Normal State and Superconductivity of \( \text{ErBa}_2(\text{Cu}_{1-x}\text{Cr}_x)_3\text{O}_{7-\delta}(x=0-0.1) \)

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The effects of Cr in \( \text{ErBa}_2(\text{Cu}_{1-x}\text{Cr}_x)_3\text{O}_{7-\delta} \) \( (x=0-0.1) \) superconductor have been investigated. The critical temperature, which was determined by DC electrical resistance measurements, showed no suppression of the onset temperature \( (T_{c,\text{onset}}) \) within the substitution range. The transition width \( (\Delta T_c) \) broadened as the Cr content is increased. The normal state changes from the metal-like to semimetal/semiconductor-like for \( x>0.03 \). Micrographs from the scanning electron microscope, X-ray diffraction pattern, and energy dispersive X-ray analysis results are used to describe the superconducting properties of these materials. The orthorhombic structure was preserved throughout the substitution range. Some possible roles of Cr in the system are discussed.

KEY WORDS: Resistivity; X-ray diffraction; \( \text{ErBa}_2(\text{Cu}_{1-x}\text{Cr}_x)_3\text{O}_{7-\delta} \) superconductor; energy dispersive X-ray analysis and microstructure.

1. INTRODUCTION

The oxygen-defect superconducting \( \text{RBa}_2\text{Cu}_3\text{O}_{7-\delta} \) \( (R=\text{most rare-earth metals}) \) with perovskite-like structure displays superconductivity with \( T_c \) exceeding 90 K. Studies on the effect of metallic substitution in these materials, especially the \( \text{YBa}_2(\text{Cu}_{1-x}\text{M}_x)_3\text{O}_{7-\delta} \) with \( \text{M}=\text{Mn}, \text{Mg}, \text{Fe}, \text{Co}, \text{Ni}, \text{Zn}, \text{Ga}, \text{Cr}, \) and \( \text{Al} \) \( (x=0-0.1) \), have provided useful information regarding the physical properties of these materials (see, e.g., [1-4]). These studies showed the importance of Cu in the superconductivity of this system. Studies on elemental substitutions have also been done on superconductors to determine their behavior in various environments. Impurities can be incorporated in the matrix of a pure superconductor to act as flux pinning centers in order to raise the critical current density.

Compared with the Y-based, studies on the substitution effect on Er-based materials are not as sophisticated. Several studies regarding the effect of substituting Cu with Fe, Ni, and Co in the Er system showed changes in the lattice parameter and a sudden drop in \( T_c \) for \( x \leq 0.05 \) [5]. The normal state and superconducting behavior can be explained in terms of the changes in the microstructure and the precipitation of dopants on grain boundaries in cases where the solubility limit of the substituted element in the parent compound is negligibly low.

This paper reports on the substitution effect of Cr for Cu in the \( \text{ErBa}_2(\text{Cu}_{1-x}\text{Cr}_x)_3\text{O}_{7-\delta} \) superconductor for \( x=0-0.1 \). The powder X-ray diffraction, DC electrical resistance–temperature measurements, together with scanning electron microscope (SEM) and energy dispersive X-ray analysis observations are used to describe their normal state and superconducting properties.

2. EXPERIMENTAL DETAILS

Samples were prepared using the solid-state reaction method. Appropriate amounts of high purity (≥ 99.99%) powders of \( \text{BaCO}_3, \text{Er}_2\text{O}_3, \text{Cr}_2\text{O}_3, \) and \( \text{CuO} \) with starting compositions \( \text{ErBa}_2(\text{Cu}_{1-x}\text{Cr}_x)_3\text{O}_{7-\delta} \) for \( x=0, 0.02, 0.03, 0.05, 0.07, \) and 0.1 were mixed thoroughly. These powders were heated for 24 h at 890-910°C with several intermittent
grindings and oven cooled before cold pressing into pellets with approximately 13 mm diameter and 4 mm thickness. The pellets were then heated at 890–910°C in air for another 24 h followed by furnace cooling to room temperature at ~40°C/h.

Samples were analyzed by the powder X-ray diffraction method using a Siemens D 5000 diffractometer with Cu-Kα source. The DC electrical resistance–temperature measurements were carried out using the four-point probe method with silver paste contacts in conjunction with a closed cycle refrigerator from CT1 Cryogenics Model 22. Scanning electron microscope (SEM) micrographs were recorded using a Philips XL 30 scanning electron microscope. The chemical composition of individual phases was analyzed by energy dispersive X-ray analysis (EDAX) using Philips PV 99 analyzer.

3. RESULTS AND DISCUSSIONS

The X-ray diffraction pattern showed that all samples were single-phased with orthorhombic and perovskite-like 1:2:3 structure. Figures 1a and 1b show the X-ray diffraction patterns for x = 0 and x = 0.1, respectively. The lattice parameters for the sample with x = 0 are a = 3.818 ± 0.001 Å, b = 3.889 ± 0.001 Å, and c = 11.670 ± 0.001 Å. The lattice parameter for samples with different Cr concentration showed very little or no change compared to the pure sample within experimental error (Fig. 2). The oxygen content for x = 0, which was estimated from the variation of the c-axis with respect to oxygen content [6], is O_{8.92} (i.e., δ = 0.08).