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Microstructures of $YBa_2Cu_3O_y$ Layers Deposited on Conductive Layer-Buffered Metal Tapes

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Abstract

$REBa_2Cu_3O_y$ (REBCO; RE: rare-earth elements)-coated conductors (CCs) have high potential for use in superconducting devices. In particular, REBCO CCs are useful for superconducting devices working at relatively high temperatures near 77 K. The important issues in their applications are high performance, reliability and low cost. To date, sufficient performance for some applications has almost been achieved by considerable efforts. The establishment of the reliability of superconducting devices is under way at present. The issue of low cost must be resolved to realize the application of superconducting devices in the near future. Therefore, we have attempted several ways to reduce the cost of REBCO CCs. The coated conductors using a Nb-doped $SrTiO_3$ buffer layer and Ni-plated Cu and stainless steel laminate metal tapes have recently been developed to eliminate the use of electric stabilization layers of Cu and Ag, which are expected to reduce the material cost. Good superconducting properties are obtained at 77 K. The critical current density (J_C) at 77 K under a magnetic self-field is determined to be more than $2x10^6$ A/cm^2. The microstructures of the CCs are analyzed by transmission electron microscopy to obtain a much higher quality. By microscopic structure analysis, an overgrowth of the buffer layer is observed at a grain boundary of the metal substrate, which is one of the reasons for the high J_C.

Keywords: Coated Conductors;Conductive buffer layers; TEM; Microstrcutures; YBCO

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1. Introduction

Since the discovery of high-T_C superconductors, the fabrication and improvement of superconducting wires have been conducted by numerous research institutes. Owing to considerable effort, $Bi_2Sr_2Ca_2Cu_3O_{10}$ silver-sheathed wires (Bi2223 SS wires) have already been commercialized [1]. Several superconducting devices, such as superconducting cables [2], motors [3] and generators [4], have been developed. However, the cost of the Bi2223 SS wires is considered to be a limitation because the fabrication of the Bi2223 SS wires uses expensive mass silver. Therefore, $REBa_2Cu_3O_y$ (REBCO, RE: rare-earth element)-coated conductors have been developed as second-generation wires to reduce the wire cost. The coated conductors have recently been commercialized [5-7]; however, they are still expensive. According to our cost analysis of the coated conductors, metal tapes, such as NiW and Hastelloy, and an electric stabilization layer using silver and copper layers are the major causes of the high cost. Consequently, NiW and Hastelloy will be replaced with common metals, such as copper or stainless steel, and metal tapes will be used as an electric stabilization layer by using a conductive buffer layer instead of silver and copper layers. The new and conventional architectures of the coated conductors are described in Fig. 1. This is the first attempt to determine the feasibility of our concept. Therefore, the architecture of the coated conductors became purposely much simpler; it is composed of a biaxially textured metal tape, a Nb-doped $SrTiO_3$ layer as a conductive buffer layer, and a $YBa_2Cu_3O_y$ (YBCO) layer as a superconducting layer.

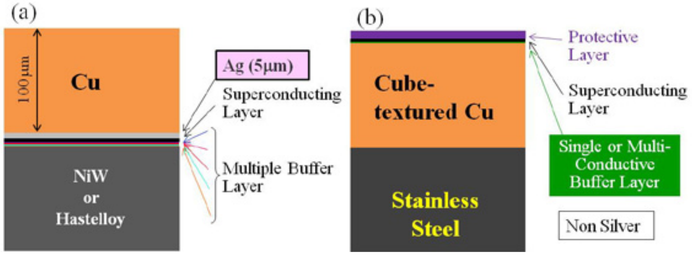

Fig. 1. New and conventional architecture of coated conductors.

In this study, the obtained sample with the new architecture was characterized by X-ray diffraction (XRD) measurements and a critical current density (J_C) measurement at 77 K under a magnetic self-field. Furthermore, because the sample exhibited relatively good properties, the microstructures were examined in detail by transmission electron microscopy (TEM).

2. Experimental Procedure

Metal tapes were obtained from Tanaka Kikinzoku Kogyo Co. Cube-textured Cu and stainless tapes were bonded by a surface activated bonding technique [8]. The Cu surfaces were polished to be clean and smooth by electrolytic polishing. Then, a 500nm Ni layer was fabricated by electroplating, and Nb-doped $SrTiO_3$ (Nb-STO) was selected as a conductive buffer layer, which was deposited by pulsed-laser deposition using a KrF excimer laser. Finally, YBCO layer was deposited by pulsed-laser deposition in the different chamber for the buffer layer fabrication. The nominal composition of the target was $Y_{0.9}Ba_2Cu_3O_y$ owing to the suppression of the yttrium-rich impurity phase. Because YBCO did not properly grow in the upper regions of the yttrium-rich impurity phase, holes were sometimes observed in YBCO layer in the cross-sectional TEM or surface SEM images. Deposition conditions of the buffer and YBCO layers are listed in Table I.

Table I. Preparation conditions of the buffer and YBCO layers

Conditions	Nb-doped $SrTiO_3$	YBCO
Wavelength (nm)	248	248
Frequency (Hz)	20	2
Laser Energy (mJ)	240	200
Gas	$2\%H_2+98\%Ar$	O_2
Pressure (Pa)	$1.2x10^{-2}$	35
Temperature (ºC)	600	790
Thickness (nm)	120	160

The structure analysis of the obtained films was carried out by XRD and TEM. J_C was measured at 77 K under a magnetic self-field by a four probe method. XRD θ-2θ scan was measured to determine the phase identity and crystal orientation. The pole figure was measured to confirm the biaxial alignment of the buffer and YBCO layers using the Nb-STO (110) and YBCO (103) peaks. TEM samples were prepared by cutting and milling using a focused-ion beam. Microscopic structure analysis