The Revolution of 3D Metamaterials and Tiny Magnetic Bubbles

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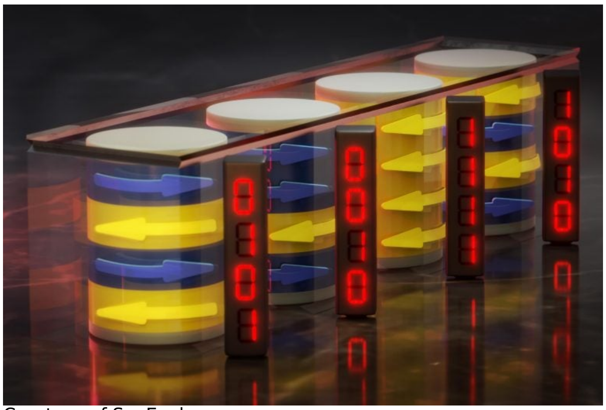

Courtesy of SynEvol
Credit: HZDR

It has been shown for the first time that complete bit sequences, as well as individual bits, can be stored in cylindrical domains, which are tiny, cylindrical regions that are only a few hundred nanometers in size. These results, which the team describes in the journal Advanced Electronic Materials, may open the door to new kinds of sensors and data storage, including magnetic neural network versions.

A narrow, cylindrical region in a thin magnetic layer is known as a cylindrical domain, sometimes known as a bubble domain by physicists. Its spins, or the intrinsic angular momentum of the electrons, point in a certain direction, which creates the magnetic moment in the material. As a result, a magnetization forms that is unique from the surroundings. Prof. Olav Hellwig of the Institute of Ion Beam Physics and Materials study at Helmholtz-Zentrum Dresden-Rossendorf describes his study topic as "imagine a small, cylinder-shaped magnetic bubble floating in a sea of opposite magnetization." Such magnetic structures, in his and his team's opinion, have enormous potential for use in spintronic applications.

The boundaries of this cylindrical domain, or peripheral regions where the magnetization direction shifts, give rise to domain walls. Precise control over the spin structure in the domain wall will be essential to the magnetic storage technology that Hellwig's group is working toward since bits can be directly encoded in either a clockwise or counterclockwise manner.

Another area of interest for the researchers is this: "Our current hard disks can hold about one terabyte on a surface the size of a postage stamp, thanks to their track widths of 30 to 40 nanometers and bit lengths of 15 to 20 nanometers." By expanding storage into the third dimension, we hope to get beyond this data-density constraint, says Hellwig.

The internal spin structure of domain walls can be manipulated via magnetic multilayer structures, as the magnetic energy involved can be varied by varying the materials and layer thicknesses. On silicon wafers, Hellwig's group applied blocks with ruthenium-separated layers of cobalt and platinum alternating layers.

Synthetic antiferromagnet is the metamaterial that is obtained. Its unique characteristic is a vertical magnetization structure where neighboring layer blocks exhibit opposite magnetization directions, resulting in an overall net neutral magnetization.

The idea of the "racetrack" memory enters the picture here. The pieces are strung like a string of pearls along the system, which resembles a racetrack. Our system's clever feature is that we can precisely regulate the layers' thickness and, consequently, their magnetic characteristics. This enables us to modify the synthetic antiferromagnet's magnetic behavior in order to store complete bit sequences as well as individual bits in the form of a domain wall's depth-dependent magnetization direction, according to Hellwig.

This raises the possibility of a regulated, quick, and energy-efficient transit of such multi-bit cylinder domains via these magnetic data highways.

Magnetoelectronics has the potential for additional uses as well. They can be utilized in spintronic components or magnetoresistive sensors, for example. Furthermore, these intricate magnetic nano-objects hold immense promise for magnetic applications in neural networks, which have the ability to process information similarly to the human brain.

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