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Effects of RE_2O_3 (RE = Tm, Sc, Yb) addition on the superconducting properties of $ErBa_2Cu_3O_y$

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ABSTRACT

We investigated the effects of added Tm_2O_3, Sc_2O_3, and Yb_2O_3 on the superconducting properties of sintered Er123 samples. Tm_2O_3 addition caused the least T_c degradation, exhibiting a T_c above 90 K even for 17 vol% addition. Samples with added Sc_2O_3 maintained a T_c at above 90 K up to an addition of 7.2 vol%, while Yb_2O_3-containing samples showed a monotonic decrease in T_c with increased vol% of added Yb_2O_3. Tm_2O_3-containing samples exhibited a slight increase in $J_c(0.1\ T)/J_c(0)$ and had constant J_c values even for 17 vol% addition. XRD and SEM results indicate that the Tm_2O_3 is very stable in the superconducting matrix.

1. Introduction

Improvement of the critical current density (J_c) of $REBa_2Cu_3O_y$ (RE123) superconductors is essential for the application of RE123 superconducting melt-textured bulk and thin films to high-performance permanent magnets or high-current-carrying wires. Introduction of artificial pinning centers (APC) into RE123 superconducting phases is a very effective technique for enhancing J_c. Significant improvements in J_c have been reported for melt-textured REBCO by adding RE_2BaCuO_5 (RE211) [1], $Y_2Ba_4CuMO_y$ [2], ZrO_2 [3], barium oxides ($BaZrO_3$ [3], $BaCeO_3$ [4], or $BaSnO_3$ [5]) to create APCs. For RE123 thin films, the J_c–B properties were also enhanced significantly by the introduction of nanometer-sized rod-shaped barium oxide into superconducting matrices [6–9]. Recently, we reported a good correlation between the stability of barium oxides in RE123 films and sintered compounds [10]. This suggests that the study of the addition of various materials into sintered samples will be of great help in the search for new APC materials suitable for high-J_c thin films in high-magnetic fields. RE_2O_3 is known to have high thermal stability and to be relatively chemically inert. However, there are few reports on the stability of RE_2O_3 in the superconducting phase [11].

In the present study, we have investigated the effects of Tm_2O_3, Sc_2O_3 and Yb_2O_3 additions on the superconducting properties of Er123 and compared their stability in the RE123 matrix.

2. Experimental

Er123 samples were prepared from Er_2O_3 (99.9%), $BaCO_3$ (99.95%), and CuO (99.99%) using a standard solid-phase reaction technique. Appropriate amounts of the reagents were thoroughly ground and calcined at 1173 K for two periods of 12 h in air, with intermediate regrinding. The resultant Er123 powder was pressed into pellets and sintered at 1233 K in air for two periods of 12 h, with intermediate regrinding. High-purity (99.9%) Tm_2O_3, Sc_2O_3, and Yb_2O_3 powders were then added to the pulverized Er123 pellets in concentrations of 1–17 vol%. The resulting powders were

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thoroughly ground, pressed into pellets and then sintered at 1233 K in air for 12 h. All samples were subsequently annealed in flowing oxygen at 1183 K for 12 h, cooled to 773 K with a 12 h stay, then cooled to room temperature in a furnace. The electrical resistivity of the samples was measured by a standard four-probe technique to determine their critical temperatures (T_c). J_c of the samples at 77 K was calculated from *B–M* curves measured by a superconducting quantum interference device (SQUID) at magnetic fields of 0–1.0 T. X-ray diffractometry (XRD) was employed to identify the phases present in the samples and determine lattice constants. The sample surfaces were characterized using a scanning electron microscope (SEM). The chemical compositions of the precipitates on the sample surfaces were determined by energy-dispersive X-ray spectroscopy (EDX).

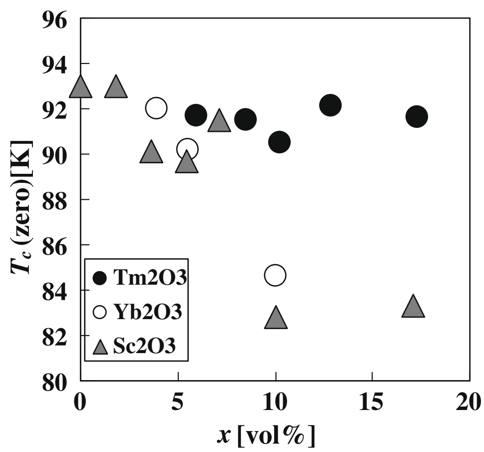

Fig. 1. Dependence of T_c on the amount of RE_2O_3 added to ErBCO sintered samples.

3. Results and discussion

The T_c of the RE_2O_3-containing Er123 sintered samples are shown as a function of the amount added in Fig. 1. Samples with Tm_2O_3 added showed the least degradation of T_c, and maintained T_c above 90 K even for 17.3 vol% addition. Maintaining high-T_c is comparable to $BaSnO_3$ with high stability in the superconducting phase [10]. Sc_2O_3-containing samples maintained a T_c above 90 K up to 7.2 vol% added, but showed degradation of T_c above 10 vol% added. Yb_2O_3-containing samples showed a monotonic decrease in T_c with increasing Yb_2O_3 content. These results indicate that Tm_2O_3 oxides are relatively stable in the superconducting matrix.

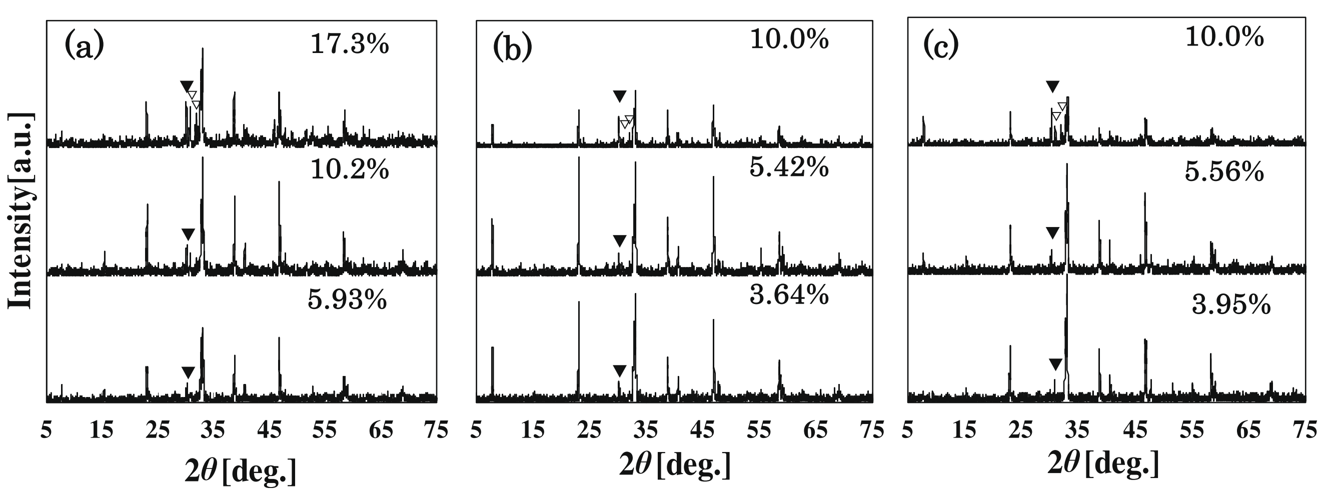

Fig. 2. XRD θ–2θ spectra for (a) Tm_2O_3, (b) Sc_2O_3, and (c) Yb_2O_3-containing ErBCO sintered samples.

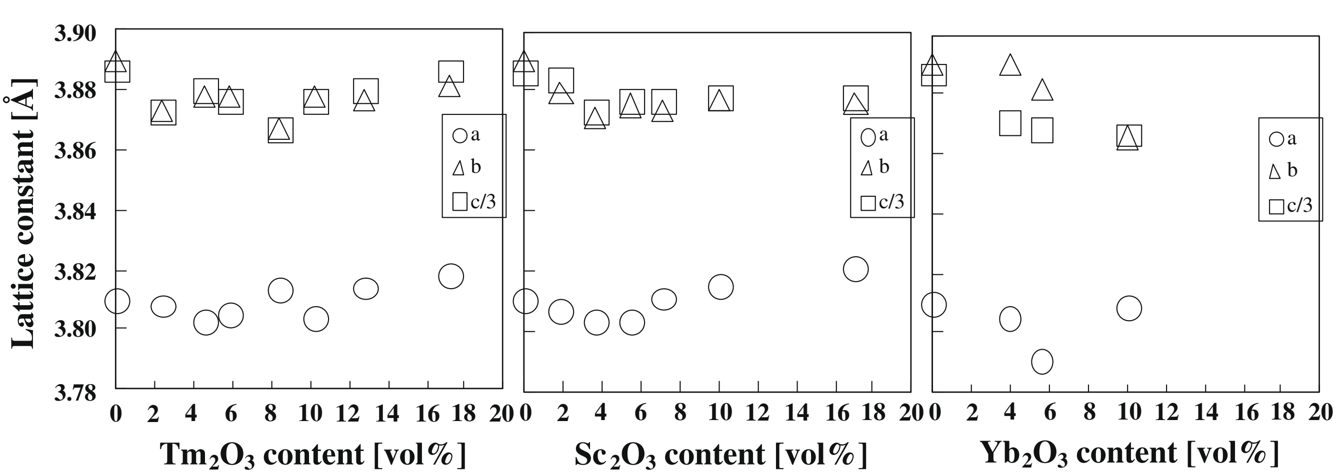

Fig. 3. Lattice constants of the RE_2O_3-containing samples calculated from the XRD patterns as a function of the amount of RE_2O_3 added.