Spinning out the future of our electronic devices

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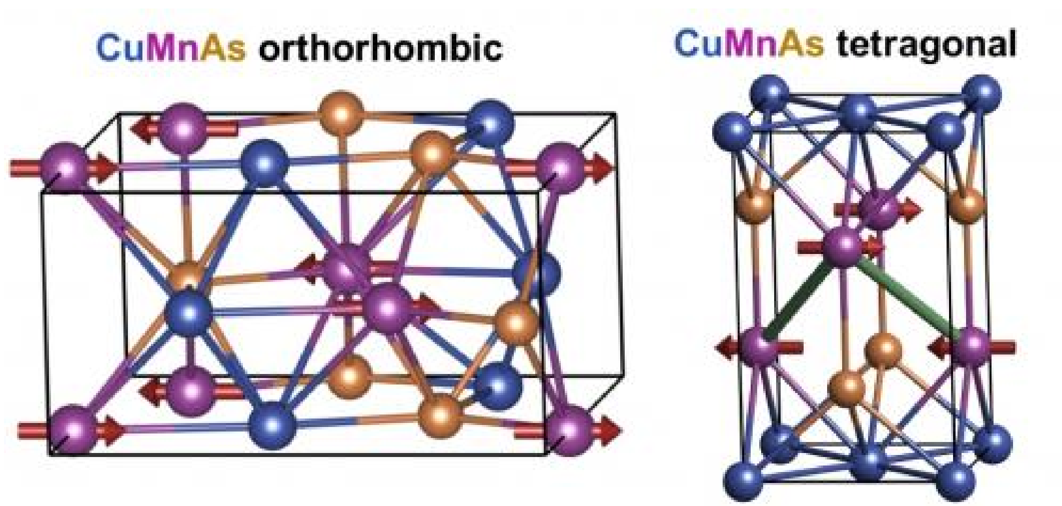

Unit cell structures of the new antiferromagnetic spintronic material, orthorhombic CuMnAs and tetragonal CuMnAs. Credit: STFC

To satisfy the world's desire for ever more processing power, at ever diminishing energy cost, in even tinier devices, scientists are looking to spintronics (spin transport electronics) to provide the next generation of high-speed, high-efficiency electronic devices.

New research, led by a team of physicists at The University of Nottingham, and published on 20 August 2013, in the journal *Nature Communications*, reports on the development of a new antiferromagnetic spintronic material, tetragonal CuMnAs, which could provide one of the answers.

Dr Peter Wadley, a research fellow in theSchool of Physics and Astronomy, said: "We are working in a relatively unexplored area of applied physics and our research provides fresh insight into the basic physics of the new field of antiferromagnetic spintronics. This material has provided us with the possibility of designing new device structures for the microelectronics industry combining spintronic and nanoelectronic functionality at room temperature."

Where conventional electronics rely only on the charge property of electrons, spintronics makes use of another fundamental quantity of electrons, termed spin.

In antiferromagnets, electron spins on adjacent atoms tend to cancel each other out. It is therefore surprising that they can perform an active role in spintronic devices. However, recent calculations and experiments have indicated a range of new physical phenomena associated with antiferromagnets, with potential memory and sensing applications. This new material, with high crystal quality and compatibility with existing semiconductors, is a promising candidate material for the new field of antiferromagnetic spintronics.

Combining logic functionality with storage capability

Most modern electronic devices are based on conventional semiconductor logic technology, which relies on the presence or absence of electrons carrying charge to operate. On the other hand many forms of memory, for example conventional hard disks, use magnetism to store data.

Dr Wadley said: "For a long time it has been the desire of physicists and industry to combine these two properties - the logic functionality of semiconductors with the storage capability of magnets - into a single material. And this is part of what spintronics is trying to do. In spintronics you rely not only on the presence or absence of charge, but also on a fundamental quantum property of electrons called their 'spin'."

Traditionally the team in the School of Physics and Astronomy at Nottingham have been accomplishing this by 'doping' conventional semiconductors with magnetic elements in order to produce dilute ferromagnetic semiconductors. This is an area that has spawned a lot of new physics and functionality, but it has suffered from a major drawback. The difficulty has been in transferring this technology into a commercial capacity because the operating temperatures are too low – devices would stop functioning at room temperature.

From ferromagnetic to antiferromagnetic

The Nottingham team, in collaboration with the Institute of Physics ASCR (Prague), decided on a different approach to the problem. They started to look at materials that are not ferromagnetic but antiferromagnetic, which is a different form of magnetic order. Antiferromagnets are already used in modern electronics but only in a secondary passive role. However, recent research has shown that they can be used as an active component in electronic devices.

Dr Wadley said: "Looking at antiferromagnets as an active component of spintronic devices opens up a whole new array of material systems to explore, many of which have high critical temperatures. With CuMnAs we now have a very nice system for exploring the new field of antiferromagnetic spintronics."

New compound grown atomic layer by atomic layer

This new compound, which is grown one atomic layer at a time, shows a number of favourable properties including a high operating temperature and compatibility with common semiconductor materials used in mainstream electronics. To establish the magnetic properties of this new material, at the atomic level, cutting-edge neutron diffraction experiments were conducted at the WISH instrument, at the ISIS neutron facility, in collaboration with Dr Dmitry Khalyavin and Professor Sean Langridge.

Professor Sean Langridge said: "Performing neutron diffraction on layers a thousand times thinner than a human hair is challenging, but the WISH instrument at ISIS is well equipped to tackle such demands. Using WISH, we were able to provide unique, absolute atomic-scale information on the antiferromagnetic structure that was vital to the understanding of this fascinating material."

The future is in a spin

Spintronics offers the possibility of lower power consumption which enables higher density computation and storage. And since antiferromagnets have no associated magnetic field, antiferromagnetic spintronics means individual devices do not interact with one another and in theory they can therefore be packed together even more densely.

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