Exotic materials using neptunium, plutonium provide insight into superconductivity

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Physicists at Rutgers and Columbia universities have gained new insight into the origins of superconductivity - a property of metals where electrical resistance vanishes - by studying exotic chemical compounds that contain neptunium and plutonium.

While superconductivity holds promise for massive energy savings in power transmission, and for novel uses such as levitating trains, today it occurs only at extremely cold temperatures. As a result, its use is now limited to specialized medical and scientific instruments. Over the past two decades, scientists have made metals that turn superconducting at progressively higher temperatures, but even those have to be cooled below the temperature of liquid nitrogen.

Still, physicists believe room temperature superconductivity may be possible. The work reported by the Rutgers and Columbia physicists is a step in that direction - shedding new light on the connection between magnetism and superconductivity.

"The exotic compounds we're studying will not become practical superconducting materials; however, by studying them we can learn the trends that govern a material's transition to superconductivity" said Piers Coleman, physics professor at Rutgers.

Coleman, along with Rutgers graduate student Rebecca Flint and Columbia postdoctoral research scientist Maxim Dzero, are publishing their findings in an upcoming issue of the journal *Nature Physics*. Their paper has been posted to the journal's advance publication web site at: http://dx.doi.org/10.1038/nphys1024.

The compounds they've studied are made out of elements in the actinide series, including neptunium and plutonium. In these materials, active electrons are in "f-orbitals." In contrast, materials that make up today's highest-temperature superconductors, including copper or iron, have active electrons in "d-orbitals." The f-electron materials generally have lower superconducting temperatures than their d-electron counterparts; but they are easier to make and may be easier to understand.

"Electrons must bind together into pairs called 'Cooper pairs' for materials to become superconducting," Flint said. "In earlier studies, a small amount of magnetism was lethal to this pairing; however, in these materials, magnetism is not bad. It actually appears to play a central role in driving the pairing effect."

These new superconductors are part of a class of materials referred to as "heavy electron superconductors," metals that are filled with tiny, atomic-sized magnets known as "spins." When electrons pass through this forest of magnets, they slow down and move sluggishly as if they were extremely heavy.

"In most heavy electron superconductors, the electrons have to get heavy before they go superconducting," said Coleman. "But in the highest temperature versions, the electrons get heavy and become superconducting at the same time."

To understand this effect, the scientists have proposed a new type of electron pairing. "We've found that the electrons form much stronger pairs if they team up with one of the tiny atomic magnets - a combination that might be called a quantum-mechanical 'menage a trios,'" said Coleman. "The spin in the middle brings the pair of electrons close together, and a stronger pair means superconductivity at higher temperatures."

The scientists hope these ideas can be applied to d-electron materials, where the superconductivity may occur much closer to room temperature.

Source: Rutgers University

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