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Morphology evolution and crack formation of $YBa_2Cu_3O_7$ on (110)$SrTiO_3$ substrates

K.H. Wu, S.P. Chen, J.Y. Juang, T.M. Uen, and Y.S. Gou

Department of Electrophysics, National Chiao-Tung University, Hsinchu,Taiwan 300

The detailed grain evolution of (103)-oriented $YBa_2Cu_3O_7$ (YBCO) films grown on as-polished and pre-annealed (110)$SrTiO_3$ was studied using atomic force microscopy (AFM). The scanning laser deposition system used in preparing the films allows us to deposit films with various thicknesses in a single deposition run. The AFM images revealed that although more regular alignment of grains at the initial nucleation for films grown on the pre-annealed substrates, there were no apparent differences in surface structure for the thicker films grown on both as-polished and annealed substrates. It was also found that as the films increased to a critical thickness, microcracks were formed in both cases.

1. INTRODUCTION

In order to take the advantage of having longer coherence length in many potential device applications, the (110)- and (103)- oriented $YBa_2Cu_3O_7$(YBCO) films deposited on (110)-oriented $SrTiO_3$ (STO) substrates have received extensive investigations recently[1-3]. Although it has been evidently demonstrated that the growth of terraces and spirals originated from screw dislocations commonly seen in c-axis oriented films is inhibited in films grown on (110)STO, the tooth-like structure originated from the growth of 90° twisted domains in (103)YBCO films has always resulted in rough surfaces, making it difficult to depositing smooth overlayers for making planar multilayer junctions. Moreover, as pointed out by Olsson et al.[4], YBCO films grown on (110)STO usually have a tendency to crack along the (001) planes. The ultimate solution for resolving all of these problems, we believe, must rely on the understanding of the evolution mechanisms of the films. Unfortunately, in most of the previous studies, the microstructure analyses have been made mainly on films that were already too thick to tell how the films actually evolved. With recent advent of a scanning pulsed laser deposition system which has been shown to be capable of depositing films with various thicknesses *in-situ*[5], we present, in this report, the results of grain evolution for YBCO films grown on both as- polished and pre-annealed (110)STO substrates.

2. EXPERIMENTAL

The scanning laser deposition setup and the details of deposition conditions for making YBCO films in-situ were reported previously[5]. Briefly, a KrF excimer laser operating at a repetition rate of 3-6 Hz with an energy density of 2-4 J/cm^2 was used. Six pieces of (110)STO substrates each with dimension of 2.5×5 mm^2 were attached simultaneously at different locations spanning over one side of a circular substrate holder. The substrate holder was then adhered to a 50-mm-diam conventional heater covered with a semicircle quartz plate. With this special setup all the individual substrates can be exposed to the laser plume by different periods of time and films with various thicknesses can be deposited under essentially the same deposition conditions[5]. In the present study, one set of substrates used were pre-annealed in oxygen at 1000 °C for 24 hours while the other set of substrates were used in their as-polished conditions. The initial surface conditions of substrates and the evolving grain morphology of YBCO films were then examined by atomic force microscopy (AFM) in all cases.

3. RESULTS and DISCUSSIONS

In Fig. 1, a series of AFM images are shown to depict how the YBCO films were evolved. On the left column of Fig. 1, films deposited on the as-polished (110)STO with thickness of 0, 2, 8, 15, 60,

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and 150 nm were shown. For comparison, films deposited on the annealed (110)STO with similar thickness are shown on the right column of Fig. 1.

As can be seen, the high temperature annealing has created a number of steps on the substrate surface. The edges of steps naturally serve as preferred nucleation sites for the first arrived constituents contained in the laser plume to form YBCO grains. Evidently, at the first 2 nm (the deposition rate was estimated to be about 0.1 nm/pulse) the YBCO grains formed on the pre-annealed substrates were aligned regularly along the step edges than those formed on the as-polished substrates. With increasing thickness, however, the distinct corrugated growth nature of (103)YBCO started to develop in both cases, thus there were no apparent differences in surface structure for films thicker than 60 nm.

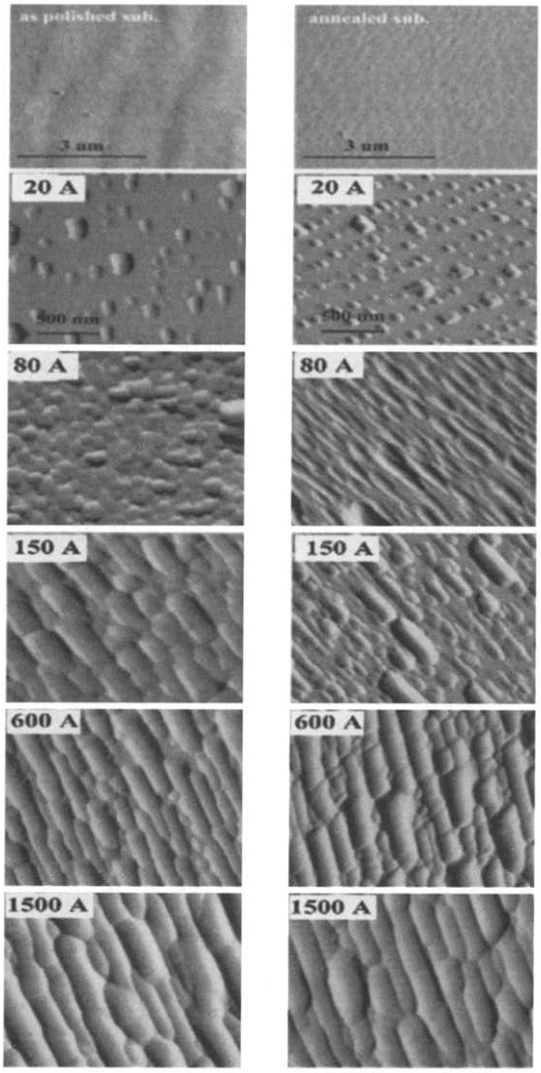

Fig. 1. AFM images of the evolution of YBCO films grown on as-polished (left column) and annealed (right column) (110) SrTiO3 substrates.

No growth of spirals or terraces were observed for (103)YBCO films. However, the existence of the domain boundaries and microcracks are the disadvantages of the (103)YBCO films. The large thermal expansion mismatch between the films and the substrate and the growth of tilted domains with the c-axis pointing ±45° from the $[\underline{1}10]_s$ direction may be the origin of the formation of boundaries and microcracks. There exists strain between these boundaries and part of the strain are expected to relax through the grain boundaries. However, as the thickness of the film increases to a critical thickness, the crack may occur. This critical thickness depends on the deposition, cooling process, and substrate treatment. We found that the critical thickness changed drastically with different cooling rates after deposition.

4. SUMMARY

In this brief report, we have shown the detailed grain evolution of laser deposited (103)YBCO films grown on (110)STO substrates. It was found that although more regular alignment of grains at the initial nucleation for films grown on the pre-annealed substrates, there were no apparent differences in surface structure for the thicker films grown on both as-polished and annealed substrates. Therefore, other ways such as changing the deposition conditions and cooling processes and utilizing of vicinal substrate to get more smooth and less crack films should be further investigated. This work was supported by NSC85-2112-M009-039.

REFERENCES

1. C. Rossel, et al., Physica C 223, 370 (1994).
2. S. Poelders, et al., Physica C 247, 309 (1995).
3. G. Oya, et al., J. Appl. Phys. 77, 5809 (1995).
4. E. Olsson, et al., Appl. Phys. Lett. 58, 1682 (1991).
5. K.H. Wu, et al., Appl. Phys. Lett. 69, 421 (1996).