Phase Relationships in High Temperature Superconductors

Phase diagrams serve as "blue prints" for improved processing of high T_c superconductor materials. Of current interest are the $Ba_2RCu_3O_{6+x}$ (R = lanthanides and yttrium) superconductors. The construction of phase diagrams of these systems and the role of phase equilibria and kinetics in the formation of the $Ba_2YCu_3O_{6+x}$ phase using barium fluoride amorphous precursor films are important for rapid advancement of the RABiTS/IBAD coated conductor technology. By providing the phase equilibria data for optimal processing, high T_c technology will be advanced through reductions in cost and improvements in performance.

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In 2003, NIST materials research has continued to provide critical information pertinent to the development of practical superconductors. This project is an integral part of the Department of Energy intensive research program focused on high T_c wires and cables for high-impact commercial applications. Our effort included two principal groups of superconductors: (1) $Ba_2RCu_3O_7$ (Y-213 and R-213, R = lanthanide) coated conductors produced by rolling assisted biaxially textured substrate/ion beam assisted deposition (RABiTS/IBAD); and (2) MgB_2.

Part of our effort has been focused on the dependence of BaO-R_2O_3-CuO_x phase relations (under carbonate-free conditions to match the processing conditions of RABiTS/IBAD conductors) on both oxygen pressure, p_{O2}, and choice of lanthanides. This year, we have completed the study of three systems, with R = Gd, Eu and Ho. The trends of phase formation and tie-line relationships with respect to lanthanide size that were found previously for R = Nd, Sm, Eu, Gd, Ho, Y, and Er, were observed in the present work. Near the BaO-rich region, phase formation was very different from what was found previously for samples prepared in the presence of carbonate.

By mixing the smaller lanthanides R′ with the larger R in the $Ba_{2-x}(R_{1+x-y}R'_y)Cu_3O_{6+z}$ superconductor, both flux-pinning and melting properties can be tailored and optimized. A trend of the extent of solid solution formation with respect to the size of R was observed in $Ba_{2-x}(Nd_{1+x-y}R'_y)Cu_3O_{6+z}$ (R′ = Gd, Y and Yb) and in $Ba_{2-x}(R_{1+x-y}Y_y)Cu_3O_z$ (R = Eu and Gd). There is considerable improvement of critical current density, $J_c(H)$, for samples with partial Y-substitution at high fields at 77 K as compared with that of Nd-213 and Y-213. This improvement is likely due to the increased flux pinning as a result of doping of Nd^{3+} in the Ba^{2+} site.

The "BaF_2 *ex-situ*" process is a promising method for producing long-length, high-quality Y-213 superconducting tapes. Previously, using a controlled-atmosphere differential thermal analysis system, we detected the presence of low temperature liquids in the multicomponent reciprocal Ba-Y-Cu//O,F system, which can be modeled in compositional space as a trigonal prism. This year, we initiated a study to understand the details of complex phase relations in selected Ba-Y-Cu//O,F subsystems: BaO-Y_2O_3-CuO_x-BaF_2, BaF_2-YF_3-CuF_2-CuO_x, BaF_2-Y_2O_3-CuO_x-YF_3, BaF_2-CuO, and BaF_2-Cu_2O. Our results explained the presence of low temperature melts, and confirmed the importance of p_{O2} in oxyfluoride melting reactions.

To control film properties, it is important to understand the details of Y-213 phase evolution from amorphous "BaF_2" films. High temperature x-ray diffraction has been successfully applied to a number of films deposited on $SrTiO_3$ model substrates (provided by Oak Ridge National Laboratory, ORNL). The phase formation sequences in the binary (BaF_2-Y_2O_3, BaF_2-CuO_x and Y_2O_3-CuO_x) and ternary (BaF_2-Y_2O_3-CuO_x) systems have been determined. Further studies of phase evolution of these films on both $SrTiO_3$ and RABiTS substrates will be conducted.

Understanding the interfacial reactions of Y-213 with buffer layers in RABiTS/IBAD films is critical to the development of coated conductor tapes. Since phase diagrams can provide information on how to avoid or control the formation of second phases, we have initiated a study of the BaO-Y_2O_3-CeO_2-CuO_x system (interaction of Y-213 with the CeO_2 buffer layer).

Efforts have continued on the measurement of enthalpy of formation and vapor pressure of MgB_2. Sources of the variability in these properties have also been determined.

Contributors and Collaborators

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