Researchers successfully test new alternative to traditional semiconductors

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COLUMBUS, Ohio -- Researchers at Ohio State University have demonstrated the first plastic computer memory device that utilizes the spin of electrons to read and write data.

An alternative to traditional microelectronics, so-called "spintronics" could store more data in less space, process data faster, and consume less power.

In the August 2010 issue of the journal *Nature Materials*, Arthur J. Epstein and colleagues describe how they created a prototype plastic spintronic device using techniques found in the mainstream computer industry today.

At this point, the device is little more than a thin strip of dark blue organic-based magnet layered with a metallic ferromagnet and connected to two electrical leads. (A ferromagnet is a magnet made of ferrous metal such as iron. Common household refrigerator magnets are ferromagnets.) Still, the researchers successfully recorded data on it and retrieved the data by controlling the spins of the electrons with a magnetic field.

Epstein, Distinguished University Professor of physics and chemistry and director of the Institute for Magnetic and Electronic Polymers at Ohio State, described the material as a hybrid of a semiconductor that is made from organic materials and a special magnetic polymer semiconductor. As such, it is a bridge between today's computers and the all-polymer, spintronic computers that he and his partners hope to enable in the future.

Normal electronics encode computer data based on a binary code of ones and zeros, depending on whether an electron is present in a void within the material. But researchers have long known that electrons can be polarized to orient in particular directions, like a bar magnet. They refer to this orientation as spin -- either "spin up" or "spin down" -- and have been working on a way to store data using spin. The resulting electronics, dubbed spintronics, would effectively let computers store and transfer twice as much data per electron.

But higher data density is only part of the story.

"Spintronics is often just seen as a way to get more information out of an electron, but really it's about moving to the next generation of electronics," Epstein said. "We could solve many of the problems facing computers today by using spintronics."

Typical circuit boards use a lot of energy. Moving electrons through them creates heat, and it takes a lot of energy to cool them. Chip makers are limited in how

closely they can pack circuits together to avoid overheating.

Flipping the spin of an electron requires less energy, and produces hardly any heat at all, he explained. That means that spintronic devices could run on smaller batteries. If they were made out of plastic, they would also be light and flexible.

"We would love to take portable electronics to a spin platform," Epstein said. "Think about soldiers in the field who have to carry heavy battery packs, or even civilian 'road warriors' commuting to meetings. If we had a lighter weight spintronic device which operates itself at a lower energy cost, and if we could make it on a flexible polymer display, soldiers and other users could just roll it up and carry it. We see this portable technology as a powerful platform for helping people."

The magnetic polymer semiconductor in this study, vanadium tetracyanoethanide, is the first organic-based magnet that operates above room temperature. It was developed by Epstein and his long-standing collaborator Joel S. Miller of the University of Utah.

Postdoctoral researcher Jung-Woo Yoo called the new material an important milestone in spintronic research.

"Our main achievement is that we applied this polymer-based magnet semiconductor as a spin polarizer -- meaning we could save data (spin up and down) on it using a tiny magnetic field -- and a spin detector -- meaning we could read the data back," he said. "Now we are closer to constructing a device from all-organic material."

In the prototype device, electrons pass into the polymer, and a magnetic field orients them as spin up or spin down. The electrons can then pass into the conventional magnetic layer, but only if the spin of electrons there are oriented in the same way. If they are not, the resistance is too high for the electrons to pass. So the researchers were able to read spin data from their device based on whether the resistance was high or low.

Collaborators at the University of Wisconsin-Madison prepared a sample of conventional magnetic film, and Yoo and his Ohio State colleagues layered it together with the organic magnet to make a working device.

As a test, the researchers exposed the material to a magnetic field that varied in strength over time. To determine whether the material recorded the magnetic pattern and functioned as a good spin injector/detector, they measured the electric current passing through the two magnetic layers. This method is similar to the way computers read and write data to a magnetic hard drive today.

The results, Yoo said, were "textbook" -- they retrieved the magnetic data in its entirety, exactly as they stored it.

The patented technology should transfer easily to industry, he added. "Any place that makes computer chips could do this. Plus, in this case, we made the device at

room temperature, and the process is very eco-friendly."

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