$La_{0.7}Sr_{0.3}MnO_3$ buffer layer and YBCO film deposited by pulsed laser deposition

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In this report, $La_{0.7}Sr_{0.3}MnO_3$ thin films were deposited on single crystal $SrTiO_3$ (STO) substrates. The deposition conditions were analysed and pure *c*-axis film was epitaxially grown. The surface of the YBCO film on the top of $La_{0.7}Sr_{0.3}MnO_3$ /$SrTiO_3$ was examined with atomic force microscopy (AFM). Superconducting YBCO thin film was deposited by pulsed laser deposition on the $La_{0.7}Sr_{0.3}MnO_3$ /$SrTiO_3$. T_c and J_c of the samples were measured and calculated through DC magnetic measurements using a physical properties measurement system (PPMS).

1. Introduction

The second generation high temperature superconductor (HTS) tape is termed 'coated conductor', that is, an $YBa_2Cu_3O_{7-d}$ (YBCO) coating on a metallic tape substrate with a multilayer buffer in between. Rolling-assisted biaxially textured substrates (RABiTS) have been developed for this purpose, and the method has become a cost effective approach to the fabrication of coated conductor [1,2]. In general, a coated conductor architecture involves epitaxial fabrication of a thin layer ~1-2 μm in depth of HTS film, usually YBCO, on one or more biaxially textured buffer layers deposited on a thick (~80 μm) flexible metal substrate (Ni or dilute Ni alloys). These buffer layers provide a template allowing reduced lattice mismatch between the YBCO and the substrate for *c*-axis aligned epitaxial growth, while providing a barrier to Ni diffusion from the metal substrate into the superconductor during deposition or ex-situ processing of the YBCO layer. For effective implementation at cryogenic temperatures (30-77 K), stabilization against thermal runaway will be required in the event of an over current situation (exceeding the critical current I_c of the HTS coating). A solution is to electrically shunt the HTS layer, either by an intermediate conductive buffer layer to a low resistivity metal substrate or by depositing a stabilizing metallic cap layer, e.g., Cu or Ag, onto the HTS coating. The latter solution will increase the cross-sectional area, hence reducing the engineering critical current density J_e (I_c per unit total cross-sectional area). The most desirable approach from an applications perspective is to deposit conductive buffer layer on the metallic tape in order to shunt the current to the tape when the HTS layer leaves the superconducting state [3]. Coupling the HTS layer adequately to a metallic tape through a conductive buffer layer also provides an overall less complicated structure with reduced resistance and an increased thermal conductivity, providing more efficient heat transfer to either a coolant bath or through the thermal diffusivity of the system.

In recent years, the study of colossal magnetoresistance (CMR) in perovskite-structured, doped lanthanum manganese oxides has generated great interest in fabricating these materials as thin film heterostructures for various technological applications. The variant $La_{0.7}Sr_{0.3}MnO_3$ (LSMO), apart from its CMR properties, is also an electrically conductive oxide with good thermal stability. Moreover, the pseudocubic lattice parameter of 3.9 Å is a

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close match to YBCO film. Therefore, it is of interest to investigate the viability of LSMO as a conductive buffer layer on RABiTS for YBCO-coated conductors. Here, we report the fabrication of $La_{0.7}Sr_{0.3}MnO_3$ buffer layer deposited by pulsed layer deposition on single crystal $SrTiO_3$ (STO) substrate.

2. Sample preparation

LSMO targets were made by sintering a pressed mixture of La_2O_3, $SrCO_3$, and MnO_2 powder according to the element stoichiometry at 1150^{o}C for 8 hours in air. X-ray diffraction (XRD) phase analysis showed it was a pure $La_{0.7}Sr_{0.3}MnO_3$ phase. LSMO and YBCO targets were ablated by an excimer KrF pulsed laser with 248 nm wavelength. The LSMO buffer layer was epitaxially deposited on STO substrate at 550^{o}C under 10 mTorr O_2 pressure. The laser beam energy was fixed at 300 mJ per pulse at 3 or 5 Hz. Single crystal (00l) STO substrates of 3x3mm^2 were attached with silver paste to a sample stage (also the heater) which was directly facing the target at an on-axis position. A laser beam was directed to the target surface at an angle of 45° to the normal of the target, with the target-substrate distance 40 mm. The size of the laser spot on the target was ~ 5×2 mm^2, and the laser pulse energy density on the target was ~ 3 J/cm^2. The target was rotated at 10 rpm.

An X-ray diffraction system was used to analyse the phase and orientation of films with XRD θ -2θ scans. The temperature and field dependences of the magnetic moment were investigated by employing a Quantum Design PPMS using a superconducting quantum interference device (SQUID) magnetometer with a maximum field of 9 T and temperature 5 < T < 300T. An atomic force microscope (AFM) was used to more fully characterize the surface morphology and roughness of the buffer layers.

3. Results

The background pressure of the deposition chamber was about 1x10^{-6} Torr. After deposition of the LSMO buffer layer, the oxygen pressure was subsequently increased to 200 mTorr, and the superconducting YBCO layer was then deposited on the buffer layers. The YBCO film was deposited within a deposition temperature range of 770 - 790°C in 200 mTorr oxygen pressure. The laser conditions were: energy 300 mJ/pulse and repetition rate 5 Hz. Following deposition, the YBCO film was quickly cooled to 450°C under the deposition pressure, and then kept for 30 min under an oxygen pressure of 700 Torr. Fig. 1 is a typical XRD plot for an YBCO(500nm)/LSMO(100nm)/STO sample. In this figure, the LSMO film just has (002) and (004) peaks, but the (002) peak has overlapped with the STO (002) and the YBCO (003) peaks, while the (004) peak has overlapped with the STO (002) and the YBCO (006) peaks. The YBCO film has a pure *c*-axis orientation.

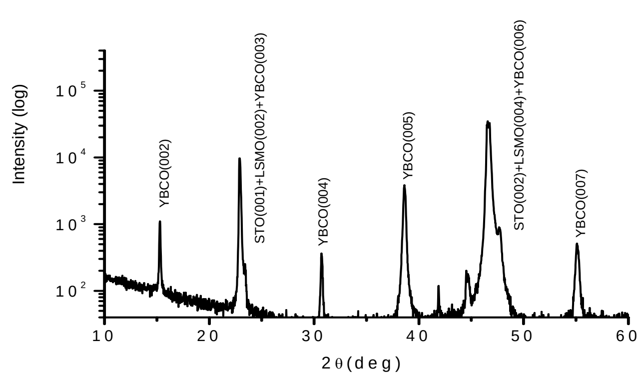

Fig. 1. XRD θ-2θ scan for a typical YBCO/LSMO/STO sample.

The T_c of the YBCO film was 90K as measured by DC magnetic measurements using PPMS. The J_c values were magnetically determined by applying the modified critical state model to the magnetic hysteresis loop via the relation $J_c = 2\Delta M/[a(1-a/3b)]$. This formula applies to a rectangular solid with field perpendicular to a face with sides b > a. Here, $\Delta M = (M^{-}-M^{+})$, where M^{-} and M^{+} are the magnetizations at temperature T measured in decreasing and increasing field *H* history, respectively. The curves shown in Fig. 2 are the $J_c(B,T)$ relationships for the YBCO film (500nm), which is consistent with reports that these $J_c(B,T)$ curves depend on the applied field and temperature through the mechanism of vortex trapping by dislocations over the entire field range. It can be seen that J_c can remain constant at some value of applied magnetic field for T ≤ 20K, which means that there is a single vortex pinning regime.

AFM was used to examine the surface morphology and roughness. Fig. 3 is the AFM image of the YBCO (500 nm) surface. There are a few large outgrowths on its surface, and the surface roughness was increased compared to the roughness of LSMO film. The AFM scan on this specimen gives a root mean square roughness over a 50 μm × 50 μm area of about 43.4 nm, including the outgrowths, and 37.3 nm over the same area if outgrowths are excluded.

From the superconductivities of YBCO on the top of LSMO buffer layer it can be seen that the LSMO a suitable conductive buffer layer for YBCO coated conductor. The work of depositing LSMO film on metallic substrates, such as Ni and Ni-alloy, is in process.

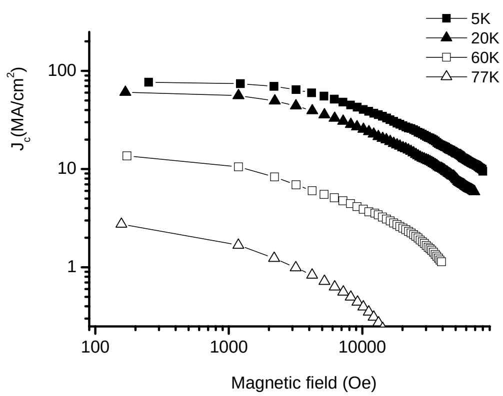

Fig. 2 Field dependence of the J_c at different temperatures for an YBCO(500nm) film on LSMO/STO.

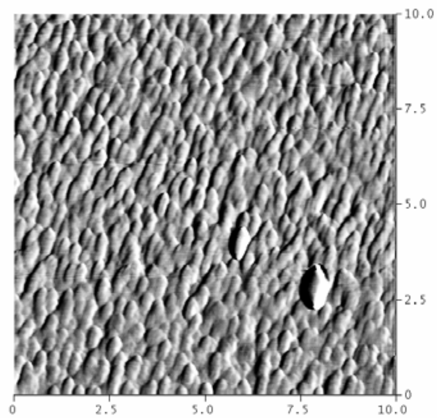

Fig 3. AFM image showing the surface morphology of the YBCO(500nm) film on LSMO/STO.

Acknowledgments

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