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J_c-B CHARACTERISTICS OF (Nd-Eu-Gd)-123 MATERIALS DOPED BY SMALL Gd-211 PARTICLES

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ABSTRACT

A concentration profile of Gd-211 particles is studied in an oxygen-controlled melt-grown $(Nd_{0.33}Eu_{0.33}Gd_{0.33})Ba_2Cu_3O_y$ pellet with a nominal content of 30 mol % Gd-211 refined by 0.5 mol % Pt and 1 mol % CeO_2 addition. A special interest is paid to the magnetic properties in dependence of the Gd-211 phase variation inside the pellet of 1.8 cm in diameter and 1 cm in height. $J_c(B)$ dependencies deduced from magnetic hysteresis curves measured by SQUID are discussed with respect to the height and position of the second peak. In view of the present experiment, the effect of the secondary phase particles to the second peak appearance seems to be indirect, entering mainly via enhancement of fluctuations in the matrix properties, especially RE-Ba substitution.

INTRODUCTION

The peak- or fishtail effect (PE, FE) in RE-123 materials is of a paramount importance for bulk HTCS applications. The character of pinning sites producing peak effect is well known, being identified with small, point-like random disorder [1,2]. Which kind of the disorder is active in some particular system as well as what is the underlying character of vortex dynamics, it is still a matter of controversial discussions. Oxygen deficiency is often declared as a principal source of this kind of pinning in RE-123 materials [1,3]. Some studies show a primary role of RE-Ba substitution in RE-123 materials with RE=Sm, Nd, Eu, or Gd, the effect of this substitution being ascribed either to core pinning [4] or to magnetic scattering [5]. Addition of fine secondary phase particles has been also shown to enhance the second peak [6,7]. To be able to identify individual contributions a broad experimental material needs to be collected. Here we present a study of an effect of concentration variation in a series of samples taken from different places of one NEG-123 pellet with addition of 30 mol % Gd-211. As all the samples were prepared under same conditions, they differ only statistically in distribution of the secondary phase particles and in fluctuation of the matrix properties.

EXPERIMENTAL

We studied oxygen-control-melt-growth processed NEG-123 samples with 30 mol % of Gd-211 particles refined by addition of 0.5 mol % of Pt and 1 mol % CeO_2. The exact technological treatment was described in Ref. [8]. A slice 1.5 mm thick was cut from the pellet of 18 mm in diameter and 10 mm in height, 3.5 mm apart of the seed (see Figure 1). From the slice, four vertical bars were cut, denoted L, LL, RR, and R, as indicated in the figure. From each bar three samples were finally prepared, from the top, middle, and bottom of each bar. All twelve samples were annealed together in 1 bar O_2 atmos-

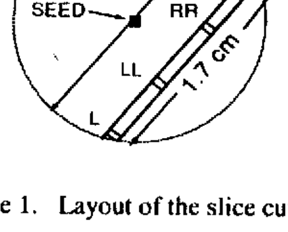

Figure 1. Layout of the slice cut from the NEG-123 pellet (top view).

phere at 600^{0}C to 300 ^{0}C for 240 h. After polishing the samples, magnetic hysteresis curves at 77 K were measured by a commercial 7 T QD SQUID, with field aligned along the c-axis. Critical current densities were calculated from magnetic hysteresis curves using the extended Bean model for a thin prism magnetized along the normal to the plane. The sample morphology was investigated by scanning electron microscope (SEM) with the aim to check variation in the Gd-211 particles distribution within the pellet. The quality of the samples was checked by measuring the dc susceptibility as a function of temperature, both in the zero-field-cooled and filed-cooled modes.

RESULTS AND DISCUSSION

All twelve investigated samples showed practically same concentration and size of the Gd-211 particles as shown in Figure 2. The average size of the particles was around 1 μm, the smallest particles being of the size 0.3 μm. This proves that the technology is able to produce samples with a homogeneous distribution of fine secondary phase particles embedded in the RE-123 matrix.

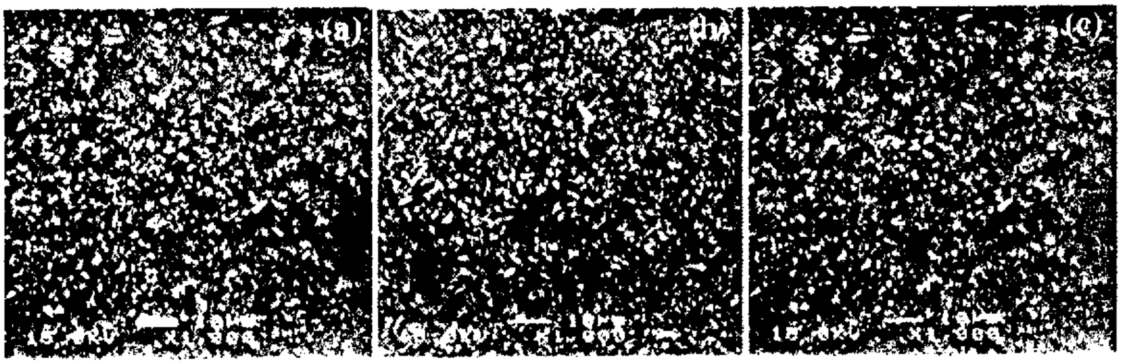

Figure 2. SEM images showing secondary phase particle distribution in the samples LL taken from (a) top, (b) centre, and (c) bottom of the pellet. White bars at the bottom of figures indicate scale of 10 μm.

Magnetic behaviour of the samples was more complicated. In all twelve samples, the critical current density at the zero field and T = 77 K reached rather high values around 70 kA/cm^2 and the irreversibility field was typically around 6 T. The secondary peak lay at fields 1.7 – 1.8 T but its height varied from sample to sample. Figure 3 shows the $J_c(B)$ curves of the samples RR and LL. The curves of the bar RR all exhibited a rather well developed fishtail peak with maximum ranging from 50 to 64 kA/cm^2. A similar value was also observed in the middle LL sample, the top LL sample had smaller peak of about 40 kA/cm^2, and in the bottom LL sample, the peak vanished nearly completely (see figure 3 (b)). The reason was easy to identify. This bottom sample was heavily contaminated by ZrO_2 coming from a support during the melt process. As the melting temperature of Gd-211 particles is higher than that of the NEG-123 matrix, the second phase particles were not practically affected by the reaction with ZrO_2. The contamination was proved by temperature dependence of dc susceptibility. While in the other samples the superconducting transition started at around 93.6 K and was completed typically within 1-1.5 K, the curve of the contaminated sample showed the same superconductivity onset, fell down to 80% of its final value within 1.6 K but then exhibited rather long tail extended up to 85.5 K. Although this sample was evidently bad, it presented a material for consideration on the operative pinning in this material. As mentioned above, the distribution of the Gd-211 particles in the bottom LL sample was evidently similar to that in the other samples. By the contamination only the peak was suppressed but superconductivity in the sample survived in the form of a background $J_c(B)$ curve that resembled that of the other samples. This leads to the conclusion that the role of even fine secondary phase particles in formation of the second peak is indirect, a variation of the matrix properties being the principal pinning source responsible for FE [9].

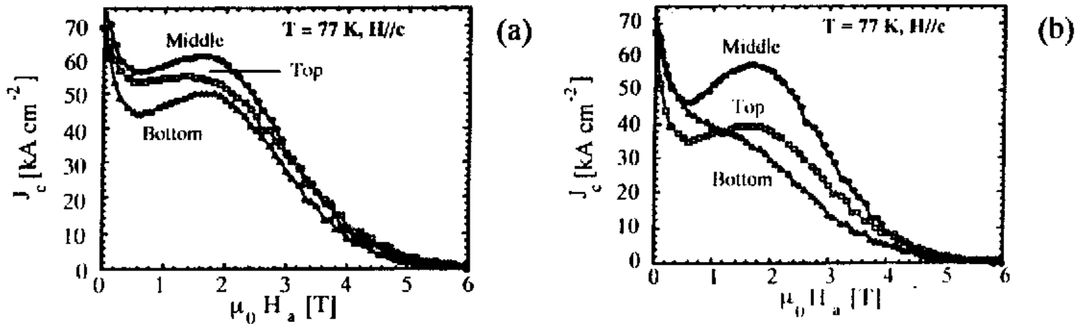

Fig.3., Critical current densities of the samples (a) RR and (b) LL.

The Ba substitution by Nd, Eu, and Gd atoms suggests itself as a primary source of the pinning. The effect of oxygen deficiency is in our samples less probable due to the good oxygenation documented by high T_c values in all the samples. We also stress that the highest peak was achieved at RR and LL positions in the middle sample, whereas at the positions R and L (closer to the pellet edge) in the top samples. This might indicate an effect of growth rate during the melt texture process on the magnetic properties of the matrix.

CONCLUSIONS

In the studied NEG-123 system, the Gd-211 particles are regularly distributed within the whole pellet crossection. Also the background $J_c(B)$ dependence is similar in all the samples. On the other hand, the peak effect, observed at field of about 1.7 T (77 K), varied from sample to sample indicating much stronger effect of the local fluctuations in the matrix than of the secondary phase particles. These particles may indirectly induce the matrix properties variation, in which the particles refinement would be important.

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