Critical Current Density for Melt-Processed Filamentary Monolithic RE123 (RE=Nd, Sm, Eu, Gd) Superconductors

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Abstract

The filamentary monolithic RE123 (RE=Nd, Sm, Eu, Gd) precursor was prepared by a solution spinning method. The precursor was partially melted under various conditions and then oxygenated. The influence of field dependence of J_c on the initial different RE element in the filamentary RE123 superconductors was examined. The high J_c values were attained for Nd123 and Eu123 samples partially melted in flowing 0.1%O_2+Ar and for Sm123 and Gd123 samples partially melted in flowing 1%O_2+Ar. The field dependence of J_c for Eu123 sample was superior to that for the other samples.

Key words: filamentary RE123 ; oxygen controlled melt growth ; initial RE element ;

1. Introduction

The oxygen controlled melt growth (OCMG) process for RE-Ba-Cu-O (RE=Nd, Sm, Eu and Gd) (RE123) superconductors is effective in achieving high critical current density (J_c) value in a high magnetic field region accompanied by a secondary peak effect at 77 K [1]. We have studied a fabrication of filamentary RE123 superconductors with high J_c values at 77 K [2] and it was found that the filamentary ternary $(Nd_{0.33}Eu_{0.33}Gd_{0.33})123$ superconductors exhibited high J_c value such as $10^4 A/cm^2$ at 77 K and 10 T. Recently, it was proposed a new technique for pinning enhancement in OCMG processed ternary RE123 bulk system superconductors by optimizing the matrix composition. Chemical fluctuation or distribution of a solid solution of RE rich 123 (RE123ss) cluster in the RE123 matrix is sensitive to the kind of RE element involved [3]. In this paper we have studied the J_c for filamentary monolithic RE123 (RE=Nd, Sm, Eu and Gd) superconductors to clarify the effect of rare earth element on the J_c for the filamentary sample.

2. Experimental

The filamentary RE123 precursor was produced by dry spinning through a homogeneous aqueous solution containing mixed acetates of RE, Ba, Cu, poly(vinyl alcohol) and organic acids as reported in a previous paper [2]. The as-drawn filament was heated to remove any volatile components and calcined. The calcined sample was partially melted under various heating conditions in flowing 0.1%O_2+Ar, 1%O_2+Ar and 20%O_2+Ar. A two step treatment was employed for the oxygenation of the sample. The first step heat treatment was at 500 °C for 5 h and the second step was 340 °C for 10 h. The J_c at 77 K was measured by a standard four probe resistive method. Silver paint was used to connect the silver sputtered parts of the sample. The samples were embedded in a substrate using a resin and mounted on a critical current measuring holder. External magnetic

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Table 1
T_c, maximum J_c value at 77 K and 0 T for the filamentary sample prepared with optimum melting temperature.

RE123	Gas flow	Temp. (°C)	T_c value (K)	J_c (10^4A/cm^2)
Nd123	0.1%O_2+Ar	990	92	3.5
Nd123	1%O_2+Ar	1020	94.5	1.4
Sm123	0.1%O_2+Ar	990	90	2.6
Sm123	1%O_2+Ar	1040	90	2.5
Eu123	0.1%O_2+Ar	1030	90	1.3
Eu123	1%O_2+Ar	1030	89	1.4
Gd123	0.1%O_2+Ar	980	91.5	1.4
Gd123	1%O_2+Ar	1020	90	2.1
Gd123	20%O_2+Ar	1080	90	1.4

fields were applied in a direction normal to the filament length using a helium-free 11 T superconducting magnet at the High Field Laboratory for Superconducting Materials, Tohoku University. Current was passed along the filament length and magnetic field was applied perpendicular to the filament length. A criterion of 5 μV/cm was used for the J_c measurement.

3. Results and Discussion

The calcined filamentary samples were partially melted under various heating conditions. Optimum heating condition for obtaining the high J_c at 77 K and 0 T was examined for the samples under various atmospheres. The optimum partial melting temperature, T_c and maximum J_c value at 77 K and 0 T for the samples are listed in Table 1.

Although the present filamentary sample starts from the chemical liquid precursor, the solidus and peritectic temperatures are considerably low. It is well known for the bulk 123 oxide that a crystal growth less than 1 °C/h is needed for good alignment and obtaining the high J_c. The optimum cooling rate for the present sample of 40 °C /h was one order of magnitude higher than that for the bulk sample owing to the filamentary morphology. The high T_c value more than 90 K is observed for the all samples. Especially, a high J_c value of 1.4x10^{4}A/cm^2 at 77 K and zero fields was attained for Gd123 sample molten in flowing 20%O_2+Ar.
The field dependence of J_c for the samples was investigated at 77 K in magnetic fields up to 10 T. Since the samples processed in flowing 0.1%O_2+Ar and 1%O_2+Ar had well aligned texture along the filament diameter as well as the filament length, a clear anisotropy on the J_c-B behavior was detected for the samples along the filament diameter. The influence of field dependence of J_c on the initial different RE elements in the filamentary RE123 superconductors was examined. The highest J_c values was attained for the

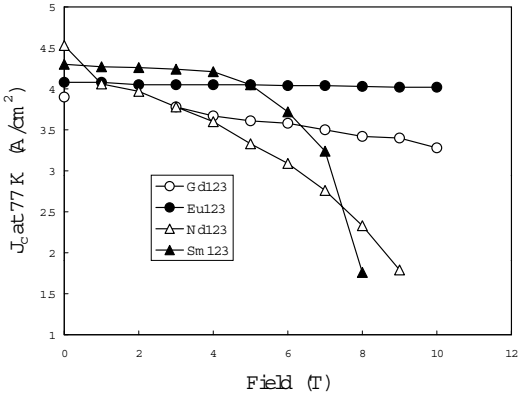

Fig. 1. The field dependence of J_c for the filamentary RE123 superconductors.

Nd123 and Eu 123 samples partially melted in flowing 0.1%O_2+Ar and for the Sm123 and Gd123 samples partially melted in flowing 1%O_2+Ar. The field dependence of J_c is listed in figue 1. The field dependence of J_c for the Eu123 sample was superior to that for the other samples and Eu123 superconductors exhibited high J_c value such as 10^4A/cm^2 at 77 K and 10 T.

Unlike Y123, which forms only a stoichiometric compound, the light rare earth elements form RE123ss. High T_c phase of RE 123ss can be stabilized in low PO_2. It is considered that Eu123ss in the present filamentary samples especially play an important role for the flux pinning force. The optimum melting temperature for Eu123 sample partially melted in flowing 0.1%O_2+Ar is rather higher than that of others. Therefore a temperature range for the liquidus phase during the partial melting became to be wider, and high T_c phase of Eu123ss was successfully precipitated. On the other hand, it should be noted that the present filamentary sample starts from chemical-liquid phase and may contain a microscopic feature such as fine chemical contamination or oxygen defect and twin plane as well as compositional fluctuations of RE123ss.

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