

Ni-Cu-Co biaxially textured substrates for YBCO tape fabrication

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One of the most promising techniques for high J_c $YBa_2Cu_3O_{7-x}$ (YBCO) tape fabrication is the deposition of superconducting thick film on a biaxially oriented metallic substrate. Until now, Ni has been the most used substrate. The ferromagnetic behavior and the low strength after recrystallization represent the main drawback of the Ni substrates. This paper presents the magnetic and structural properties of a new metallic substrate based on $Ni_{50}Cu_{50}$ solid solution. The role of copper is to decrease the Curie temperature of Ni and, as a consequence, to reduce the ac losses in the substrate. The Curie temperature linearly decreases with copper concentration, reaching the zero value for about 65 at % Cu. In order to increase the strength, the $Ni_{50}Cu_{50}$ was alloyed with 3at. %Co. The (100)[001] cube texture was induced in $(Ni_{50}Cu_{50})_{97}Co_3$ solid solution by cold rolling processing followed by a recrystallization thermal treatment at 900 °C for 4 hours in high vacuum (10^{-7} Torr). The as obtained tapes exhibit a sharp, well developed cube texture with the FWHM of ω -scans of 6°, respectively. The scanning electron microscope (SEM) analyses have revealed that the tapes exhibit a good morphology appropriate for the epitaxial deposition of buffer layer and of the YBCO film.

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1. Introduction

The rolling assisted biaxially textured substrates (RABiTS) technique is a very promising route for HTS coated conductor production [1]. Until now, nickel and nickel based alloys have been extensively used as substrate in the RABiTS approach. However, for $YBa_2Cu_3O_{7-x}$ (YBCO) coated conductor on Ni, additional hysteretic loss occurs when it is used in AC applications. Recently many efforts have been made to find alloying elements that will reduce or even suppress the ferromagnetism of nickel, but in the same time preserves the cubic texture.

Several studies have been carried out on non-magnetic Ni-Cu alloys [2-4]. In this work, the non-magnetic $Ni_{50}Cu_{50}$ tapes were alloyed with 3at. % Co in order to increase its strength.

In the RABiTS method, the oxide buffer layers are epitaxially deposited on the biaxially textured substrate in order to suppress the diffusion of Ni into the YBCO film and to prevent the substrate oxidation during the deposition of superconducting film. Nevertheless, the randomly orientation nickel or copper oxides can be formed when buffer layers such as CeO_2 or Yttrium stabilized Zirconia (YSZ) were deposited on Cu-Ni alloy substrate, resulting in the degradation of the superconducting properties of the YBCO film. In order to inhibit the growth of the native oxides two ways are to be considered. The first one is to use a reducing atmosphere during buffer layer deposition and the second one uses an epitaxial noble metal layer as an oxygen diffusion barrier between the substrate and the oxide buffer layers. Among the noble metals, Pd has been shown to grow epitaxially on Ni-alloy substrates in a wide

range of deposition conditions. Despite the large lattice mismatch with Ni (about 10 %) it has been observed a significant texture improvement in the case of the Ni-W substrates [5].

2. Experimental

The solid solutions were prepared from pure Ni, Cu and Co having a purity of about 99.95% in an argon - arc furnace with water cooled copper hearth. The samples were melted several times in order to improve homogeneity. The as-obtained material was heat-treated in high vacuum (10^{-7} Torr) at 850 °C for 12h.

The (001)[100] texture was induced in a conventional way by cold-rolling process to a thickness of 100 μ m corresponding to a thickness reduction of 97.6%, followed by a recrystallization treatment at 900°C for 4 h in high vacuum (10^{-7} Torr) or a two step annealing.

An oxidation resistant biaxially textured Pd layer has been grown by e-beam evaporation. The deposition took place in high vacuum under different temperature in order to investigate the temperature effect on the texture quality of the palladium film. The thickness of the palladium layer was of about 200 nm.

The X-ray θ -2 θ scans was performed using a Rigaku Geigerflex diffractometer with $Cu-K\alpha$ radiation. X-ray diffraction (XRD) measurements for texture analysis were performed on a Seifert XRD 3003 PTS, equipped with a four-circle goniometer suitable for texture measurements.

Morphological and structural characterizations were done using a high-resolution scanning electron microscope (LEO 1525), the microscope was equipped with an

OXFORD INCA Crystal Electron Backscatter Diffraction (EBSD) system, enabling a quantitative characterization of the crystallographic orientations and grain-to-grain misorientations.

The magnetic behavior of the samples was studied by means of a vibrating sample magnetometer (VSM).

3. Results

a) Ni-Cu-Co tapes

As the first step, the microstructure of the ingots was investigated using electron microscopy. As it can be seen in Fig. 1, the microstructure of the ingots contains some Ni-rich second phase particles about 20 microns in diameter. The presence of these particles is undesired because they can hinder the formation of the cube texture after the recrystallization. Some voids are also present.

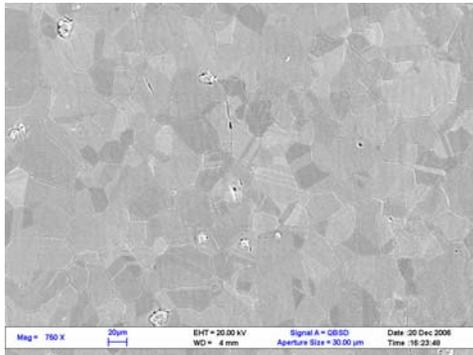


Fig. 1. The microstructure of the Cu-Ni alloy ingot.

As it can be seen from Fig. 2, the texture obtained in the annealed Ni-Cu-Co tapes is a strong cube texture with a small amount of $\{221\}$ $\{122\}$ twinned grains. The full width at half maximum (FWHM) of the rocking curves (RC) for the samples are 6° in the rolling direction (RD) and 9.3° in the transverse direction (TD). The two step anneal is giving better results for Ni-Cu alloys, but in the case of the $(\text{Ni}_{50}\text{Cu}_{50})_{97}\text{Co}_3$ solid solution the “classical” 900°C for 4 hours treatment gives the best results. Even better results in terms of the cube textured fraction are obtained raising the annealing temperature to 1000°C as reported in Fig. 3.

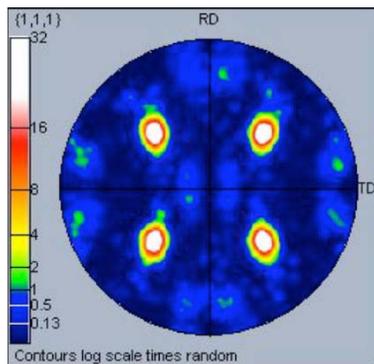


Fig. 2. (111) EBSD pole figures of the $(\text{Ni}_{50}\text{Cu}_{50})_{97}\text{Co}_3$ tapes after 4 hour annealing in high vacuum at 900°C .

The grain boundaries are very evident, suggesting the fact that thermal grooving is stronger than in the case of the Ni-W alloys.

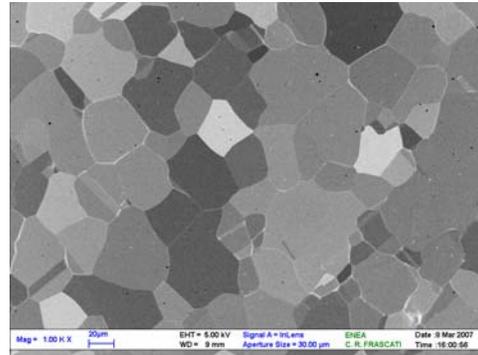


Fig. 3. SEM image of the textured $(\text{Ni}_{50}\text{Cu}_{50})_{97}\text{Co}_3$ tape.

The Curie temperature of the substrate was obtained using magnetization versus temperature measurements. The Curie temperatures T_C were extrapolated at $M=0$ using a $M \sim (T_C - T)^{1/3}$ type curve fit.

It is to be noted that by alloying the $\text{Ni}_{50}\text{Cu}_{50}$ solid solution with 3 at. % Co the Curie temperature increases from 21.5 K to approximately 157 K .

b) The palladium deposition

As it was already shown on both Ni-W and Ni-Cr-W tapes the deposition of a Pd over-layer on the substrate surface before leads to an improvement of the substrate texture and roughness providing a better template for the oxide buffer layers epitaxial growth.

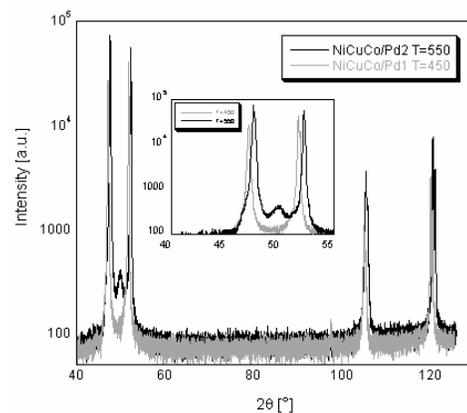


Fig. 4. The θ - 2θ scan for the Pd 1 and Pd 2 layers deposited on the $(\text{Ni}_{50}\text{Cu}_{50})_{97}\text{Co}_3$ substrate.

In this study palladium was epitaxially deposited on the $(\text{Ni}_{50}\text{Cu}_{50})_{97}\text{Co}_3$ tape. The palladium layer was deposited at two temperatures at 450°C (Pd 1 layer) and at 550°C (Pd 2 layer). In Fig. 4, it is shown the θ - 2θ scan for the Pd layers deposited at both temperatures. In the inset, is presented in

logarithmic scale the X-ray spectra between the 50-55° angles. The small peak between the (200) reflections for the Pd and $(\text{Ni}_{50}\text{Cu}_{50})_{97}\text{Co}_3$ is caused by the inter-diffusion of the Pd and Ni during the deposition [5].

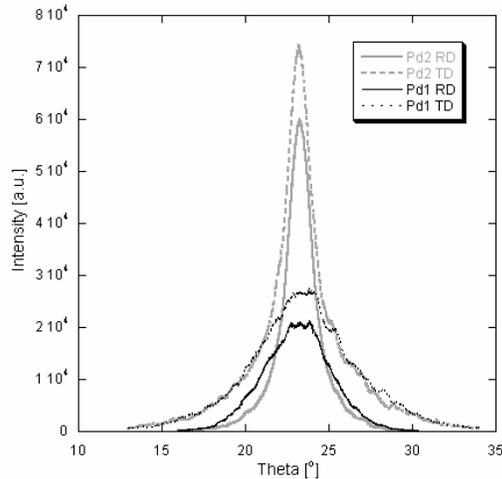


Fig. 5. Presents the rocking curves of the two Pd layers deposited at 450 °C and 550 °C.

The rocking curve of the (200) peak of the film deposited at 450 °C has a FWHM for the TD of 6.1° and 4.6° for the RD. The film deposited at higher temperature is better oriented having FWHM, of 2.1° for the TD and 1.75° for the RD. The values of the FWHM were obtained using a pseudo-Voigt fit of the measured rocking curves. Fig. 5 presents the rocking curves of the two layers.

SEM investigations of the microstructure of the Pd layers show a continuous film.

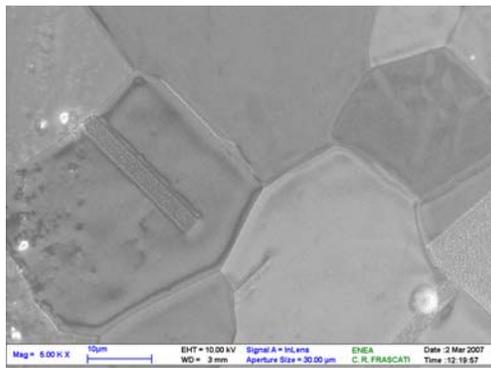


Fig. 6. SEM image of the surface of the Pd layer.

As it can be seen in the Fig. 6, the growth mechanisms differ on the twinned grains.

4. Conclusions

A sharp cube textured $(\text{Ni}_{50}\text{Cu}_{50})_{97}\text{Co}_3$ substrate was obtained through heavy cold rolling followed by recrystallization heat treatment. The FWHM of the rocking curve of the (200) peak is less than 10°. The oxidation resistance was increased by depositing an epitaxial Pd layer. The FWHM of the rocking curve of the best Pd layers is about 2°. The area fraction of the twinned grains is less than 5%. The SEM investigations revealed a smooth surface with some voids and somewhat pronounced grain boundaries of the substrate and a smooth surface of the Pd layer, appropriate for the epitaxial deposition of buffer layer and of the YBCO film.

Acknowledgments

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