Breakthrough in high-temperature superconductivity

August 18 2005

Scientists at the University of Aberdeen have made a major breakthrough towards the mechanism of high-temperature superconductivity. Results from studies of a crystal structure of a new chemical compound containing copper and ruthenium have provided valuable insight into the mechanism of high-temperature superconductivity. The new results have shown for the first time that the mechanism of high-temperature superconductivity (when there is no resistance to the flow of electrical current) is actually coupled to the crystal lattice.

This is extremely exciting as this new discovery could lead to a breakthrough in the theory of high-temperature superconductivity, which has been puzzling scientists for nearly 20 years, according to a study published in this week's issue of Nature.

A metal consists of a lattice of atoms. Electrons can dissociate from these atoms and travel through the lattice making the metal a conductor of electrical current. The atoms within the metal are actually vibrating. The electrons, which are travelling through the lattice, can collide with the vibrating atoms and this results in a reduction of the electrical current. This is known as electrical resistance. Superconductors are so-called because they do not exhibit electrical resistance and hence do not suffer from losses in electrical current.

Dr Abbie Mclaughlin, RSE Fellow, Department of Chemistry, is leading the research and explains: "We are interested in the chemistry of materials that show fascinating physical properties which may be important in the technologies of the future. We are particularly interested in synthesising new layered materials which have an interesting property, such as magnetism, in one layer and another property, such as superconductivity, in another layer. It is then possible to observe how the two different phenomena compete with one another which can in itself lead to the observation of novel physics."

Unlike normal conductors a superconductor exhibits zero electrical resistance. Unfortunately, superconductivity is only observed at very low temperatures. Currently, the record temperature at which superconductivity is observed is -113 °C. Practical applications include superconducting magnets for MRI scanners and magnetic levitation trains.

Chemical compounds that superconduct at temperatures >-238°C are known as "high-temperature superconductors". There is currently no complete theory for high-temperature superconductivity. However it is thought that once a final theory has been established it will be possible to design new superconducting materials which show no electrical resistance at higher temperatures – with the possibly at room temperature.

Dr Mclaughlin continued: "This would lead to a plethora of technological possibilities such as high performance electric motors. At the same time there would be a huge conservation in energy by using superconducting power cables to transmit electricity to consumers. At present a considerable amount of energy is lost due to electrical resistance. "

Energy losses due to electrical resistance in the transmitting power cables were reported at 7.4% in the UK in 1998.

At the same time this new chemical compound being developed by Dr

Mclaughlin and collaborators - a copper and ruthenium containing oxide material - also exhibits a variety of other useful properties. Firstly, a phenomenon known as negative magnetoresistance, has been observed at low temperature. Materials exhibiting this property show a large increase in electronic conductivity on application of a magnetic field and are currently used in memory storage devices in computers.

At low temperatures this new compound also exhibits a property known as negative thermal expansion. Most materials expand as they are heated but this is not the case for this new compound. Negative thermal expansion is extremely unusual and practical applications can be found in areas ranging from electronics to dentistry.

Dr Mclaughlin added: “This collaborative research project aims to shed more light on the theory of high-temperature superconductivity. We also hope to learn more about the mechanism behind the large negative magnetoresistances and negative thermal expansion observed in this material and hopefully design new materials which could then be used in practical applications at room temperature.”

The collaborative research project involves Professor Paul Attfield from the Centre for Science at Extreme Conditions and School of Chemistry, University of Edinburgh, and Dr Falak Sher from the Department of Chemistry, University of Cambridge. They bring together a unique blend of materials chemistry to develop and study new materials with fascinating properties.

For a full copy of the paper which is published in this week’s edition of Nature, please visit: www.nature.com/nature/journal/ … abs/nature03828.html