Researchers solve one mystery of high-temperature superconductors

November 28 2005

An experimental mystery – the origin of the insulating state in a class of materials known as doped Mott insulators – has been solved by researchers at the University of Illinois at Urbana-Champaign. The solution helps explain the bizarre behavior of doped Mott insulators, such as high-temperature copper-oxide superconductors.

In a paper published in the Nov. 2 issue of the journal *Physical Review Letters*, physics professor Philip Phillips and graduate student Ting-Pong Choy show that lightly doped Mott insulators are, in fact, still insulators. The scientists' theoretical results confirm previous experimental findings obtained by other researchers.

Unlike low-temperature superconductors, which are metals, high-temperature superconductors are insulators in their normal state. This has puzzled scientists, because half of the electron states are empty.

"Mott insulators have many available states for electrons to occupy, so you would expect these materials to conduct like metals," Phillips said. "Experiments have shown, however, that they act as insulators."

Even more surprising, when Mott insulators are lightly doped with holes – thereby creating even more places for electrons to occupy – the material still refuses to conduct.

Strong electron interaction is the key to understanding doped Mott insulators, Phillips said. "All energy scales are inextricably coupled. If

you attempt to separate them, you destroy the physics of the Mott state."

The fact that lightly doped Mott insulators are still insulators is an intrinsic property of Mott physics (that is, Mottness), the researchers claim. The insulating state is not caused by disorder, exotic excitations or something external to the system.

"In most materials, if you kill superconductivity by applying a large magnetic field, the resistivity falls to some finite value," Phillips said. "In doped Mott insulators, however, the resistivity climbs to infinity. The background state uncovered as a result of destroying superconductivity is an insulating state."

A future experiment could easily prove the researchers' claims. While chemical doping causes disorder in the material, the technique of photodoping creates holes without causing disorder.

"If experimenters create such holes and still see this insulating state, then we will know for a fact that insulating doped Mott insulators is due to Mottness," Phillips said.

Source: University of Illinois at Urbana-Champaign