

Partial Melting in Filamentary Sm-Ba-Cu-O Superconductors under Various Oxygen Atmospheres

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Abstract

The filamentary Sm123 precursor prepared by a solution spinning method was partially melted in flowing 0.1%O₂+Ar and 1%O₂+Ar and oxygenated. The obtained sample showed T_c value of around 90 K and exhibited dense and well-aligned texture along the filament diameter as well as the direction of filament length. Maximum J_c values of 2.6×10^4 A/cm² and 2.5×10^4 A/cm² were attained for the sample partially melted at 990°C in flowing 0.1%O₂+Ar and the sample partially melted at 1040°C in flowing 1%O₂+Ar, respectively. A high J_c value more than 10^4 A/cm² with good reproducibility was observed for the sample melted in flowing 1%O₂+Ar over a melting temperature ranging from 1020°C to 1060°C.

Key words: filamentary Sm123; oxygen controlled melt growth; critical current density;

1. Introduction

The oxygen-controlled-melt-growth (OCMG) processed bulk LRE-Ba-Cu-O superconductors (LRE: light rare earth = Nd, Sm, Eu and Gd) have significant potential for practical application of high T_c superconductors due to the enhanced secondary peak effect in intermediate magnetic fields and high critical current density (J_c) value in a high field region at 77 K [1]. For the applications of superconducting magnet and power cable operated at 77 K, it is necessary to form the LRE123 superconductors into a tape or wire. However, few studies have been carried out towards establishment of the fabrication techniques and improvement of superconducting properties for the tape or wire type LRE superconductors processed by the OCMG.

We have studied fabrication and characterization of filamentary monolithic LRE123 superconductors

except Sm123 and it was found that the filamentary LRE123 superconductors showed relatively high transport J_c value more than 10^4 A/cm² at 77 K and self filed [2]. In this paper we have studied the fabrication and characterization of filamentary monolithic Sm123 superconductors prepared by solution spinning and the OCMG process in order to establish the fundamental data.

2. Experimental

The filamentary Sm123 precursor was prepared by a solution spinning method, through a homogeneous aqueous solution containing mixed acetates of Sm, Ba and Cu, poly(vinyl alcohol), propionic acid and 2-hydroxy isobutyric acid. An acetate mixture with the nominal composition of Sm:Ba:Cu = 1.18:2.12:3.09 was dissolved in the solution, and then the homogeneous aqueous solution was concentrated to obtain a viscous spinning dope. The dope was extruded as a

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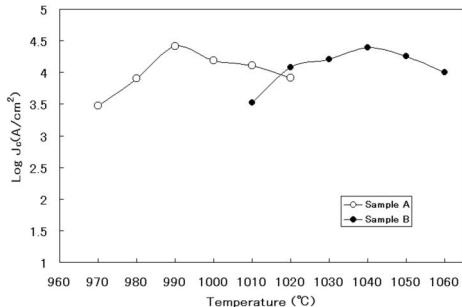


Fig. 1. Critical current density J_c at 77 K and self-field for filamentary samples partially-melted at various temperatures.

filament into a hot air zone, and coiled on a winding drum. The precursor filament was heated to 450 °C at a rate of 25 °C/h and then calcined at 800 °C for 15 min in flowing O₂ to remove any volatile components and CO₂. The calcined filament was partially melted under various heating conditions in flowing 0.1%O₂+Ar (Sample A) and 1%O₂+Ar (Sample B). The oxygenation was carried out by a two-step treatment, which was at 500 °C for 5 h firstly, and at 340 °C for 10 h secondary, in flowing O₂ gas. The T_c and transport J_c at 77 K and self-field were measured by a standard DC four-probe resistive method. The microstructure of the samples was also studied using X-ray diffraction (XRD) and a scanning electron microscope (SEM) with energy dispersive X-ray (EDX) analysis.

3. Results and Discussion

The diameter of the filamentary Sm123 sample after partial-melting was about 80 μ m. The calcined samples were partially melted at various temperatures for 30 min under reduced atmosphere. Then the samples were cooled by two steps, first cooling step from molten temperature by 100 °C at a cooling rate of 30 °C/h and second step to 500 °C was at a cooling rate of 50 °C/h. Temperature dependence of the resistivity for the samples heated was measured. Sample A and B showed metallic behavior from room temperature to the transition onset, and then the resistivity rapidly decreased to zero around 90 K with a transition width of 2 K. It was found that the structure of the samples was mixture of dominant Sm123 phase and second phases such as Sm211 from XRD pattern. The intensity of reflection peak from Sm211 phase for Sample A was higher than that for Sample B.

The filamentary samples were partially melted at various temperatures in flowing 0.1%O₂+Ar and 1%O₂+Ar to obtain high J_c values at 77 K and self-field. The relation between partial-melting temperature of the OCMG process and the transport J_c

value at 77 K and self-field was shown in Figure 1. The J_c values of the filamentary samples are strongly dependent on the OCMG temperature and an ambient atmosphere. Maximum J_c value of 2.6×10^4 A/cm² and 2.5×10^4 A/cm² is attained for Sample A partially melted at 990 °C and Sample B partially melted at 1040 °C, respectively. Sample B exhibited a high J_c value more than 10^4 A/cm² over a wide melting temperature ranging from 1020 °C to 1060 °C with good reproducibility. The optimum melting temperature for Sample A is lower by 50 °C than that for Sample B. It was reported that the peritectic decomposition temperature for the bulk Sm123 superconductors in flowing 0.1%O₂+Ar was lower by about 40 °C than that for the bulk Sm123 in flowing 1%O₂+Ar [3].

The SEM photographs of the fracture surface for Sample A and B was observed. Both samples showed a dense and well-aligned structure. The thickness of crystal layer for Sample B was larger than that of Sample A. Further SEM observation of the longitudinal cross-sectional surface of Sm123 superconductor exhibited a dense microstructure without pores and well aligned texture not only along the filament length but also the direction of filament diameter.

It is also known that the LRE123 superconductors generate LRE_{1+x}Ba_{2-x}Cu₃O_y (LRE123ss) type solid solution due to the fact that ionic radius of LRE is close to that of Ba, and the T_c value decreases with increasing x value of LRE123ss. Melt-process in low oxygen partial pressure is effective either to decrease peritectic decomposition temperature and to suppress the formation of the LRE123ss with large x value. However, the reproducibility in J_c value for Sample B was superior to that for Sample A. An averaged EDX analysis on the five cross-sectional surface region of Sample B partially melted at 1050 °C represented the compositional atomic ratio of Sm:Ba:Cu=1.09:1.93:3.00, which indicated a little stoichiometric deviation from the 123 compositional ratios after melt process. This shows that partial-melting in flowing 1%O₂+Ar results in the suppression of the formation of the LRE123ss with large x value for the filamentary Sm123 superconductors.

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