Vortex-antivortex pairs found in magnetic trilayers

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A international team of researchers has discovered magnetic vortex-antivortex pairs arising from correlated electron spins in a newly engineered trilayer material. The discovery could advance memory cells and points to the potential development of 3-D magnetic logic circuits.

The researchers from the Nanomaterials and Nanotechnology Research Center of the University of Oviedo in Spain, and the University of Porto in Portugal, reported their findings this week in *Applied Physics Letters*. The collaboration also included a research group at Alba Synchrotron in Catalonia, Spain.

The team's work is part of a relatively new field of research called topological spintronics. Spintronics exploits the intrinsic spins of electrons and their resulting magnetic properties in material, as well as the electrons electrical charge, to store and process information.

Topological spintronics uses rotating geometrical "defects" in the overall charge carrying topology of a material to control magnetic behavior. Microscopic physical defects, such as stretching, bending and twisting, can be driving phenomena that researchers look to use.

The defects the team studies in its trilayers are bifurcations, which are created in the midst of the striped-domain pattern. Think of a forked road within a row of straight roads. These bifurcations cause vortex-antivortex pairs to move together along the "magnetic roads" either in one orientation or the opposite, depending on their polarities. The bottom of the fork confines and guides the propagation of the vortices.

The effect was observed in magnetic trilayers in which a hard magnetic layer, difficult to demagnetize, was sandwiched between two softer magnetic layers, with a total thickness of 160 nanometers.

"The vortex-antivortex motion requires the interplay between the hard and soft magnetic layers as well as the stray fields of the whole magnetic trilayer," said Maria Vélez, co-author of the paper and associate professor of condensed matter physics at the University of Oviedo.

Her team's research opens up new possibilities in the nascent field of 3-D nanomagnetics, which has evolved through recent discoveries of new magnetic effects at the atomic level, as well as advances in characterization methods such as in the X-ray magnetic microscopy technique used by the group.

The researchers found that the vortex-antivortex pairs in the soft magnetic layers exhibited a correlated motion that extends several micrometers along the magnetic stripes during magnetization reversal. These long travel distance effects could increase the efficiency in controlling magnetic memory and logic devices. The findings are based on X-ray microscopy and micromagnetic calculations.

"Vortex-antivortex propagation is guided by the magnetic stripe-domain pattern of the material, not by a lithography-defined wire geometry. This implies that the direction of motion can be changed at any moment by a proper sequence of applied magnetic fields. This is a clear advantage over fixed geometries like the lithographically defined current carrying lines in conventional electronic devices," Vélez said. It's as if the conducting paths for vortex motion in the magnetic trilayers can be dynamically rewired.

"In addition, the use of a magnetic potential to confine vortex-antivortex motion is crucial to obtain long propagation distances of several microns, avoiding annihilation at wire edges," Vélez also said.

The propagation is confined at either the top or bottom of the film surfaces depending on the topological characteristics of the stripe pattern dislocation. This effect could allow the coupling of magnetic circuits across the sample thickness in multilevel devices with a higher degree of spatial integration than in current 2-D magnetic circuits.

More information: A. Hierro-Rodriguez et al, Deterministic propagation of vortex-antivortex pairs in magnetic trilayers, *Applied Physics Letters* (2017). DOI: 10.1063/1.4984898

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