Study helps explain behavior of latest high-temp superconductors

EurekAlert

HOUSTON -- (May 3, 2011) -- A Rice University-led team of physicists this week offered up one of the first theoretical explanations of how two dissimilar types of high-temperature superconductors behave in similar ways.

The research appears online this week in the journal *Physical Review Letters*. It describes how the magnetic properties of electrons in two dissimilar families of iron-based materials called "pnictides" (pronounced: NICK-tides) could give rise to superconductivity. One of the parent families of pnictides is a metal and was discovered in 2008; the other is an insulator and was discovered in late 2010. Experiments have shown that each material, if prepared in a particular way, can become a superconductor at roughly the same temperature. This has left theoretical physicists scrambling to determine what might account for the similar behavior between such different compounds.

Rice physicist Qimiao Si, the lead researcher on the new paper, said the explanation is tied to subtle differences in the way iron atoms are arranged in each material. The pnictides are laminates that contain layers of iron separated by layers of other compounds. In the newest family of insulating materials, Chinese scientists found a way to selectively remove iron atoms and leave an orderly pattern of "vacancies" in the iron layers.

Si, who learned about the discovery of the new insulating compounds during a visit to China in late December, suspected that the explanation for the similar behavior between the new and old compounds could lie in the collective way that electrons behave in each as they are cooled to the point of superconductivity. His prior work had shown that the arrangement of the iron atoms in the older materials could give rise to collective behavior of the magnetic moments, or "spins," of electrons. These collective behaviors, or "quasi-localizations," have been linked to high-temperature superconductivity in both pnictides and other high-temperature superconductors.

"The reason we got there first is we were in a position to really quickly incorporate the effect of vacancies in our model," Si said. "Intuitively, on my flight back (from China last Christmas), I was thinking through the calculations we should begin doing."

Si conducted the calculations and analyses with co-authors Rong Yu, postdoctoral research associate at Rice, and Jian-Xin Zhu, staff scientist at Los Alamos National Laboratory.

"We found that ordered vacancies enhance the tendency of the electrons to lock themselves some distance away from their neighbors in a pattern that physicists call 'Mott localization,' which gives rise to an insulating state," Yu said. "This is an entirely new route toward Mott localization."

By showing that merely creating ordered vacancies can prevent the material from being electrical conductors like their relatives, the researchers concluded that even the metallic parents of the iron pnictides are close to Mott localization.

"What we are learning by comparing the new materials with the older ones is that these quasi-localized spins and the interactions among them are crucial for superconductivity, and that's a lesson that can be potentially applied to tell experimentalists what is good for raising the transition temperature in new families of compounds," Zhu said.

Superconductivity occurs when electrons pair up and flow freely through a material without any loss of energy due to resistance. This most often occurs at extremely low temperatures, but compounds like the pnictides and others become superconductors at higher temperatures -- close to or above the temperature of liquid nitrogen -- which creates the possibility that they could be used on an industrial scale. One impediment to their broader use has been the struggle to precisely explain what causes them to become superconductors in the first place. The race to find that has been called the biggest mystery in modern physics.

"The new superconductors are arguably the most important iron-based materials that have been discovered since the initial discovery of iron pnictide high-temperature superconductors in 2008," Si said. "Our theoretical results provide a natural link between the new and old iron-based superconductors, thereby suggesting a universal origin of the superconductivity in these materials."

SOURCE [1]

Source URL (retrieved on *07/10/2014 - 5:21pm*):
http://www.ecnmag.com/news/2011/05/study-helps-explain-behavior-latest-high-temp-superconductors

Links:
[1] http://www.eurekalert.org/pub_releases/2011-05/ru-she050311.php