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Controlling magnetism with an electric field

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There is a big effort in industry to produce electrical devices with more and faster memory and logic. Magnetic memory elements, such as in a hard drive, and in the future in what is called MRAM (magnetic random access memory), use electrical currents to encode information. However, the heat which is generated is a significant problem, since it limits the density of devices and hence the performance of computer chips.

Scientists are now proposing a novel approach to achieve greater memory density while producing less heat: by using an electric field instead of a current to turn magnetism on and off, thereby encoding the electrical devices.

The University of Miami (UM) researcher and colloborators did not discover electrical control of magnetism, but a new understanding of the phenomenon. The study shows how the electric field, and not the change in the electron density in the film (called doping), leads to control of magnetism in current experiments. The findings are published in the journal *Scientific Reports*.

"Our work shows a new path to using a magnetic capacitor which uses electric field to control magnetism," says Stewart Barnes, physicist at the UM College of Arts and Sciences, and corresponding author of the study. "The energy dissipation involved is much lower than produced with an electric current, drastically reducing the heat."

Electricity and magnetism are two aspects of the electromagnetic force. Ampère's law says that when charged particles flow in a conductor, they produce a magnetic field. The intensity of an electric current flowing in a wire determines the intensity of this field near the wire. On the other hand, an electric field in the space around a given charge is given by Coulomb's law. It determines the force on a second nearby charged particle. There is no charge flow.

Traditionally, magnetism is activated in an electromagnet by passing a current through a coil around a magnetic material. This coil generates a magnetic field. The new method uses a capacitor, a device used to generate an electric field, to control the magnetism of a magnetic material.

"With the electrical control of magnetism, you use a capacitor in which one element is magnetic and, simply by charging the capacitor, you change the direction of the magnetism, say from being in the plane of the film to being perpendicular," says Barnes.

This property of magnetic materials, where the magnetization is oriented in a preferred direction, is called anisotropy. The new approach developed by the researchers is founded on a relativistic effect called Rashba spin-orbit coupling. The effect arises from the interaction between the spin of an electron and an electric field.

"We use this Rashba effect to produce a magnetic anisotropy, which leads to our control of magnetism," says Barnes. "We produce the electric field, in part, by a proper choice of the magnetic and non-magnetic elements in our bi-layer and by generating an electric field with a capacitor."

The new mechanism has been studied, theoretically, in sandwiches of magnetic materials and non-magnetic metals or semi-conductors. The analysis of a number of such sandwiches helps answer technical questions associated with the control of magnetism of thin ferromagnetic films, as might be used in memory and logic devices.

Thin magnetic films with a controllable perpendicular magnetic anisotropy (PMA) have important applications, not only for MRAM and logic, but also for electromechanical devices, such as actuators, which are devices that transform an electrical signal into motion. For that reason, an internal electric field that can be used to engineer such a PMA is of great interests.

The researchers are planning experiments which verify the basic principles of the current study and to simulate the materials involved using a computer. The study is called "Rashba Spin-Orbit Anisotropy and the Electric Field Control of Magnetism" Co-authors are Jun'ichi Ieda and Sadamichi Maekawa, from the Advanced Science Research Center of the Japan Atomic Energy Agency, in Tokai, and CREST, Japan Science and Technology Agency, Sanbancho in Tokyo.

More information: Paper: www.nature.com/srep/2014/14021 … /full/srep04105.html

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