Rare-earth Information Center Insight

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Rare Earth Based High Temperature Superconducting Wires

The Office of Utility Technologies, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy held its annual peer review of the *Superconductivity Program for Electric Systems* in Washington, D.C., July 26-27. Significant progress continues to be made, and demonstration projects in a number of areas, including power cables, fault current limiters, and motors, are nearing completion. These projects are based on tapes produced by the so-called oxide powder in tube (OPIT) method, and use Bi-Sr-Ca-Cu-O (BISCCO) high temperature superconductors. Of interest to the rare earth community are the so-called "second-generation" superconductors, $YBa_2Cu_3O_7$ (Y123), biaxially textured films on buffered metallic substrates. The difficulty in producing wires of high temperature superconductors is a result of the extreme anisotropy of the materials. For the orthorhombic Y123 material, the superconducting current flows almost exclusively in the basal plane. As a consequence, to carry currents over long lengths, something that is essentially a long, thin single crystal must be produced. It turns out that a high degree of c-axis texture is not sufficient, and texture of the *a* and *b* axes within the plane is also required. A number of methods of depositing highly textured films have been developed, and they share, in common, the need for a highly texture substrate. As has previously been discussed in the *RIC Insight,* there are two methods of producing these substrates currently being investigated. A group, lead by Los Alamos National Laboratory (LANL), is using ion-beam-assisted deposition (IBAD) to deposit a textured buffer layer on a commercial metal tape. In this process, texture is induced by an ion beam impinging on the sample during deposition. For IBAD films, the texture develops as the film thickness increases. Since the IBAD process essentially requires a fixed number of ions per atom deposited, this is the rate limiting step in the production of long lengths of conductors. Originally, LANL used yttria stabilized zirconia (YSZ) for the IBAD layer, and a 5000 Å thick film was required. While the longest lengths of conductor have been produced using the YSZ, short length conductors using 100 Å thick MgO layers have now been prepared. The use of MgO should result in a 50-fold increase in the rate for the process.

A second team, lead by Oak Ridge National Laboratory (ORNL), is developing a process called Rolling Assisted Biaxial Textured Substrates (RABiTS). Where the LANL approach starts with an untextured metal ribbon and deposits a textured substrate, the RABiTS approach uses a textured Ni substrate produced by a conventional rolling process. Unfortunately, it is not possible to deposit Y123 directly on Ni as Ni diffuses into Y123 replacing Cu, which destroys the superconductivity. Oxidation does not exactly do the Ni a lot of good either. As a result, this process also requires a ceramic buffer layer, which acts as a diffusion barrier for the Ni. This year, ORNL reported that a number of their industrial partners are now capable of producing the texture metal substrates, and they are developing a non-magnetic substrate Ni 13%Cr. While the RABiTs process would seem to be inherently faster, the development of a suitable buffer layer configuration appears to be problematic. A number of groups are working on wet

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chemistry routes for coating continuous buffer layers on the textured metal substrate. Sandia National Laboratory, in particular, is developing a sol-gel process. The buffer layer must, of course, form epitaxially on the Ni in order to maintain the texture.

A third attractive alternative, called inclined substrate deposition, is currently being evaluated for long lengths by Argonne National Laboratory (ANL). In this process, the substrate is simply inclined with respect to the vapor flux during the *e*-beam deposition of MgO. Texture is developed very rapidly, but, unfortunately, the resulting surface is stepped, which is not ideal for the deposition of the superconductor. It remains to be seen if this method will produce useful conductors.

Once the textured substrates are prepared, the Y123 must be deposited expitaxially on top of the buffer layer. This can be done very nicely by pulsed laser deposition (PLD), but this is rather slow for producing the kilometer lengths required for applications. Again significant progress is being made in wet chemical processes for depositing the films. At the current time, all of the processes for depositing the thick film Y123 produce films, which appear to carry current only in the first µm. Since the underlying metal substrates and buffer layers are of order 100 µm thick, this puts a severe limit on the engineering critical currents which can be obtained.

For information on the DOE *Superconductivity Program for Electric Energy Systems*, contact James Daley, Office of Power Technologies, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, Washington, D.C. 20585.

CO Sensing

Carbon monoxide, CO, can attach to hemoglobin "producing a reduction in cellular respiration", i.e. it cuts down the oxygen supply in the blood, which damages tissue by oxygen starvation. Since CO is a byproduct of incomplete combustion, it is a common toxic environmental pollutant, and there is a need for reliable low cost sensors. Most research on CO sensors focuses on SnO_2-based materials that have a high surface activity for CO reaction. A recent paper by C. M. Chiu and Y. H. Chang {*Mater. Sci Eng. A*, **266**, 93-8 (1999)} reports that perovskite materials also display highly catalytic properties for the oxidation of CO in bulk forms. The system they have investigated in $La_{0.8}Sr_{0.2}Co_{1-x}Ni_xO_{3-\delta}$. Thus, the perovskite-based rare earth oxides are not only high temperature superconductors and colossal magnetoresistance materials, but CO sensors as well. When Ni is substituted for Co, oxygen vacancies are formed. When the oxygen vacancy diffuses to the surface, it can split an O_2 molecule with a CO so that the vacancy is filled, and the CO becomes CO_2. Filling the vacancy changes the charge balance, and, hence, the electrical resistivity of the perovskite. For the vacancies to diffuse, the sensor must be operated at an elevated temperature 200°C where 50 ppm of CO in air causes about a 10% change in the resistance.

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