Nano World: Water for denser nano-memory

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Water and electronics ordinarily do not mix, but water fragments might help control memory bits in electronics only nanometers or billionths of a meter in size, potentially leading to simpler, incredibly dense computer data-storage devices, experts tell UPI's Nano World.

Researchers say water fragments could enable a memory-storage density of more than 100,000 trillion bits per cubic centimeter. This would enable a device the size of an iPod Nano to hold enough MP3 music to play for roughly 300,000 years without repeating a song or enough DVD-quality video to play some movies for 10,000 years without repetition. However, significant technological challenges, including the assembly of the water fragment-terminated nanowires and a scheme for efficiently writing data to and reading from them, have yet to be developed, the researchers said.

The scientists investigated ferroelectrics, which are technologically key materials that can essentially behave as switches that can be toggled one of two ways by electric fields. As such, ferroelectrics can encode and store data as ones and zeroes, binary digits more familiarly known as bits.

The key to making ferroelectrics remain stable at the nanoscale in either their one or zero state is how well dampened surface charges are. If these are improperly dampened, they destabilize the ferroelectricity.

Typically, metallic electrodes sandwiching the ferroelectrics are used to dampen surface charges. A team of researchers at Drexel University and the University of Pennsylvania in Philadelphia and Harvard University in Cambridge, Mass., through years of painstaking work discovered molecules sticking onto nanowires can prove more effective at damping surface charges. Their findings, at times requiring 200 hours of analysis per nanowire, make up "a step toward practical, inexpensive, ultrahigh density computer memory," said researcher Andrew Rappe, a theoretical physical chemist at the University of Pennsylvania.

"We are particularly excited that water is the key ingredient in making these wires 'remember' their state," said researcher Alexie Kolpak, a University of Pennsylvania graduate student in theoretical physical chemistry. The scientists reported their findings in the journal Nano Letters.

The researchers experimented with ferroelectric ceramic nanowires made of barium titanate crystals. They found water fragments called hydroxyls should help stabilize ferroelectricity in smaller nanowires than previously imagined, at roughly three nanometers in room temperature or an eighth of a nanometer at cooler temperatures. Organic molecules known as carboxylate also demonstrated this capability. The smaller the nanowire, the more memory bits can be crowded together for denser computer data storage.

A hydroxyl is a water molecule that is missing a hydrogen atom. This means it is made of a hydrogen atom and an oxygen atom and possesses a dangling molecular bond, Rappe explained. The dangling bonds on the hydroxyls or the carboxylates can unite with surface charges on the nanowires. "A match made in heaven. Both are happy," Rappe said.

Karin Rabe, a computational materials physicist at Rutgers University at Piscataway, N.J., found the close collaboration between the theoretical and experimental work the researchers demonstrated will help build confidence among experimentalists that such "theoretical results can provide guidance and insight to help move things forward," she said.

Researcher Jonathan Spanier, a physicist at Drexel University, noted their work suggests that control of the responses within nanowires by attaching different molecules to their surfaces could allow for new methods of their assembly into complex and useful systems. "It's as if the 'wrapping' actually can help determine what their contents end up being," Spanier said.

Brian Stephenson, a materials scientist at Argonne National Laboratory in Illinois, and his colleagues with the Rappe group also recently found ferroelectricity could persist down to unexpectedly small dimensions of 1.2 nanometers in ultrathin films of lead titanate due to the effect of molecules stuck on the films. They also found the way the electric polarization pointed in their films depended on the chemical nature of what compounds adhered to them, and "one can imagine using this effect to make electronic nanosensors and nanomanipulators of the chemical environment."

Future experiments will analyze other kinds of coatings, oxides and nano-structures, Rappe said. Spanier noted they are in ongoing communications with major semiconductor device manufacturers.

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