Cryogenic Cooling Decreases Fabrication Time and Increases Stability of High-Temperature Superconductive Ceramic in Polymer Matrixes

Degradation of superconductive properties in high-temperature superconductive ceramics (HTSCs) is primarily due to continuous adsorption of water vapor during exposure to environmental conditions. Addition of a polymer is a common form to prevent this problem, but the procedures used for synthesizing such a composite usually go beyond a 12-h-long process. A group of researchers from National Taiwan University led by W.-F. Su, in collaboration with S. Nedilko from Kiev National Taras Shevchenko University in Ukraine, have applied cryogenic cooling in the composite fabrication process, reducing the time frame to under 1/2 h.

Their investigation involved a superconductive ceramic widely studied in the literature, Bi-2212 ($Bi_2Sr_2CaCu_2O_x$), as described in the August issue of the *Journal of the American Ceramic Society* (p. 2673; DOI: 10.1111/j.1551-2916.2007.01813.x). First, they prepared the ceramic using a two-stage precursor method. Separately, they mixed ethylene glycol dimethacrylate, an organic monomer, with benzoyl peroxide as an initiator in a flask and then immersed the flask in liquid nitrogen. After the mixture had frozen, they placed a sample of the ceramic on top of the frozen monomer inside the flask, and then sealed and evacuated the flask before retrieving the package from the liquid nitrogen. The monomer then filled the ceramic voids while thawing at room temperature. Finally, the researchers removed the thus-formed composite from the vacuum and polymerized it.

Characterization of the resulting composite using x-ray diffractometry (XRD) revealed that no damage or breakdown occurred in the original ceramic phase, which was still clearly present in the diffraction pattern. The scientists also measured resistivity and magnetic susceptibility for the superconducting volume fraction on both the ceramic and the composite, before and after exposure to water vapor. The results revealed that the changes in resistivity with increased temperature for both ceramic and composite were very similar and that both exhibited a superconducting transition temperature of 83 K. However, after exposure to 87% relative humidity (RH) for 30 days, the resistivity of the ceramic increased dramatically, whereas the composite retained its initial behavior.

The change in superconducting volume fraction, as measured by magnetic susceptibility, decreased in the composite by only 5% with respect to that of the ceramic. After exposure to 99% RH for 7 days, the superconducting volume fraction measured 18% less in the ceramic than in the composite. The superconducting transition temperature after such exposure remained the same for the composite, whereas it decreased to 79 K for the ceramic. Thus, the resultant composite required significantly less processing time while retaining the superconductive properties of Bi-2212 and also achieving additional improved environmental stability.

SIARI SOSA

Discovery of "Hidden" Quantum Order Improves Prospects for Quantum Supercomputers

An international team of scientists, led by G. Xu of The Johns Hopkins University, has detected a hidden magnetic "quantum order" that extends over

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chains of nearly 100 atoms in a material that is otherwise magnetically disordered. The findings, which were published online July 26 in *Science* (DOI: 10.1126/science.1143831), could have implications for the design of devices and materials for quantum information processing, including large-scale quantum computers capable of tackling problems exponentially faster than can conventional computers.

The team studied a ceramic material, Y_2BaNiO_5, consisting of chains of nickel-centered oxygen octahedra laid end-to-end. The chains comprise a quantum spin liquid in which electron spins (analogous to tiny bar magnets) point in random directions with no particular order, even at very low temperatures. To measure the quantum order through this classically disordered liquid, the scientists used neutrons to image the magnetic excitations, also called "flips," and the distances over which they could propagate. They found that, despite the apparent classical disorder, magnetic excitations could propagate over long distances of up to 30 nm at low temperature, an increase of almost an order of magnitude over the classical antiferromagnetic correlation length.

The team members also found that they could limit coherence or make it disappear by introducing defects into the material through chemical impurities or heating. These defects "break the chains" into independent subchains, each with its own hidden order. This part of the research is the first step toward engineered spin-based quantum states in ceramics.

The team's results are important because they demonstrate that the magnetic moments of a large number of atoms can band together to form quantum states much like those of a very large molecule. Although, on the surface, these atomic "magnets" seem to be disorganized and disordered, the team was able to discern "a beautiful, underlying quantum order," said team member Collin Broholm, professor in the Henry A. Rowland Department of Physics and Astronomy at Johns Hopkins' Krieger School of Arts and Sciences.

"Quantum mechanics is normally appreciated only on the atomic scale. However, here we present evidence for a very long and very quantum mechanical magnetic molecule," Broholm said. "While disordered to a classical observer, the magnetic moments of almost 100 nickel atoms arranged in a row within a solid were shown to display an underlying quantum coherence limited only by chemical and thermal impurities. The progress we made is really a demonstration of quantum coherence among a larger number of atoms in a magnet than ever before."

In addition, the team established the factors that affect the distance over which the hidden quantum order can be maintained. That distance, as well as how it changes as a result of heating and chemical impurities in the material, could well prove to be essential in determining whether the material will have practical applications.

"Apart from the sheer beauty and mystique of quantum order beyond the atomic scale, there are very exciting prospects for applications in quantum computing to dramatically speed a wide range of computing that our society relies upon," Broholm said. □

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