Helping Out a High-Temperature Superconductor

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Researchers at the U.S. Department of Energy's Brookhaven National Laboratory have discovered a way to significantly increase the amount of electric current carried by a high-temperature superconductor, a material that conducts electricity with no resistance. This is an important step in the drive to create superconductor-based electric and power-delivery devices, such as power transmission lines, motors, and generators. The results are explained in the September 12, 2005, online edition of *Applied Physics Letters*.

"In theory, superconducting materials can conduct an enormous amount of electric current. But when incorporated into actual devices, certain factors tend to limit the current," said Brookhaven materials scientist Qiang Li, a co-author on the paper. "We studied these factors and found that one, which we call 'substrate roughness,' can actually significantly increase the current-carrying capacity."

The superconducting material studied here consists of the elements yttrium, barium, copper, and oxygen. Dubbed YBCO, it is a member of a class of copper- and oxygen-containing superconductors called "cuprates." Cuprates are "high-temperature" superconductors because they superconduct at temperatures much "warmer" than conventional superconductors (although still very cold) — for example, -300°F rather than -440°F. This difference, while not huge, is enough to make cuprates more viable for practical applications than materials that must be kept much colder.

In many of these applications, YBCO films are deposited onto a 'normal' metal surface (the "substrate"), forming components known as coated conductors. One of the factors widely thought to degrade the performance of coated conductors is the roughness of the metal surface.

To verify this, Li and his colleagues set out to study and measure how the roughness of the substrate affects the current-carrying capacity of YBCO.

The researchers deposited a YBCO layer onto a substrate prepared with two distinct areas: a rough, corrugated region with nanometer sized ridges and grooves, and a smooth region. This configuration allowed the group to directly compare the behavior of the YBCO film on both surface types. They were able to do this using electrical-transport measurement techniques, which track the amount of supercurrent passing through the material, and "magneto-optical" imaging, a technique used to study superconductors by following their magnetic behavior.

"What we found is remarkable and surprising," said lead author Zuxin Ye, a graduate student under Li's supervision. "Rather than limiting the current, the nanoscaled corrugated surface produces more than a 30 percent increase in the supercurrent carried by the YBCO films. This suggests that metal substrates with some degree of roughness at the nanoscale might help improve the performance of high-temperature superconductors."

The work is the result of a collaboration between scientists in Brookhaven Lab's Materials Science Department, the Condensed Matter Physics group within the Physics Department, and the Lab's Center for Functional Nanomaterials. It was supported by the Office of Basic Energy Sciences within the U.S. Department of Energy's Office of Science.

Source: BNL