Available online at www.sciencedirect.com

SCIENCE DIRECT®

Physica C 433 (2005) 43–49

PHYSICA C

www.elsevier.com/locate/physc

# Thickness effects of $SrTiO_3$ buffer layers on superconducting properties of $YBa_2Cu_3O_{7-\delta}$ coated conductors

H. Wang [a,*], S.R. Foltyn [a], P.N. Arendt [a], Q.X. Jia [a], Y. Li [a], X. Zhang [b]

[a] Superconductivity Technology Center, MS K763 Los Alamos National Laboratory, Los Alamos, NM 87545, United States
[b] Mechanical Engineering Department, Texas A&M University, College Station, TX 77843-3123, United States

Received 31 July 2005; received in revised form 21 September 2005; accepted 22 September 2005
Available online 2 November 2005

**Abstract**

A thin layer of $SrTiO_3$ has been successfully used as a buffer layer to grow high quality superconducting $YBa_2Cu_3O_{7-\delta}$ (YBCO) thick films on polycrystalline metal substrates with a biaxially oriented MgO template produced by ion-beam-assisted deposition (IBAD). Using this architecture, 1.5 μm-thick-YBCO films with an in-plane mosaic spread in the range of 2–3° in full width at half maximum, and a critical current density over 2 MA/cm$^2$ in self-field at 75 K have been achieved routinely. More interestingly, we found the thickness of $SrTiO_3$ buffer layers strongly affects the properties of YBCO films. The critical current density of YBCO films increases dramatically when the thickness of $SrTiO_3$ buffer layer reaches an optimum range of 40–120 nm. Microstructure studies, including transmission electron microscopy (TEM), X-ray diffraction (XRD) and scanning electron microscopy (SEM), and ion-milling experiments suggest that the YBCO texture evolution, STO outgrowths and STO surface dents are strongly related to STO thickness. They are the key factors for YBCO self-field $J_c$ variation.


*Keywords:* YBCO coated conductor; $SrTiO_3$; Buffer; Transport properties

## 1. Introduction

Recently, tremendous efforts have been made towards scaling up the superconducting $YBa_2Cu_3O_{7-\delta}$ (YBCO) coated conductors to commercial length and further developing various applications, such as generators, motors and transmission

* Corresponding author. Tel.: +1 505 665 3383; fax: +1 505 665 2992.
*E-mail address:* wangh@lanl.gov (H. Wang).

0921-4534/$ - see front matter 
doi:10.1016/j.physc.2005.09.010

cables. Many methods have been reported for achieving YBCO texture on long metal substrates, but basically they all fall into two categories. The first one is the growth of a biaxially oriented oxide template, by ion-beam-assisted deposition (IBAD) [1,2] or inclined substrate deposition [3], on a conventional polycrystalline metal substrate. The second technique uses a biaxially oriented metal substrate as the template for the growth of YBCO films [4]. For both of these techniques, at least one buffer layer is needed to grow high quality YBCO films on the metal substrates. Several buffer layer materials, such as $Y_2O_3$ or $CeO_2$ for IBAD yttria-stabilized zirconia (YSZ) [5], and $LaMnO_3$ [6,7] or $SrRuO_3$ [8] for IBAD MgO, have been successfully used for growth of high performance YBCO films. These buffer layers show structural compatibility, thermal stability, and chemical stability with YBCO and the underlying template material. Additionally, the diffusion barrier properties of these buffer layers need to be considered as well.

In our previous research, we have developed an improved buffer layer for IBAD MgO: $SrTiO_3$ (STO) [9]. Our choice of STO is based on the routinely sharp texture (about 3° in-plane and 1.5° normal to the film plane) and high self-field $J_c(J_c^{sf})$ values (2–3 MA/cm$^2$ for a 1.5 μm YBCO thickness, at 75 K, self-field) that have been produced on IBAD MgO. This performance means that we have now achieved YBCO $J_c^{sf}$ values on superalloy substrates that are as good as for films on single-crystal oxide substrates [10]. More interestingly, we found that optimum STO deposition parameters (deposition temperature and $O_2$ pressure) can reduce the STO outgrowths on the surface of STO buffer and improve the properties of YBCO films dramatically. The formation mechanism for these epitaxial STO particles, and the reason that their surface density is temperature dependent, were explained by a model proposed by Chang et al. [11] to account for similar particles observed on YBCO surfaces. Basically, for a given substrate temperature and deposition rate, one can find a specific film thickness for which there is complete coalescence and an absence of outgrowths; at this thickness the film is smoothest. This thought led us to further pursuing the thickness effects of STO buffer on the microstructure of STO itself and the properties of YBCO films. This work has helped us to further understand the growth mechanism of STO buffer and routinely produce high-$J_c^{sf}$ films on IBAD MgO.

## 2. Experimental

The depositions of STO buffer layers (thickness varies from 0 to 360 nm) and YBCO films (about 1.5 μm thick) were performed by pulsed laser deposition with a KrF excimer laser (Lambda Physik 210 $\lambda = 248$ nm, 10 Hz). The substrates are Hastelloy C276 with MgO templates which consist primarily of an IBAD-MgO layer and a homo-epitaxial MgO layer. Detailed MgO template processing conditions can be found elsewhere [12,13]. All the substrates used in this experiment were cut from a continuously-processed meter-long-tape with similar MgO texture to ensure that no substrate effects were introduced. The substrate temperature and oxygen pressure for STO growth were kept at 820 °C and 300 mTorr, respectively. YBCO films were deposited thereafter on these buffers at an optimized substrate temperature of 760 °C and $O_2$ pressure of 200 mTorr. X-ray diffraction analyses including normal $\theta$–$2\theta$ scan, $\Phi$-scan and rocking curve, were performed for STO and YBCO films. Scanning electron microscopy (SEM) was used to study the surface morphology and roughness of as-grown YBCO and STO buffer layers for various buffer thicknesses. Cross-sectional microstructure studies of these as-deposited films, including transmission electron microscopy (TEM) and high resolution TEM, were performed with a JEOL-3000F analytical electron microscope with point to point resolution of 0.17 nm. All the YBCO films were characterized by measurement of the transition temperature ($T_c$) and critical current density ($J_c$) at liquid nitrogen temperature in self-field.

## 3. Results and discussion

STO buffer layers were deposited for different time periods from 0 to 36 min. With a pulse rate