Electrically conducting oxide buffer layers on biaxially texted nickel alloy tapes by reel-to-reel MOCVD process

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Abstract. Reel-to-reel MOCVD process for continuous growth of electrically conducting buffer layers on biaxially textured Ni5W tapes has been developed. The new buffer layer architecture is presented: 200 nm (La,Ba)2CuO4 / 40 nm (La,Ba)MnO3 / Ni5W. Constituting layers with high structural quality have been grown on moving tapes (in plane FWHM ≤ 6° and out of plane FWHM ≤ 3°).

1. Introduction

Epitaxial growth of oxide film on textured metal tape without oxidation of the metal is one of the most challenging tasks in production of coated conductors. PLD, sputtering, evaporation and other deposition techniques have been successfully used to grow such buffer layers [1]. Metalorganic chemical vapor deposition (MOCVD) is an attractive alternative to these methods [2]. Its advantages are comparatively low cost (no high vacuum is needed), easy scalability, conformal deposition on non-planar substrates, etc.

Up to now, oxides with fluorite or fluorite-related structure (CeO2, Y2O3, La2Zr2O7, etc. [3]) or rock salt structure (NiO [4] or MgO [5]) have been widely used as a buffer layer material. These oxides are dielectrics and separate HTS layer from the metal substrate, prohibiting electrical current to flow through the massive metal substrate in case of HTS’ layer quenching. This situation can lead to destruction of the cable. Therefore, electrically conducting buffer layer materials are regarded to be more promising in this aspect. Conducting oxides with perovskite structure such as LaNiO3 [6], (La,Sr)TiO3 [7] and (La,Sr)MnO3 [8] were tested for this purpose. The analysis of thermodynamic stability, however, rules out LaNiO3 – since it does not coexist with metallic nickel [9] and (La,Sr)TiO3 – because it is not stable at oxygen partial pressures needed for YBCO growth [7]. In contrast, (La,Sr)MnO3 coexist with both Ni and YBCO (Fig.1). In this paper we present our recent results on development of reel-to-reel MOCVD process for the growth of electrically conducting buffer layers on moving Ni5W tape. (La,Ba)MnO3 (LBMO) and (La,Ba)2CuO4 (LBCO) have been chosen for the layer architecture. This buffer layer system possesses following attractive features: only 5 metallic elements are needed for the whole coated conductor system (La, Mn, Y, Ba and Cu),
LBCO layer can be easily grown at comparatively low temperature (<700°C), LBCO is superconducting below 35 K.

2. Experimental

The MOCVD setup has been described in details elsewhere [9]. 2,2,6,6-tetramethylheptane-3,5-dionates of Ba, La, Mn and Cu were used as volatile precursors. The description of band evaporator used can be found in Ref 14. To avoid the oxidation of the metal tape, the deposition of the first layer – LBMO – is performed at low oxygen partial pressure (Table 1). Low p(O₂) value in deposition zone is attained by variation of initial gas composition (NH₃ or H₂ are used as reducing agents, H₂O is used as oxidizing agent) [4]. 10 mm wide and 80 μm thick Ni5W tapes delivered by evico GmbH (Dresden, Germany) were used as substrates. The second layer was grown in oxidative atmosphere (Table 1). The samples grown have been characterized by XRD (SIEMENS D 5000 diffractometer) and SEM (CamScan electron microscope with EDAX 9800 system).

Table 1. Growth conditions and characteristics of 1st and 2nd buffer layers.

| Material          | Temperature, °C | p(O₂), bar   | Band velocity, m/h | Thickness, nm |
|-------------------|-----------------|--------------|--------------------|---------------|
| La₀.₈Ba₀.₂MnO₃    | 800             | 10⁻¹⁷ - 10⁻¹⁵| 1                  | 20-40         |
| La₁.₇Ba₀.₃CuO₄    | 670             | 0.001        | 3                  | 200           |

3. Results and Discussion

LBMO, the first layer in the buffer system, is thermodynamically compatible with both Ni substrate and the following LBCO layer (Fig.1 presents the data for strontium substitution since they are more present in literature, however, the data should be rather similar for barium-substituted compounds used in our work. Dashed line for LSMO is interpolation of experimental data, solid line). Correspondingly, no oxidation of substrate has been observed after the LBMO growth (i.e., no NiO peaks occurred on XRD θ-2θ scans). The doping level up to x = 0.25 has been realized for LBMO, which is confirmed by the gradual change of the lattice parameter (Fig.2). The doping level of ≥ 0.20 corresponds to metallic conductivity at 300 K and below [15].

Figure 1. Stability ranges of (La,Sr)MnO₃ [10], (La,Sr)₂CuO₄ [11], YBa₂Cu₃O₇-x [12] and NiO [13].

Figure 2. Out-of-plane lattice parameter of (La,Ba)MnO₃/Ni5W films vs. barium content.
Figure 3. LBCO/LBMO/Ni5W buffer system. (a) θ-2θ scan (inset: rocking curve); (b) φ-scans.

Figure 4. SEM images of LBMO/Ni5W (a) and LBCO/LBMO/Ni5W (b) buffers.

The XRD study of the whole buffer layer system is presented in Fig.3. It can be seen that texture of Ni5W substrate is inherited by LBMO and LBCO layers. However, small peak corresponding to unoriented growth of LBCO is observed, as well as some NiO formation is evident. Further optimization of the growth conditions is necessary to solve these problems. We suppose that especially enlargement of the deposition zone resulting in increase of the deposition rate and tape velocity may help to avoid nickel oxide formation. Another approach is the increase of the thickness of LBMO layer, which is also possible via larger deposition reactor. The construction of according experimental setup at IOT TU Braunschweig is now in progress.

Surface morphology of LBMO and LBCO/LBMO layers is shown in Fig.4. It can be seen that no remarkable change in morphology, which is typical for textured Ni5W tapes, occurs. The films possess consolidated microstructure without cracks. Some outgrowths are observed on the surface of LBCO/LBMO/Ni5W surface.

The work on deposition of superconducting YBCO layers on the developed buffer layer system is in progress.

4. Conclusions

New electrically conducting buffer layer system for the growth of coated conductors has been developed and grown by reel-to-reel MOCVD approach. The system consists of 200 nm (La,Ba)2CuO4 layer grown on 40 nm of (La,Ba)MnO3, which is grown in reducing atmosphere directly
on textured Ni5W tape. High epitaxial quality of this buffer was confirmed by XRD: in plane FWHM ≤6° and out of plane FWHM ≤3°. The work is in progress to grow superconducting YBCO layers on this buffer.

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