Study Yields Surprising New Insight into High-Temp Superconductors

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(PhysOrg.com) -- Recently, an international group of researchers discovered that the underlying mechanism producing high-temperature superconductivity in a widely studied class of copper-oxygen-based superconductors may be different than scientists have long been assuming.

The research group, composed of scientists from institutions in the UK, China, Switzerland, and Japan, was studying one member of a class of compounds that do not contain copper yet can superconduct at temperatures in the region of a few dozen degrees Kelvin (while still ultra-cold by everyday standards, these temperatures are much "warmer" than those needed by conventional superconductors).

The new materials are called pnictides. They have very similar layered structures as the copper-oxygen compounds (known as cuprates), containing alternating layers of FeAs (iron arsenide) compared to alternating layers of CuO (copper oxide) for the cuprates. Both the pnictides and cuprates only become superconducting when significantly "doped" away from an antiferromagnetic parent compound via the addition of impurity atoms.

The discovery that pnictides become superconductors in the high-temperature range (by researchers in Japan, announced in January 2008) was surprising because, until that point, the only layered-structure materials that superconduct in this range were cuprates. The finding sparked speculation among researchers in the field as to whether the

pnictides work in a similar way as the cuprates.

"We discovered that the pnictides and the cuprates share a common magnetic trait, suggesting that the mechanisms governing high-temperature superconductivity in the cuprates may be related to magnetic correlations," said the study's corresponding researcher, physicist Alan Drew of Queen Mary University of London and the University of Fribourg, in Switzerland, to *PhysOrg.com*.

In the February 22 online edition of Nature Materials, Drew and his colleagues present research showing that cuprates and pnictides have similar magnetic properties and that both display a link between magnetism and superconductivity. The pnictide they studied is SmFeAsO1-xFx, where Sm is the rare metal samarium and fluorine (F) is a dopant. The "x" subscript indicates that the number of oxygen and fluorine atoms can vary.

The group studied the material using a technique called muon spin rotation/relaxation, in which muons are implanted into the sample. Muons are subatomic particles that can be thought of as very heavy electrons. They can probe the magnetic environment of a material at the smallest level because of their "spin," a property that gives a particle a very small magnetic field, like a tiny bar magnet.

Watching how the muons' polarization changes—rotates, relaxes, etc.—as it interacts with the nuclei and electrons in the sample yields information about the sample's atomic-level magnetic properties. The group used this technique to record the magnetic changes occurring in the material as they doped it with fluorine atoms.

"Our test revealed an obvious overlap of superconducting and magnetic states in the material, even at doping levels where we would expect the magnetism to disappear," said co-researcher Christian Bernhard of the

University of Fribourg. "This suggests to us that scientists may need to question what we think we know about cuprates."

High-temperature superconductivity in the cuprates is widely believed to be due to charge carrier pairing. Electrons teams up with other electrons to form "Cooper pairs," which move through the material's copper-oxide layers. Exactly what causes the electrons to pair up is still not known, however.

More information: A. J. Drew, Ch. Niedermayer, P. J. Baker , F. L. Pratt, S. J. Blundell, T. Lancaster, R. H. Liu, G. Wu, X. H. Chen, I. Watanabe, V. K. Malik, A. Dubroka, M. Rössle, K. W. Kim, C. Baines and C. Bernhard, *Nature Materials* advance online publication, 22 February 2009 DOI: 10.1038/nmat2396