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Fabrication of Y_2O_3 buffer layer on polished Ni substrates for YBCO superconducting tape*

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Abstract: Highly cube textured Ni tapes are produced by heavy cold rolling and recrystallization annealing. The textured nickel tapes have been proven to be suitable substrates for YBCO superconducting tape. Nevertheless, rolling damage and grain boundary grooves on Ni influence the epitaxial growth of highly textured buffer and YBCO layers. The polishing of the Ni substrate surface may play a crucial role in making it beneficial to epitaxial film deposition. In our work, several polishing methods were adopted on Ni to reduce the depth of rolling damage and grain boundary grooves. On the polished Ni substrates, textured Y_2O_3 buffer layers were deposited using RF sputtering. XRD results show that in-plane texture of Y_2O_3 films will minish with the decreasing of the Ni substrate surface roughness. AFM results show that average grain size of the Y_2O_3 film is biggest and surface is coarse in film on flatter Ni surface.

Key words: Ni; substrates; polishing; buffer layer

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1 Introduction

In recent years, worldwide research efforts have been made to develop YBCO superconducting tapes. Two promising approaches for the profitable production of long YBCO tapes that are suitable for carrying high currents in magnetic fields are RABiTS (Rolling Assisted Biaxially Textured Substrates)[1] and IBAD (Ion Beam Assisted Deposition) methods[2]. In RABiTS process, the necessarily strong biaxial texture of the YBCO film is achieved by epitaxial growth of buffer layers and the superconducting film on a highly textured substrate. It has been shown that nickel is well suited as a substrate material because it forms a very strong cube texture after rolling and recrystallization[3]. Epitaxial ceramic buffer layers are deposited on substrate to prevent Ni diffusion into the YBCO layer and to transfer a strong biaxial texture from the substrate to the YBCO layer[4]. Many techniques including pulsed laser deposition, sputtering and electron beam evaporation have been tried for buffer layer deposition[5-7].

In order to obtain high-Jc YBCO superconducting tape, highly cube textured Ni substrate is required and there is a lot of work underway to reinforce cube texture in substrate[8]. On the other hand, the surface

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finish and modification of the Ni substrate influence the growth of the subsequent layers too[9]. Although rolling damage can be minimized by the use of high quality rollers, the presence of grain boundary grooves formed by thermal etching is an inevitable consequence of the recrystallization process[10]. It has been shown that these grooves can be transferred through the buffer layer and into the YBCO film and influence the superconducting properties[11]. Besides grooves, various surface contaminations (result from the lubricants and rolling surface) will affect the phase and texture evolution of the buffer layer[12]. Therefore, the use of an effective smoothing and cleaning procedure is required for nonideal Ni substrate.

In this paper, we fabricated the Y_2O_3 film on textured Ni substrates which were polished by various techniques and discuss the effect of substrate roughness and morphology on deposition of Y_2O_3 film. Y_2O_3 has been deposited as a buffer layer for YBCO using the electron beam evaporation[13] and thermal evaporation[14] technique.

2 Experimental

2.1 Ni substrate polishing

The biaxially textured Ni tapes were prepared by rolling process (deformation>95%) followed by recrystallization thermal treatment[6]. The tapes were then polished by means of mechanical polishing (MP), chemical polishing (CP) and electropolishing (EP) respectively. Polishing processes are summarized in Table 1.

Table 1 Summary of substrate polishing conditions

Polishing method	Conditions
Mechanical polishing (MP)	Ground with SiC paper followed by polishing with diamond paste
Chemical polishing (CP)	Solution of nitric acid and acetic acid; 20—60℃; 30—90 s
Electropolishing (EP)	Solution of phosphoric acid; 3—5A/dm^2; 10—30 min

2.2 Deposition of Y_2O_3 film using magnetron sputtering

Y_2O_3 film was deposited on the cube textured Ni substrates using RF sputtering technique. We used Y_2O_3 disc of 65mm diameter for the sputtering target. Substrate temperature was 600—750℃ and Ar/H_2 sputtering gas was maintained at a pressure of 0.5-20 Pa.

2.3 Texture and morphology measurements

Texture evaluation of Y_2O_3 film was analyzed using X-ray diffraction(XRD). The surface morphology of the film was examined using atomic forced microscopy (AFM).

3 Results and discussion

AFM images of the polished Ni substrates are indicated in Fig 1. It shows that the smoothest surface is obtained from EP method and the mean surface roughness of polished Ni is 25 nm (MP), 20 nm (CP) and 8 nm (EP) respectively.

Fig. 2 shows X—ray diffraction $\theta-2\theta$ scan of Y_2O_3 films deposited on polished Ni. As our samples were all prepared on the same condition, the main parameter influencing the orientation transition is the surface feature of the substrate and the thickness of the film. In order to minimize the influence of film

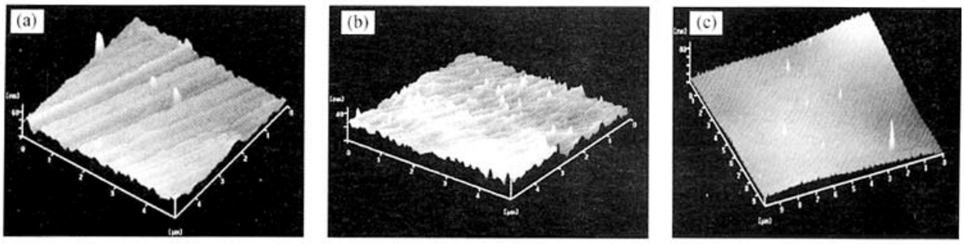

Fig. 1 AFM images of Ni substrates polished by mechanical polishing (a), chemical polishing (b) and electropolishing(c)

thickness on texture development, we control the thickness of the films below 100 nm. Results show that (400) textured Y_2O_3 films were formed on EP sample. Nevertheless, Y_2O_3(222) peak is founded in MP sample and CP sample. It is evidence that epitaxial films will potentially grow on flatter surface. Fig. 3 shows this tendency.

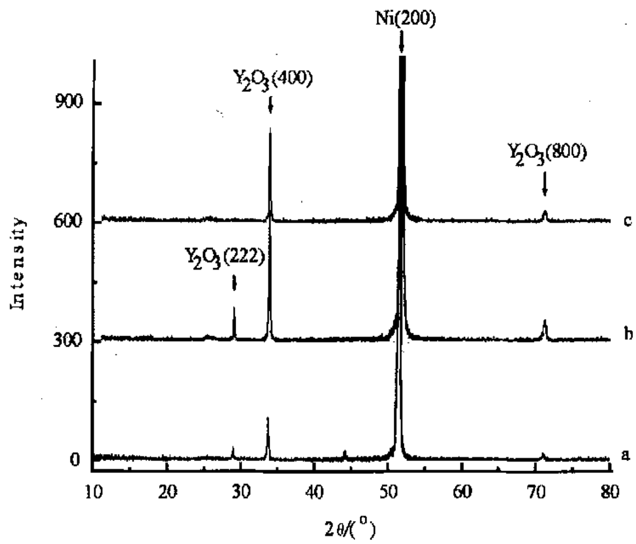

Fig. 2 $\theta-2\theta$ scan of Y_2O_3 film deposited on Ni substrates polished by mechanical polishing (a), chemical polishing (b) and electropolishing (c)

The Fig. 2 indicates that epitaxial film tends to grow on smoother surface. In order to investigate in-plane texture development, we study the X-ray diffraction ϕ—scan for the films. The full width half maximum (FWHM) value for ϕ—scan is 26° on MP sample and 22° on CP sample. The result shows that rough surface is correlated to a decrease of in-plane texture. It seems that the degree of in-plane texture was dependent upon the type of roughness and rough features lowered the average effective angle of incident adatom flux during deposition, thereby decreasing the development of in-plane texture[15].

Fig. 4 shows AFM images of Y_2O_3 films on polished Ni. It can be seen that crack-free and homogeneousY_2O_3 films were developed. On EP sample, average crystallite size of the film is obviously larger than others and surface is coarse. On the contrary, Y_2O_3 films on EP Ni and CP sample have smoother surface and smaller grains. The EP surface is flatter and mobility of the sputtering atoms on the surface is considerable. On this surface, adsorbed particles collide with one another and form cluster easily. The clusters continuously collide with incoming particles and grow in size rapidly. As a result, large grains are formed.

Compare to flatter EP surface, ridges and scratches are considerable on MP sample and CP sample. These sites are favorable nucleation sites for growth. Nucleation occurs more easily on these two surfaces and nucleation density is higher relatively. Generally, high nucleation density led to smoother and finer film. Differently, surface features of film on MP substrate somewhat resemble the morphology of the substrate. The substrate defects such as deep scratches, which come from mechanical polishing, may disturb the nucleation and morphology of the film on it.

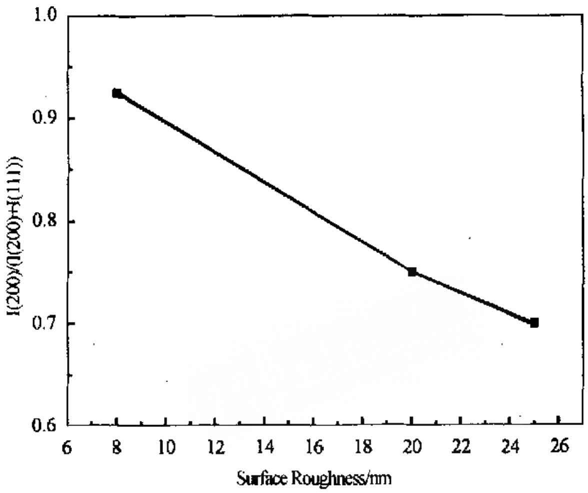

Fig. 3 Intensity ratio, $I_{(200)}/(I_{(200)}+I_{(111)})$ of Y_2O_3 film with substrate surface roughness

We consider that different treatments of substrate surface have effect on orientation and morphology of subsequent layer. The influence is complicated and should be investigated in detail. Our further work about it is being done.

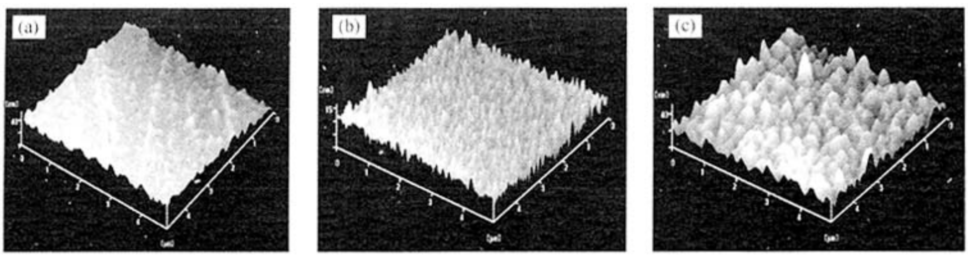

Fig. 4 AFM images of Y_2O_3 film on Ni substrates polished by mechanical polishing (a), chemical polishing (b) and electropolishing (c)

4 Conclusions

Mechanical polishing, chemical polishing and electropolishing were adopted on Ni substrates to improve surface quality. Crack-free and textured Y_2O_3 films have first been deposited on polished Ni substrates by using RF sputtering. Mechanical polished substrate and chemical polished substrate is relatively rough and disturb epitaxial Y_2O_3 film growth. With the decreasing of the substrate surface roughness, in-plane texture of Y_2O_3 films will minish. On the other hand, average grain size of the Y_2O_3 film is bigger, and surface is coarse in film on flatter electropolished Ni. The surface features of film on mechanical polished substrate somewhat resemble the morphology of the scratched substrate.

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