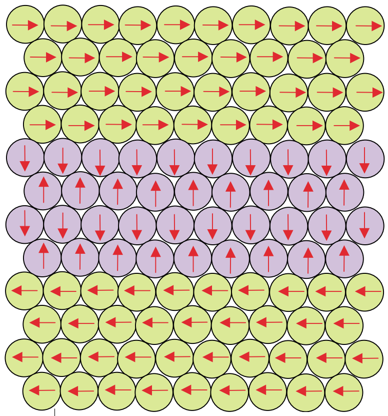
Ultrathin layers of magnetic materials have huge potential for the electronics industry but show complex behaviour uniquely studied by neutrons

Magnetic multilayers

>> JON GOFF

Jon Goff working at ILL



The magnetic structure of the iron manganese $[Fe_9/Mn_4]_{300}$ multilayer

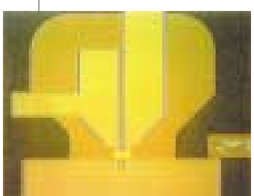
Over the past 20 years, physicists have developed techniques that allow them to deposit, in a controlled way, sequential layers of atoms in regular crystalline planes on a surface. One such method is molecular beam epitaxy (MBE) in which beams of atoms are fired onto a surface. As a consequence it is now possible to create, for example, multilayers of metals with exotic magnetic properties. Magnetic multilayers have a panoply of practical applications. They can be used to produce devices that exploit the spin rather than the charge of the electron. This new field of magnetoelectronics looks set to revolutionise the electronics industry.

One type of device made of magnetic layers, called a spin valve, is already employed as a read head for computer hard disks, and this has led to dramatic improvements in data-storage densities. Arrays of spin valves have also been used to create non-volatile random access memory (meaning the information is not lost when the computer is switched off).

Exploring magnetic ordering

Studies of magnetic multilayers are also opening a new window on our understanding of magnetism. By alternating layers of metals with different magnetic properties, for example, we can explore how magnetic ordering (the precise arrangement of the electron spins in the layers) propagates across the layers. The coupling mechanism between the layers is often intricate, and neutron scattering techniques are ideal for investigating them. Instrument D10 at ILL has been used to study a number of magnetic systems which aim to throw light on important problems in condensed matter research.

A magnetic read head based on the spin-valve concept



Seagate

Recently, we have been investigating multilayers made from transition metals, iron (Fe) and manganese (Mn), which will allow us to understand the basic physics underpinning the next generation of magnetoelectronic devices. Of particular interest is what happens at the interfaces between the layers.

Manganese at room temperature has an unusually complex crystal structure and we don't know how the spins are ordered in this form. However, at elevated temperatures, manganese forms much simpler cubic crystals. Fortunately, MBE provides a unique way of depositing this cubic form at low temperatures using an iron layer as a template. In this way a multilayer could be built up of composition $[Fe_9/Mn_4]_{300}$, where the subscripts labelling the elements refer to the number of atomic planes in the average bilayer and the last subscript to the number of bilayers.

Iron is, of course, ferromagnetic, with all spins aligned. We found, however, that the blocks of nine Fe layers coupled antiferromagnetically (spins oppositely aligned) across the manganese blocks at room temperature. The Mn itself orders with a simple antiferromagnetic structure below a temperature of 187K with spins pointing along the growth direction, perpendicular to those of the Fe (see figure above). Furthermore, the neutron scattering results show that the Mn blocks also couple across the iron blocks.

Theory predicts that the cubic manganese would form either an antiferromagnetic structure with spins in the same direction as the iron, or a helical structure. The fact that the moments in the Mn are perpendicular to those of the Fe may be due to conflicting magnetic interactions (frustration) at the interfaces. ■

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