New superconductors present new mysteries, possibilities

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Johns Hopkins University researchers and colleagues in China have unlocked some of the secrets of newly discovered iron-based high-temperature superconductors, research that could result in the design of better superconductors for use in industry, medicine, transportation and energy generation.

In an article published today in the journal *Nature*, the team, led by Chia-Ling Chien, the Jacob L. Hain Professor of Physics and director of the Material Research Science and Engineering Center at The Johns Hopkins University, offers insights into why the characteristics of a new family of iron-based superconductors reveal the need for fresh theoretical models which could, they say, pave the way for the development of superconductors that can operate at room temperature.

"It appears to us that the new iron-based superconductors disclose a new physics, contain new mysteries and may start us along an uncharted pathway to room temperature superconductivity," said Chien, who teamed up on the research with Tingyong Chen and Zlatko Tesanovic, both of Johns Hopkins, and X.H. Chen and R.H. Liu of the Hefei National Laboratory for Physical Science at Microscale and Department of Physics, University of Science and Technology of China in Anhui, China.

Superconductors are materials that can carry electrical current without friction and as a result, don't waste electrical energy generating heat. (Imagine your laptop computer or PC not getting warm when it is turned on.) This means that an electrical current can flow in a loop of superconducting wire forever without a power source. Today, superconductors are used in hospital MRI machines, as filters in cell phone base stations and in high-speed magnetic levitating trains.

Unfortunately, most of today's superconducting materials can only function and operate at extremely low temperatures, which means that they must be paired with expensive supercooling equipment. This presents researchers with a grand challenge: to find superconducting material that can operate at more "normal" temperatures.

"If superconductors could exist at room temperatures, the world energy crisis would be solved," Chen said.

Chen explains that though all metals contain mobile electrons which conduct electricity, a metal becomes a superconductor only when two electrons with opposite "spins" are paired. The superconductor energy "gap," which is the amount of energy that would be needed to break the bond between two electrons forming such a pair to release them from one another, determines the robustness or strength of the superconducting state. This energy gap is highest at low temperatures, but vanishes at the temperatures at which superconductivity ceases to exist.

"This gap -- its structure and temperature dependence -- reveal the 'soul' of the superconductor, and this is what was measured in our experiment," Chien said.

The team measured this gap and its temperature variation, revealing that the pairing mechanism in iron-based superconductors is different from the one in more traditional, copper-based, high-temperature superconductors. To the researchers' surprise, their results were incompatible with some of the newly proposed theories in this mushrooming field.

"In the face of this discovery, it is clear that we need to reexamine the old and invent some new theoretical models," Tesanovic said. "I predict that these new, iron-based superconductors will keep us physicists busy for a long, long while."

Source: Johns Hopkins University

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