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Pallewatta, Pallewatta G A P; Yue, Zhao; Grivel, Jean-Claude

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DEVELOPMENT OF STRONTIUM TITANATE THIN FILMS ON TECHNICAL SUBSTRATES FOR SUPERCONDUCTING COATED CONDUCTORS

Pallewatta P.G.A.P. *, Zhao Y., Grivel J.C.

*Technical University of Denmark, Department of Energy Conversion and Storage,
P.O. Box 49, DK-4000 Roskilde, Denmark

$SrTiO_3$ is a widely studied perovskite material due to its advantages as a template for high temperature superconducting tapes. Heteroepitaxial $SrTiO_3$ thin films were deposited on Ni/W tapes using dip-coating in a precursor solution followed by drying and annealing under reducing conditions. Nearly complete coverage of the underlying substrate was obtained for bi-layers and tri-layers. The 3rd coating is grown with a better homo-epitaxial growth, resulting in an improvement of the orientation factor. The obtained thin films have been characterized in terms of caxis texture and surface morphology, suggesting a good template for further deposition of YBCO superconducting layers.

INTRODUCTION

High Temperature Superconducting (HTS) tapes have a significant potential for contributing to sustainable energy solutions, through application in various cryogenic power devices. In the 2nd generation HTS tapes technology, a superconducting thin film has to be coated on biaxially textured substrate tapes that have enough mechanical strength for practical use in power turbines for example. When considering coating $YBa_2Cu_3O_{7-\delta}$ (YBCO) superconducting thin films on Nickel-Tungsten (Ni/W) substrates, the need of a buffer layer becomes an essential part to protect the Ni/W substrate from oxidization during the YBCO deposition process [1] (see Figure 1). Lattice matching with the underlying material is essential in order to ensure a high quality epitaxial growth of each new coating [2]. $SrTiO_3$ (STO) is widely studied as a candidate buffer layer due to its perovskite crystal structure and good chemical stability [3-11]. Here, the lattice mismatch between STO with Ni/W and YBCO is about 9.9% and 1.5% respectively.

Deposition of $SrTiO_3$ thin films has been reported using several methods such as pulsed laser deposition (PLD) [8,9], sputtering [10], chemical vapour deposition (CVD) [11] and chemical solution methods [3-7]. In order to meet the needs of cost effective large scale deposition on long substrate tapes, the dip coating technique can be considered as a promising method among the chemical solution deposition (CSD) methods. Few studies on $SrTiO_3$ thin films have been reported on technical substrates. Yet, fully covered continuous $SrTiO_3$ buffer coatings with a good crystallinity still have to improve for the further deposition of high performance YBCO films.

In this work, $SrTiO_3$ thin films were deposited on technical metal tapes using dip-coating in a precursor solution followed by drying and annealing under reducing conditions. The obtained thin films with thicknesses of 50~100nm, have been characterized in terms of texture and surface morphology.

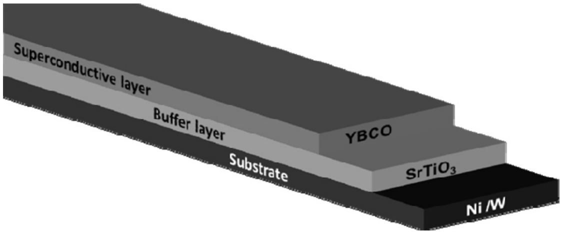

Figure 1 Schematic view of a 2nd generation HTS tape (not to scale)

EXPERIMENTAL

The solution preparation was carried out in a glove box with Ar atmosphere, due to the moisture sensitivity of the starting chemicals. Strontium acetate [$(CH_3CO_2)_2Sr$; Sigma Aldrich] and Titanium (IV) butoxide [$Ti(O(CH_2)_3CH_3)_4$; Sigma Aldrich] were used as Sr & Ti sources. Glacial acetic acid [CH_3COOH ; Sigma Aldrich] and 2-methoxyethanol [$CH_3O(CH_2)_2OH$; Sigma Aldrich] were used as chelating agent and solvent. A precursor solution with the concentration of 0.3M was prepared with continuous stirring at 70°C. Commercial Ni/5%W textured substrates [80μm; Evico] cut into 10mm × 20mm pieces, ultrasonically cleaned in acetone [CH_3COCH_3] and ethanol [CH_3COOH], were used for dip-coating with continuous withdrawal speed of 60mm/min. After drying in reducing atmosphere of Ar/5%H2 for ½ hour, the coated samples were annealed in a tubular quartz furnace for single-step heat treatment, allowing the coated film to crystallize. The samples were annealed at 950°C in reducing atmosphere of Ar/5%H_2 for 1 hour, and quenched just after that heat treatment. For multi-coatings, after each annealing process, the samples were ultrasonically cleaned in ethanol for the next dip-coating.

The film thickness measured by ellipsometer [FILMetrics] was estimated to approximately 50~100nm. X ray diffraction (XRD) scans were performed in a STOE diffractometer with Cu Kα radiation. Scanning electron microscope (SEM) observations were performed in a Supra 35 instrument. Crystallographic texture of the tri-layer was investigated using a Field Emission Gun Scanning Electron Microscope (FEGSEM) Zeiss Supra 35 instrument equipped with an HKL Technology Channel 5 Electron BackScatter Diffraction (EBSD) detector. In this EBSD study, a step size of 4μm was used on a scanning area of at least 0.14mm^2 along the rolling plane of the tri-layer/substrate.

RESULTS AND DISCUSSION

$SrTiO_3$ thin films fabricated on Ni/5%W textured substrates at an annealing temperature of 950°C exhibit excellent crystallographic orientation as shown by XRD θ-2θ scans in Figure 2.

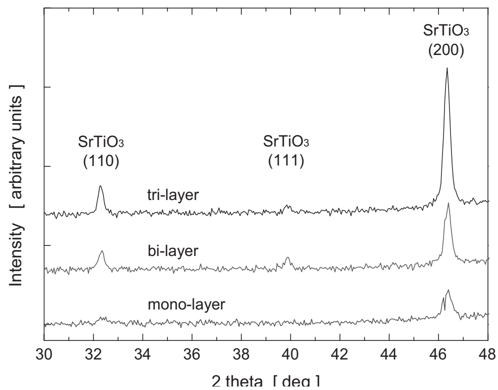

Figure 2 XRD θ-2θ scans of mono- and multi-coated $SrTiO_3$ films

The diffraction peaks near $2\theta \approx 32.4°$, 40°, and 46.5° are corresponding to the (110), (111), and (200) reflections of $SrTiO_3$. Based on the Lotgering orientation concepts [12], the orientation factor f_L for the desired $SrTiO_3$ peak of (200) calculated using formula (1a) for mono-, bi-, and tri- layers were figured as f_L = 0.89, 0.71, and 0.82 rspectively.

$$f_L = \frac{\sum I_{h00}}{\sum I_{h00} + \sum I_{hkl}} \quad (1a)$$

The images of surface morphology were obtained using SEM as shown in Figure 3. The bi-layer & tri-layer films seem to be covered homogeneously except for some porosity. However, the mono-layer film seems to be discontinuous. In the mono-layer, $SrTiO_3$ grains are expected to grow as a highly oriented seed layer, with an island-like hetero-epitaxial growth. The next coating deposited on the single coating is expected to have a good homo-epitaxial growth, but with a lower orientation factor due to the discontinuity of its seed template. After the second coating, the Ni/W substrate is fully covered except for some pinholes. The next coating deposited on the bi-layer is grown with a better homo-epitaxial growth, resulting in an improvement of the orientation factor.

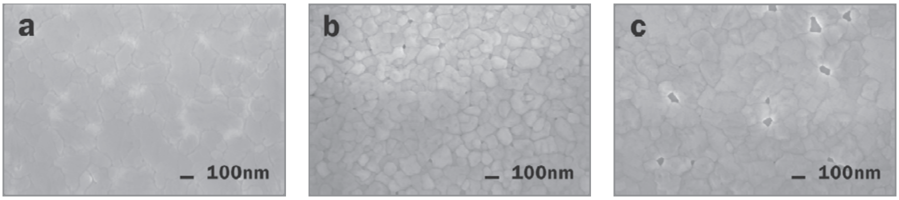

Figure 3 SEM images of (a) mono-layer (b) bi-layer and (c) tri-layer of $SrTiO_3$ films

In the pole figure analysis, as shown in Figure 4, it was observed that the tri-layer consist of a favourable cube texture. The vertical & horizontal axes are representing the Rolling Direction (RD) & the Transverse Direction (TD) respectively. Besides the cube texture, there is a sheer evidence of some minorsecondary texture components in the pole figure, suggesting that the surface texture of the tri-layer still needs to be improved for the YBCO deposition.

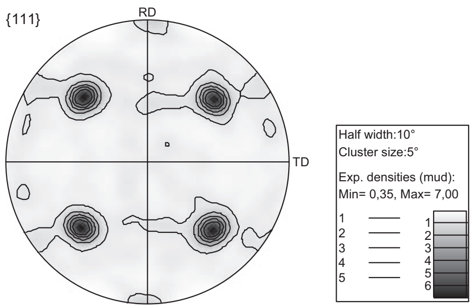

Figure 4 {111} pole figure of a tri-layer $SrTiO_3$ film

CONCLUSION

$SrTiO_3$ buffer coatings have to be fabricated with an excellent orientation and also complete coverage of the underlying Ni/W substrate. Therefore, triple coatings are expected to serve as an excellent buffer template for the further deposition of YBCO.

Further work is in progress in order to improve the surface quality of this type of buffered substrate and assess its suitability for further deposition of a superconducting layer.

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