First all-antiferromagnetic memory device could get digital data storage in a spin

January 14 2016

If you haven't already heard of antiferromagnetic spintronics it won't be long before you do. This relatively unused class of magnetic materials could be about to transform our digital lives. They have the potential to make our devices smaller, faster, more robust and increase their energy efficiency.

Physicists at The University of Nottingham, working in collaboration with researchers in the Czech Republic, Germany and Poland, and Hitachi Europe, have published new research in the prestigious academic journal *Science* which shows how the 'magnetic spins' of these antiferromagnets can be controlled to make a completely different form of digital memory.

Lead researcher Dr Peter Wadley, from the School of Physics and Astronomy at The University of Nottingham, said: "This work demonstrates the first electrical current control of antiferromagnets. It utilises an entirely new physical phenomenon, and in doing so demonstrates the first all-antiferromagnetic memory device. This could be hugely significant as antiferromagnets have an intriguing set of properties, including a theoretical switching speed limit approximately 1000 times faster than the best current memory technologies."

This entirely new form of memory has a set of properties which could make it extremely useful in modern electronics. It does not produce magnetic fields, meaning the individual elements can be packed more closely, leading to higher storage density. Antiferromagnet memory is also insensitive to magnetic fields and radiation making it particularly suitable for niche markets, such as satellite and aircraft electronics.

If all of this potential could be realised, antiferromagnetic memory would be an excellent candidate for a so-called "universal memory", replacing all other forms of memory in computing, and transforming our electronic devices.

How did they do it?

Using a very specific crystal structure, CuMnAs, grown in almost complete vacuum, atomic layer by atomic layer—the research team has demonstrated that the alignment of the 'magnetic moments' of certain types of antiferromagnets can be controlled with electrical pulses through the material.

Dr Frank Freimuth of the Peter Grünberg Institute and the Institute for Advanced Simulation in Jülich said: "The electric current brings about a quantum mechanical torque on individual spins and allows each of them to tilt 90 degrees". An effect first predicted by Dr Jakub Zelezny in Prague, Professor Tomas Jungwirth and colleagues at Nottingham.

What makes antiferromagnets better than ferromagnets?

Ferromagnets react to external magnetic fields. For magnetic strips on credit cards or hard drives on computers, this effect is useful as it allows data to be written. But it is necessary to shield these materials from unwanted magnetic fields, generated for instance by certain kinds of medical equipment, so that data is not deleted by mistake.

Antiferromagnetic materials are not influenced by magnetic fields, and are of no use in magnetic data writing methods commonly utilised today. Until now, it has only been possible for them to be used in the field of information technology in combination with other classes of materials.

But antiferromagnets are magnetically more robust and can, in principle, be switched much faster than ferromagnets, so the research team decided to look for a way to develop them into an independent data storage material class.

As a result, they have succeeded in electrically controlling the switching and read-out of the magnetic moment of an antiferromagnetic material.

The potential

Dr Wadley said: "In contrast to current (ferromagnetic) memory technologies, our antiferromagnetic memory cannot be erased even by large magnetic fields. It also does not generate magnetic fields, meaning that the individual memory elements could be packed more closely together, leading to denser memory storage. Another foreseen advantage, which is yet to be established, is the speed by which information can be written in antiferromagnetic memories. Its physical limit is hundreds to thousands of times greater than in ferromagnets.

"The potential increase in speed of operation, robustness, energy efficiency and storage density could have a huge commercial and societal impact."

This research, funded by the Grant Agency of the Czech Republic, the Engineering and Physical Sciences Research Council (EPSRC) in the UK and an EU 7th Framework Programme Grant. Dr Wadley, working with Dr Kevin Edmonds, Dr Richard Campion, Dr Andrew Rushforth, Professor Tomas Jungwirth and Professor Bryan Gallagher in the School of Physics and Astronomy in Nottingham now intends to fully explore this new effect and to produce prototype USB demonstrator memory devices.

MMM Intermag 2016 conference

On the day this research is published (Thursday 14 January 2016) Dr Wadley will be presenting his work at the MMM Intermag conference in San Diego—the largest conference on magnetism, which is held in the USA.

He said: "In August 2013 *Nature Communications* we published our first paper on this relatively unexplored area of applied physics. This latest study has taken 2 years to complete. A few years ago the field of antiferromagnetic spintronics was a very niche area. In the last year myself and colleagues have given upward of 20 invited talks at major international conferences. In this coming year there are symposia and sessions dedicated entirely to this exciting new emergent area of electronics research."

More information: "Electrical switching of an antiferromagnet" www.science.sciencemag.org/con … 2/14/science.aab1031

Provided by University of Nottingham