Complex order parameter in unconventional ruthenate superconductors confirmed

Since its superconducting properties were first discovered over a decade ago, the pairing symmetry of strontium ruthenium oxide has been widely explored and debated. Now, a team of scientists led by FS-MRL researcher, Dale Van Harlingen, that includes graduate students Francoise Kidwingira and Joel Strand, and Yoshiteru Maeno (Kyoto University) believe the debate is over. Their observations provide pretty unambiguous evidence for ‘p-wave’ symmetry with a complex order parameter that breaks time-reversal symmetry in this unconventional superconductor. Their discovery was reported in the Nov. 24 issue of the journal Science.

The superconducting order parameter characterizes the nature of the pairing interaction that forms Cooper pairs. It controls many of its properties, and provides a crucial clue to the microscopic mechanism responsible for the superconductivity. Conventional superconductors that form Cooper pairs through phonon interactions have an “s-wave” symmetry with an isotropic order parameter. Unconventional superconductors, however, have anisotropy in either or both the phase and magnitude of the order parameter.

Using Josephson interferometry, a technique that Van Harlingen’s group pioneered a decade ago, the researchers showed that the high-temperature superconducting cuprates had “d-wave” symmetry. Using this approach, they observed highly modulated diffraction patterns across single edge junctions, which implies the existence of chiral domains. Abrupt changes seen in the diffraction patterns as a function of magnetic field or time indicate these domains are dynamical, changing their size or orientation. The presence of these domains and the distinctly different diffraction patterns observed on orthogonal faces of the same single crystal confirms the ‘p-wave’ triplet spin pairing state and the complex nature of the superconducting order parameter in the ruthenate superconductors. They are now applying the technique to a wide range of superconducting materials suspected of having unconventional symmetry.

This work is partially supported by DOE/BES Materials Sciences and Engineering Division through the FS-MRL Materials Research Cluster (MRC) on Quantum Materials at the Nanoscale.

UI News Bureau Physical Sciences Editor James E. Kloeppel contributed to this article.
Each quarter, Advances introduces the researchers involved in the FS-MRL and highlights their recent accomplishments. Our research activities are extending the frontiers of materials science. Together, we are transforming fundamental scientific discoveries into technological advances in the areas of flexible electronics, superconductor devices, photonics, and energy materials (e.g., catalysts, fuel cells, and photovoltaics).

I hope that you enjoy learning more about the Frederick Seitz Materials Research Laboratory and our impact on the scientific community and society as a whole.

Jennifer A. Lewis
FS-MRL Interim Director

3D heterogeneous systems - the next generation of electronics

John Rogers, Ralph Nuzzo, and their research team have developed simple methods that allow the integration of wide ranging, dissimilar classes of transistors and other semiconductor devices on a single substrate, in two- or three-dimensional layouts. The approach uses specialized rubber “stamps” with functional “inks” consisting of high performance semiconductor materials in the form of ribbons, wires, and bars. A printing operation delivers these materials to virtually any type of substrate, including lightweight, flexible plastic sheets. Circuits built in this way offer electrical and mechanical attributes that would be impossible to achieve using conventional, wafer-based approaches to electronics.

Rogers and his co-authors explain the fabrication processes together with the operation of the resulting devices and circuits in their recent paper, which appeared in the December 15, 2006 issue of Science magazine. The process begins with the synthesis of different semiconductor nanomaterials on separate substrates. Repeated application of an additive, transfer printing process that uses elastomeric stamps and these nanomaterials as ‘inks’ yields high performance 3D-HGI electronics that incorporate any combination of these (or other) semiconductors.

Their paper demonstrates several devices, including silicon MOSFETs, GaN HEMTs, GaAs diodes and even transistors that use carbon nanotubes, formed in various combinations on rigid as well as mechanically flexible substrates in single and multilayer configurations. Besides these examples, the same methods enable integration of optical, sensing and micromechanical devices with these electronics to yield complete, multifunctional systems.

This work is supported by DOE/BES Materials Sciences and Engineering Division through the FS-MRL Materials Research Cluster (MRC) on Programming Function via Soft Materials.

Office of Engineering Communications Writer Rick Kubetz contributed to this article.

Other Highlights

Charles Zukoski has been elected to the National Academy of Engineering (NAE). His citation reads “for research on the manipulation of particle interactions to alter their suspension properties, and for leadership in education.”

His research is supported by DOE/BES Materials Sciences and Engineering Division through the FS-MRL Materials Research Cluster (MRC) on Programming Function via Soft Materials.

Khalid Hattar, Ph.D. student in Ian Robertson’s group, is the winner of the Materials Today cover competition for 2006. His image, which consists of a colorized transmission electron microscopy (TEM) image of the fractal pattern created during an in situ TEM study of the Au-Si eutectic reaction at approximately 363°C, appeared on the cover of this journal’s December 2006 issue. The winning image was taken on the JEOL 4000 TEM in the FS-MRL central facilities.