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Fabrication of YBCO films on Ag substrate by TFA-MOD method①

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Abstract: Biaxial aligned YBCO films have been successfully deposited on Ag {110} ⟨110⟩ textured polycrystalline substrates by metal-organic decomposition (MOD) method using Trifluoroacetate Salt (TFA). The influence of firing temperature and Ag surface defects on phase purity and texture, surface morphology of YBCO films was studied. Holding temperature at 900 ℃ for 30 min benefits to improve orientation and connectivity of YBCO films. The surface of YBCO films deposited on unpolished Ag substrate has many holes and stripes, which are parallel to the rolling stripe on Ag substrates. To eliminate the rolling stripe on the Ag surface, Ag substrates were polished prior to films deposition. The film grown on polished Ag substrates has a smooth surface and good connectivity of grains without parallel stripes. The YBCO films have an onset of transition around 90K and critical current densities of 15 000 A/cm^2.

Key words: YBCO; TFA-MOD; textured Ag; coated conductor
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1 INTRODUCTION

MOD has a variety of advantages, such as precise controllability of composition, wide flexibility to coating objects and a low cost non-vacuum approach to ceramic films. Additive can be added to the precursor solution to meet the experimental demand. So many studies about this method have been done in recent years. The YBCO films with high J_c were fabricated on $LaAlO_3$ and $SrTiO_3$ single crystal substrates[1-4] by the TFA-MOD method at the beginning. However, it is not proper to fabricate large area films and long tapes with single crystal substrates. At the later time, long YBCO tapes with high J_c values were also reported on Ni tapes[5-7] by this method, with in-plane aligned buffer layers, which had multi-layered structures. A stabilizing layer of Ag is also required for protection against over current when an insulating buffer layer is used. So, the manufacturing process of buffer layers and over-coated Ag layer make this method time-consuming and complicated. A way to solve this problem is that the YBCO film is directly deposited on a textured Ag tape without any buffer layers by MOD method. Meanwhile whole Ag tape can be used as a stabilizing layer for protection against over current. In view of its simplicity, it will be a promising practical preparation method. However, up to now no such a report about this aspect has been seen. In this paper, YBCO films were fabricated on polycrystalline Ag substrates by a TFA-MOD method. We concentrated on the influence of firing temperature and Ag surface defects on phase purity, texture and surface morphology of YBCO films.

2 EXPERIMENTAL

A TFA precursor solution was prepared by dissolving the acetate of Y, Ba and Cu in distilled water in a 1∶2∶3 cation ratio with stoichiometric quantity of TFA, then water and acetic were removed by an evaporator to yield a blue glassy residue. The coating solution with total metallic concentration of 1.5 mol/L was made by dissolving the residue into methanal. The gel films were coated onto Ag {110} ⟨110⟩substrates by spin-coating method for 2 min at 5 000 r/min.

The heat treatment of the coating film was applied by two stages heating profiles, which are shown in Fig. 1. In the first calcination stage, the film coated TFA solution was decomposed to an amorphous precursor film by slowly heating up to 400 ℃ in a humid oxygen atmosphere. In the second calcination stage, the amorphous precursor film was heated up to 900 ℃ in a humid argon and held for 30 min in a dry argon. Humid atmospheres mentioned above in the furnace were produced by bubbling the inlet gas through an attached reservoir of de-ionized water. After growth, films were slowly cooled to 500 ℃. Post-oxygenation was carried out at 500 ℃ for 90 min followed by naturally cooling to room tempera-

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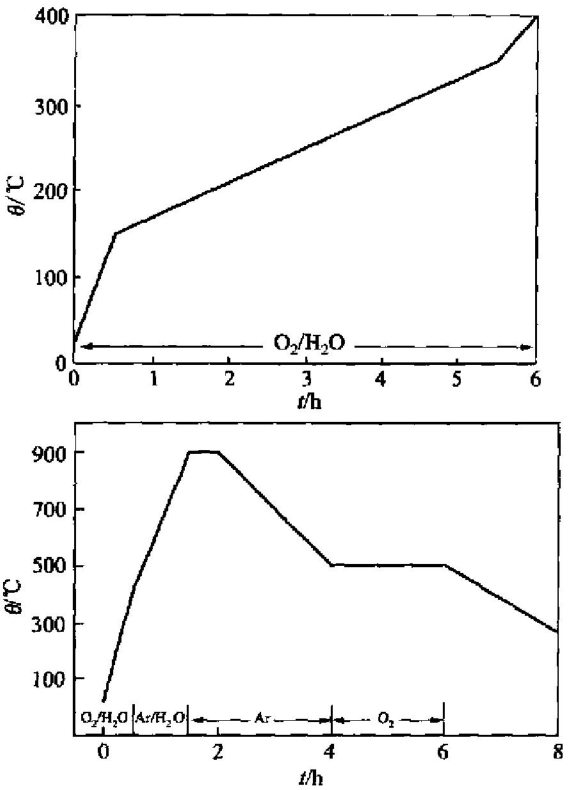

Fig. 1 Heating profiles of heat treatment
(a) —Low-temperature; (b) —High-temperature

The phase purity and texture of YBCO films were analyzed by X-ray diffraction and pole figure. SEM was used to evaluate the surface morphology of films. T_c and J_c were measured using a standard four-probe method at 77 K and zero magnetic field.

3 RESULTS AND DISCUSSION

3.1 Phase purity and texture of YBCO films

A {110} 〈110〉 textured Ag tape which was prepared by ourselves was used as the substrate to deposit YBCO films. Fig. 2 shows X-ray diffraction patterns of films fired at different temperatures. The results show that the films grown in the range of 400 – 700 ℃ mainly contain oxide, fluoride and oxy-fluorid from trifluoroacetate salts decomposition. The film fired at 800 ℃ has most YBCO diffraction peaks with some of BaF_2. When the firing temperature is 900 ℃, the pure YBCO film with stronger (103) peaks (*a*-axis) besides (00*L*) peaks can be fabricated. After the samples being held at 900 ℃ for 30 min, we can get single *c*-axis aligned films without *a*-axis orientation. Some investigators propose that an increase of *a*-axis oriented grains is due to low firing temperature and slow growing rate in the heating process[8, 9]. However, the firing temperature was high enough to give faster growing rate in our experiment. We think that different orientations may be due to a competition between "surface and interface energies" of the film[10]. Generally, the *a*-axis requires only shorter migration distance to be formed, but has higher surface energy. Whereas, with the *c*-axis growing, surface energy is lower, and the required large thermal energy for longer migration is supplied. Therefore, the samples were held at 900 ℃ for a while, which will supply sufficient energy and time for grains growth and rearrangement along *c*-axis texture[11]. To get further texture information, the (103) plane pole figures were carried out for the films with and without being held at 900 ℃ (Fig. 3). Though the in-plane texture of the film without being held at 900 ℃ is weaker than that of film with being held at 900 ℃, the YBCO layers are all biaxially textured and grown epitaxially on Ag {110} 〈110〉 multicrystal substrate. The epitaxial relationships between the YBCO film and the Ag substrate are $\langle 100\rangle_{YBCO}$ or $\langle 010\rangle_{YBCO}$ // $\langle 110\rangle_{Ag}$, $\{001\}_{YBCO}$ // $\{110\}_{Ag}$ plane.

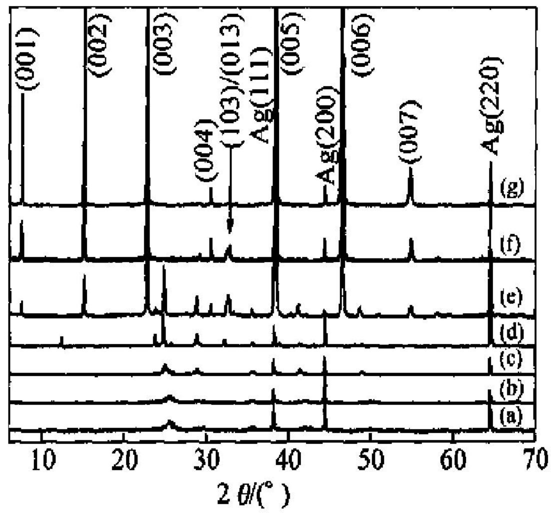

Fig. 2 X-ray diffraction patterns of films fired at different temperatures
(a) —400 ℃; (b) —500 ℃; (c) —600 ℃; (d) —700 ℃; (e) —800 ℃; (f) —900 ℃; (g) —900 ℃, 30 min

3.2 Surface morphology

Large numbers of global particles and *a*-axis grains (Fig. 4(a), rectangular grains appear to be *a*-axis oriented) are clearly observed in the microstructure of samples without being held at 900 ℃ by SEM. The result is consistent with that of XRD. Additionally, the crystal grains are loose and unconnected near *a*-axis grains. However, the sample with being held at 900 ℃ has a dense and flat surface, and fine connectivity with quadrate particles (Fig. 4(b)).

The surface defects of Ag substrates have a detrimental influence on the surface morphology of YBCO films[12, 13]. Fig. 5(a) presents the SEM image of the Ag substrates. Clearly, this figure shows parallel striations that may be formed during the rolling process. The YBCO films deposited on the unpolished Ag substrates are quite rough and connective poorly with many holes. Many stripes,

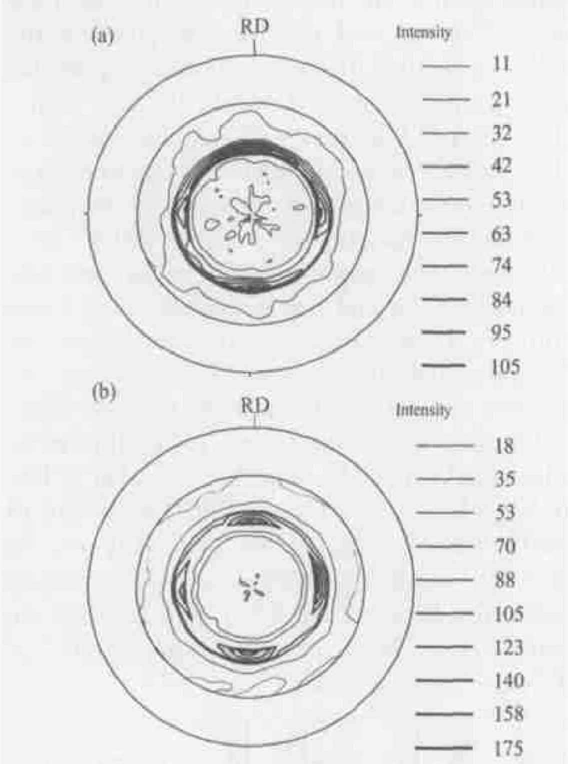

Fig. 3 (103)-plane pole figure of YBCO films
(a) —Without being hold at 900 ℃;
(b) —With being hold at 900 ℃

which are parallel to the rolling striations on Ag substrates, are also observed on the surface of YBCO film (Figs. 5(b) and (c)). To eliminate the bad influence, we polished Ag surface prior to films deposition. Figs. 6(a), (b) and (c) show the

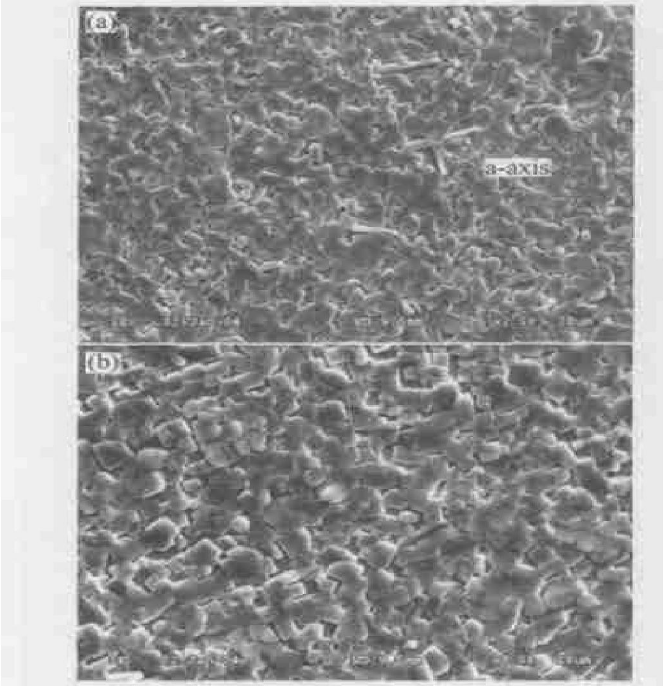

Fig. 4 SEM photographs of surface morphology of samples
(a) —Without being hold at 900 ℃;
(b) —With being hold at 900 ℃

SEM photographs of the polished Ag surface and the YBCO film on polished Ag substrates, respectively. After being polished, Ag surface becomes flat without rolling stripe. Therefore, the film grown on polished Ag substrates has a smooth surface and good connectivity of grains, and the

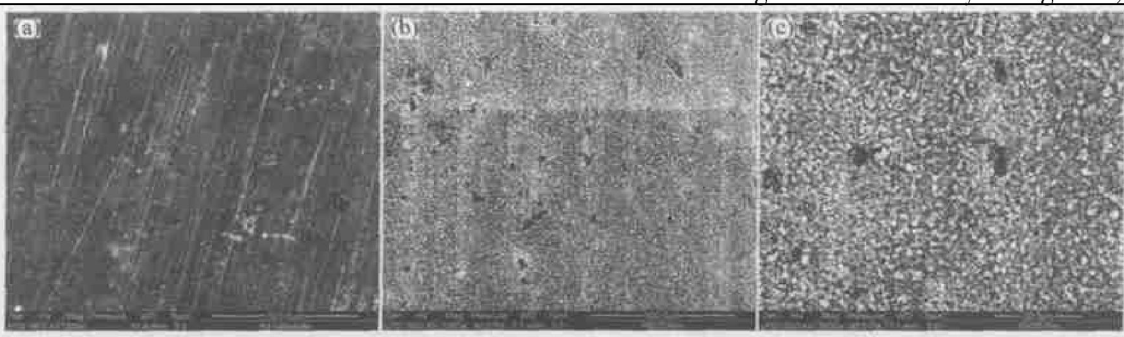

Fig. 5 SEM micrographs of unpolished Ag substrate and YBCO films
(a)—Unpolished Ag substrates; (b) and (c)—YBCO film prepared on unpolished Ag substrates

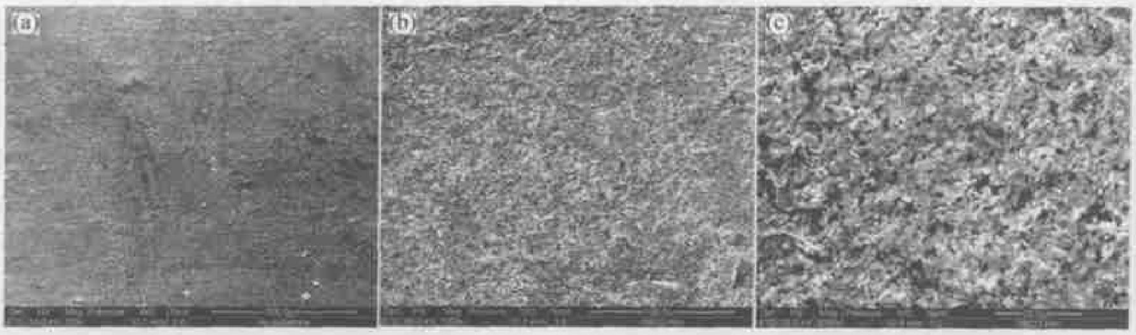

Fig. 6 SEM micrographs of polished Ag substrate and YBCO films
(a)—Polished Ag substrate; (b) and (c)—YBCO film prepared on polished Ag substrate

film is absent of parallel stripes. From the matter, polishing of Ag substrates prior to films deposition is useful in improving surface quality of YBCO films.

3.3 Superconducting properties

T_c of these films is around 90 K. The J_c value reaches 15 000 A/cm^2 at 77 K and zero magnetic field, which is much lower than those of films produced on $LaAlO_3$ or $SrTiO_3$ single crystals. However, the value compares favourably to the value obtained for YBCO films on polycrystalline Ag prepared by other chemical methods[14, 15]. The YBCO tapes with better superconductivity can be obtained by further optimized deposition conditions.

4 CONCLUSIONS

Biaxial aligned YBCO films have been successfully deposited on Ag {110} ⟨110⟩ textured polycrystalline substrates by TFA-MOD method. Holding temperature at 900 ℃ for 30 min benefits to improve orientation and connectivity of YBCO films. Polishing of Ag substrates prior to films deposition is useful in improving surface quality of YBCO films. The YBCO films have an onset of transition temperature around 90 K and critical current densities of 15 000 A/cm^2. These results offer promise to the applicability of these solution process routes to coated conductor fabrication.

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