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Generate ferromagnetism in antiferromagnetic materials using voltage only



A research with outstanding participation of the UAB has developed an innovative strategy to control magnetism by voltage in antiferromagnetic materials. This advance could contribute to the development of more efficient and safer magnetic memories.

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Switching a magnetic bit—the fundamental operation in magnetic memories—relies on electric currents. This inevitably leads to significant energy losses and heat dissipation. In a world increasingly driven by data, reducing this energy cost has become a major technological challenge.

A promising alternative is magneto-ionics: instead of using electric current to manipulate magnetism, voltage is used to drive the motion of ions and induce redox processes — internal chemical reactions. Because the current involved in voltage-driven processes is minimized, energy dissipation can be potentially reduced, opening the door to low-power memory and computing devices.

In antiferromagnetic materials, neighboring spins align in opposite (antiparallel) directions, resulting in no net magnetization. For this reason, antiferromagnets are considered

magnetically “invisible”. This property makes them particularly attractive for technologies where magnetic information could remain hidden and also allows bits to be packed more closely together since there are no stray magnetic fields causing interference between neighboring elements.

While magneto-ionics has been widely explored in ferromagnetic systems—modulating properties such as saturation magnetization, coercivity, or magnetic anisotropy—its potential in antiferromagnetic materials has remained rather unexplored.

When a ferromagnet is adjacent to an antiferromagnet, the interaction between the two magnetic phases can produce an effect called exchange bias. This effect usually appears after a cooling in the presence of a magnetic field and is key in many magnetic memory technologies. A clear signature of this phenomenon is a shift of the magnetization versus magnetic field (M-H) hysteresis loop along the applied magnetic field axis.

In our new work, published in *ACS Nano*, we demonstrate that exchange bias can be generated, suppressed, and tuned at room temperature through a magneto-ionic process in a single antiferromagnetic NiCoO layer. In contrast to conventional approaches, this method avoids the thermal treatments typically required for thin-film fabrication as well as for setting the exchange bias direction, thereby enhancing energy efficiency, since NiCoO is under an applied magnetic field. Moreover, the entire functionality is achieved within a layer.

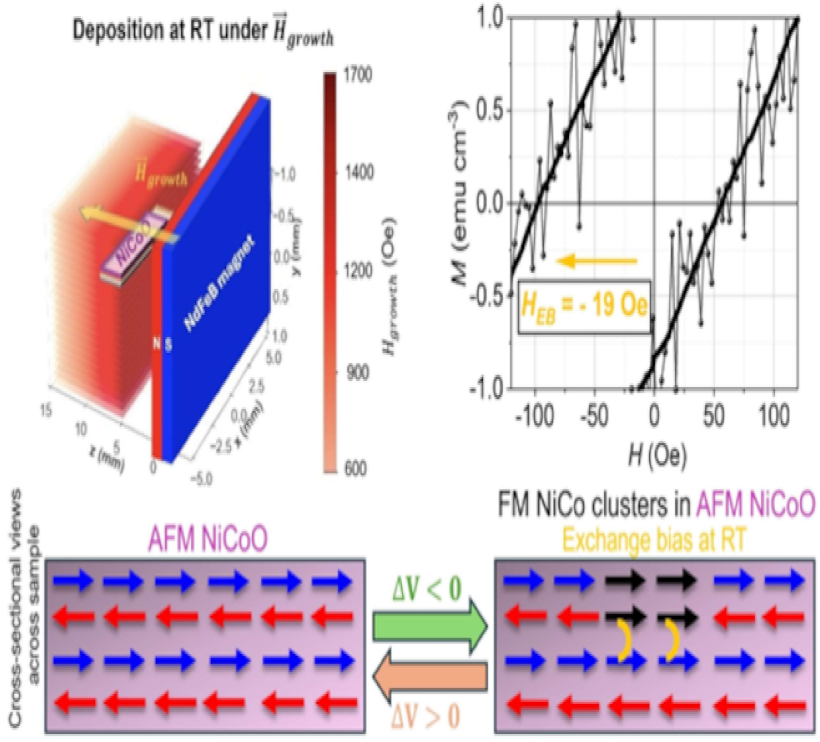


Figure 1. (Upper-left) Distribution of the magnetic field generated by the permanent magnet positioned near the sample. (Upper-right) Shifted hysteresis loop M-H after voltage actuation. (Bottom) The antiferromagnet NiCoO single layer system with embedded clusters of ferromagnetic NiCo after voltage actuation.

These results pave the way for programmable exchange bias controlled by magneto-ionics and open a path toward using voltage to hide magnetic data, potentially enabling new anti-hacking strategies in future magnetic memory technologies. The work is also appealing for antiferromagnetic spintronics applications.

The study was led by Associate Professor Enric Menéndez (Serra Húnter fellow) from the Department of Physics of UAB. It is part of the PhD Thesis of Simone Privitera, funded through the MSCA-COFUND DOCFAM+ program, and has been supervised by ICREA Professor Jordi Sort, Professor Aitor Lopeandia and Enric Menéndez. This work has been carried out in collaboration with the Catalan Institute of Nanoscience and Nanotechnology, the Institute of Radiation Physics (Helmholtz-Zentrum Dresden–Rossendorf), Universidade Tecnológica Federal do Paraná, Spin-Ion Technologies, and the Centre de Nanosciences et de Nanotechnologies from the Université Paris-Saclay.

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