Magnetism has the pull to transform our digital lives

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Credit: University of Nottingham

Digital memory and security could be transformed according to new research, which has for the first time showed that antiferromagnets can be easily controlled and read by switching the direction of ordinary electrical currents at super-fast speed.

Physicists at the University of Nottingham, have published new research in the prestigious academic journal *Nature Nanotechnology* which shows how the 'magnetic order' of these antiferromagnets can be efficiently controlled to create a memory device potentially a 1,000 times faster than current technologies – a discovery that could transform digital memory, making devices smaller, much faster, more secure and energy efficient.

Lead researcher Dr. Peter Wadley, from the School of Physics and Astronomy at the University of Nottingham said: "Recently in

Nottingham we showed for the first time that antiferromagnets can be easily controlled and read using ordinary electrical currents, and in doing so demonstrated the first all-antiferromagnetic memory device. This research takes this one step further and shows an even more efficient way of controlling them with fewer electrical contacts. Using antiferromagnets in spintronics is not an incremental change from previous approaches but really a whole different ball game. 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 new form of memory could be extremely useful in modern electronics. Antiferromagnets do not produce magnetic fields, meaning the individual elements can be packed more closely, leading to higher storage density. Antiferromagnetic memory is also insensitive to magnetic fields and radiation making it particularly suitable for niche markets, such as satellite and aircraft electronics.

Explaining magnetism

Magnetic materials have been technologically important for centuries, from the compass to modern hard disks. However almost all of these materials have belonged to one type of magnetic order : ferromagnetism. This is the type of magnet we are all familiar with from fridge magnets to washing machine motors and computer hard disks. They produce an external magnetic field that we can "feel" because all of the tiny atomic magnetic moments that constitute them like to align in the same direction. It is this field that causes fridge magnets to stick and that we sometimes see mapped out with iron filings.

Because they lack an external magnetic field antiferromagnets are hard to detect and until now hard to control. For this reason they have found almost no applications. Antiferromagnets produce no external magnetic field because all of the neighboring constituent tiny atomic moments point in exactly opposite directions from each other. In doing so they cancel each other out and no external magnetic field is produced: they won't stick to fridges or deflect a compass needle.

But antiferromagnets are magnetically more robust and when you switch an antiferromagnet it can happen approximately 1000 times faster than a ferromagnet. This could create computer memory which operates far faster than current memory technology.

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. Wadley continues: "If you are able to control antiferromagnets they move very quickly. We have just demonstrated control by single picosecond laser pulses, which places them in the Terahertz regime (~1000 times faster than the best commercial memories). We have also demonstrated efficient electrical means of controlling them at room temperature using currents of the same order as commercial memory devices. This means we might not be so far from commercial application and has led to a huge amount of interest in the research field in the last 2 years."

Impact on society

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.

Dr. Wadley concludes: "With the ability to control antiferromagnets we are closer than ever to being able to apply this commercially. Antiferromagnetics have the potential to out-compete other forms of memory which would lead to a redesign of computing architecture, huge speed increases and energy savings. The additional computing power could have large societal impacts in many areas, including computing heavy areas like cancer research and research into degenerative diseases."

More information: Peter Wadley et al. Current polarity-dependent manipulation of antiferromagnetic domains, *Nature Nanotechnology* (2018). DOI: 10.1038/s41565-018-0079-1

Provided by University of Nottingham