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Preparation of $SrTiO_3$ buffer layers on $Ba_xSr_{1-x}TiO_3$ seed layers buffered Ni tapes by chemical solution deposition

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Abstract

$SrTiO_3$ (STO) buffer layers were prepared via chemical solution deposition (CSD) on different $Ba_xSr_{1-x}TiO_3$ (BST, x = 0, 0.3, 0.5) seed layers buffered Ni(200) tapes. It was found that (200) texture of the STO buffer layer was the best when the seed layer was $Ba_{0.3}Sr_{0.7}TiO_3$. Additionally, the annealing temperature effects on the textures of STO(200) buffer layers were also studied, it was found that the STO buffer layers showed the best (200) texture when the annealing temperature was 900 °C.

PACS: 68.55.−a
Keywords: Buffer layer; $SrTiO_3$; Chemical solution deposition

1. Introduction

Among the several preparing methods for $YBa_2Cu_3O_{7-\delta}$ (YBCO) coated conductors, the rolling-assisted biaxially textured substrates (RABiTS) process is a non-vacuum method, with lower requirement to the equipments, being easy to be scaled up [1]. Additionally, it has been reported that using an all-chemical approach, YBCO coated conductors have critical current densities exceeding 1 MA/cm^2 at 77 K and zero applied magnetic field [2].

To fabricate YBCO coated conductors using RABiTS process, one of the key technological challenges is to fabricate low-cost, scalable and high quality buffer layers. The buffer layers have to be able to support the oriented growth of

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YBCO, to protect the metal substrates from oxidation as well as have chemical and crystal compatibility with Ni and YBCO. $SrTiO_3$ (STO) has the character of perovskite structure and is stable. In addition, the lattice parameter of 0.3905 nm of STO provides a very close lattice match with YBCO (2.3% mismatch) and Ni substrate (11.1% mismatch) [3]. Therefore, STO is considered to be one of the most suitable buffer materials for the preparation of YBCO coated conductors. To obtain high quality STO buffer layers, some authors [2,4] pointed out that a very thin template served as seed layer is first grown to provide orientation, followed by growth of precursor STO layers to provide thickness. In our previous research works, it was found that the texture of (200)-oriented STO film was not ideal when the seed layer was STO. In order to improve the textures of STO(200) films, Dawley and Siegal et al. [2,5] pointed out that the textures could be improved when some Ba element were added into STO due to the appearance of some transient BaF_2-related liquid phase. However, Dawley et al. [5] fabricated only $Ba_xSr_{1-x}TiO_3$ (BST) films on Ni(200) tapes, whose dielectric constants were too high to used as buffer layers for YBCO coated conductors.

Based on the analysis for the works of others mentioned above, we think that the textures of STO buffer layers may be improved when we use BST as seed layers. For BST seed layers, with the increasing of Ba content, the transient BaF_2-related liquid phase increases which is favorable for subsequent (200)-oriented STO films; However, the mismatches between BST seed layer versus STO layer and BST seed layer versus Ni substrate increase linearly with the increasing of Ba content in BST seed layers, which is harmful to the growth of (200)-oriented STO films. As described above, we think there should exist an optimal Ba content in seed layers to improve the textures of subsequent STO layers.

In this work, STO buffer layers with thickness of about 200 nm were fabricated on different $Ba_xSr_{1-x}TiO_3$ ($x = 0$, 0.3, 0.5) seed layers buffered Ni(200) substrates using spin-coating technique. The effects of BST seed layers and annealing temperatures on the textures of STO buffer layers were studied. The results showed that the BST seed layers and annealing temperatures could affect remarkably the textures of subsequent STO layers and the possible reasons were also discussed.

2. Experimental

High purity cold-rolled Ni (99.999%) tapes with rolling reduction of 98% were cleaned in ultrasonic cleaner with chloroform, acetone and ethanol prior to heat treatment in a tube furnace at 1000 °C for 60 min. with 4% H_2–Ar gas flux. Then the Ni tapes were cut into pieces with sizes of 10×10 mm^2 for use.

The detailed solution preparation methods for both STO and BST seed layers could be found elsewhere [2,5]. In brief, the BST seed layer solutions were produced by reacting titanium isopropoxide (Alfa Aesar) with acetylacetone before combining it with a solution of Ba and Sr acetate (Alfa Aesar) dissolved in trifluoroacetic acid (TFA). The solution for subsequent STO layers was prepared by dissolving Sr acetate in heated glacial acetic acid followed by the addition of Ti butoxide (Alfa Aesar) and diluted by methanol to desired concentration. In our work, the seed layers solution concentration was 0.05 M and the solution concentration for the subsequent STO layers was 0.25 M.

A spinning rate of 4000 rpm and time of 60 s were used during the process of deposition for the seed layer, followed by the hot-plate treatment at 300 °C for drying the films. The dried films were quickly heated to desired temperature and kept at this temperature for 2 h under humid 4% H_2/N_2 atmosphere. The above deposition, drying and annealing procedures were repeated for two times for the preparation of the subsequent STO layers after the seed layer were deposited.

For the sake of description, we define here the 900 °C-annealed seed layer samples of $SrTiO_3$, $Ba_{0.3}Sr_{0.7}TiO_3$ and $Ba_{0.5}Sr_{0.5}TiO_3$ deposited on Ni(200) substrates as sample A_s, B_s and C_s, respectively; correspondingly, STO samples deposited on these three different seed layers buffered Ni(200) tapes are defined as sample A, B, and C, respectively. The $Ba_{0.3}Sr_{0.7}TiO_3$ seed layers annealed at 850, 900 and 950 °C are defined as

B_{s85}, B_{s90} and B_{s95}, respectively; Correspondingly, STO buffer layers deposited on these three seed layers are defined as samples B_{85}, B_{90} and B_{95}, respectively.

The microstructure were identified by FEI designed field-emission scanning electron microscopy (FE-SEM) and Park Scientific Instruments designed Autoprobe CP type atomic force micrography (AFM); A Philips X'pert PRO X-ray diffractometer (XRD) with CuKα radiation was used to carry out the θ–2θ scan and the in-plane ϕ scan investigations.

3. Results and discussion

Fig. 1 shows the XRD θ–2θ scan results of the sample A, B and C, respectively. It can be seen that there exists an obvious peak attributed to STO(1 1 0) in the sample A, whereas, there have no obvious peaks about STO(1 1 0) in the samples B and C. The results suggest that it is effective to improve textures of (2 0 0)-oriented STO films when some Ba elements are added into seed layers.

Fig. 2 shows the XRD in-plane ϕ scan results of the sample B and C. It can be seen clearly that the in-plane orientation of the sample B is more excellent than that of the sample C, which suggests that it is more effective to improve the texture of (2 0 0)-oriented STO film when $Ba_{0.3}$ $Sr_{0.7}TiO_3$ is used as seed layer. The results suggest that the higher in-plane texture of the sample B compared with that of sample C may be related to the competition results between the quality of transient BaF_2-related liquid phase and the lattice mismatch between the subsequent STO layers and the BST seed layers. The results also suggest that there exists an optimal Ba content in the seed layer to induce the highly (2 0 0)-oriented STO buffer layer, in our experiments, the optimal Ba content is 0.3, i.e., the seed layer is $Ba_{0.3}Sr_{0.7}TiO_3$.

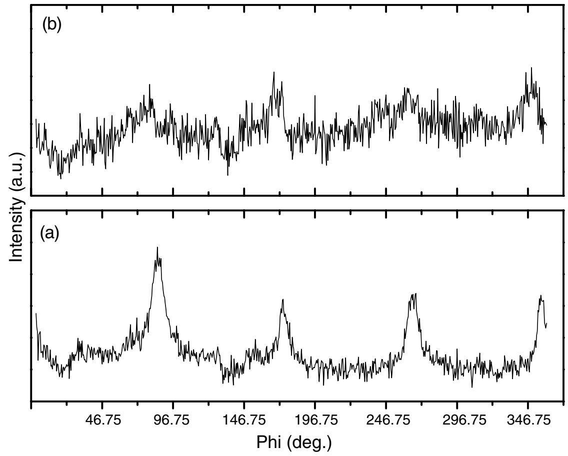

Fig. 2. The in-plane ϕ scan results of the sample B (a) and C (b), respectively.

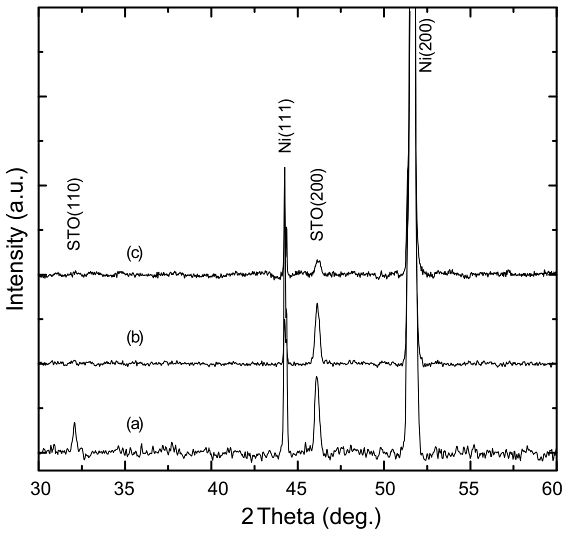

Fig. 1. The θ–2θ scan results of the sample A (a), B (b) and C (c), respectively.

The FE-SEM and AFM patterns (not shown here) of the samples A, B and C show that there exist no obvious differences in these three samples. For examples, Fig. 3 shows the FE-SEM and AFM results of the sample B. It can be seen that the STO buffer layer is relatively dense and smooth (the root-mean square roughness, RMS, is 7.8 nm obtained in 1×1 μ^2 area range) which suggests that it is suitable to grow other types of buffer layers or YBCO films on the sample B.

Fig. 4(a)–(c) show the XRD θ–2θ scan results of the sample B_{85}, B_{90} and B_{95}, respectively. It can be seen that all the three samples are highly (2 0 0)-oriented, which indicates that the annealing temperatures within in our experiments do not affect the out-of-plane orientation remarkably.

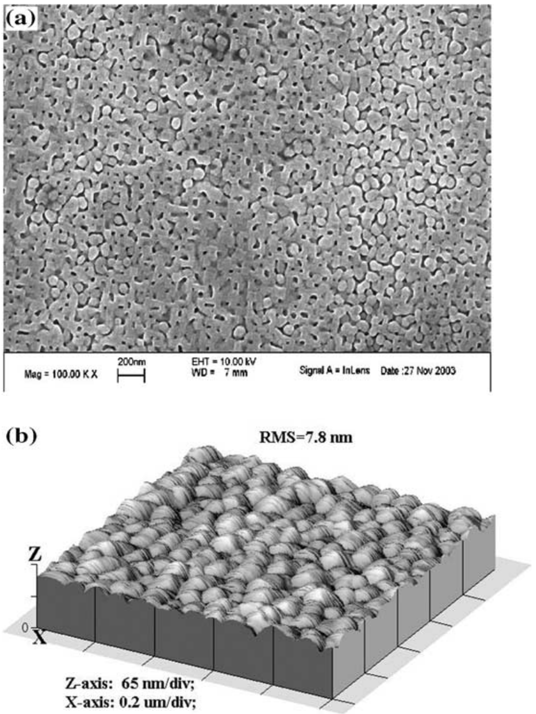

Fig. 3. The FE-SEM (a) and AFM (b) results of the sample B.

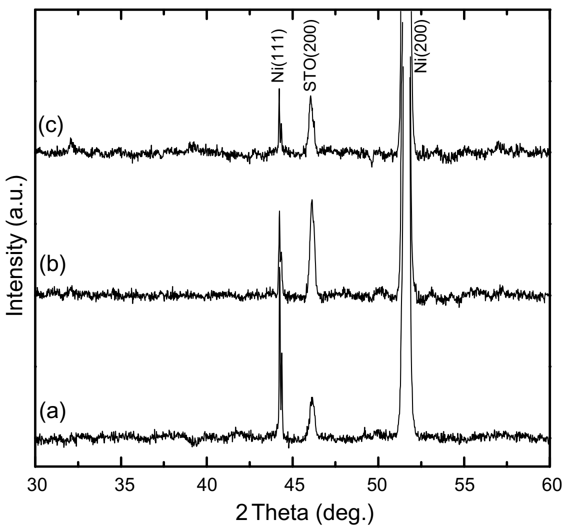

Fig. 4. The θ–2θ scan results of the sample B_{85} (a), B_{90} (b) and B_{95} (c), respectively.

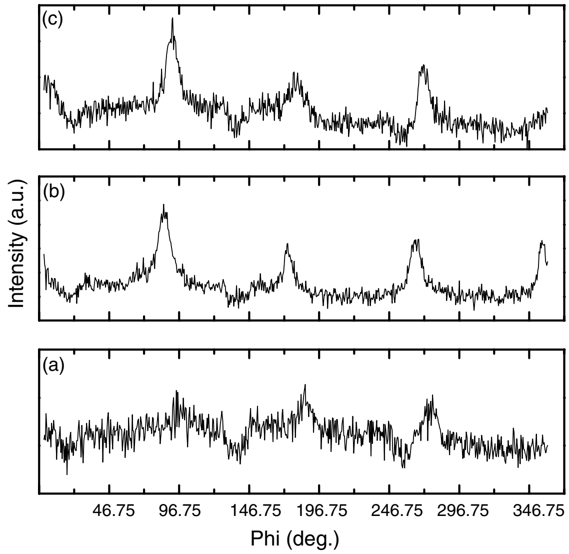

Fig. 5. The in-plane phi scan results of the sample B_{85} (a), B_{90} (b) and B_{95} (c), respectively.

Fig. 5(a)–(c) show the in-plane phi scan results of the sample B_{85}, B_{90} and B_{95}, respectively. It can be seen that the sample B_{90} has the best in-plane texture, whereas, the in-plane texture of the sample B_{85} is the worst. As discussed by Schwartz et al. [6], the orientation of thin film is affected dominantly by the orientation of the first layer, i.e., the seed layer in our experiments. In order to check the micrograph of the $Ba_{0.3}Sr_{0.7}TiO_3$ seed layers annealed at different temperatures, we carried out the FE-SEM experiments. The results are shown in Fig. 6(a)–(c), respectively. It can be seen that some abnormal grains exist in the sample B_{s85}, which may be related to the low melting temperature materials. For the sample B_{s90}, the grain is fine and dispersed uniformly. For the sample B_{s95}, although the grain size is similar to that of the sample B_{s90}, the grains do not disperse uniformly as that of the sample B_{s90}. As discussed by Schwartz et al. [7] that the seed layer should be fine and dispersed uniformly to induce highly oriented subsequent film, in our experiments, it is found that at 900 °C annealing temperature, the grains of the $Ba_{0.3}Sr_{0.7}TiO_3$ seed layer are fine and rectangular-like and dispersed uniformly resulting in the best in-plane orientation of the subsequent STO buffer layers.

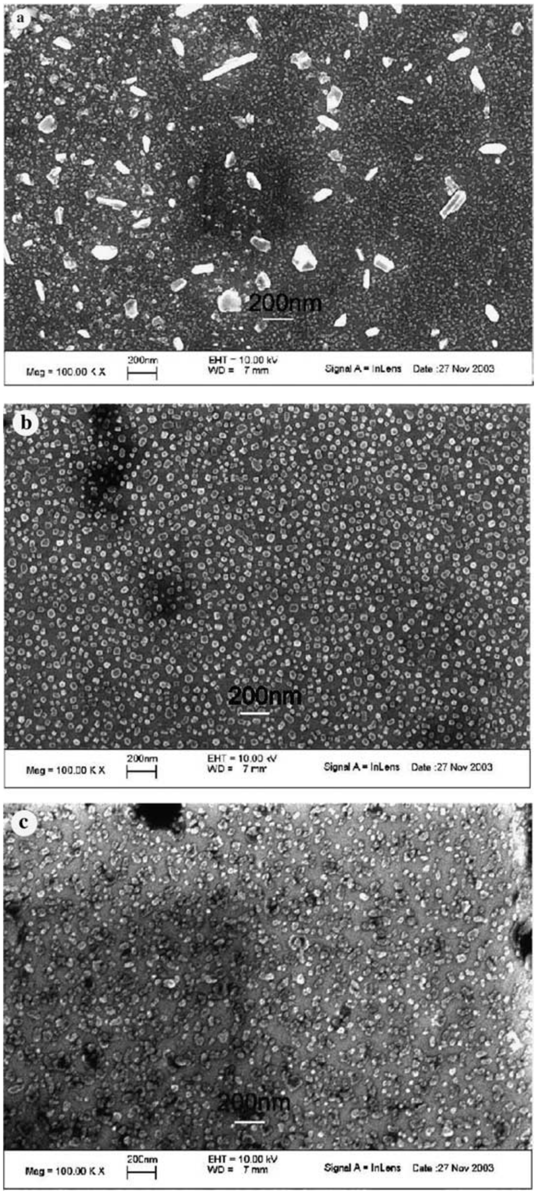

Fig. 6. The FE-SEM results of the sample B_{s85} (a), B_{s90} (b) and B_{s95} (c), respectively.

4. Conclusion

$SrTiO_3$ (STO) buffer layers were fabricated using chemical solution deposition (CSD) on different $Ba_xSr_{1-x}TiO_3$ (BST, $x = 0$, 0.3, 0.5) seed layers buffered Ni(200) tapes. The results showed that the texture of (200)-oriented STO buffer layer was the best when the seed layer was $Ba_{0.3}Sr_{0.7}TiO_3$. Additionally, the annealing temperature effects on the textures of STO(200) buffer layers were also studied, it was found that the STO buffer layers showed the best (200) texture when the annealing temperature was 900 °C.

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References

[1] T. Araki, I. Hirabayashi, Supercond. Sci. Technol. 16 (2003) R71.
[2] M.P. Siegal, P.G. Clem, J.T. Dawley, R.J. Ong, M.A. Rodriguez, D.L. Overmyer, Appl. Phys. Lett. 80 (2002) 2710.
[3] Y.X. Zhou, S. Bhuiyan, S. Scruggs, H. Fang, M. Mironova, K. Salama, Supercond. Sci. Technol. 16 (2003) 901.
[4] J.T. Dawley, R.J. Ong, P.G. Clem, J. Mater. Res. 17 (2002) 1678.
[5] J.T. Dawley, P.G. Clem, Appl. Phys. Lett. 81 (2002) 3028.
[6] R.W. Schwartz, P.G. Clem, J.A. Voigt, E.R. Byhoff, M.V. Stry, T.J. Headly, N.A. Missert, J. Am. Ceram. Soc. 82 (1999) 2359.
[7] Schwartz, Chem. Mater. 9 (1997) 2325.