More evidence for 'stripes' in high-temperature superconductors

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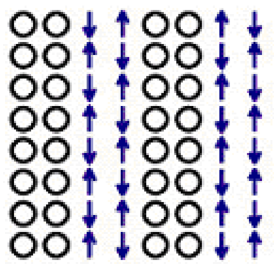

A schematic diagram illustrating stripe order in materials such as LBCO 1:8. Circles indicate the hole-doped copper sites. Up and down arrows represent magnetic moments (orientation of electron spins) on undoped copper sites. Alternating "stripes" of holes and magnetic regions may be necessary for superconductivity.

An international collaboration including two physicists from the U.S. Department of Energy's Brookhaven National Laboratory has published additional evidence to support the existence of "stripes" in high-temperature (Tc) superconductors.

The report in the April 27, 2006, issue of *Nature* strengthens earlier claims that such stripes -- a particular spatial arrangement of electrical charges -- might somehow contribute to the mechanism by which these materials carry current with no resistance. Understanding the mechanism for high-Tc superconductors, which operate at temperatures warmer than traditional superconductors but still far below freezing, may one day help scientists design superconductors able to function closer to room temperature for applications such as more-efficient power transmission.

In the material the scientists studied, as in all materials, the atoms' negatively charged electrons repel one another. But by trying to stay as far apart as possible, each individual electron is confined to a limited space, which makes the electrons "unhappy" in the sense that it costs energy. "It's like putting a bunch of claustrophobics into a crowded room," says Brookhaven physicist John Tranquada, who leads the Lab's role in this work.

To achieve a lower-energy state, the electrons arrange themselves with their spins aligned in alternating directions on adjacent atoms, a configuration known as antiferromagnetic order. Through chemical substitutions, the scientists can effectively "dope" the material with electron "holes," or the absence of electrons, to allow the electrons/holes to move more freely and carry current as a superconductor.

The big question is: How do those electrons/holes arrange themselves?

"Our earlier research suggests that the holes segregate themselves into stripes that alternate with antiferromagnetic regions," Tranquada says. Their conclusion is based on observing a similar magnetic signature in a well-known high-Tc superconductor and a material known to have such charge-segregated stripes. Ironically, the stripes in the latter material are observable only at a particular level of doping where the material loses its superconductivity. But because the magnetic spectra were so similar, Tranquada says, "We inferred that the stripes might also be present in the superconducting materials, just more fluid, or dynamic -- and harder to observe."

Since then, Tranquada's group has been looking for additional experimental signatures to back up their controversial claim. In the current experiment, they examined the effect of the stripes on vibrations in the crystal lattice. Lattice vibrations, or phonons, are known to play a role in pairing up the electrons that carry current in conventional superconductors.

At the Laboratorie Leon Brillouin, Saclay, in France, the researchers bombarded samples of superconducting materials and the same stripe-ordered non-superconductor with beams of neutrons and measured how the beams scattered. Comparing the energy and momentum of the incoming beams with those scattered by the samples gives the scientists a measure of how much energy and momentum is transferred to the lattice vibrations.

Each of these vibrations, like a vibrating guitar string, normally has a particular, well-defined frequency for a given wavelength. But in the superconductor experiment, at a particular wavelength, the scientists observed an anomaly: a wider range of frequencies in the lattice vibrations.

"It's as if a musician were able to make a single guitar string produce a chord," Tranquada says.

The scientists observed this anomalous signature most clearly in samples with observable stripe order -- that is, the special material that loses its superconductivity with a particular level of doping. But they also saw it in samples of good superconductors.

"Seeing this feature in both stripe-ordered samples and in good superconductors without static stripes leads us to believe that the signature is indicating the presence of dynamic stripes," Tranquada says.

"This result suggests that stripes are common to copper-oxide superconductors and may be important in the mechanism for high-Tc superconductivity," he adds. To further support their case, Tranquada notes that the anomalous signature goes away in cases where the superconducting material is either under- or over-doped. In this case, the material no longer acts as a superconductor, and may no longer have stripes, he says.

Source: Brookhaven National Laboratory