NEWS

May 7, 2007

Speckles expose magnet's noisy secrets

Physicists have long been able to measure the tiny thermal fluctuations in the magnetization of ferromagnetic materials like iron, but measuring similar "noise" from antiferromagnetic materials like chromium has proved far harder. Now, however, physicists in the US and the UK have measured these fluctuations in an antiferromagnet for the first time and found that they occur at surprisingly low temperatures. This means that it could be difficult to use antiferromagnets in certain data-storage and spintronic devices (*Nature* 447 68).

Ferromagnets such as iron can contain tiny "domains", in which all the individual magnetic moments point in the same direction. In an unmagnetized piece of iron, the magnetic moments of the individual domains can point in different directions, but by applying a magnetic field the domains can be made to point in the same direction. This gives the material a bulk magnetic moment – or magnetization -- that persists even if the field is removed.

It has been known for almost a century that thermal energy can cause random movement of the boundaries between domains – called domain walls. This “noise” can be measured by detecting small jumps in the magnetization using a coil of wire placed near the ferromagnet and it can provide information about a material's magnetic properties.

However, measuring similar fluctuations in antiferromagnets had not been possible. The problem is that these materials, in which the magnetic moments of neighbouring atoms point in opposite directions, have no bulk magnetization. It is therefore impossible to detect the fluctuations using conventional magnetic probes such as a coil.

Now, Oleg Shpyrko and colleagues at Argonne National Laboratory near Chicago have worked out a clever way to eavesdrop on the antiferromagnetic domain walls in chromium using a beam of coherent X-rays from Argonne’s Advanced Photon Source.

Working with physicists from the University of Chicago and University College London, the team exploited the fact that antiferromagnetism in chromium arises from its conduction electrons rather than the atoms themselves. The electrons exist in “spin density waves" (SDWs), in which the spin density of the electrons alternates in direction, and the amplitude of the magnetization varies sinusoidally with position. Although the X-rays could not probe the SDWs directly, each SDW is accompanied by a commensurate electron charge density wave (CDW), the presence of which can be detected using a technique called X-ray photon correlation spectroscopy (XPCS).

The team scattered a coherent beam of X-rays from a chromium sample. This produced an interference pattern called a speckle that was captured by a CCD camera over a period of several hours. The precise appearance of the speckle pattern is related to the arrangement of CDWs in a tiny portion of the sample. By watching how the speckle changed over time, Shpyrko and colleagues were able to observe changes in the antiferromagnetic domains over distances a small as 1 µm.

Shpyrko told *Physics Web* that the group were somewhat surprised to see domain fluctuations occurring on a timescale of about one hour at temperatures as low as 4 K. Physicists usually regard domain walls as relatively large structures that require a significant amount of thermal energy to move. The Argonne result, however, suggested that at very low temperatures the walls are moving thanks to quantum mechanical tunnelling.

Antiferromagnetic materials are currently used in read heads for magnetic storage devices and show promise for use in spintronic devices, which could make use of both the spin and charge of the electron to process information. However, any future technologies that rely on the precise location of antiferromagnetic domains could be affected by this tunnelling. A solution, according to Shpyrko, is the introduction of defects or impurities in the antiferromagnetic materials, which tend to fix the domain locations.

The researchers are now turning their attention to the study of other magnetic materials including those that can contain both ferromagnetic and antiferromagnetic domains. Shpyrko also believes that the technique could be used to study quantum phase transitions in antiferromagnets.

About the author

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