Phase Relationships in High Temperature Superconductors

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Phase diagrams are central to the successful processing of high T_c superconductor materials as conductors for power transmission. Of current interest for rapid advancement of second-generation coated conductor technology are the $RBa_2Cu_3O_{6+x}$-type superconductors. Issues addressed by current studies include the mixing of smaller and larger R ions to optimize flux-pinning and melting properties, determination of phase relations in the Ba-Nd-Cu-O system under conditions similar to industrial processing, and the phase evolution of $YBa_2Cu_3O_{6+x}$ from barium-fluoride containing precursors.

Two parallel technologies are currently being pursued for the development of practical bulk conductors using cuprate high-temperature superconductors. The powder-in-tube (PIT) process, in which silver tubing is filled with superconductor powder and repeatedly rolled and heated,`is the preferred method of fabrication for Bi-Pb-Sr-Ca-Cu-O (BSCCO)-based superconductors. We have recently determined the primary phase fields for the principal superconducting phases in the multi-component BSCCO system. The rolling assisted by biaxially textured substrate/ion beam assisted deposition (RABiTS/IBAD) coated-conductor technology, in which the superconductor phase is used as a coating on a thin metallic ribbon substrate, is of interest primarily for fabrication of $RBa_2Cu_3O_7$-type (R=lanthanide and yttrium) superconductors. Current phase equilibria research is focused on understanding the dependence of the BaO-R_2O_3-CuO_x subsolidus relations on both oxygen partial pressure and choice of lanthanides. One of the most promising methods for producing high-quality superconductor is the *ex situ* method using e-beam co-evaporated Ba-F-Y-Cu precursor films on RABiTS, followed by a post-annealing in the presence of H_2O vapor. The details of phase evolution of the superconducting phase during this process, however, are not understood. It is important to determine the role of phase equilibria, specifically, whether an intermediate fluorine-containing low-temperature liquid forms, and, whether its formation plays a role in governing the formation of the Y123 phase. The investigation of the system BaF_2-BaO-Y_2O_3-CuO_x-H_2O is a second major thrust of our phase equilibria project.

To match the processing conditions of the RABiT/IBAD coated-conductors, we have established an experimental procedure for minimizing the presence of CO_2 by using carbonate-free BaO. The phase diagrams of the Ba-Nd-Cu-O system under purified air (900 ºC – 930 ºC) and under 0.1% O_2 (810 ºC) were completed. Detailed study of .the subsolidus diagrams also included the characterization of the solid solution series $Ba_{2-x}Nd_{1+x}Cu_3O_{6+z}$. A comparison of the Ba-Nd-Cu-O phase diagrams prepared under different conditions was also made.

By mixing Yb with the Nd123 solid solution, both melting and flux-pinning properties can be tailored and optimized. The solid solution range of $(Nd,Yb)_{1+x}Ba_{2-x}Cu_3O_z$ under pure air, 2% O_2 and 0.1% O_2 was shown to decrease as the oxygen partial pressure decreased. Characterization of the single phase region was conducted using neutron and X-ray diffraction. Melting temperatures were determined using DTA. Onset Tc values were obtained using AC magnetic susceptibility and SQUID measurements.

Our Mettler thermobalance system has been modified to allow different partial pressures and flow rates of water to react with samples in the Ba-Y-Cu-F-O system and subsystems. DTA/TGA studies of the eutectic melt composition in the BaO-Y_2O_3-CuO system were conducted at various oxygen pressure under three processing conditions: (1) in the presence of water vapor, (2) with the addition of BaF_2 , and (3) with the presence of both H_2O and BaF_2. The partial pressure and flow rate of water were found to be critical in these experiments for the formation of the Y213 phase.

Results of our research have been reported at three international conferences in FY2000, and will be discussed during two invited lectures. The importance of this work is also acknowledged by the Department of Energy which has provided continuous partial support. By providing the phase equilibria data as the basis for optimal processing, high T_c technology will be advanced through reductions in cost and improvements in performance. It is anticipated that high T_c products in areas such as power transmission, motors, magnets, and energy storage will have a significant impact on the marketplace. High T_c-based power technologies are widely regarded as environmentally friendly as well as potentially cost effective due to their increased efficiency.

Contributors and Collaborators

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