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Buffer layers grown by replicating the texture of an original template tape

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Abstract

We propose a fabrication method of the buffer layers, whose biaxial textures are replicated from an original template tape. The purpose of this method is economical texturing process for coated conductors. At first we prepared a biaxially textured metal tape (TM-tape). Then a sacrifice layer (SA), a buffer layer (BU) and a thick metallic layer (SM) were sequentially deposited on the TM-tape. SA-layer and BU-layer were deposited epitaxially to copy the texture of the TM-tape. SA-layer was dissoluble in water. SM-layer with the textured BU-layer was separated and could be used for a supporting tape for the further growth of a superconducting layer. In this way, it is possible to reuse the original textured TM-tape many times. In this paper, we report the results of our experiments, in which we used a biaxially Ni tape, BaO film, STO film, and a thick Ag film for TM-tape, SA-layer, BU-layer, and SM-layer, respectively. The Ag/STO layers were successfully separated form the Ni tape by dissolving the BaO layer in water. The texture quality of the STO layer was well secured after the separation.

Keywords: Coated conductors; Replication; BaO

1. Introduction

There have been plenty of efforts for the commercialization of coated conductors (CCs) in several companies [1]. However, the requirements of low price and high quality for general marketing seem to be not fulfilled yet [2]. CCs consist of biaxially textured superconducting films supported by metallic tapes. The superconducting films form their textures as they grow epitaxially on the low-lying textured buffer layers. There are the several methods of texture formation, IBAD, RABiTS, and ISD [3–5].

The length of useful CCs is typically from hundreds to thousands of meters. Since the tape is so long, it is difficult to provide well textured templates with high yields [6]. This difficulty might increase the percentage of failure. Thus, we think that the individual texturing process may be not economical in the case of mass production. The repetitive difficulties in texturing for every texturing processes cause an increase of the production cost. If one can obtain the textures of many CC tapes by replicating one well textured original template by a reliable method, the production cost of CCs as well as the percentage of failure in texturing can be reduced.

In this paper, we propose a fabrication method of the buffer layers, whose biaxial textures are replicated from an original template tape. By this method, we think that it is possible to fabricate many offspring tapes with copied textures from a highly textured template metallic tape (TM). The procedure of our experiment is illustrated in Fig. 1. A sacrifice layer (SA) and a buffer layer (BU) are deposited epitaxially so as to copy the biaxial texture of TM-tape, and then a thick supporting metallic layer (SM) is deposited. After dissolving the s-layer in solvent, the tape which consists of the textured BU-layer and SM-layer is separated from the TM-tape. Extra oxide layer (EO)

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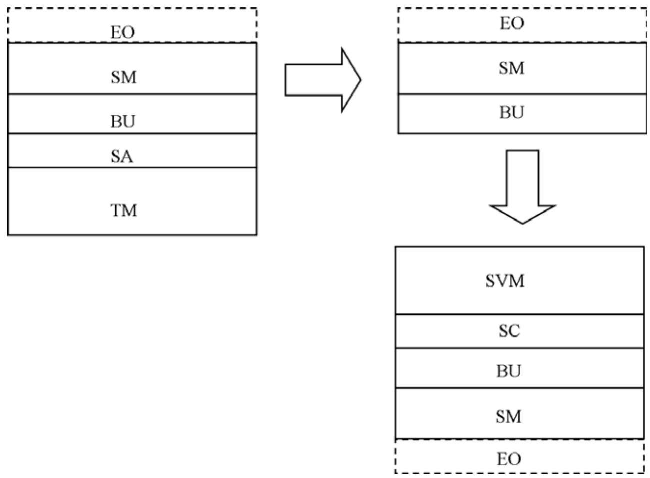

Fig. 1. Replication processes proposed. The s-layer (SA), the buffer layers (BU), and the supporting layer (SM) are deposited successively on the original template tape (TM). After dissolving the SA in a solvent, the tape composed of the BU and SM is separated from the TM. Then a SC can be grown epitaxially on the BU of the separated tape.

might be deposited on the other side of SM-layer before being separated in order to prevent the separated tape from curling. Then the superconducting layer (SC) can be grown epitaxially on the buffer layer of the separated tape using an appropriate additional buffer layer. One more metallic layer (SVM) might be deposited on the superconducting layer for stabilizing the vortex state [7].

By repetition of the replication process, one can obtain many textured offspring tapes from one original TM-tape. We will describe the detailed processes for BU/SM tapes.

There are four requirements for these processes. First of all, one must prepare the best biaxially textured metallic tape, which will be used as an original TM-tape. To copy the texture of TM-tape repeatedly, it should be a quite thick metallic tape and its surface should be cleaned after each process. The appropriate material for TM-tape is a biaxially textured Ni tape. Secondly, one need SA-layer which should be grown epitaxially on the original TM-tape and removed in the following process after playing the role of the texture template for BU-layer. Thus the SA-layer should be oxide and dissolvable in appropriate liquid such as water in order to separate BU/SM/EO-layers from TM-tape. Thirdly, the thick SM-layer is necessary for a strong supporting after separation. This layer needs not to be textured. However, the texture of BU-layer should be secured without any degradation during the separation. Fourthly, the stabilizing layer (SVM-layer), which is also another metallic layer, should be deposited on the superconducting layer. This is because SM-layer cannot play the role of stabilizing because of the electrical separation by the buffer layer between SC-layer and SM-layer. The appropriate material for SVM-layer is an Ag film.

The material properties required for the two roles, stabilizing and supporting, are different; the strength and the stiffness are required for SM-layer while the good conductivity is required for SVM-layer. SM-layer should be as thick as several tens of μm for enough strength. If highly strong and stiff material is selected for this metallic layer, the thickness can be reduced. Since the metallic layer must be deposited with high speed evaporation at the room temperature, it cannot be textured. Thus the supporting layers in our replication method are not textured. In our experiment, we used a thick Ag film for SM-layer temporarily. We are looking for the best material for this.

We would refer our old paper to show the possible solution for the second requirements [8]. In Ref. [8], we deposited the BaO film as an SA-layer on a single crystalline YSZ substrate. The BaO layer was grown epitaxially. Then we deposited a STO buffer layer (BU) epitaxially on the SA-layer. We deposited a thick Pt layer on the STO layer and deposited one more STO buffer layer on the Pt film to prevent curling during the following separation process and then we separated the STO/Pt/STO film by dissolving the BaO layer in water. Actually this method was developed to obtain an extremely thin Pt membrane. Then we could successfully deposit a YBCO film on the textured STO layer of the STO/Pt/STO membrane. This method, which we used in Ref. [8], indicates that BaO can be a good candidate of SA-layer.

By taking advantage of the method in Ref. [8], we tested the requirements mentioned above. We deposited BaO layer for SA-layer, and STO for BU-layer on a biaxially textured Ni tape instead of YSZ crystal. In this paper, we report the details of our experiments and the results of preparation of BU/SM with replicated texture.

2. Experimental

We rolled a 3 mm thick Ni plate to a ~80 μm thick tape and annealed it for the cube texture in Ar–H_2 atmosphere at −900 °C while the NiO layer on the surface was deoxidized by the hydrogen gas [9,10]. We used this biaxially textured Ni tape as an original TM-tape. Any NiO layer at the surface, which might be formed thereafter, was again deoxidized by the Ba deposition in the subsequent process.

Usually the CeO_2 films are used for the oxide buffer layers on the textured Ni tapes [11]. However, we could not find a good solvent for dissolving the CeO_2 layer. Since the BaO films are soluble in the water, we can use them for SA-layers on the Ni tapes. Another merit of the use of BaO is the small value of the electron negativity of Ba (0.9 eV). Thus we expected that the epitaxial growth of the BaO layer on the Ni template is possible by the reactive deposition using water vapor similarly as in the case of CeO_2 growth on Ni tape [12–15]. Since the electron negativities of Ce (1.1 eV) and Ba are much smaller than those of Ni (1.8 eV) and H (2.1 eV), they can be oxidized by water vapor without the formation of NiO. The partial pressure of water vapor was chosen to optimize the reaction of Ba at a given deposition rate.

A small lump of Ba was evaporated using a stainless boat, while the water vapor of 1×10^{-5} Torr partial pressure was supplied into the evaporation chamber for the