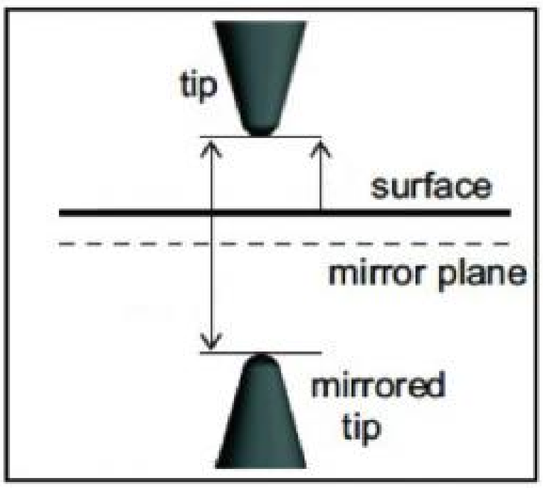
Researchers find magnetic link to high-temperature superconductivity

February 24 2011, by Lori Ann White



The sharp, magnetized tip of the probe used in this study induces an answering field in the superconductor in a phenomenon called the Meissner Effect. The strength of the response at each point gave SIMES researchers new information about the superconducting state of the pnictide. (Image courtesy Lan Luan)

Researchers from the Stanford Institute for Materials and Energy Science, a joint SLAC-Stanford institute, have seen strong indications of a relationship between the superconductive and magnetic properties of high-temperature superconductors -- a relationship long suspected but difficult to investigate experimentally. Any step toward a real understanding of high temperature superconductors is a big step right now. Today's superconductors need extreme cold to keep conducting electricity with 100 percent efficiency, but extreme cold is not cheap. If current research leads to room temperature superconductors, superconducting technologies such as loss-less power lines and levitating high-speed trains will be economically as well as technically feasible.

A paper in last week's Physical Review Letters explains how the researchers, led by Kathryn Moler, attacked the mystery by employing a new technique to investigate a suspected connection between magnetism and superconductivity in high-temperature superconductors called iron pnictides. The researchers "doped" the pnictide crystals (in this case barium iron arsenide) with varying amounts of cobalt, replacing some of the iron. Then they subjected the crystals to miniscule magnetic probes to see how they would react. They took readings mere microns apart across the face of each crystal.

"This gave us information about how many superconducting electrons were actually in a superconducting state," explained SIMES researcher Lan Luan, first author on the paper, who recently defended her doctoral thesis based on this research. Previous experiments had been able to capture data only across the bulk of a material, Luan explained, but the "spot measurements" her team took gave a more detailed look into the electronic and superconductive behavior of the pnictide.

The researchers saw three trends emerge which could be explained by an interrelationship between the magnetic and superconductive properties of the doped barium iron arsenide crystals. The first trend showed fewer electrons available to act as superconducting electrons in the underdoped crystals, which had too little cobalt for optimal superconductivity, and the overdoped crystals, which had too much. Underdoping and overdoping reduce the number of charge carriers, or electrons available to become superconducting electrons.

"The magnetic phase and the superconducting phase competed over electrons," Luan said.

The second trend revealed a connection between the amount of cobalt in the crystal and the amount of energy needed to disrupt the superconducting state—to kick electrons out of the smooth flow of charge. Again, the effects of the doping could combine with naturally occurring magnetic properties to explain the results.

The third trend showed that superconducting properties appeared more quickly in underdoped and optimally doped crystals as the temperature decreased, as if superconductivity suddenly won out over magnetism in the continuing battle for electrons.

"Unconventional superconductivity is a field full of controversy," Luan said. What controversy can't touch is the data. "This is the first quantitative data set across the superconducting dome"—from underdoped to optimally-doped to overdoped barium iron arsenide. Even if her group's exact interpretation falls, the data remain.

More information: prl.aps.org/abstract/PRL/v106/i6/e067001

Provided by SLAC National Accelerator Laboratory