Physicists isolate bound states in graphene-superconductor junctions

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Illinois physics professor Nadya Mason led a team that isolated unique electron bound states that form in graphene-superconductor junctions. Photo by Ivan Petrov

(PhysOrg.com) -- Illinois researchers have documented the first observations of some unusual physics when two prominent electric materials are connected: superconductors and graphene.

Led by University of Illinois physics professor Nadya Mason, the group published its findings in the journal Nature Physics.

When a current is applied to a normal conductor, such as metal or graphene, it flows through the material as a stream of single electrons. By contrast, electrons travel in pairs in superconductors. Yet when a normal material is sandwiched between superconductors, the normal metal can carry the supercurrent.

Normal metals can adopt superconducting capacity because the paired electrons from the superconductor are translated to special electron-hole pairs in the normal metal, called Andreev bound states (ABS).

"If you have two superconductors with a normal metal between, you can actually transport the superconductivity across the normal material via these bound states, even though the normal material doesn't have the electron pairing that the superconductors do," Mason said.

ABS are extremely difficult to measure or to observe directly. Researchers can measure conduction and overall magnitude of a current, but have not been able to study individual ABS to understand the fundamental physics contributing to these unique states.

Mason's group developed a method of isolating individual ABS by connecting superconducting probes to tiny, nanoscale flakes of graphene called quantum dots. This confined the ABS to discrete energy levels within the quantum dot, allowing the researchers to measure the superconducting ABS individually and even to manipulate them.

"Before this, it wasn't really possible to understand the fundamentals of what is transporting the current," Mason said. "Watching an individual bound state allows you to change one parameter and see how one mode changes. You can really get at a systematic understanding. It also allows you to manipulate ABS to use them for different things that just couldn't be done before."

Superconductor junctions have been proposed for use as superconducting transistors or bits for quantum computers, called qubits. Greater understanding of ABS may enable other applications as well. In addition, it may be possible to use the superconducting graphene quantum dots themselves as solid-state qubits.

"This is a unique case where we found something that we couldn't have discovered without using all of these different elements – without the graphene, or the superconductor, or the quantum dot, it wouldn't have worked. All of these are really necessary to see this unusual state," Mason said.

More information: The paper, "Transport Through Andreev Bound States in a Graphene Quantum Dot," is available online at www.nature.com/nphys/journal/v … /full/nphys1911.html

Provided by University of Illinois at Urbana-Champaign

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