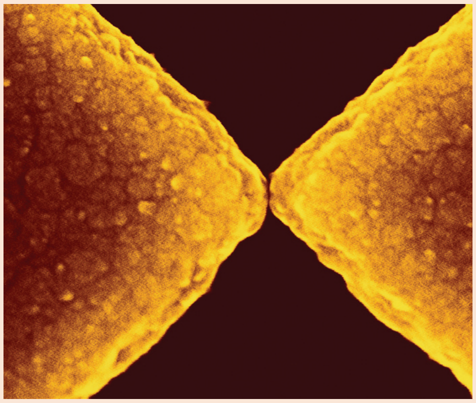
Anisotropic magnetoresistance goes ballistic

MAGNETIC MATERIALS

The desire for increased storage density means that magnetic read sensors need to be miniaturized. Scaling down these devices to the subnanoscale leads to different behavior from that observed in bulk materials. Researchers from the University of Nebraska-Lincoln (UNL) and the Institut de Physique et de Chimie des Matériaux de Strasbourg (IPCMS), France have demonstrated experimentally that the nature of anisotropic magnetoresistance (AMR) in atomic-size conductors is profoundly different because a ballistic mechanism of electron transport occurs in the absence of scattering [Sokolov *et al.*, *Nat. Nanotechnol.* (2007) doi:10.1038/nnano.2007.36].

AMR is the change in the electrical resistance of ferromagnetic bulk metals with magnetization direction, and was recognized as important following the development of thin film technology.

By measuring, *in situ*, the ballistic conductance of electrodeposited Co nanocontacts, the researchers find that the conductance changes in a step-wise fashion when the saturation magnetic field changes direction. This behavior is the signature of the ballistic AMR (BAMR) effect, which stems from spin-orbit coupling and conductance quantization. When the dimensions of a metallic conductor are comparable to the electron's wavelength, the conductance becomes quantized, reflecting the discrete number of electronic bands crossing the Fermi energy. Varying the magnetization direction changes the number of bands at the Fermi energy because of the spin-orbit interaction, and hence the magnitude of the quantized ballistic conductance.



Scanning electron micrograph of a magnetic nanocontact obtained by the electrochemical filling of a prepatterned 100 nm gap between electrodes. [Courtesy of B. Doudin (IPCMS) and A. Sokolov (UNL).]

"We think that BAMR may be appealing for future generations of ultra-small electronic devices, such as magnetic read heads, quantum switches, and logic circuits, because of the possibility to control the quantized conductance by applied magnetic fields" says Andrei Sokolov of UNL.

Catherine Reinhold

Unraveling the superconductivity mystery

MAGNETIC MATERIALS

Although 20 years have passed since the discovery of high-temperature superconductivity, a satisfactory theoretical explanation for the phenomenon has still not been found. Researchers from the Carnegie Institution of Washington, the South China University of Technology, and the Chinese University of Hong Kong have begun to unravel the mystery with the discovery that two different physical parameters – pressure and the substitution of different isotopes of oxygen – have a similar effect on the properties of cuprate superconductors [Chen *et al.*, *Proc. Natl. Acad. Sci. USA* (2007), doi: 10.1073/pnas.0611473104].

High-temperature superconductors, such as ceramic Cu oxides, have much higher superconducting transition temperatures T_C, the temperature where electrical resistance disappears, than conventional superconductors. The isotope effect, where one isotope of an element is substituted for another, is an important experimental probe for revealing the underlying mechanism of superconductivity. In conventional superconductors, the isotope effect provided key evidence for phonon-mediated pairing. However, the situation is much more complex in high-T_C superconductors.

Cuprate superconductors consist of Cu and O atoms in a layered structure. In this study, the researchers substituted ^{16}O with the heavier ^{18}O, and obsreved a change in the transition temperature. The different masses of the isotopes cause a change in lattice vibrations, which in turn affects the binding force that pairs electrons together to travel through the material freely.

The researchers also show that manipulating the compression of the crystalline lattice of the high-temperature material has a similar effect on the superconducting T_C.

The results suggest that phonons are integral to the flow of electrons by binding electrons in pairs under these conditions. The researchers suggest that lattice vibrations are important to the way the high-T_C materials, as well conventional superconductors, function and that the role of phonons should not be overlooked to explain cuprate superconductivity.

Catherine Reinhold

Disorder for spintronics

MAGNETIC MATERIALS

A team of researchers from JILA (a joint venture between the University of Colorado and the National Institute of Standards and Technology, Colorado) and the University of Manchester, UK has used ultrashort pulses of laser light to reveal why some electrons hold their spin positions better than others [Chen *et al.*, *Nat. Phys.* (2007) doi:10.1038/nphys537]. This work may help to improve spintronic devices, which exploit the spin of electrons in addition to or instead of their charge.

Successful implementation of spin-based electronics requires preservation of the electron spin coherence.

In the case of spintronic circuits, electrons need to maintain their spin states for tens of nanoseconds while traveling microscale distances through electronic circuits or between devices.

The researchers show that electrons actually hold their spins the longest (three nanoseconds) when confined around defects or disordered areas in semiconductors, and loose their spin alignment in just a few hundred picoseconds when flowing through perfect areas of crystal. This explains the role of electron density. At very low densities, electrons are strongly confined to different local environments, whereas at extremely high densities, electrons start colliding and lose spin coherence quickly. The point of maximum spin coherence occurs at the crossover between these two conditions.

This work is the first to characterize the electronic disorder in semiconductors and connect it to spin dynamics. However, the results present a design challenge for spintronic devices because of the compromise required between increasing spin-coherence time and improving transport properties.

Catherine Reinhold