PHYSICS NEWS FLASH

UT Physicists Probe High-Temperature Superconductivity in Nature

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Some people meet neutrons in middle school and then forget all about them. They learn how the neutron and proton are roommates in the nucleus, and how the neutron has no electrical charge, but after that they don't pay much attention to these subatomic particles. Yet Dr. Pengcheng Dai knows that neutrons can be powerful tools, and by using them to probe materials he and his research group have moved closer to understanding high-temperature superconductivity. The results are published in the article "Resonance in the electron-doped high-transition-temperature superconductor $Pr_{0.88}LaCe_{0.12}CuO_{4-\delta}$," which appears in the July 6 issue of *Nature*.

Superconductivity—the phenomenon where electric current hums along with no resistance—was first discovered in 1911. In the late 1950s scientists got down to the mechanics of the process and found that the electrons carrying the current form pairs to move it along in an orderly, seamless fashion. Typically, negatively-charged electrons repel each other. But when a substance like mercury, for example, is cooled to extremely low temperatures, vibrations in a material's atomic structure, or *lattice*, create a positively-charged space between the electrons, binding them in pairs. The temperature where a material becomes a superconductor is called its transition, or critical, temperature (*Tc*). Magnetic resonance imaging, particle accelerators, and geological sensors are all made possible by superconductivity.

Dr. Dai's Research Group, Summer 2005

In 1986, however, everything changed with the advent of high-temperature (high-*Tc*) superconductors. Although electrons in these materials also pair up, scientists were stumped as to why, because the lattice vibrations, called *phonons*, aren't strong enough to maintain pairing at higher temperatures. Although the consensus has been that phonons themselves are not enough to induce high-*Tc* superconductivity, what exactly is the "glue" that binds electrons for superconductivity is still a subject of controversy. All parent compounds of high-temperature superconductors contain copper oxide layers that are antiferromagnetic—they have no net magnetism. Yet they become superconducting when either electrons or "holes"—a vacant electron position that behaves as if it were an electron with a positive charge—are added in a process called doping. Although static antiferromagnetic order disappears with doping, short-range magnetic fluctuations persist in superconducting samples. This has lead researchers to conclude that magnetic fluctuations can be the "glue" for binding the electron pairs.

In the *Nature* article, Dr. Dai's group reports the first observation of magnetic resonance excitation in electron-doped high-temperature superconducting materials. Their method was neutron scattering, which takes advantage of the neutron's "magnetic moment" to measure the size and direction of dynamic magnetization (dynamic susceptibility) in a material. Using these tiny particles to probe a copper oxide compound including the metallic elements praseodymium, lanthanum, and cerium (PLCCO), the UT group not only found the magnetic resonance excitation, but also discovered that resonance energy is fundamental in all high-*Tc* superconducting materials—regardless of whether electrons or holes have been added. This brings physicists a step closer to deciphering how superconductivity works in the high-temperature realm. The more scientists know about how an electric current can move without resistance through different materials and at different temperatures, the more likely that superconductivity could be channeled for loss-free power transmission or magnetic levitating trains, among other applications.

Graduate student Stephen Wilson, who earned his bachelor's degree in physics at UT, is the lead author on the paper. Co-authors are Dr. Dai, post-doc Shiliang Li, graduate student Songxue Chi, Dr. H.J. Kang (a former student from Dr. Dai's group who earned her Ph. D. from UT in 2005), and Dr. J.W. Lynn of the NIST Center for Neutron Research.

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