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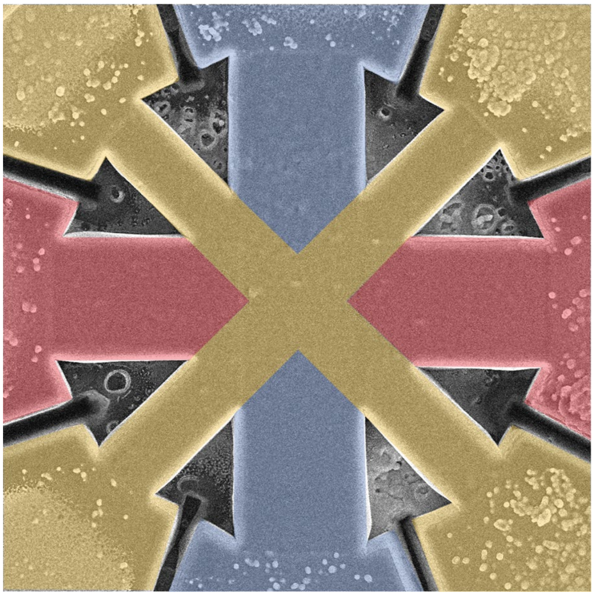
ANTIFERROMAGNETIC SPINTRONICS

Transition metal dichalcogenides to the rescue

> We have discovered a new switching mechanism and a material class that could be used as a component for memory and processing applications

Antiferromagnets (AFMs) are robust against perturbations from magnetic fields, produce no stray fields and can switch at THz speeds. Thus, they hold promise as materials for ultrafast, stable memories. However, precisely because of their insensitivity to magnetic fields, manipulating their magnetization is difficult. Current-induced internal fields provide a means to switch AFMs, opening up their practical applications. Writing in *Nature Materials*, James Analytis and colleagues report an antiferromagnetic memory device based on a magnetically intercalated transition metal dichalcogenide that is accessible electronically and works with very low current densities.

'We have discovered a new switching mechanism and a material class that could be used as a component for memory and processing applications,' comments Analytis. 'A graduate student, Nityan Nair, and postdoc, Eran Maniv, discovered that the material functions at ultra-low power and, in principle, can be miniaturized without loss of functionality; the spins on the iron sites respond to currents around 100 times smaller than those used in any other materials with a similar response.' The material, $Fe_{1/3}NbS_2$, consists of layers of the transition metal dichalcogenide NbS_2 intercalated with iron atoms, and exhibits an antiferromagnetic ordering up to 42 K.



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Applying current pulses along two orthogonal directions in devices based on $Fe_{1/3}NbS_2$ single crystals results in switching from a high-resistance to a low-resistance state or vice versa, depending on the current direction. The current pulses act similarly to an in-plane magnetic field, writing a preferred orientation in the antiferromagnetic state. Once switched, the device is stable. The orientation of the AFM can then be determined from resistivity measurements, thus the device works as a magnetic memory that can be written and read electronically.

'We didn't know that $Fe_{1/3}NbS_2$ would work so well, but we had clues it would work,' explains Analytis. 'The core idea is a simple symmetry argument: we knew that $Fe_{1/3}NbS_2$ has a chiral structure; we also knew it is magnetic (it contains iron). Magnetism and chirality, when combined, often enable novel magnetoelectric effects, because by symmetry they have to work together. The original research on this material was done back in the 70's by none other than Stuart Parkin (one of the pioneers of giant magnetoresistance), but they didn't look at how magnetism and chiralty could be coupled.'

Previous measurements suggested that the material has antiferromagnetic moments parallel to the *c* axis, but the strong coupling of in-plane magnetic fields with the antiferromagnetic order observed in this work hints at the presence of an in-plane component of the magnetic moments. During the writing process, current pulses reorient such in-plane components of the antiferromagnetic order, which in turn influences the resistivity of the sample, allowing electrical read-out. "Maniv's recent data suggests the behavior is much richer than what we observed so far: there is a very interesting interplay with disorder, which can also couple to the different symmetries of the system," adds Analytis. "There appear to be different magnetic instabilities that are all close in energy, and we believe there may be ways to electrically switch electrons between different magnetic states. Lots more work to do!"

The family of intercalated transition metal dichalcogenides is vast, thus it might be possible to identify materials that, based on the same mechanism, switch at room temperature. "In principle, if we could raise the temperature, these (or similar) materials could be used as the basis for magnetic memory storage, with ultra-fast responses and ultra-low powers," concludes Analytis. "We plan to try different materials, different elements and perhaps layer different magnetic systems together. So far results look promising."

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ORIGINAL ARTICLE Nair, N. L. et al. Electrical switching in a magnetically intercalated transition metal dichalcogenide. *Nat. Mater.* https://doi.org/10.1038/s41563-019-0518-x (2019)