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Synthesis and Characterization of Pr_2O_3 Buffer Layers by Sol-Gel Process for YBCO Surface Coated Conductors

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Key words
YBCO; Sol-gel; and Buffer layers

Abstract

Pr_2O_3 films were deposited using a sol-gel process from solutions derived from praseodymium (III) isoproxide. Homogenous, crack-free, and dense films were deposited on Ni tapes between temperatures of 600°C and 850°C for YBCO surface coated conductors. These films were characterized by XRD, SEM and AFM. According to XRD pattern, Pr_2O_3 film is successfully grown on Ni substrate. It was found that microstructures of the films are dense, continuous, crack-free and pinhole-free. As a result, it is accepted that Pr_2O_3 film is suitable for YBCO surface coated conductors.

YBCO Yüzey Kaplanmış İletkenler İçin Sol-jel Prosesiyle Pr_2O_3 Buffer Katmanların Sentezlenmesi ve Karakterizasyonu

Anahtar kelimeler
YBCO; Sol-jel; ve Buffer katmanlar

Özet

Pr_2O_3 filmler sol-jel prosesiyle praseodimiyum (III) isoproksit kullanılarak hazırlanan çözeltilerile kaplanmışır. YBCO yüzey kaplanmış iletkenler için Ni şerit altlıklar üzerine homojen, çatlaksız ve yoğun filmler 600°C ve 850°C sıcaklıklar arasında kaplanmıştır. Bu filmler XRD, SEM ve AFM ile karakterize edilmiştir. XRD desenine göre, Pr_2O_3 film Ni altlık üzerine başarılı bir şekilde büyütülmüştür. Filmlerin tüm mikro yapılarının yoğun, sürekli, çatlaksız olduğu ve iğne deliği içermediği belirlenmiştir. Sonuç olarak, YBCO yüzey kaplanmış iletkenler için Pr_2O_3 filmin uygun olarak kabul edilebilir.

1. Introduction

Recently, $YBa_2Cu_3O_{7-\delta}$ (YBCO) thin films on flexible metallic substrates, such as Ni, and Ni alloys have attracted much attention for long length superconducting tapes (Chung *et al.* 2005). However, direct deposition of YBCO films on these substrate materials causes numerous problems at their interface in addition to the degraded crystallinity due to large lattice mismatch. Several buffer layers have been used to solve these problems (Reeves *et al.* 2003; Akin *et al.* 2003). Until now, CeO_2, yttria-stabilized zirconia (YSZ), MgO, Y_2O_3, $BaTiO_3$, $SrTiO_3$, $PbTiO_3$, $BaZrO_3$, $LaAlO_3$, $CaTiO_3$, $NdGaO_3$, and various architectures with RE_2O_3 (RE:Yb, Pr, Eu, Ho, Er, Tm, Sm, Lu, Gd, Dy, and Tb) have been reported as promising buffer layer candidates (Driessche *et al.* 2005; Celik *et al.* 2000). From these layers, perovskite materials, SrTiO3, $LaAlO_3$, $PbTiO_3$, and $BaZrO_3$, have some advantages such as good lattice match, oxidation protection of Ni for YBCO processing, and chemical compatibility with Ni. Pr_2O_3 has attracted particular attention in recent years, owing to its high dielectric constant and possibility to form epitaxially films on metallic surfaces (Sohal *et al.* 2006).

The purpose of this study is to produce pinhole-free and crack-free Pr_2O_3 thin films on Ni tapes using a reel-to-reel sol-gel process for YBCO surface coated conductors.

2. Material and Method

Pr_2O_3 thin films were produced on Ni tapes from Pr based organometallic compounds using a reel-to-reel continuous sol-gel process. Praseodymium (III)-isoproxide was seperately dissolved in acetylacetone which was used as chelating agent at 60°C for 3 hour. Finally, the solution were diluted with methanol and stirred at room temperature for 24 hours.

Ni tapes (kindly supplied by Plastronic-Eurus) (0.07 mm x 1.43 mm) were cleaned with HNO_3+HF+H_2O solution and rinsed with acetone. The Ni tapes were then dipped into the solutions at a withdrawal rate of 1 cm/sec in a reel-to-reel set up. They were dried at 300°C for 1 min and the dried samples were then heat treated at 600°C for 2 min in a vertical 3 zone furnace in the same set up. These procedures were repeated to achieve the desired film thickness. Finally, the films were annealed to densify them at 850°C for 30 min in a horizontal furnace. Sol-gel processes of YBCO films on these perovskite buffer layers are described elsewhere.

The crystalline phases in the films were identified using X-Ray Diffraction (XRD). The microstructures of these films were observed by scanning electron microscopy (SEM). The morphological quality of the thin films was determined with the help of atomic force microscopy (AFM) (Nanosurf Easyscan II).

3. Results and Discussion

The growth directions and the crystallinity of the film were explored by X-ray diffraction (XRD). A detailed study of the crystalline structure of the Pr_2O_3 and Ni substrate was realized by X-ray diffraction measurements as shown in Figure 1. It can be clearly seen from the XRD results that phases are formed and neither intermetallics nor any other phases are formed. That is the desired textured structure for both Ni substrate and buffer layer. The texture of films directly affects film quality as mechanical stability and critical current density. Such buffer layers must provide both an oriented lattice matched surface for epitaxial YBCO growth and a metal diffusion barrier to protect the metal substrate during superconductor film growth. According to the pattern, Pr_2O_3 film is successfully grown on Ni substrate.

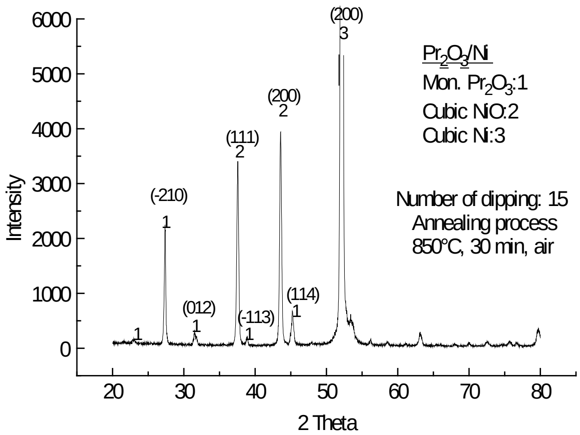
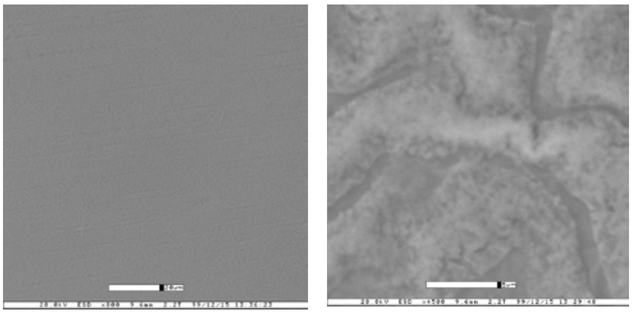


Figure 1. X-ray diffraction pattern of Pr_2O_3 deposited on Ni substrate.

Figure 2 illustrates SEM micrographs of Pr_2O_3 films on Ni Tapes before and after annealing at 850°C for 30 min in O_2 atmosphere. Generally, all microstructures are dense, continuous, crack-free and pinhole-free. Besides, the surfaces of these films are homogenous, uniform and smooth. As shown from the images, the grooves at the grain boundaries of substrate still remain visible at all the deposited thin films, due to the grain boundary grooving, which is a characteristic of biaxially textured nickel substrate.

The surface roughness of Pr_2O_3 films after annealing at 850°C for 30 min. was characterized with atomic force microscopy (AFM). As Sohma et al. mentioned, it is important to control surface roughness for the production of uniform and high J_c superconducting films on the buffered substrates. AFM images of the buffer layers shown in Figure 3 indicate that the surface of buffer layer is nearly dense, uniform and smooth.



(a) (b)

Figure 2. SEM micrographs of Pr_2O_3 films on Ni tapes (a) before and (b) after annealing.

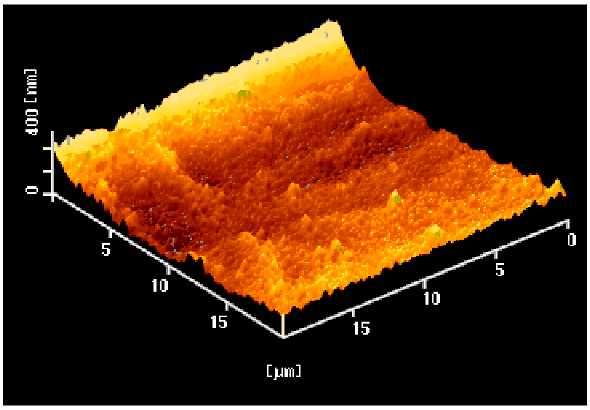


Figure 3. AFM micrograph of Pr_2O_3 films on Ni substrates.

4. Conclusions

We have demonstrated the growth of Pr_2O_3 thin films on textured Ni tapes by the sol-gel dip coating process. XRD results clearly show that phases are formed and that neither intermetallics nor any other phases formed. It is clearly seen from the SEM and AFM micrographs that all microstructures of the films are dense, continuous, crack-free and pinhole-free. It can be concluded that Pr_2O_3 film is suitable for YBCO surface coated conductors.

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