Materials Research Science and Engineering Centers

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Table-top imaging of current-driven spin motion in an antiferromagnet

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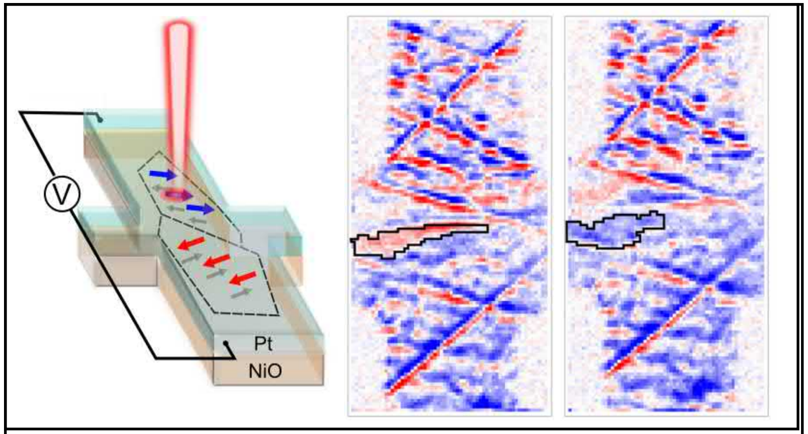
Antiferromagnetic materials contain atoms with spins that alternate between opposite directions, so there is no net magnetic field. This makes antiferromagnets notoriously difficult to study. On the other hand, they are attractive for information storage because the magnetic domains can be switched very quickly, and they are insensitive to perturbing magnetic fields. Cornell researchers have demonstrated a table-top technique for imaging antiferromagnetic spin orientation based on heat flow along an interface between materials. The team used their microscope to monitor changes in magnetic order produced by electric current, revealing that they could rotate antiferromagnetic domains and move domain boundaries. These results are promising for the development of high-performance memory devices.



Local laser heating of a NiO/Pt bilayer produces electric fields that depend on the orientation of the spin of the NiO atoms at the interface. This mechanism enables imaging of regions with specific magnetic order. When current is applied to the device, new antiferromagnetic domains are created. One such domain is outlined with a black line. When the direction of current is reversed, the domain re-orients (shown as a change of color in the figure).

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Studies of Topological "Nodal Lines" for Magnetic-Device Control

The most efficient mechanism for controlling next-generation magnetic memory devices is spin-orbit torque, in which spin current generated in one material can flow to an adjacent magnetic layer and apply a torque that will reorient the layer's magnetization. There is a world-wide search to discover materials that can maximize this effect. An interdisciplinary research team at Cornell University has investigated how a special type of electronic band structure affects spin-orbit torques. This structure, known as a Dirac nodal line, is a topological pattern in which two electron energy bands in a metal touch at certain values of electron momentum, rather than being separate. By using strained growth of the metal IrO_2 in different orientations to turn Dirac lines on and off, the Cornell group demonstrated that the presence of the Dirac lines can provide a large enhancement of spin-orbit torque.

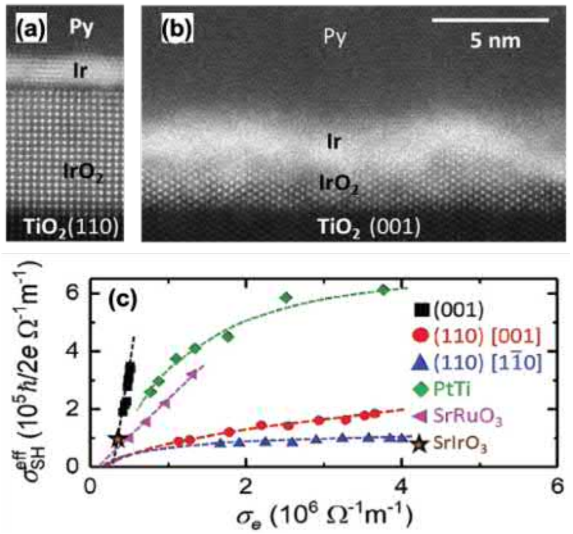

Figure: IrO_2 films grown in two different orientations, (110) and (001), with Ir caps to prevent oxidation of the Permalloy (Py) magnetic layer. (c) Spin torque efficiency vs. electrical conductivity for a growth orientation with Dirac nodal lines [(001)] and one in which the nodal lines are gapped [(110)], demonstrating the enhancement, and comparing to other oxides and optimized platinum.