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A new method to control the spin current and moment rotation in antiferromagnetic insulators

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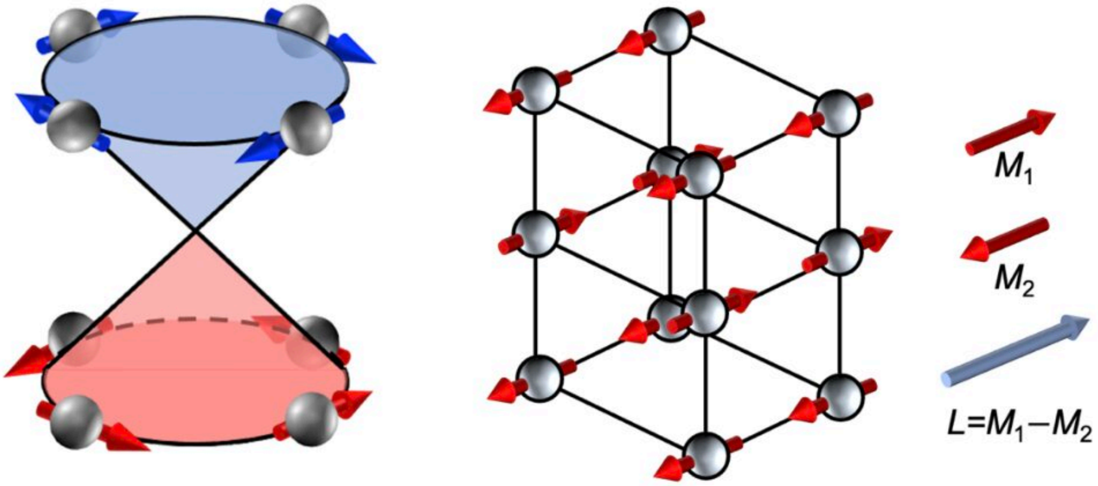

Figure 1. Spin momentum locking in topological insulator （left）and antiferromagnetic（right）

Credit: Chen et al.

Antiferromagnetic materials, materials in which atoms are arranged so that all neighboring atoms are anti-parallel (i.e., pointing in the opposite direction) to them, can have several advantageous properties for the development of devices. Due to their fast spin dynamics and negligible stray fields, they could be particularly favorable for creating high-speed memory devices with a lot of storage capacity and low power consumption.

Before this can happen, however, engineers must be able to efficiently detect and control the electrical current and rotation of moments (i.e., measure of a force's tendency to cause a body to rotate) in antiferromagnetic materials. So far, this has proved challenging, particularly using conventional measurement methods.

Researchers at Tsinghua University, ShanghaiTech University, and Beijing University of Technology have recently devised a new method to control the spin current and antiferromagnetic moments in antiferromagnetic materials. In their paper, published in *Nature Electronics*, they specifically demonstrated this using bilayer $(Bi,Sb)_2Te_3/\alpha\text{-}Fe_2O_3$, a structure that contains a topological insulator and an antiferromagnetic insulator.

"Our recent work is based on one of our previous papers, published in *Physical Review Letters (PRL)*," Cheng Song, one of the researchers who carried out the study, told TechXplore. "In the *PRL* paper, we demonstrated switching antiferromagnetic moment with spin current from spin Hall effect. In our new study, we wanted to show the interaction between antiferromagnetic moments and spin current from topological surface states, since the topological surface state would be more efficient in charge-spin conversion."

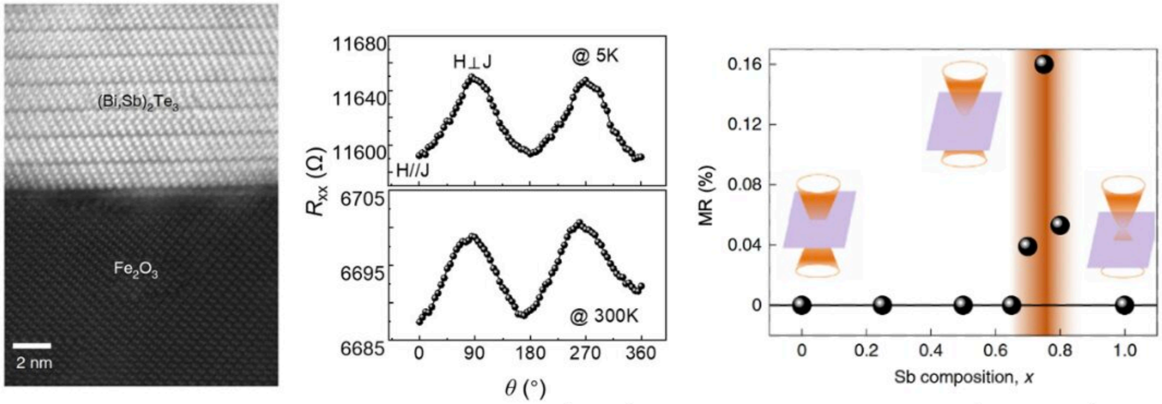

Figure 2. TEM for $(Bi,Sb)_2Te_3/\alpha\text{-}Fe_2O_3$ （left） 、 magnetoresistance （middle） and Sb composition-dependent magnetoresistance（right） 。

Credit: Chen et al.

Song and his colleagues showed that the orientation of antiferromagnetic moments in the antiferromagnetic insulator component of their sample ($\alpha\text{-}Fe_2O_3$) could modulate the spin current reflection at the interface with the $(Bi,Sb)_2Te_3$ layer. As a result, the moment rotation in the antiferromagnetic material could be controlled via the spin current, specifically through a giant spin-orbit toque that is generated by the ($Bi,Sb)_2Te_3$ layer's topological surface state.

"Spin current can be generated via topological surface states from topological insulators, then being injected to adjacent antiferromagnetic insulators," Song explained. "The efficient spin-charge conversion can bring about large magnetoresistance response (antiferromagnet control of spin current) and low switching current density (spin current control of antiferromagnet)."

In initial experiments, Song and his colleagues found that their method successfully allowed them to control antiferromagnetic moments in their material sample. They also recorded a highly promising switching current density (i.e., a very important parameter for the development of memory devices).

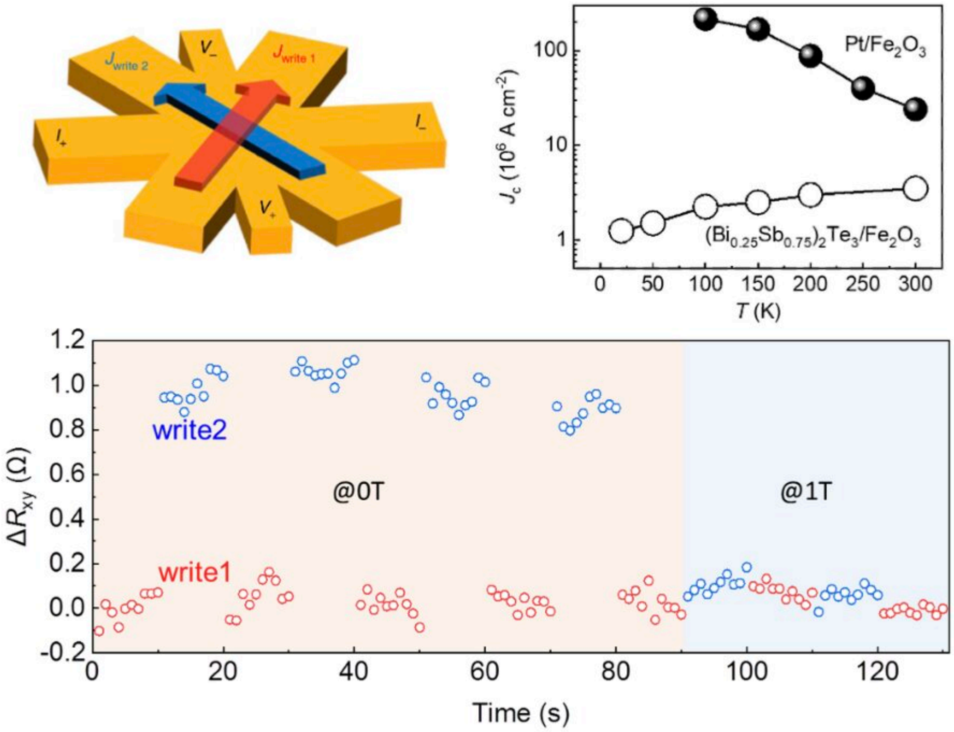

Figure 3. Switching device schematic (up left) ， Current induced Hall resistance change in $(Bi_{0.25}Sb_{0.75})_2Te_3/\alpha\text{-}Fe_2O_3$ (down)。 Temperature-dependent current-sinduced switchingss in $Pt/\alpha\text{-}Fe_2O_3$ and $(Bi_{0.25}Sb_{0.75})_2Te_3/\alpha\text{-}Fe_2O_3$ (up right)。

Credit: Chen et al.

"Using Sb compositions, we tuned the Fermi level and resultant room temperature magnetoresistance (observed in a very narrow region)," Song said. "The Sb ~0.75 corresponds to Fermi Level locating on Dirac point, leading to low switching current density of ~10^6 A cm^-2."

The findings collected by this team of researchers highlight the potential value of their approach for attaining greater control over devices based on antiferromagnetic materials. In the future, they hope that this will pave the way towards the generation of new next-generation random access memory devices.

"In our next studies, we will try to combine a topological insulator with an antiferromagnetic random access memory," Song added. "We also plan to enable the reading via magnetic tunnel junctions and the writing by topological surface states."

More information: Xianzhe Chen et al, Control of spin current and antiferromagnetic moments via topological surface state, *Nature Electronics* (2022). DOI: 10.1038/s41928-022-00825-8

X. Z. Chen et al, Antidamping-Torque-Induced Switching in Biaxial Antiferromagnetic Insulators, *Physical Review Letters* (2018). DOI: 10.1103/PhysRevLett.120.207204

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