Influence of Ag substrate surface condition on surface morphology of YBCO film

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YBCO films were grown on polycrystalline Ag substrates by a metal-organic decomposition (MOD) method using Trifluoroacetate Salt (TFA). The surface defects of the Ag substrates, such as rolling stripe and crystal boundary, were found to have a detrimental effect on the crystal orientation and surface morphology of YBCO films. The surface of YBCO films deposited on Ag substrate annealed in vacuum has many holes and stripes, which are parallel to the rolling stripe on Ag substrates. At the crystal boundary grooves on Ag substrates annealed in Ar environment, the film compositions are not superconducting phases but oxide phases of Cu-O and Ba-Cu-O. To eliminate the rolling stripe and grooves on the Ag surface, we used cold rolling polished Ag as substrates. The film grown on cold rolling polished Ag substrates has a smooth surface and good connectivity of grains without parallel stripes and grooves. The films composition is also uniformity.

INTRODUCE

MOD has a variety of advantages, such as precise controllability of composition, wide flexibility to coating objects and a low cost non-vacuum approach. So many studies about this method have been done in recent years. The long YBCO tapes with high Jc values of over $1MA/cm^2$ were also reported on Ni tapes by this method, with in-plane aligned buffer layers, which were multilayered structures [1-2]. 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 such that the YBCO film is directly deposited on a textured Ag tape without any buffer layers by a 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.

Many factors influence the quality of the YBCO films grown on Ag substrates [3]. One important factor is the substrate-surface roughness. It is known that a strict treatment to reduce the substrate-surface roughness is usually required before the YBCO film deposition even for the oxide single crystal substrate such as STO etc [4]. However, for the soft metal such as Ag, it is much more difficult to reduce the surface roughness and get a smooth surface, especially for polycrystalline silver. Therefore the surface roughness influence on the YBCO film growth will be much more serious, which might be the main reason for the high inhomegeneity and the low J_c of the YBCO films grown on Ag substrates.

In this paper we have prepared YBCO films on polycrystalline Ag substrates by a metal-organic decomposition (MOD) method using Trifluoroacetate Salt (TFA). From experiment we have observed that the surface defects of the Ag substrates annealed in vacuum and Ar environment, such as rolling stripe and crystal boundary grooves, have a detrimental effect on the composition and surface morphology of YBCO films. In order to remove the bad effect, we deposited YBCO films on cold rolled Ag substrates polished by mechanical way.

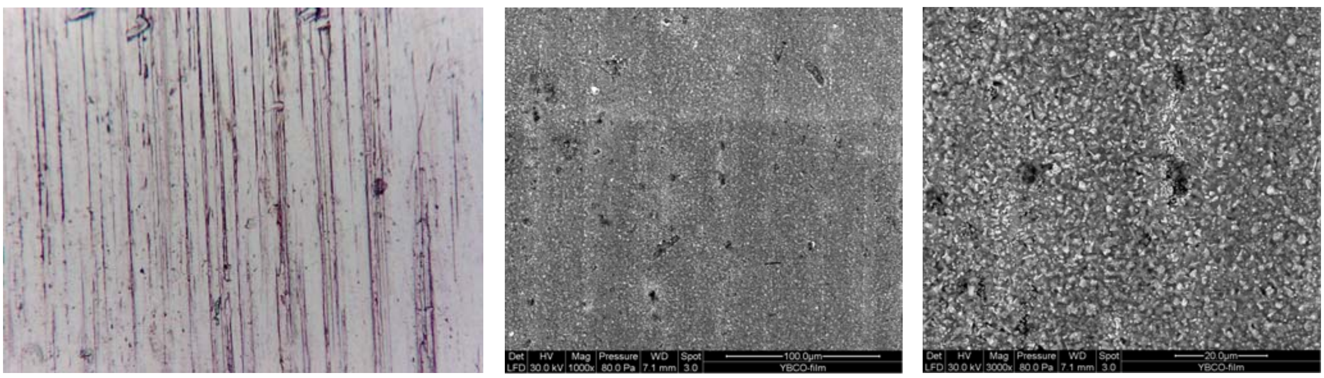
EXPERIMENT

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, and then water and acetic were removed by an evaporator to yield a blue glassy residue. The coating solution with total metallic concentration of 1.5mol/l was made by dissolving the residue into methanal. The gel films were coated onto Ag {110} <110>substrates by spin-coating method or dip-coating method.

The heat treatment of the coating film was applied in two stages with the heating profiles that are showed in our previous paper [5]. In the first calcination stage, the film coated the 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 humid argon and held for 30 min in dry argon. After growth, films were slowly cooled to 500℃. Post-oxygenation was carried out at 500℃ for 90 minutes followed by naturally cooling to room temperature.

RESULTS AND DISCUSSIONS

Figure 1a presents the optical image of the Ag substrates annealed in vacuum. Clearly, his figure shows parallel striations that may have been formed during the rolling process. Many stripes, which are parallel to the rolling striations on Ag substrates, were also observed on the surface of YBCO film (figure 1b). Additionally, the YBCO films deposited on the Ag substrates are quite rough and connective poorly with many holes (figure 1c).

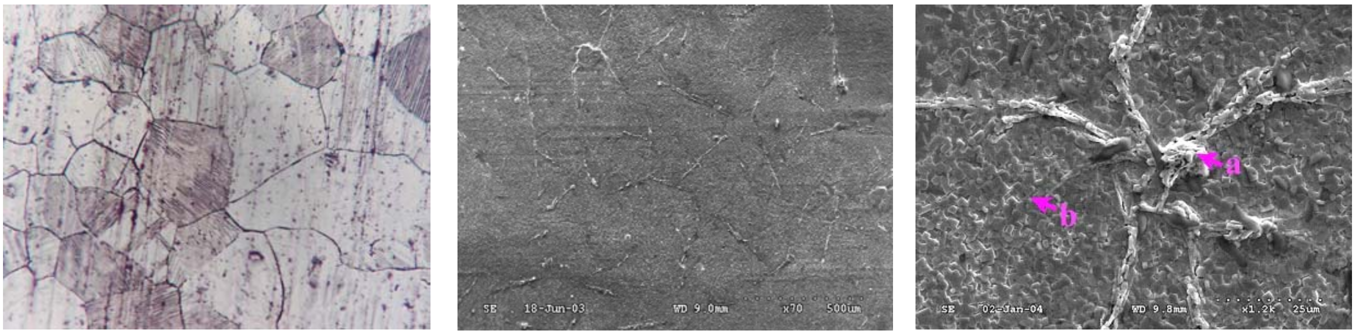


(a)100× (b)1000× (c)3000×

Figure 1 The surface morphologies of Ag substrate in vacuum and YBCO film

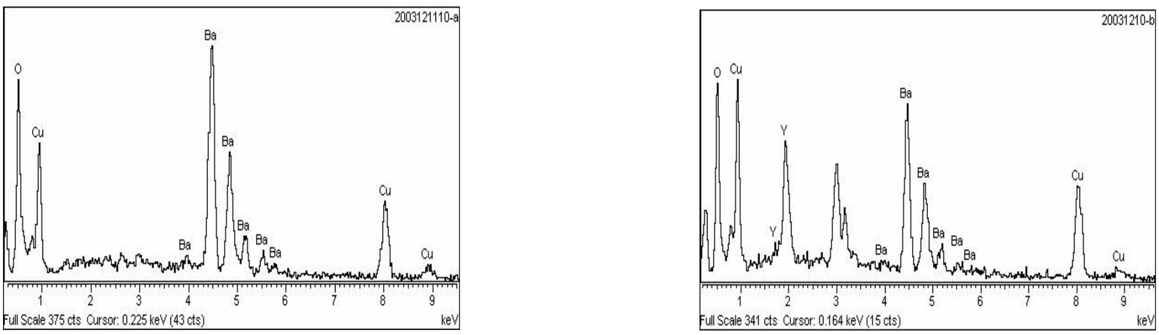
To eliminate the rolling stripe on the Ag surface, we annealed it in flowing Ar atmosphere. As can be seem from figure 2a, after annealing, grooving of the grain boundaries of the Ag became more pronounced. These too many grooving may contribute to the roughness of YBCO films [6]. Irregular contour of Ag grains boundaries is clearly present on the surface of YBCO films (figure 2b). The EDS results (figure 3a) show that the atom simplified ratio of Y: Ba: Cu: O of point a and b in Fig 2c is 0: 1: 1: 2 (Fig. 3a) and 1: 2: 3: 7(Fig. 3b), respectively, which indicates that the composition of point a is not a superconducting phase, but the phase of Ba-Cu-O. When the grooves are small, the lateral usually can cover it over growth of the YBCO grains surrounding it, with no influence on the good YBCO film growth. For large size grooves, they will strongly influence the quality of the film on them. For the detailed film microstructure and the related forming mechanism, film growth kinetic theory can give a reasonable interpretability.

Due to the anisotropic surface free energy of YBCO crystal nucleus, its shape is usually a thin disc and its surface usually keeps (001) face: the face with lowest free energy [7]. The nature of the thin disc shape of YBCO nucleus decides that YBCO film nucleation will be very sensitive to the substrate surface morphology. For the thin disc nucleus, it has a very large substrate nucleus interface. Therefore, the substrate-nucleus interface energy becomes specifically important to decide the total free energy of the nucleus. The YBCO nucleuses on the flat substrate surface area can remains its lower energy face contacted with the substrate surface and interface energy will be much lower. Therefore, the YBCO nucleus can easily grow to be larger and larger. However, when the YBCO crystal nucleates on the rough substrate grooves will introduce much higher-interfacial energy and YBCO nucleus will be unstable and difficult to grow up. In this case, the other oxide phases such as Cu-O and Ba-Cu-O can nucleate in the surface grooves since these crystal have not so strong anisotropy of the free energy as YBCO. Their substrate/nucleus interfacial energy will not be influenced by the surface roughness so much. In other words, the rough surface will not cause the obvious increase of the free energy for the nucleation of other oxide phases. Therefore, on the rough substrate grooves, it is possible that the free energy for the nucleation of other oxide phases will be lower than that for the nucleation of YBCO crystal. As a result, instead of YBCO crystal, Cu-O and Ba-Cu-O can preferentially nucleate and grow in the surface grooves.



(a)100× (b)70× (c)1200×

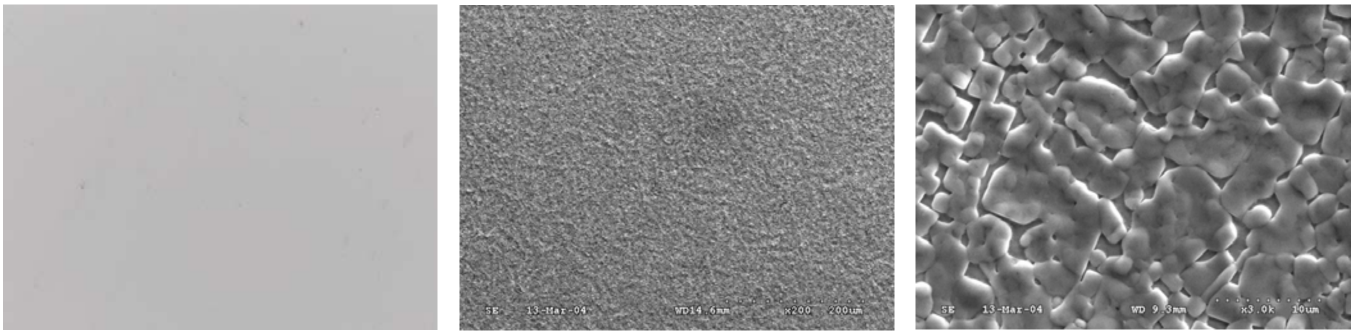
Figure 2 The surface morphologies of Ag substrate in Ar environment and YBCO film



(a) point a (b) point b

Figure 3 The EDS results of point a and b in figure 2 (c)

Ag substrates annealed in vacuum and Ar environment are so soft that they don’t get a smooth surface polished by mechanical way. By controlling rolling conditions, we can gain the cold-rolling Ag substrates whose {110} <110> texture can form during head treatment of the precursor film [8]. The cold-rolling Ag substrate is hard enough to be polished by mechanical way. After being polished, Ag surface becomes very flat and smooth without rolling stripe and grooves. Therefore, the film grown on cold rolling polished Ag substrates has a smooth surface and good connectivity of grains without parallel stripes and grooves. The films composition is also uniformity. Figure 4a, 4b and 4c show the SEM photographs of the surface morphologies of polished Ag substrate and the YBCO film on polished Ag substrates, respectively. From the matter, Polishing of Ag substrates prior to films deposition were found to be useful in improving surface quality of YBCO films.



(a)100× (b)200× (c)3000×

Figure 4 The surface morphologies of the cold-rolling Ag substrate poloshed by mechanical way and YBCO film

CONCLUSIONS

We have prepared YBCO films on all kinds of Ag substrates by a metal-organic decomposition (MOD) method using Trifluoroacetate Salt (TFA). From experienment we have observed that the surface defects of the Ag substrates annealed in vacuum and Ar environment, such as rolling stripe and crystal boundary grooves, have a detrimental effect on the composition, crystal orientation and surface morphology of YBCO films. Finally, we get YBCO films with a smooth surface and even composition on cold rolled Ag substrates polished by mechanical way.

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