Researchers at Hewlett-Packard (HP; Palo Alto, CA) have demonstrated a device they say could one day replace the transistor, averting the time when silicon devices can no longer get small enough to pack more computing power onto a chip.

Philip Kuekes, Duncan Stewart, and Stanley Williams of HP's Quantum Science Research Group created what they call a crossbar latch, which has the ability to store the ones and zeros that are the basis of computer logic, as well as restore degraded signals and flip the bits from zero to one and back. "It gave us three things that, together, are the missing pieces in our puzzle of how to build a nanocomputer," says Stewart, a research physicist at HP.

To build their latch device, the researchers lay down a series of parallel nanowires made of platinum and titanium. On top of the wires they deposit a single layer of organic molecules, in this case, steric acid about 1 to 2 nm deep. Then they lay down more wires running perpendicular to the first set. Where two wires cross, there is an active device made up of the steric acid that is sandwiched between the wires.

By applying the right voltages along the wires, the researchers control a quantum physical state of the molecule (the quantum mechanical tunneling effect). In one state, the electrons can pass through easily, and in the other, their passage is blocked.

Simple Logic

With two wires running north to south and another running east to west, there is a pair of crossing points. Voltages on the two north-south wires set the crossing point in opposite states. Another voltage traveling along the east-west wire represents either a logical one or zero. A zero affects one of the two cross points; a one affects the other. Because the state of the molecule remains stable until a new voltage is applied, that state stores the one or the zero.

Signals traveling along wires tend to degrade, but having the north-south wires connected to a power supply allows them to restore the signal that comes along the east-west wire. Inverting the voltages on the north-south lines flips the zero to a one, and vice versa.

Although the researchers were able to build simple-logic circuits before, Stewart says the crossbar latch allows researchers to string them together, providing all the logical actions necessary for computing. "A computer is nothing but little pieces of logic linked together with these so-called logical latches," he says. "It works even better than we expected."

The architecture is much simpler than that of today's transistors; this simplicity is important when design features reach such a small scale, he says. It also allows the device to compensate for defects by routing the logic around junctions that do not work.

The researchers' latches measure about 2 nm, whereas the features in today's transistors are at 90 nm. Stewart says he doubts they can get much below 30 nm. The 2-nm latches would be built using imprint lithography, in which a master mold stamps out a design in a resist that is then cured with heat or UV radiation.

Future research will consist of testing a variety of materials for the wires and the organic molecules in hopes of increasing switching speeds. Stewart says the technology could start to work its way into computer chips by about 2012, although it will probably work in conjunction with standard silicon processes first. As to whether it will eventually supplant the silicon transistor, Stewart cannot say.

"All I can say is that, for the first time, we have a demonstration that we have something working at this nanometer-length scale that replaces the function of a transistor," he says.

Dimitri Antoniadis, a professor in the Quantum-Effect Devices group at the Massachusetts Institute of Technology (Cambridge, MA), says it is too early to say what the potential impact of HP's work might be. "This technology has been pursued for a long time," Antoniadis says. "It is still of highly exploratory nature." —Neil Savage