Neutrons have helped uncover exciting new materials that conduct electricity without resistance

Inside high temperature superconductors

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An artist's impression of a German Transrapid maglev train being built in Shanghai using superconducting technology

Oxides are normally insulators because their electrons are intimately associated with the atoms. Metals can conduct because the electrons are free to move. But there are some oxides that become electrical superconductors, having zero electrical resistance above the temperature of liquid air – cold but easy to produce and handle. This is truly amazing, and a few years ago would have been thought impossible.

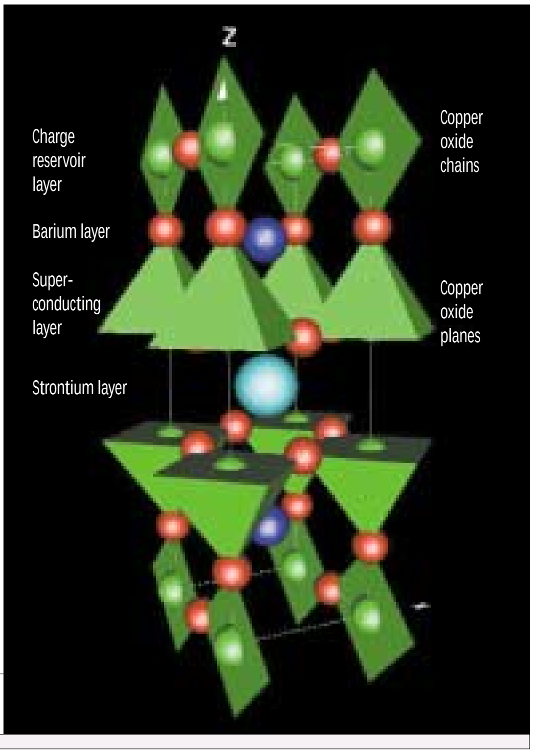
Neutrons were important for understanding why one of the most famous of these materials, YBCO ($YBa_2Cu_3O_7$) could be either insulating or superconducting, depending on how it was produced. The difference was found to be the amount of oxygen, and oxygen is much more easily seen with neutrons than with X-rays. Neutron diffraction at ILL and elsewhere found that the superconducting layers were 'doped' by so-called 'charge reservoir' layers – the square copper oxide chains in the figure opposite.

This neutron picture of the structure immediately suggested a search for other materials containing different charge reservoirs – a very successful search since much higher superconducting temperatures were soon found in materials containing bismuth or mercury oxide charge reservoirs. There are many uses for materials as strange as superconductors, apart from simply making very efficient power cables and faster, cooler computer chips.

3D brains and levitating trains

One of the most important applications for these new superconductors is in making more efficient electromagnets, such as those used in hospitals for magnetic resonance scanners. Instead of using X-rays, a patient is placed in a strong magnetic field and signals from atoms in the body tissue are recorded to reconstruct a 3D computer image of vital organs. These images can reveal blood clots in the brain, tumours and other conditions that can be precisely located and treated.

Magnets and superconductors might also be used to make more efficient maglev trains, floating above electrical coils in the 'rails'. This is possible because superconductors exclude magnetic fields from their interior – the Meissner effect. When a magnetic field is applied to a superconductor, spontaneous electric currents flow in it resulting in an induced magnetic field that exactly opposes the applied field, resulting in a repulsive force. The train can then be supported, guided and even propelled using a kind of linear electric motor in the rails. ■



The layered structure of yttrium barium copper oxide showing the square copper-oxide chains

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