Interface-controlled antiferromagnetic tunnel junctions offer new path for next-gen spintronics

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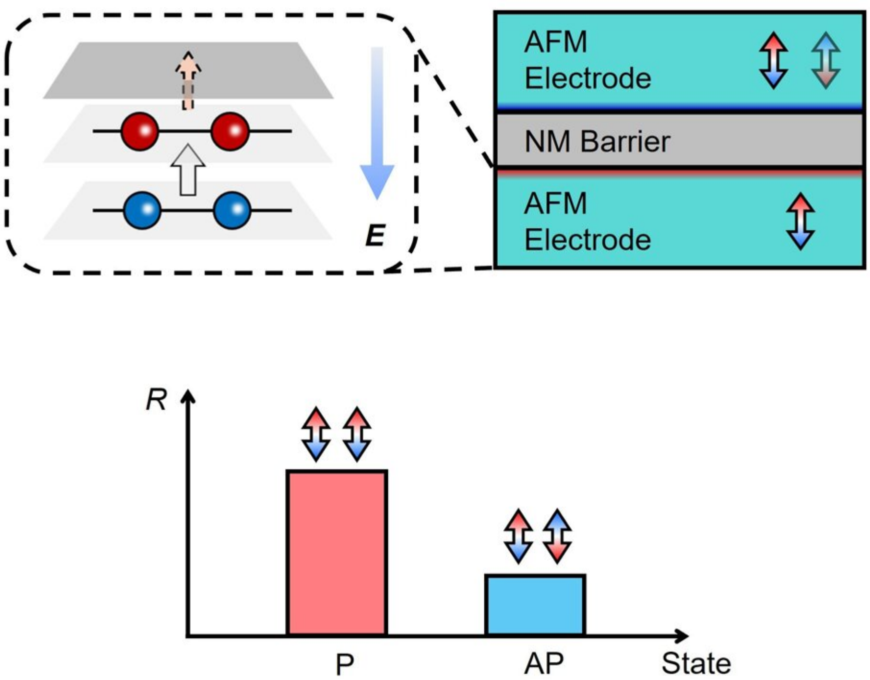

Antiferromagnetic tunnel junction with interface-driventunneling magnetoresistance. Credit: Shao Dingfu

A research team led by Prof. Shao Dingfu at the Institute of Solid State Physics, the Hefei Institutes of Physical Science of the Chinese

Academy of Sciences, has unveiled a new mechanism for achieving strong spin polarization using antiferromagnetic metal interfaces.

Their findings, published in *Newton* recently, propose a third prototype of antiferromagnetic tunnel junction (AFMTJ), paving the way for faster and denser spintronic devices.

As electronics demand smaller size, higher speed, and lower energy use, spintronics—using both electron charge and spin—offers a strong alternative to traditional devices. Magnetic tunnel junctions (MTJs), a key spintronics technology, are already used in data storage but face limits due to slow response speeds and unwanted magnetic fields from their ferromagnetic parts.

Antiferromagnetic (AFM) materials avoid these issues. They have no net magnetism, no stray fields, and much faster spin responses, making them ideal for future devices. However, current AFM tunnel junctions depend on specific bulk properties, which greatly limits material options.

In this research, the team tackled this challenge by shifting focus to interface effects, which have often been underestimated. They discovered that by suppressing bulk effects, certain AFM materials—particularly A-type antiferromagnets—can exhibit strong spin polarization at smooth and stable interfaces, even if the material itself lacks bulk spin-split states.

Using first-principles modeling, the team designed a new AFMTJ composed of a two-dimensional A-type AFM metal (Fe_4GeTe_2) and an insulating BN barrier. Despite the spin-degenerate nature of Fe_4GeTe_2's band structure, significant spin-polarized currents emerged due to interface-driven effects. These currents remained robust regardless of the electrode's thickness or layer parity, confirming their interface origin.

Crucially, the junction exhibited a tunnel magnetoresistance (TMR) of nearly 100%—on par with conventional designs—by switching the relative orientation of the interfacial magnetic moments. This approach expands the range of materials suitable for spintronic devices, especially given that many AFM materials can be grown with A-type stacking by tuning growth directions.

Commenting on the work, Prof. Jose Lado (Aalto University) and Prof. Saroj P. Dash (Chalmers University of Technology) wrote in an accompanying *Newton* commentary: "Uncompensated interfaces in antiferromagnets bring new opportunities for van der Waals heterostructures," praising the study's conceptual breakthrough and practical significance.

This research not only challenges the long-held belief that bulk effects are essential for AFM spintronic applications but also lays a foundation for high-performance, interface-engineered devices in the post-Moore era.

More information: Liu Yang et al, Interface-controlled antiferromagnetic tunnel junctions, *Newton* (2025). DOI: 10.1016/j.newton.2025.100142

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