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Surprise discovery in the search for energy efficient information storage

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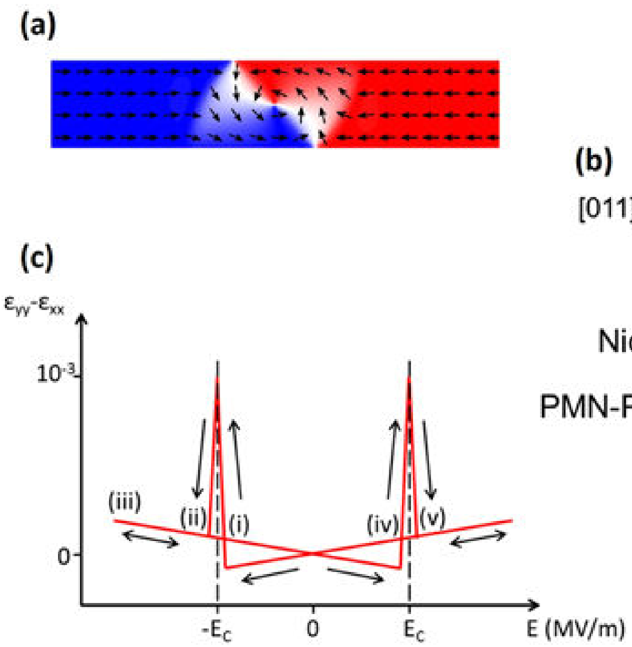

Device geometry and characteristics. Credit: *Scientific Reports* (2017). DOI: 10.1038/s41598-017-07944-9

Today almost all information stored on hard disc drives or cloud servers is recorded in magnetic media, because it is non-volatile (i.e. it retains the information when power is switched off) and cheap. For portable devices such as mobile phones and tablets, other forms of non-magnetic memory are used because the technology based on magnetism is impractical and is not energy efficient. In an age of mass data storage and portable devices which collect and process information, the search is on to find smaller, faster, cheaper and more energy efficient ways, of both processing and storing increasing amounts of data.

In the course of their research into the use of magnetic domain walls (local regions of magnetic "charge" usually driven by magnetic fields) to increase our capacity for information storage and logical processing, physicists at the University of Nottingham have discovered a phenomenon which has allowed them to 'manipulate' the structure of a magnetic domain wall.

The research carried out by researchers in the Spintronics Group in the School of Physics and Astronomy, in collaboration with York University, has been published in the open access journal *Scientific Reports* (*Scientific Reports* 7, Article number: 7613 (2017) DOI: 10.1038/s41598-017-07944-9). It could provide a route to creating a new class of highly efficient, non-volatile information processing and storage technology.

Dr Andrew Rushforth, from the School of Physics and Astronomy, said: "In the drive towards increasingly miniaturised, portable devices, the need to store and process information with low power consumption is becoming a critical issue. Concepts for information storage and logical processing based on magnetic domain walls have great potential for implementation in future information and communications technologies."

Magnetic media

The main benefit of using magnetism is the fact that the magnetic state remains stable when power is removed from the device, enabling non-volatile storage of information. By contrast, most processors and random access memory (RAM) chips store information using electrical charge which is fast, but dissipates when the device is powered down.

Magnetic random access memory (MRAM) is a promising form of non-volatile RAM based on magnetism which has recently found applications in some niche markets. In MRAM information is written using electrical current which generates heat and stray magnetic fields.

To date there are no technologies which use magnetism to process information.

Harnessing magnetism to process and store information

A solution to these problems may lie in the use of magnetic domain walls. A magnetic domain wall forms in a magnetic wire and separates regions where the magnetisation points in opposite directions. Under certain conditions it consists of a region in which the magnetisation rotates around a central vortex core, which points into or out of the wire.

An analogy would be the way in which water rotates around a vortex core as it drains down a plug hole. The sense of rotation of the magnetisation in the vortex wall—its chirality—can be clockwise or anticlockwise. There have been proposals to use the chirality to both store and process information. The problem is finding a way to manipulate the vortex domain wall.

Previously it has been shown that the chirality can be manipulated by applying magnetic fields to complicated nanowire geometries, but the use of magnetic fields is wasteful of energy and limits the ability to address individual domain walls selectively.

A surprising discovery

The researchers have discovered a way to control the chirality of the vortex domain wall using an electric field.

Dr Rushforth said: "We didn't set out to switch the chirality of the domain walls. We were actually trying to see if we could make them move. When we noticed that the chirality was switching, we were rather surprised, but we realised that it was an interesting and novel effect that could potentially have important applications. We then had to go back to the office and perform micromagnetic calculations to understand why and how the phenomenon occurs."

The team used the strain induced by an electric field applied to a piezoelectric material (which deforms mechanically in response to an electric field) to manipulate the chirality of the domain wall.

The knowledge is at an early stage. Until now it hasn't been obvious how one could control magnetic domain walls reversibly and predictably using electric fields. This research helps to solve that issue, but there remain practical issues to be addressed.

The next stage in the work will be to investigate how the chirality switching depends upon the material properties and the geometry and dimensions of the magnetic wire.

The University of Nottingham has filed a patent application for a memory device based on the effect.

More information: R. P. Beardsley et al, Deterministic control of magnetic vortex wall chirality by electric field, *Scientific Reports* (2017). DOI: 10.1038/s41598-017-07944-9

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