Georgia Tech

Research News

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RAPID COATING FOR FLEXIBLE WIRE:

NEW CHEMICAL DEPOSITION PROCESS SPEEDS

PRODUCTION OF THIN-FILM SUPERCONDUCTORS

Using a new chemical vapor deposition (CVD) process to coat flexible fibers with a thin film of superconducting material, researchers at the Georgia Institute of Technology have increased deposition rates by a factor of 50 to 200 while achieving promising critical temperatures and maximum current capacity.

Principal Research Scientist Dr. W. Jack Lackey and his team believe CVD offers greater versatility and control for producing extremely thin-film superconductors on flexible metal or ceramic filaments. These superconducting wires are needed for high-performance motors, microelectronic devices, microwave cavities, and super-strong magnets such as those found in certain non-invasive diagnostic instruments, explained Lackey, who holds multiple patents on CVD techniques.

"A thin film gives you the opportunity to produce a better crystal structure than the bulk methods," said Dr. D. Norman Hill, from the School of Materials Engineering at Georgia Tech. "You can control the rate of deposition and the form of the structure. Also, a thin film tends to carry more current and behave better in magnetic fields than the bulk forms."

Existing CVD technology for thin-film superconductors yields a coating just one or two microns thick -- roughly one-fiftieth the diameter of a human hair -- during a one-hour deposition run. The new Georgia Tech process yields 50 to 200 microns per hour, depending on production conditions. "Instead of evaporating materials and channeling them through the furnace with gas, we are sending finely-ground powders into the reactor," said Dr. Kent E. Barefield, director of Georgia Tech's School of Chemistry and a principal researcher.

During an early stage of research, the Georgia Tech team achieved a critical temperature of 85 degrees Kelvin, or -306 degrees Fahrenheit. Since the material loses all resistance to electrical current at 85 K, it could be cooled with inexpensive liquid nitrogen, rather than more costly liquid helium, which has a lower boiling point. Further, Lackey has reported that the material can carry up to 40,000 Amperes of electricity per square centimeter (4×10^4 A/cm^2) with no loss of superconductivity.

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To further assess the material, the Oak Ridge National Laboratory will measure electromagnetic properties. However, Lackey has been encouraged by the quality of thin-film superconductors produced by Japanese researchers using a similar, but slower CVD process. He will disclose his findings this week at the Materials Research Society conference.

As the first step toward commercialization, a prototype magnet will be produced by Georgia Tech's research partner, American Magnetics, Inc. of Oak Ridge, Tenn. "The goal of our project is to wind a magnet with this superconducting wire," said materials engineering researcher Dr. W. Brent Carter, another key member of the research team. "Unlike a conventional magnet, a superconducting magnet doesn't use any energy; there's no electrical energy dissipated in the form of resistance, and consequently, you can operate with much less power."

Georgia Tech researchers modified a standard metal-organic CVD process to eliminate a series of complicated metal-source "bubblers" or vaporizers. In the past, carrier gas was used to transport metal sources into a reactor. Since the flow rate, temperature, and pressure must be controlled for each bubbler, the process has often been delicate and time-consuming. To make matters even more difficult, reagent sources for the commonly-used "1-2-3 Superconductor" (yttrium, barium and copper) provide low vapor pressure. If heat levels are increased to speed vaporization, these metal sources undergo chemical reactions and form undesirable compounds, explained Research Engineer John Hanigofsky.

To improve this situation, Lackey replaced the vaporizers with a powder feeder. A combination of finely-ground ytrrium, barium and copper metal-organic powders are mixed with argon gas before flowing into the horizontal reactor, thus eliminating the need for complex controls. During a five- to 30-minute period, researchers feed between two and 10 grams of powder into the reactor. Future goals include upgrading the feeder to achieve constant flow rates.

Thus far, the technique mostly has been demonstrated using rectangular, single-crystal magnesium oxide substrates, but several types of flexible, thin fibers also have been coated. Ultimately, the team plans to coat inexpensive, commercially-available ceramic or metal fibers, possibly made of aluminum oxide and/or silicon dioxide. Other possible substrate materials include silicon carbide and carbon coated with a layer of an oxidation protective material. A coating barrier between the fiber and the superconductor should eliminate any undesirable chemical reactions. "We would like to put a two-micron coating on a four-micron fiber," Hill said. "To maintain high current carrying capability, the volume of coating should represent a substantial portion of the entire wire."

Meanwhile, Lackey has designed a Continuous Fiber Coater. Design plans call for the addition of a spool to feed fiber into the bottom of a vertical furnace, through the reactor, and onto a second, motorized spool affixed to the top of the coater. (Sponsored by DARPA.)

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