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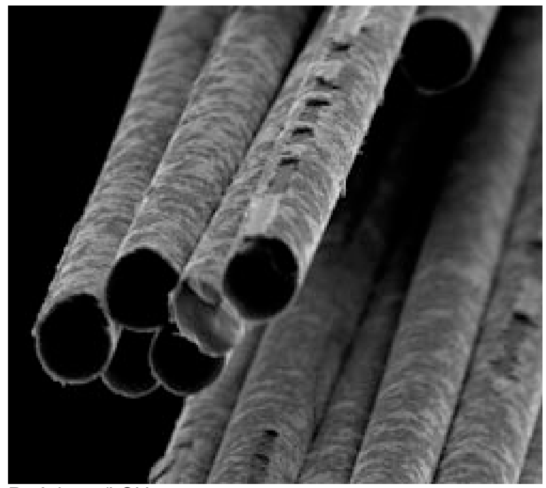
Get Wired for Superconductivity



P. Adams/LSU

Live wires. These 7-micron-thick wires carry current without resistance and have an unprecedented combination of strength and light weight.

A research team has created a new type of superconducting wire that not only carries a high electric current without resistance but also is remarkably strong, light, thin, and long. As the team reports in the August *Physical Review B*, the wires are made from an unusual magnesium-carbon-nickel compound layered around a carbon fiber. Experiments with the wires strongly suggest that the compound is an "exotic" superconductor whose properties can't be explained by the standard theory of superconductivity. Improved versions of the wires could be used in the electromagnets needed in a new class of spacecraft propulsion systems.

The explanation for superconductivity in standard materials such as niobium and lead has been in textbooks for decades, but unconventional superconductors--known as exotics--remain mysterious. Some researchers believe that the recently discovered superconductor $MgCNi_3$ may bridge the gap between conventional superconductors and the most important class of exotic compounds, called cuprates, which can superconduct at temperatures higher than 100 degrees Kelvin. $MgCNi_3$, which superconducts up to only about 8 degrees Kelvin, has a crystal structure similar to the cuprates, but it is simpler and does not contain copper or oxygen.

If $MgCNi_3$ exhibits its own distinct exotic properties, it could help researchers understand electron behavior in cuprates and other materials. But the difficulty of synthesizing it has meant that not everyone can agree on whether it is unconventional, much less on the details of its behavior. "The experiments fall on both sides of the question," says Bob Cava of Princeton University, the material's inventor.

Phil Adams and David Young from Louisiana State University in Baton Rouge have now synthesized this superconductor in a new, thread-like form, which is better for testing its electrical properties than the flat films and powdery pellets that researchers have made before. The team put 3- to 5-millimeter-long nickel-coated carbon fibers in an evacuated tube with magnesium vapor and then heated the whole package in a 700-degree-Celsius oven for up to 30 minutes. The result was a core of carbon covered by an 80-nanometer-thick sheath of the new compound. The structure is "kind of like a cannoli," Adams says.

The team then measured the critical current--the current above which the fibers' superconductivity breaks down. When the researchers subjected the fibers to increasing temperatures and magnetic fields, the critical current dropped much more abruptly than predicted by the standard superconductivity theory, adding to the growing evidence that the material is exotic.

Adams and his colleagues were surprised by the size of the critical current: They extrapolated to an absolute zero value of 40 million amperes per square centimeter, 10 times higher than predicted from previous experiments with packed powders and almost as high as the theoretical maximum for non-high-temperature superconductors. Such a current would produce a magnetic field of up to 15 tesla in these wires--powerful enough to use in several futuristic spacecraft propulsion systems, which is why the Army has awarded Adams' team a grant to develop the technology.

The team could easily manufacture much longer wires by starting off with longer carbon fibers, Adams says. Plus, he says, their carbon cores could make them stronger than steel, so an electromagnet made from the wires wouldn't need a heavy structure to support it. Adams "has the strength and superconductivity built into the same unit," says John Cole of NASA's Marshall Space Flight Center in Huntsville, Alabama. "It's like my dream come true, in a way," says Cava, "to invent a material that is controversial and gets people thinking."

--Chelsea Wald

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Recent *Focus* stories on high-temperature superconductivity: 27 February 2004, 27 February 2002

Scaling Behavior of the Critical Current Density in $MgCNi_3$ Microfibers
D.P. Young, M. Moldovan, and P.W. Adams
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