# Laying-on of atoms: Quantum-well wires

Atomic layer by atomic layer, a group of researchers in California has succeeded in building wires so minuscule that 400,000 of them could easily lie across the top of this T. At this nanometer, or billionths-of-a-meter, scale — tiny even by Lilliputian standards — the multi-wire structures show quantum electronic behaviors that scientists say may usher in a generation of more efficient, chip-sized lasers, superfast, light-driven computers and other optical devices.

Most nanoconstruction workers use fine beams of ions or electrons in their attempts to chisel ultrafine structures into, say, crystals of the semiconductor gallium arsenide. Instead of etching material away, Pierre M. Petroff and his colleagues at the University of California, Santa Barbara, use a technique called molecular beam epitaxy to grow such structures.

"I got this idea about 10 years ago by watching my daughter play with blocks," Petroff told Science News. "I play with atoms. It's analogous to making a wall with bricks. And this way, you can make ultrasmall wires directly" instead of indirectly with techniques that first chip material away.

For about 15 years, scientists have been able to build quantum-well structures, which are made of flat, superthin layers of one type of semiconductor such as gallium arsenide sandwiched between layers of less conductive material. Quantum wells already lie at the heart of some high-speed transistors and solid-state lasers sometimes used in devices such as laser printers.

The California scientists build even more intricate structures, called quantum-well-wire arrays, by using molecular beam epitaxy to lay down vertically and sometimes horizontally alternating layers of gallium arsenide and less conductive materials, in this case aluminum arsenide and aluminum gallium arsenide. By starting with a gallium-arsenide "staircase" crystal with atom-size steps, the researchers build up a "tilted superlattice" of the quantum-well wires (see micrograph). "They have demonstrated an unprecedented control in their ability to build perpendicular structures," remarks Leonard C. Feldman, head of thin-film semiconductor research at AT&T Bell Laboratories in Murray Hill, N.J.

In the arrays, two relatively thick layers of aluminum gallium arsenide make a sandwich out of two thinner layers, one made of gallium arsenide and another of alternating strips of aluminum arsenide and gallium arsenide. This geometric arrangement spatially confines carriers of electrical charge such as electrons and "electron holes," which are mobile, positively charged microregions of a material that pair with free electrons. The electron-hole pairs, called excitons, cannot move up or down because of the two aluminum-gallium-arsenide barrier layers. And the thin strips of aluminum arsenide keep them from moving laterally. So the excitons can venture only along the gallium-arsenide wires.


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*Transmission electron micrograph of a section through a quantum-well-wire array. Gallium-arsenide wires are the darker, slanted lines in the central, horizontal band.*

"In doing so, you give the electrons an additional series of properties," Petroff says. For one, the spatially confined electrons take on a small number of discrete, or quantized, energy levels. Also, compared with the simpler quantum wells, quantum-well wires allow more electrons into those energy levels. "This means you can make more efficient lasers," he says.

Unlike silicon-based semiconductors, gallium-arsenide quantum-well devices can transform electronic energy-changes into light. As excited electrons relax by reconnecting with the positively charged electron holes in the gallium arsenide, they emit light of specific wavelengths. It is this "optoelectronic" property that has Petroff and other scientists looking toward a not-so-distant future when powerful and superfast gallium-arsenide chips talk to each other via tiny laser beams.

This same light-emitting property enabled the California researchers to verify they actually had built the complex quantum-well-wire array and not some simpler structure such as a quantum well. Using a laser probe, they pumped up the energy of a standard, well-understood quantum well using a range of wavelengths. They then monitored the light emitted by the quantum well's excited electrons as they relaxed to lower energy levels. The suspected quantum-well-wire array got the same treatment. Not only did the patterns of emitted light from the two devices differ, but the pattern emitted by the array corresponded well with what the researchers had predicted from theoretical calculations of electrons confined in such structures.

"Theirs is the first real experimental confirmation of having actually made what they set out to make [quantum-well-wire arrays]," comments James P. Harbison, a crystal grower at Bellcore in Red Bank, N.J., the research arm of the regional Bell companies. *— I. Amato*

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# New way of keeping donor livers healthy

The first large-scale clinical trials of an experimental organ-preservation fluid kept human livers alive as long as 24 hours — a finding that may "revolutionize" the field of liver transplantation, researchers say. The new method may increase the number of livers available for transplantation and allow surgeons to schedule surgery, rather than performing emergency procedures on livers that last just 10 hours in conventional solution.

Transplants are the last hope for patients with end-stage liver disease, but a key barrier to transplantation has been the shortage of usable livers. The 10-hour time limit required transplant teams to get donor livers from the same geographic region, and even then they had to rush the organs back to the hospital. The experimental fluid, developed in 1987 by University of Wisconsin-Madison researchers (SN: 7/4/87, p.5), keeps livers alive longer, allowing transplant teams to fly across the United States and even overseas for a suitable liver.

Satoru Todo, Thomas E. Starzl and their colleagues at the University of Pittsburgh looked at 185 livers treated with the experimental solution and 180 prepared with Collins fluid, the traditional organ-preservation fluid. They found that 44 percent of livers in the experimental group lasted longer than 9.5 hours and some were stored as long as 24 hours. In contrast, livers preserved with Collins fluid showed deterioration after 5 hours, and all were unusable after 9.5 hours, the researchers report in the Feb. 3 Journal of the American Medical Association.

The Pittsburgh team also compared 151 first-time liver-transplant patients who received livers preserved with the experimental fluid with 144 controls who got livers prepared conventionally. Liver-function tests performed a week after surgery showed abnormalities in controls who received a liver stored longer than 5 hours. There was no correlation between test results and storage time in the experimental group. Furthermore, experimental patients proved less likely to require a second transplant.

The experimental preservation fluid was developed by University of Wisconsin researchers Folkert O. Belzer and James H. Southard. Nobody knows exactly how the solution works, but Southard says it seems to prevent liver cells from swelling when they are chilled, a condition that leads to organ death. The solution, now being tested by transplant centers nationwide, may not be necessary for all types of organs, he adds. Kidneys, for example, can be kept for several days using conventional preservation methods. *— K.A. Fackelmann*