Quantum fluctuations are key in superconductors

January 8 2010

(PhysOrg.com) -- New experiments on a recently discovered class of iron-based superconductors suggest that the ability of their electrons to conduct electricity without resistance is directly connected with the magnetic properties of those electrons.

Results of the experiments appear in the Jan. 8 issue of *Physical Review Letters*. The tests, which were carried out by a team of U.S. and Chinese physicists, shed light on the fundamental nature of high-temperature superconductivity, said Rice physicist Qimiao Si, a co-author on the study.

If better understood, high-temperature superconductors could be used to revolutionize electric generators, MRI scanners, high-speed trains and other devices.

In the study, scientists from Rice University, the University of Tennessee, Oak Ridge National Laboratory (ORNL), the National Institute of Standards and Technology (NIST), the Chinese Academy of Sciences' Institute of Physics and Renmin University in Beijing examined several iron-arsenide compounds. These are the "undoped" parents of the iron "pnictides" (pronounced: NICK-tides), a class of materials that were found to be high-temperature superconductors in 2008.

The experiments set out to test theoretical predictions that Si and collaborators published in the Proceedings of the National Academy of

Sciences last March. They predicted that varying the size of some atoms in the parent compounds could allow physicists to tune the material's quantum fluctuations. These types of fluctuations can create tipping points called magnetic "quantum critical points," a state that exists when a material is at the cusp of transitioning from one quantum phase to another.

Using neutron-scattering facilities at NIST and ORNL, the team bombarded the materials with neutrons to decipher their structural and magnetic properties. The tests, which supported Si's theoretical predictions, determined that the strength of magnetic order in the materials was reduced when arsenic atoms were replaced with slightly smaller phosphorus atoms.

"We found the first direct evidence that a magnetic quantum critical point exists in these materials," Si said.

The results were made possible by the efforts of Nanlin Wang, a physicist from the Chinese Academy of Sciences' Institute of Physics, and his research group. They created a series of samples with varying amounts of phosphorous substituting for arsenic.

The discovery of high-temperature superconductivity in copper-oxide ceramics in 1986 led physicists to realize that quantum effects in electronic materials were far more complex than anticipated. One of these effects is quantum criticality. Criticality occurs near a tipping point that a material goes through when it changes phases. Many phase changes -- like ice melting into water -- occur because of thermal fluctuations. But quantum criticalities and quantum phase changes arise solely from quantum fluctuations.

"Our finding of a quantum critical point in iron pnictides opens the door for new avenues of research into this important class of materials," said

University of Tennessee/ORNL physicist Pengcheng Dai, a neutron scattering specialist.

Si said, "The evidence from this study bolsters the hypothesis that high-temperature superconductivity in the iron pnictides originates from electronic magnetism. This should be contrasted to conventional low-temperature superconductivity, which is caused by ionic vibrations."

Provided by Rice University

Citation: Quantum fluctuations are key in superconductors (2010, January 8) retrieved 24 April 2024 from https://phys.org/news/2010-01-quantum-fluctuations-key-superconductors.html