고온 초전도체를 위한 Ru/Ni 기판의 제조와 특성 분석

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Fabrication and Characterization of Ru/Ni Substrates for Superconductor Applications

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Abstract - Ru thin films were deposited on bi-axially textured Ni tape using rf-magnetron sputtering for a conductive buffer layer of high Tc superconductor applications. (002) textured Ni films were fabricated as the deposition temperature was over 600℃. Rocking curves of the films showed similar alignment to those the Ni tapes. The resistivity of the tapes fabricated below 600℃ was around 20μΩ-cm which is good for the conductive layer for tape superconductor applications.

1. Introduction

Tape superconductors consist of supeconductor/insulator/metal tape. The roles of the insulators are the lattice matching and diffusion barrier between superconductor and metal. When the superconductors are quenched in accident, resistance occurs in the superconductor, and excess current flows only through the superconductor. In this case, very thin superconductor layer will be easily burned out and whole system will be in danger. In order to solve this possible problem, Ag layer is deposited on the top of the superconductor. There is another suggestion for a possible solution of this problem, in which we may use a conductive oxide layer between superconductor and metal. Two kinds of conductive oxides: $LaNiO_3$[1] and CaRuO3[2] are investigated. LaNiO3 has reaction with superconductor, and an additional diffusion barrier layer is required, so that CaRuO3 is better candidate. However, Deposition of CaRuO3 directly on Ni substrate may form NiO in the interface, so that a buffer layer is required. In this study, Ru metal is chosen for the buffer layer and deposited using sputtering process.

2. Experimental Procedure

Biaxially textured Ni substrates were obtained from randomly oriented high purity (99.9%) Ni sheets, which were firstly mechanically deformed by rolling with dimension 8 mm3 mm500 mm and then were made into Ni tapes as 80 m10 mm12 m. Ni tapes were annealed in vacuum chamber at 800°C, the mixed gases of H2 (10%) and Ar (90%) were flown into the chamber and base pressure was kept around 100 mTorr. The velocity of the Ni tapes was about 1 cm/min.

The film depositions were conducted in a four-target rf magnetron sputtering system, using a Ru target. The target-to-substrate distance, and the base pressure were 9.5 cm, and more than 10 mTorr, respectively. The substrates were mounted on a heater block, centrally located under the target in an on-axis geometry. After pre-sputtering the target for 10 min with a closed shutter, the Ru films were deposited at temperature between 300°C and 700°C, at growth rates of 1.6~2.3 nm/min. The Ar flowing rate was maintained at 50 sccm. DC voltage was kept at 300 V and current around 0.03 A. The surface and cross-section morphology, phase structure, and out-of-plane mosaic distribution were measured by SEM, pole figure. The surface composition analysis was measured by SEM with EDAX analyzer. The crystalline phase analyses were made by X-ray diffractio.

2. Results and Discussion

2.1 XRD and Pole Figure

Fig.1 (a) shows XRD pattern of Ni substrate before deposition, it indicates a strong *c*-axis orientation of the Ni substrate. The strong peak observed at 2θ of 51.86° is indexed to be Ni (200), there are two weak satellite peaks belongs to Ni around 2θ of 46.6° and 49.7°. The textured Ni orientation was characterized by XRD pole figure analysis. Fig.1 (b) shows the (111) pole figure for Ni before deposition. A typical (200) pole figure exhibits *c*-axis orientation of the textured Ni substrate.

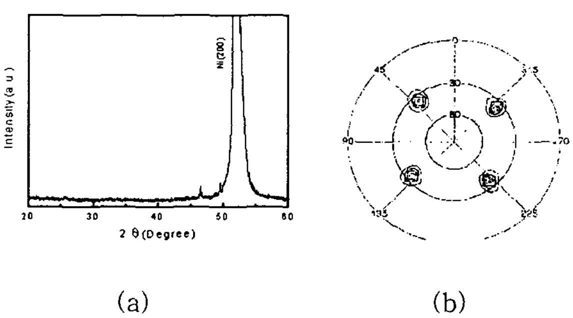


Fig. 1(a) XRD pattern and (b) (111) pole figure of Ni substrate.

Fig. 2 shows the XRD patterns of Ru thin films on Ni (200) substrate at different temperatures. One can find that the (002) peaks of Ru become stronger as increasing temperatures from 300 to 700℃, at the same time, the (101) peaks become weaker. There exists NiO (111) peak above 600℃. It is reasonable to reduce that higher deposition temperature will give rise to alignment and crystallinity of Ru thin films, as well as NiO formation.

Fig. 3 shows the relative intensity ratio of $I_{(002)}/I_{(100)}$ and $I_{(002)}/I_{(101)}$ as a function of deposition temperature. The values of relative intensity will increase as increasing the temperatures from 300 to 700°C. The (200) peak intensity of Ru thin films will increase too as shown from 21.8% (300°C) to 94.4% (700°C) in Fig. 3. From the observations, it may be concluded that an increasing temperature will benefit to the texturing of Ru thin films on textured Ni (200) substrate.

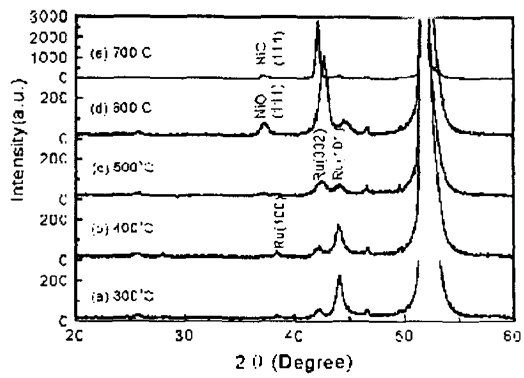


Fig. 2. XRD patterns of Ru/Ni sampes deposited at different temperatures.

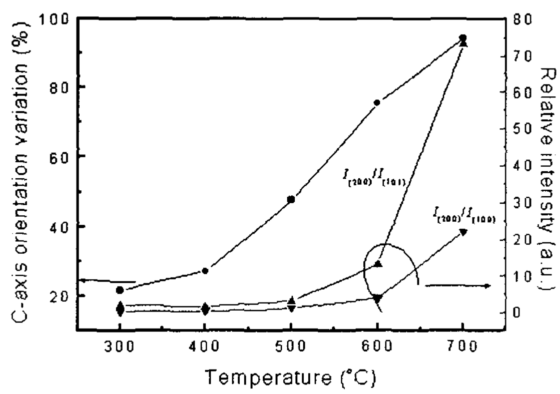
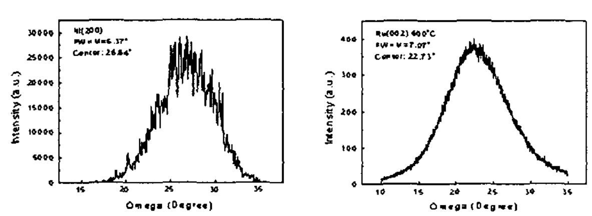


Fig. 3. Relationship between c-axis texturing and deposition temperature.

Out-of-plane textures of the Ru(002) thin films and Ni(200) are shown in Fig. 4. The FWHM -rocking curve scan on the (200) peak reflection of Ni is 6.37°. The FWHM -rocking curve scans on the (002) peak reflections of Ru(002)/Ni(200) thin films at 600, 700, and 72 0℃ are 7.97°, 7.15°, and 8.64°, respectively. These results reveal good c-axis alignment among layers.



(a) (b)

Fig. 4. Rocking curves of (a) Ni and (b) Ru/Ni.

2.2 SEM Microstructure

Fig. 5 shows the SEM images of Ru thin films at different temperatures. One can find there are some larger grains and aggregation as increasing the substrate temperatures. It is obvious that the average grain size is larger for the films deposited under higher temperature. Moreover, there are more pores or voids in the Ru thin films from these surface SEM images. There are some islands structure grains were found in the film deposited at higher temperature.

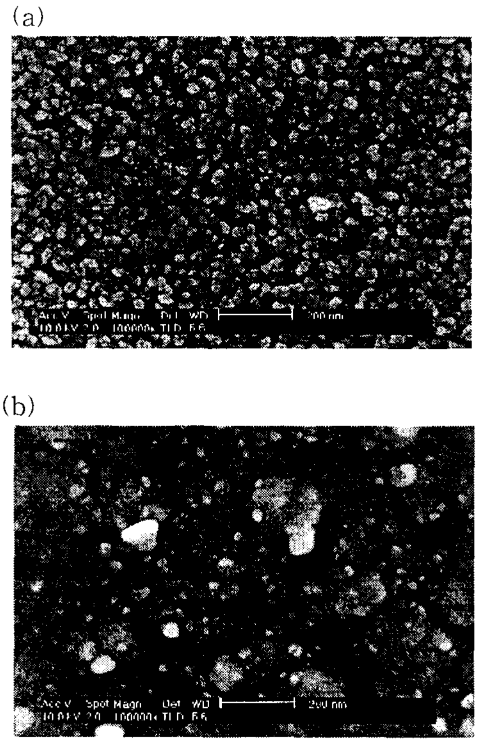


Fig. 5. SEM images of Ru/Ni films deposited at (a) 500 and (b) 600℃.

Fig. 6 shows the cross-section SEM images for Ru thin films deposited at various temperatures. It is obvious that deposited temperature will have a great effect on the microstructure of Ru thin films, we can deduce that there are different growth mechanisms, e.g., columnar or grainy growth, for Ru thin films deposited at different temperatures. Ru thin films deposited at 300°C and 400°C are shown as columnar growth, whereas these films deposited at 500°C and 600°C, or above this temperature, are shown mainly grainy growth. It seems hard to understand that higher temperature will benefited to the perfect alignment along *c*-axis (Ref. Fig. 2 XRD patterns of Ru), while columnar growth was found at lower deposited temperature.

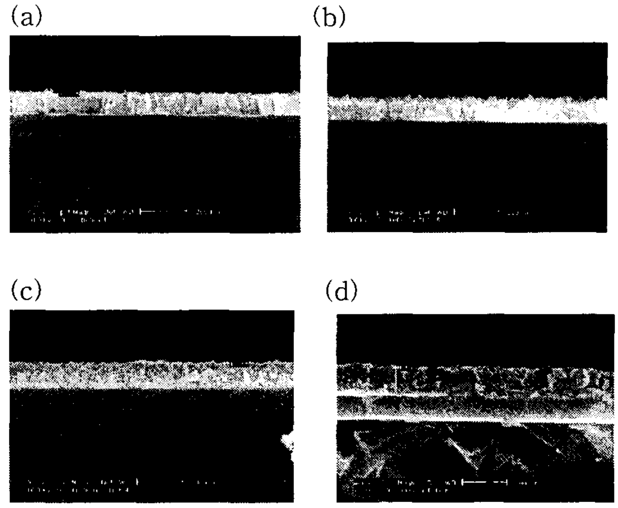


Fig. 6. Cross sectional images of Ru/SiO2/Si at different temperatures: (a) 300, (b) 400, (c) 500 and (d) 600℃.

2.3 Resistivity

Fig. 7 shows resistivities of Ru thin films deposited on different temperatures from 300 to 700°C. Resistivities of Ru thin films calculated without and with thickness of Ni substrate were shown in Fig. 7(a) and (b), respectively. Whereas it is unreasonable to get the too low value in resistivity, it is only 0.03~0.05 μΩcm for Ru thin films deposited from 300 to 600°C and 1.52 μΩcm for Ru thin film deposited at 700°C. There is a little increase in resistivity as increasing the depositing temperature from 300 to 600°C and an abrupt increase from 600 to 700°C as shown in Fig. 7(a). It seems reasonable to calculate the resistivities including the substrate thickness, the reisistivities are around 23~30μΩcm for Ru thin films deposited from 300 to 600°C and

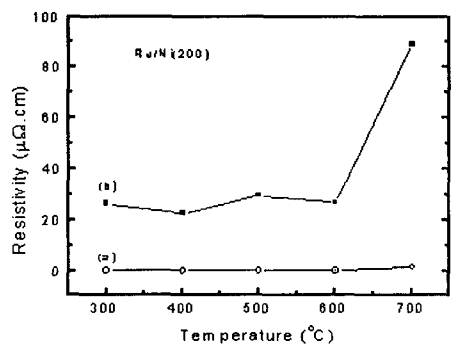


Fig. 7. Plot of resistivity vs. deposition temperature.

89.3μΩcm for Ru thin film deposited at 700°C as shown in Fig. 7(b). We can suggest that higher temperature above 600°C will degrade the conductivity of Ru thin films on Ni substrates.

3. Summary

Biaxially textured Ru/Ni substrates were fabricated on Ni tapes using sputtering. The ruthenium films were aligned to (001) orientation when they were deposited above 600℃. Microstructure shows fairly smooth surface and no columnar grain growth. The resistivity of the sample was around 20μΩcm. Ru film is a candidate of conductive interlayer between conductive multicomponent oxides and Ni substrate.

4. Acknowledgement

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