Microgravity Processing of Oxide Superconductors

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Since the discovery of superconductivity in lanthanide-based perovskite systems, considerable effort has been concentrated on the synthesis and characterization of these materials. The YBaCuO system has received the most intense study, as this material has shown promise for the application of both thin film and bulk materials. There are many problems with the application of bulk materials: weak links, poor connectivity, small coherence length, oxygen content and control, environmental reactivity, phase stability, incongruent melting behavior, grain boundary contamination, brittle mechanical behavior, and flux creep. The extent to which these problems are intrinsic or associated with processing is the subject of controversy. Fundamental to the resolution of this controversy is a clear understanding of the phase relationships in these systems, especially at elevated temperatures. In general, the phase diagram studies of the YBaCuO system have concentrated on solid state reactions and on the Y_2BaCu0_x + liquid $\rightarrow$ $YBa_2Cu_3O_{7-\delta}$ peritectic reaction. Little information is available on the complete melting relations, undercooling, and solidification behavior of these materials.

There has been little success in producing oxide superconductor materials in bulk which possess suitable properties for technological application. Over the past several years, researchers have used a variety of substitutions to the $YBa_2Cu_3O_{7-\delta}$ composition in an effort to find a compound which exhibits superior superconducting properties in bulk. The substitution of other rare earth elements for yttrium, either full or partial, has been found to have little or no deleterious effect on electronic properties. However, it does affect the liquidus and phase relations, lowering the liquidus and increasing the width of the superconducting phase from a line compound to a solid solution.

The primary goal of the research reported here is to understand the microstructures which develop under the non-equilibrium solidification conditions afforded by melt processing in copper oxide superconductor systems. Experiments have been conducted using a drop furnace for small powders (50-100 micron diameter) capable of operating at up to 1750 °C in a pure oxygen environment. The experiment matrix consisted of various compositions of Nd/Y rare earth elements, all at the 1:2:3 composition, processed at twenty five degree increments in the drop furnace. Heat transfer calculations predict that the powders reach the furnace temperature during free fall in the furnace. The processed powders were analyzed using x-ray diffraction, optical microscopy, scanning electron microscopy, and energy dispersive x-ray analysis. The liquidus at the Y-1:2:3 composition, the Nd-1:2:3 composition, and intermediate partial substitution points between pure Y-1:2:3 and Nd-1:2:3 has been defined. Microstructures of drops processed below the liquidus reveals information on the high temperature phase relations in the system. In general, as the amount of Nd is increased, the primary rare earth oxide (Nd or Y) is less likely to form, and intermediate phases, such as 2:1:1 predominate. Samples that are heated above the liquidus undercool significantly and form the 1:2:3 phase directly from the melt in all compositions studied.