MAGNETO-OPTICAL CHARACTERIZATION OF (Nd$_{0.33}$Eu$_{0.33}$Gd$_{0.33}$)Ba$_2$Cu$_3$O$_y$ BULK SUPERCONDUCTORS WITH DIFFERENT Gd-211 CONTENT

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ABSTRACT: We have investigated the ternary (Nd$_{0.33}$Eu$_{0.33}$Gd$_{0.33}$)Ba$_2$Cu$_3$O$_y$ (NEG-123) bulk superconductors with different amounts of Gd$_2$BaCuO$_5$ (Gd-211) second phase by using magneto-optical (M-O) imaging technique. An external magnetic field was applied parallel to the c-axis of the sample at various temperatures. The observed flux pattern images reflect the $J_c$-$B$ characteristics of rectangular samples in perpendicular magnetic field. The M-O results are compared with DC magnetic measurements. The results show that fine dispersion of Gd-211 is effective in improving the pinning performance.

KEYWORD: Magneto-optical observation, (Nd$_{0.33}$Eu$_{0.33}$Gd$_{0.33}$)Ba$_2$Cu$_3$O$_y$, critical current, 211 particles

INTRODUCTION

It is well known that the RE-Ba-Cu-O (RE: Nd, Sm, Eu, Gd) bulk superconductors prepared by the oxygen-controlled-melt-growth (OCMG) process exhibit high $T_c$ and $J_c$ values, thus are expected as the most promising materials for applications [1,2]. Recently, it has been demonstrated that OCMG processed ternary compounds (RE1-RE2-RE3)-Ba-Cu-O in which three rare earth elements are mixed at the RE site in the same proportion, exhibit a large critical current density $J_c$ [3]. Transmission electron microscopic observations show that submicron-sized Gd211 particles are finely distributed in the matrix [4], which contribute to the enhancement in flux pinning. In this work, we have investigated the ternary NEG123 bulk superconductors with different amounts of Gd211 second phase by using M-O imaging technique.

EXPERIMENTAL

The magneto-optical (M-O) imaging, based on the Faraday rotation in an indicator film, is a useful method to understand the magnetization behavior of superconducting materials because it allows direct local and dynamic observations of flux distributions [5]. The M-O system consists of an electromagnet, a cryostat and an optical microscope connected to a CCD camera. The images are transferred to a data processing system for detailed analyses. The sample was mounted on the cold finger in the cryostat and an indicator film was placed on the sample surface. We employed Bi-doped...
iron-garnet films with in-plane magnetization as an indicator film. The sample is cooled by helium gas in the temperature range of 20 to 300 K. The magnetic field is applied perpendicular to the sample surface, up to a maximum value of 5 kOe. Powders of Nd₂O₃, Eu₂O₃, Gd₂O₃, BaCO₃ and CuO were weighed to have a nominal composition of \((\text{Nd}_{0.33}\text{Eu}_{0.33}\text{Gd}_{0.33})\text{Ba}_2\text{Cu}_3\text{O}_y\). The powders were ground thoroughly and calcined at 880 °C for 24 h with intermediate grinding, which was repeated three times, and then were pressed into pellets and sintered at 1020°C for 48 h [3, 6]. NEG 123 bulk samples with a volume fraction of 10 (A), 20 (B), 30 (C) and 40 mol% (D) of Gd211 secondary phase were prepared using a mixture of sintered NEG 123 and commercial Gd211 powders. The samples also contain 0.5 mol. % Pt in order to refine the 211 particle size. Finally, the samples were cut into a rectangular bar with dimensions of 1.0×1.0×0.5 mm³ and polished mechanically to obtain a flat and shiny surface.

RESULTS AND DISCUSSION

(a)  
(b)  
Figure 1 (a) TEM micrograph of NEG123 with 30 mol% NEG211, (b) SEM micrograph of NEG123 with 30 mol% of Gd211 second phase

A TEM micrograph of NEG-123 with 30 mol% NEG211 is shown in fig. 1 (a). It is found that the sample contains NEG211 and Gd211 particles. The small 211 particles mainly consist of Gd in the rare earth site. A SEM micrograph of NEG123 with 30 mol% of Gd211 second phase is presented in Fig. 1 (b), which shows that a number of fine Gd211 inclusions are trapped in NEG123 matrix [4].

Figure 2 shows the M-O images of NEG123 with 20 mol % Gd211 (sample B). Flux shielding behavior with applying field of 900 Oe at 18K is presented in Fig. 2 (a). Figures 2 (b) and (c) present the remnant states obtained after zero-field-cooling (ZFC), after applying 5 kOe and decreasing it to zero at 18K and 77 K, respectively. Figure 2 (d) presents the image after field-cooling (FC) in 900 Oe and reducing to 0 Oe at 77 K. The regions where magnetic field is present are imaged as bright areas. The sample shows a flux penetration like single grain with no weak-links being present in the matrix. The field penetration [Fig. 2 (a)] is isotropic, as predicted by the critical state model. Figure 2 (b) shows a dark Meissner area located in the center of the sample, surrounded by a bright region of trapped flux. At 77 K, the sample is completely penetrated by flux (fully penetrated state) as shown in Fig. 2 (c). Although the results are not presented, all samples (A, C and D) show homogeneous flux penetration and remnant state.