Researchers team up to probe iron-arsenic superconductors with new instrument

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Researchers at the U.S. Department of Energy's Ames Laboratory are part of collaborative team that's used a brand new instrument at the DOE's Spallation Neutron Source to probe iron-arsenic compounds, the "hottest" new find in the race to explain and develop superconducting materials. Rob McQueeney, an Ames Laboratory physicist, was part of that team whose findings, published in the Oct. 10 issue (101) of *Physical Review Letters,* mark the first research produced with the aid of the new tool.

The Spallation Neutron Source – SNS for short – is the DOE's sprawling new $1.4 billion complex operated by Oak Ridge National Laboratory in the rolling green hills of eastern Tennessee. The SNS uses a pulsed neutron beam to provide information about the structure and dynamics of materials that cannot be obtained from X-rays or electron microscopes. Although neutral in electrical charge, neutrons interact with the nucleus. The neutron's magnetic moment can also interact with magnetic spins in a material. As neutrons from the beam pass through a material, they scatter off the nuclei and spins. By measuring the speed and angle of the scattered neutrons, scientists are able to develop detailed information about the positions and the motion of the nuclei and spins within the material.

McQueeney serves on the Executive Committee of the Instrumentation Development Team for ARCS, a wide angular-range chopper spectrometer designed to measure the vibrations of atomic nuclei. The sixth of the proposed 24 instruments to be built at the SNS, ARCS is undergoing final testing and is available for general use this fall, but McQueeney is already impressed with the results.

"The preliminary results are amazing," McQueeney said. "I have experience with a similar instrument and ARCS blew it away," adding that it produces better results from smaller samples in a much shorter time frame.

The timing of the testing phase for ARCS was ideal because in the preceding months, a new class of superconducting materials – pnictide compounds based on iron and arsenic – was discovered. This allowed McQueeney and collaborators at Oak Ridge National Laboratory and California Institute of Technology to look specifically at lanthanum-iron-arsenide (LaFeAsO0.89F0.11). One of the samples studied was produced by McQueeney's Ames Laboratory colleague, physicist and crystal-growth expert Paul Canfield. When this new class of superconductors was first announced, Canfield was able to quickly replicate the results and develop additional compounds.

The phenomenon of superconductivity is caused by the pairing of conduction electrons due to forces within the crystal. The origin of this pairing is one of the great unsolved mysteries in the field of high-temperature superconductivity.

"There are two prevailing ideas behind superconductivity," McQueeney said. "One is that pairing is mediated by lattice vibrations. The other is that it's mediated by magnetic or spin fluctuations."

Since neutrons are capable of measuring both the lattice vibrations and spin fluctuations, they are an ideal probe to gain an understanding of superconductivity.

The experiments focused on understanding the role of lattice vibrations in the new superconductors. The vibration of atoms within the crystal lattice creates a pattern of waves called phonons. When a neutron collides with this lattice, it can give up some of its energy to create a phonon. The difference in the neutron's energy before and after the collision is equal to the phonon energy.

"Our measurements did not support the conventional electron-phonon mediated superconductivity," McQueeney said, adding that theoretical calculations matched up fairly well with measurements obtained with ARCS. While the results are an important first step, there is still much work to be done to determine the origin of superconductivity in the iron-arsenides. McQueeney and his collaborators are continuing studies of phonons and spin excitations in these compounds.

The quest to understand and develop superconductor technology has important energy implications. By their nature, and as the name implies, superconductors can conduct electrical current with virtually no power loss, unlike conventional electric transmission lines which lose up to 30% due to resistance in the system. Basic research to understand the atomic interactions that make superconductors work, and to potentially control those properties, is one way that Ames Laboratory strives to address the scientific challenges facing our country.

Source: Ames Laboratory

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