Superconducting nanowires show ability to measure magnetic fields

June 16 2005

By using DNA molecules as scaffolds, scientists have created superconducting nanodevices that demonstrate a new type of quantum interference and could be used to measure magnetic fields and map regions of superconductivity.
Researchers at the University of Illinois at Urbana-Champaign have fabricated and studied nanostructures consisting of pairs of suspended superconducting wires as tiny as 3 to 4 molecular diameters (typically 5 to 15 nanometers) in width. The team consisted of physics professors Alexey Bezryadin and Paul Goldbart, and graduate students David Hopkins and David Pekker. Their work is described in the June 17 issue of the journal *Science*.

"Our measurements on these two-nanowire devices revealed a strange class of periodic oscillations in resistance with applied magnetic field," Bezryadin said. "Through experimentation and theory, we found both an explanation for this odd behavior and a way to put it to work."

To make their nanodevices, the researchers began by placing molecules of DNA across a narrow trench (about 100 nanometers wide) etched in a silicon wafer. The molecules and trench banks were then coated with a thin film of superconducting material (molybdenum-germanium). The result was a device containing a pair of homogeneous, superconducting nanowires with extremely fine features.

"In the absence of a magnetic field, these ultra-narrow wires exhibited a nonzero resistance over a broad temperature range," Bezryadin said. "At temperatures where thicker wires would already be superconducting, these DNA-templated wires remained resistive."

Tuning the strength of a magnetic field applied to the device, however, caused highly pronounced and periodic oscillations in resistance, at any temperature in the transition region.

"The applied magnetic field causes a small current to flow along the trench banks, and this current then causes a large change in resistance," Goldbart said. "The strength of the current is controlled only by the magnetic field and the width of the banks supporting the wires."

The resulting periodic oscillation is a reflection of the wave nature of matter that goes to the very heart of quantum mechanics, Goldbart said. "Unlike ordinary matter, the electrons in these wires are behaving as though they are one quantum mechanical object in one great quantum mechanical wave function."

Metallic nanodevices based on DNA scaffolds could be used in applications such as local magnetometry and the imaging of phase profiles created by supercurrents – in essence a superconducting phase gradiometer, the researchers report.

"By taking advantage of DNA self-assembly processes, complex scaffolds could be created for electronic devices with features having molecular-scale dimensions," Bezryadin said.

In related work, to appear in the August issue of the journal Nanotechnology (published online in May), Bezryadin and undergraduate student Mikas Remeika improved the nanofabrication process by using a focused electron beam to locally alter the shape and structure of metallized nanowires.

Performed in a transmission electron microscope, electron-beam sculpting and crystallization can modify small segments of the nanowires, with a spatial resolution of approximately 3 nanometers, Bezryadin said. The technique could be used to fabricate novel electronic nanodevices, such as single-electron transistors, with dimensions less than 10 nanometers.

Funding came from the National Science Foundation, the Alfred P. Sloan Foundation and the U.S. Department of Energy.

Source: University of Illinois at Urbana-Champaign

Citation: Superconducting nanowires show ability to measure magnetic fields (2005, June 16) retrieved 22 September 2024 from
https://phys.org/news/2005-06-superconducting-nanowires-ability-magnetic-fields.html

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