Template engineering demonstrates possibilities of new superconducting material

March 1 2010, by Sandra Knisely

(PhysOrg.com) -- A breakthrough approach by University of Wisconsin-Madison researchers and their collaborators in fabricating thin films of a new superconducting material has yielded promising results: The material has a current-carrying potential 500 times that of previous experiments, making it significant for a variety of practical applications.

The new approach and results appeared online in the journal Nature Materials today (Feb. 28) and illustrate a significant step forward in superconductor research.

"We've shown how to grow quality, single-crystal thin films of this class of materials, so people can study the fundamental properties and limits of them," says Chang-Beom Eom, a UW-Madison professor of materials science and engineering, who led the collaboration between UW-Madison and teams from the National High Magnetic Field Laboratory and the University of Michigan.

Superconductors are powerful materials that conduct electricity with no resistance, meaning no loss of electricity. Among the various possibilities of superconductors, a team in Japan is exploring how to make high-speed, levitating trains with superconductors that theoretically could travel as fast as airplanes. More immediately, superconductors are used in MRI machines.

While superconductors have enormous potential, they work only at very low temperatures. The copper-oxide-based superconductors, which have the highest operating temperature, work at approximately minus 180 degrees Fahrenheit.

Another major challenge is how much current superconductors can carry. For example, a levitating train would require a superconductor and magnet larger than currently is practical. However, if a superconductor had high current-carrying abilities, the mass of the superconductor and magnet theoretically could be small enough for real applications.

This second challenge is part of what Eom's team has addressed. Recently, scientists have discovered an alternative to copper-oxide superconductors. Called pnictides, the materials are based on iron and arsenide and are promising because they have relatively high transition temperatures, along with other ideal properties.

Until now, no one has been able to study the intrinsic properties of pnictides because it has been impossible to fabricate a single crystal of it with all of the material grains pointing in the same direction. "The quality of the films is crucial because imperfect films contain many crystal boundaries, which obstruct the current, as work published by our team late last year has shown," says Eom.

Eom and his team hypothesized that the pnictide thin films couldn't grow properly because the substrate used most commonly by researchers is oxide-based. Thin films like to grow in the same way as the material beneath them. Hence, the metallic-based pnictides couldn't thrive on the oxide substrate.

The researchers then engineered a thin template to place on top of the oxide substrate. This template has both metallic and oxide elements, meaning it can interface with both the substrate and the thin film. With the template, the film grows in a more ideal arrangement. The template also acts as a nucleation layer, or barrier, between the conducting thin film and the non-conducting, or insulating, substrate. (The template can't be used as the substrate itself because it becomes conducting when the film grows. As a very thin, intermediate layer, the template allows the film to grow, but has only a negligible effect on electrical measurements.)

Previously, researchers were only able to measure 10,000 amps of electricity per .06 cubic inch, which is a relatively useless amount. With the template, which is made of barium titanate or strontium titanate, Eom's team has demonstrated that pnictide thin films are capable of producing 5 million amps per .06 cubic inch — a 500-fold increase that brings pnictide current capacity into the usable range.

The team's three-pronged research — including the hypothesis about why previous approaches failed, the new template engineering solution and the significant carrying capacity results — will help other researchers learn more about pnictides and expand basic knowledge about superconductivity in general. Beyond superconductors, the template approach can be applied whenever a researcher wants to grow a metallic film on an oxide substrate.

"When any new material is discovered, we want to understand the fundamental mechanisms of it," says Eom. "We now have perfect, single-crystal thin films of pnictides in order to do that."

More information: www.nature.com/nmat/index.html

Provided by University of Wisconsin-Madison

Citation: Template engineering demonstrates possibilities of new superconducting material (2010, March 1) retrieved 26 April 2024 from https://phys.org/news/2010-03-template-

possibilities-superconducting-material.html