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$(La,Sr)TiO_3$ as a conductive buffer for RABiTS coated conductors

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Abstract

We report on the epitaxial growth of $LaTiO_3$ on biaxially textured (0 0 1) Ni. This investigation centers around the potential use of $(La,Sr)TiO_3$ as a conductive buffer layer for subsequent growth of high temperature superconducting films for coated conductors. Epitaxy of $LaTiO_3$ on Ni is achieved using pulsed-laser deposition. Excellent in-plane and out-of-plane alignment is confirmed via X-ray diffraction. For undoped $LaTiO_3$ films, the oxide/metal interface is not stable against substrate oxidation, reflective of the propensity of $LaTiO_3$ to accommodate excess oxygen in the lattice. Future work will focus on Sr-doped $LaTiO_3$ films as this should alleviate these limitations.

Keywords: Coated conductors; Wires; Epitaxial films; Buffer layers

1. Introduction

In recent years there has emerged significant interest in the development of coated conductors based on epitaxial high temperature superconducting films deposited on metal tapes [1,2]. One particular approach based on the use of rolling assisted biaxially textured substrates (RABiTS) requires the growth of oxide buffer layers on biaxially textured metal surfaces. These buffer layers must be epitaxial with respect to the biaxially textured metal tape, chemically robust, and suitable for subsequent superconductor film growth. For a practical conductor, the ability to accommodate current flow in the event of a local supercurrent quenching event may also be desirable. With the RABiTS process, an obvious approach to redirecting large current flows in the event of a local failure would be to shunt the current through the metallic substrate. However, this requires the formation of conductive buffer layers that also satisfy the criteria listed above [3].

One candidate material system for use as a conductive buffer is $(La,Sr)TiO_3$ [4–6]. $LaTiO_{3+x}$ is an interesting defect perovskite system, with transport properties varying from insulating to metallic based on oxygen stoichiometry. When synthesized with low oxygen content (reduced conditions), $LaTiO_3$ is metallic at high temperature, with a metal–insulator transition occurring at reduced temperature. As oxygen is added, ordered

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phases are observed. For $0.1 < x < 0.2$, the material is metallic at all temperatures. As more oxygen is loaded into the lattice, intergrowths are introduced. At $x = 0.4$, the material becomes a semiconductor. For $x = 0.5$, the material becomes ferroelectric as an order $La_2Ti_2O_7$ phase. With an extreme sensitivity to oxygen content, $LaTiO_{3+x}$ is not particularly attractive as a conductive buffer for RABiTS applications. The need to maintain metallic conductivity in an oxidized state necessitates cation doping in order to maintain carrier density as well as to reduce oxygen diffusivity. The most likely candidate dopant is Sr substituted on the La site. In this paper, we report on initial results for the $(La,Sr)TiO_3$ system serving as a potential conducting buffer layer for RABiTS. The results reported here are limited to $LaTiO_3$ films with no Sr doping. The objective is to investigate conditions necessary for achieving epitaxy of this system on Ni surfaces, as well as to experimentally investigate the stability of epitaxial oxide/metal interfaces when the oxide layer ($LaTiO_{3+x}$) undergoes structural changes due to the addition of oxygen to the lattice.

The growth of $LaTiO_3$ on (0 0 1) Ni was investigated using pulsed-laser deposition. A KrF (248 nm) excimer laser was used as the ablation source. Laser energy densities on the order of 1–3 J/cm^2 were utilized. Films were deposited at temperatures ranging from 500–770 °C in vacuum with a base pressure of 3×10^{-5} Torr. A polycrystalline $LaTiO_3$ target was used as the ablation target material. Total deposition time was 0.5–1 h with a laser repetition rate of 5 Hz. In most cases, the films were rapidly cooled in vacuum following growth.

Epitaxial $LaTiO_{3+x}$ films could be obtained on biaxially textured (0 0 1) Ni at substrate temperatures ranging from 620 to 770 °C, although the most consistent results were obtained above 720 °C. Fig. 1 shows the surface normal X-ray diffraction scans for films deposited at different temperatures. Note that films deposited at 620 °C show a distinct increase in the out-of-plane lattice spacing. $LaTiO_{3+x}$ is known to undergo structural phase transitions as x is increased. Room temperature measurements of the film resistance indicate that films deposited under reducing conditions at 720–770 °C are highly conductive.

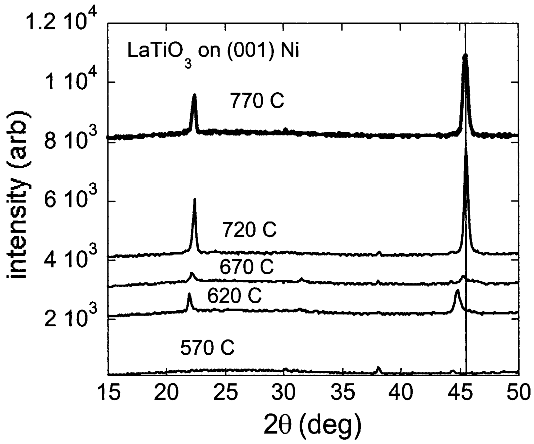

Fig. 1. X-ray diffraction θ–2θ scans taken the surface normal for $LaTiO_3$ films deposited on (0 0 1) Ni at various temperatures using pulsed laser deposition.

High resolution X-ray diffraction scans shows that the films are (0 0 1) oriented with good in-plane epitaxy. The rocking curve of the (0 0 4) peak for the film deposited at 770 °C shows a full-width half-maximum of 3.7°, which is better that that of the biaxially-textured Ni substrate. X-ray phi-scans shown in Fig. 2 indicate that the $LaTiO_3$ film is completely in-plane aligned with peak widths on the order of 9.6°. The in-plane mosaic of the biaxially textured Ni is approximately 10°. Recent work by Cantoni et al. indicates that nucleation of

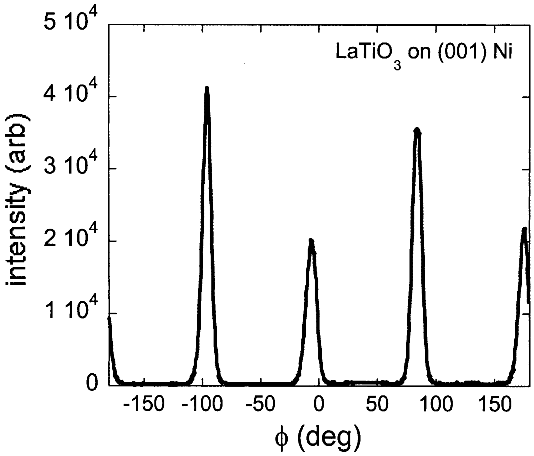

Fig. 2. In-plane φ-scans taken through the $LaTiO_3$ (0 2 0) showing excellent in-plane alignment.

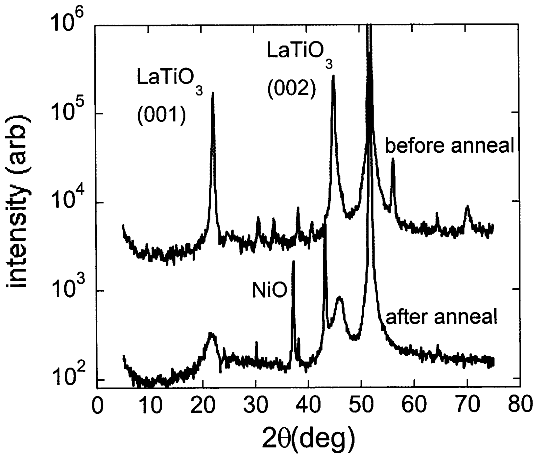

Fig. 3. X-ray diffraction scans for an epitaxial $LaTiO_3$ film on (0 0 1) Ni taken before and after annealing in 200 mTorr oxygen at 700 °C.

epitaxial oxides on the (0 0 1) Ni surface is facilitated by an ordered sulfur layer [7]. It is assumed that ordered sulfur also participates in the nucleation of $LaTiO_3$ on Ni with the sulfur is supplied via residual impurities in the Ni substrate. This needs to be confirmed via reflection high-energy electron diffraction.

Annealing experiments on epitaxial $LaTiO_3$ on Ni were performed in order to investigate the stability of $LaTiO_3$ under conditions suitable for subsequent growth of $YBa_2Cu_3O_7$ film growth. Previous work has shown that $LaTiO_{3+x}$ possesses a high propensity for taking up additional oxygen in the lattice as the valence state of Ti increases from +3 to +4. Fig. 3 shows the effects of annealing an epitaxial $LaTiO_3$ film on (0 0 1) Ni in 200 mTorr of oxygen at 700 °C for 30 min. Significant oxidation of the substrate is observed along with a significant reduction and shift of the $LaTiO_3$ diffraction peaks. Similar experiments for epitaxial $LaTiO_3$ on $SrTiO_3$ did not show a reduction in $LaTiO_3$ diffraction peak intensity, indicating that the interface between $LaTiO_3$ and Ni is relatively unstable. It is anticipated that doping the $LaTiO_3$ matrix with Sr will help to accommodate the conversion of Ti valence, reduce oxygen diffusion, and maintain metallic conductivity. Clearly, buffer layer stability and oxygen diffusivity is an important factor in constructing a viable RABiTS architectures.

In conclusion, we have investigated the growth of $LaTiO_3$ on (0 0 1) Ni using pulsed laser deposition. The results show that epitaxy can be achieved, although the stability of the $LaTiO_3$/Ni interface is limited to reduced conditions. Future efforts will address the stability of (La,Sr)TiO_3/Ni structures.

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