Pitt scientists help develop way to control electron spin

Friday, January 24, 2003

By Byron Spice, Post-Gazette Science Editor

Politicians may be famous for "spin control" following speeches, but researchers at the University of Pittsburgh and the University of California at Santa Barbara have demonstrated the sort of spin control that could lead to revolutionary new types of high-speed electronic devices.

Their findings, published online by the journal Science yesterday afternoon, show that it's possible to use electrical fields, rather than magnetic fields, to manipulate a property of electrons known as "spin." By using electrical fields to push and pull electrons within a specially engineered semiconductor, they found they could change the orientation of the electrons' spin based simply on the electrons' location within the material.

That's a control technique that's compatible with today's electronic technology and thus may eliminate a technical hurdle to developing spin-based electronics, or spintronics.

"Is this the ultimate answer? I suspect not," said David Awschalom, a physicist and director of the Center for Spintronics and Quantum Computing at the University of California at Santa Barbara. Other researchers are pursuing alternate control techniques that might do the same thing even better, he said.

Yesterday's announcement nevertheless is a first and represents a leap forward in the rapidly advancing field of spintronics, he added. Spintronic devices might combine the functions of today's microprocessors and memory chips and require far less wiring to interconnect devices. That would significantly reduce heat generated by computer chips, which is a limiting factor in their speed.

Electron spin also might provide the basis for even more exotic quantum computers, said Jeremy Levy, a Pitt physicist and director of its Center for Oxide-Semiconductor Materials for Quantum Computation. Quantum computers would be adept at factoring very large numbers, an ability that would allow cryptologists to break virtually any known encryption technique.

Electrons, the negatively charged particles outside atomic nuclei, can be thought of as spinning balls of electrical charge. Each is spinning on an axis which can be pointed in different directions. Through a quirk of quantum physics, however, measurements of spin always show an orientation that is either up or down, Levy noted.

In today's computers, electrical current is used to open and close switches, called transistors. Information is stored and processed as a series of 1s and 0s, with each switch representing a 1 or a 0 depending on whether it is open or closed. In a spintronic computer, electrons wouldn't be used just to open and close switches; rather, the electrons themselves would represent digital bits, with an up spin representing a 1 and a down spin representing a 0.

Spin is closely associated with magnetism and scientists have long known how to manipulate the spin of electrons and their nuclei by using magnets. In magnetic resonance imaging, or MRI, for instance, a powerful magnet is used to get atoms in the body spinning in the same orientation.

But trying to use magnets to manipulate electrons on the scale of a computer chip is problematic. The idea cooked up about a year ago by Levy and Awschalom was not to change the magnetic field, but to change the electron's environment.

One of Awschalom's graduate students, Yuichiro Kato, created a semiconductor sandwich for the experiment -- a layer of aluminum gallium arsenide between two layers of gallium arsenide and flanked by metal plates. The concentration of aluminum varied within the middle layer of aluminum gallium arsenide; by using electrical fields to move electrons between areas of different aluminum concentrations, Kato showed that the electrons' spin could be controlled.

Gallium arsenide is a popular semiconductor for such experiments. But one of the goals of Levy's interdisciplinary group at Pitt is to find ways of doing the same thing in silicon, the material used in most computer chips.

The ability to control spin is not the only hurdle facing spintronics, Levy and Awschalom emphasized. For instance, researchers still have to develop sensors that can rapidly measure spin.

Levy and Awschalom nevertheless expressed confidence that spintronic devices might become a reality in the next five years. A spintronic effect, called giant magnetoresistance, already is widely used to read data from high-capacity computer hard drives, he noted.

Byron Spice can be reached at bspice@post-gazette.com or 412-263-1578.