An electrical switch for magnetism (w/ Video)

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Researchers at MIT have developed a new way of controlling the motion of magnetic domains—the key technology in magnetic memory systems, such as a computer's hard disk. The new approach requires little power to write and no power to maintain the stored information, and could lead to a new generation of extremely low-power data storage.

The new approach controls magnetism by applying a voltage, rather than a magnetic field. It could lead to magnetic storage devices in which data is written on microscopic nanowires or tracks, with magnetic "bits" of data hurtling along them like cars on a racetrack.

The new findings are described in a paper published this week in the journal *Nature Nanotechnology*, written by assistant professor of materials science and engineering Geoffrey Beach and graduate students Uwe Bauer and Satoru Emori.

"For hundreds of years, if you had a magnetic material and you wanted to change the direction in which the material was magnetized, you needed another magnet," Beach explains. His team's work represents an entirely new way to switch magnetic states using just a change in voltage, with no magnetic field—a much lower-power process. What's more, once the magnetic state is switched, it holds that change, providing stable data storage that requires no power except during reading and writing.

The researchers show that this effect can be used to enable new concepts such as "racetrack memory," with magnetic bits speeding along a magnetic track. While there have been laboratory demonstrations of such devices, none have come close to viability for data storage: The missing piece has been a means to precisely control the position and to electrically select individual magnetic bits racing along the magnetic track.

"Magnetic fields are very hard to localize," Beach says: If you're trying to create tiny magnetic bits on a nanowire or track, the magnetic fields from the electromagnets used to read and write data tend to spread out, making it difficult to prevent interaction with adjacent strips, especially as devices get smaller and smaller.

But the new system can precisely select individual magnetic bits represented by tiny domains in a nanowire. The MIT device can stop the movement of magnetic domains hurtling at 20 meters per second, or about 45 mph, "on a dime," Beach says. They can then be released on demand simply by toggling the applied voltage.

To achieve this feat, the MIT team built a new type of device that controls magnetism in much the same way that a transistor controls a flow of electricity. The key ingredient is a layer of ion-rich material in which atoms have been stripped of electrons, leaving them with an electric charge. A voltage applied to a small electrode above this thin layer can either attract or repel those ions; the ions, in turn, can modify the properties of an underlying magnet and halt the flow of magnetic domains. This could lead to a new family of "magneto-ionic" devices, the researchers suggest.

The effect depends on chemical interactions at the boundary between thin layers of magnetic metal and solid-state electrolyte materials that are sandwiched together, Beach says. "So it's really the interfacial chemistry that determines the magnetic properties," he says.

In practice, such a system would use a wire or strip of ferromagnetic material with a series of regularly spaced, small electrodes on top of it. The magnetic bits between these electrodes can then be selectively written or read.

Once the orientation of the magnetic bit between two electrodes has been set by this device, "it inherently will retain its direction and position even in the absence of power," Beach says. So, in practice, you could set a magnetic bit, "then turn the power off until you need to read it back," he says.

Because the magnetic switching requires no magnetic field, "there is next to no energy dissipation," Beach says. What's more, the resulting pinning of the magnetic bits is extremely strong, resulting in a stable storage system.

The key ingredients of the system are "very simple oxide materials," Bauer says. In particular, these tests used gadolinium oxide, which is already used in making capacitors and in semiconductor manufacturing.

Dan Allwood, a researcher in materials physics at the University of Sheffield who was not involved in this research, says that it "not only offers a novel technical path to control dynamic magnetization processes in patterned nanostructures, but in doing so also presents new physical processes in how voltage can influence magnetic behavior more generally. Understanding the detailed origins of these effects could allow the creation of simple, low-power information-technology devices."

In addition to magnetic storage systems, the MIT team says, this technology could also be used to create new electronic devices based on spintronics, in which information is carried by the spin orientation of the atoms. "It opens up a whole new domain," Beach says. "You can do both data storage and computation, potentially at much lower power."

More information: The paper is titled "Voltage-controlled domain wall traps in ferromagnetic nanowires."
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