less energy.

Even in its infancy, superlattice research has produced the unexpected. Leroy Chang,

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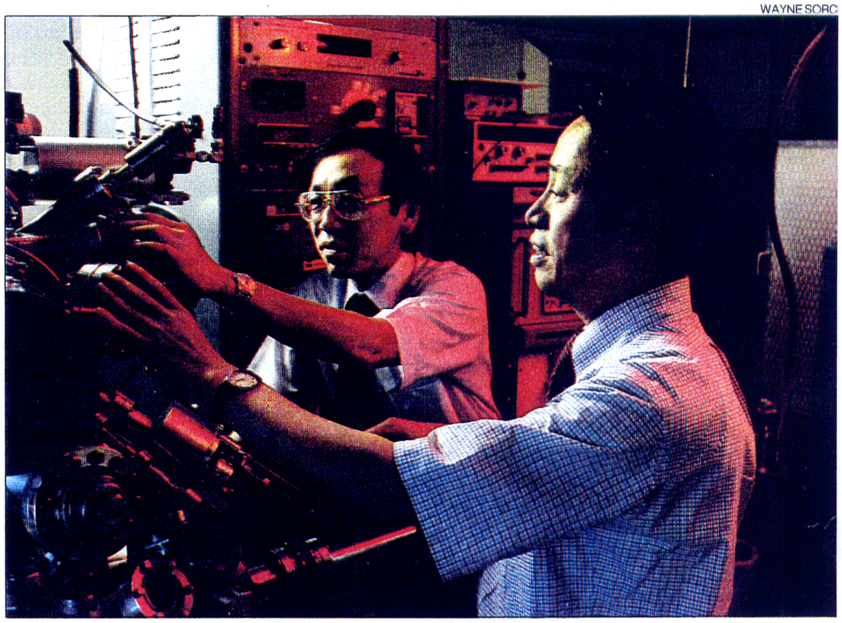

Physicists Leroy Chang and Leo Esaki make superlattices from semiconductor materials in their IBM laboratory

an IBM physicist, and four colleagues alternated atoms-thick layers of two semiconductors and produced a superlattice that was more metallic—in other words, a far better conductor of electricity—than either of its constituents. "A rather remarkable transformation," says Chang, who is enthusiastic about the possibilities of the new process. "The physics is truly beautiful."

Until now only a handful of labs have been producing superlattices, because the necessary vacuum chambers and ovens are so difficult to build; also, it takes many hours to create one tiny sample. But commercially produced equipment is coming onto the market, and this will make it possible for several universities to enter the field. Predicts Schuller: "In four or five years, this will be *the* field in material science."

—Marcia Bartusiak

**For his discovery of electron tunneling, a phenomenon that occurs in semiconductors heavily "doped" with impurities*