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Development of Cube Texture in a Silver-Nickel Bi-layer Sheet

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Abstract

An Ag/Ni bi-layer sheet was fabricated by the combination of powder metallurgy, diffusion bonding, cold rolling and texture annealing processes. After heat treating the cold rolled thin Ag/Ni bi-layer sheet at 900℃ for 4h, the excellent cube texture was developed on nickel surface. Qualitative chemical analysis using EPMA showed that inter diffusions of Ni and Ag in Ag/Ni bi-layer composite were negligible. It showed that Ag can be used as a chemical barrier for Ni and vice versa.

Keywords: nickel, silver, cube texture, chemical barrier

I. Introduction

Among the high-T_c oxide superconductors(T_c> 77K), $YBa_2Cu_3O_{7-\delta}$ (YBCO) has the advantage of magnetic field resistance in critical current density(J_c) at 77K, in addition to high T_c and J_c. Therefore, there has been many approaches for fabricating high J_c YBCO film on polycrystalline substrates in order to use it as a current carrying conductor. However, the weak superconducting coupling of high-angle grain boundaries act as a bottle neck in achieving a high J_c YBCO polycrystalline conductor.

In order to overcome the weak coupling, Iijima et al.[1] deposited biaxially aligned YSZ buffer layer films on Ni-based alloy (HASTELLOY C-276) using the ion beam assisted deposition(IBAD). A high J_c YBCO tape conductor with the J_c of 10^6 A/㎠ was obtained by the subsequent deposition of biaxially aligned YBCO films on the biaxially aligned YSZ buffer layer.

Goyal et al.[2] succeeded in fabricating high J_c superconducting tapes by epitaxial deposition of ceramic buffer layers and YBCO thick films on a cube textured Ni substrate. The fabrication technique of cube textured Ni metal is so simple to scale up industrially. However, pure nickel has some disadvantages for practical applications because of its relatively weak mechanical properties and strong ferromagnetism that cause magnetic hysteresis loss in ac applications. Therefore it is needed to improve these properties of nickel without sacrificing sharp cube texture which is most important to obtain a high J_c YBCO film conductor.

The joining of dissimilar material with nickel metal may be one of the ways to modify the properties of the Ni metal substrate, RABiTS(rolling-assisted-biaxially-textured-substrate).The prerequisite in selecting a joining material is that the nickel metal should have a sharp cube texture when it is processed by severe cold rolling and long heat treatment after joining. It has been known that the development of cube texture in a nickel sheet is suppressed by the incorporation of impurity atoms in the metal[3]. Therefore, in order to meet this requirement, the joined material should be chemically inert to nickel while the joined interface should be mechanically strong enough not to be split during severe mechanical deformation and high temperature annealing processes. Good adhesion between joined metals usually indicates the presence of a chemical reaction. Therefore, it is a subtle problem to compromise these two properties.

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The Ag/Ni system has been selected because Ni has a very low solubility in Ag, while Ag has about 1 atomic percent solubility in Ni at relatively high temperature of around 960 ℃[3]

In this work, we report the development of cube texture in a Ag/Ni bi-layer composite that was prepared using the combination of powder metallurgy, diffusion bonding, cold rolling and the texture annealing process.

II. Experimental

Starting materials were high purity silver powder(3N) and nickel powder(4N) with a particle size of 5~10㎛. Ag/Ni coupled compact was prepared by uniaxial pressing followed by a cold isostatic pressed with a 200 MPa for 1 min. The Ag/Ni coupled green compact was heated to 900℃ with a heating rate of 100 ℃/h, held for 4h and then furnace cooled. The sintered Ag/Ni block was cold rolled to a thickness of 105㎛ with stress relief anneal at 600℃ for 30min at a thickness of 1.7 mm. In order to obtain a cube texture, the Ag/Ni bi-layer sheet was heat treated at 900℃ for 4h with a heating rate of 500℃/h. All the heat treatment was done in a vacuum at a pressure of ~ 5.0x 10^{-6} Pa.

The texture was measured by a Schultz reflection method. The α angle (rotation angle around an axis perpendicular to the goniometer axis) of the cube texture was measured between 20° and 90° . The microstructures were observed by an optical microscope(OM) and scanning electron microscope (SEM). The sectional chemical composition change along Ag/Ni interface was measured by electron probe microanalyser(EPMA)

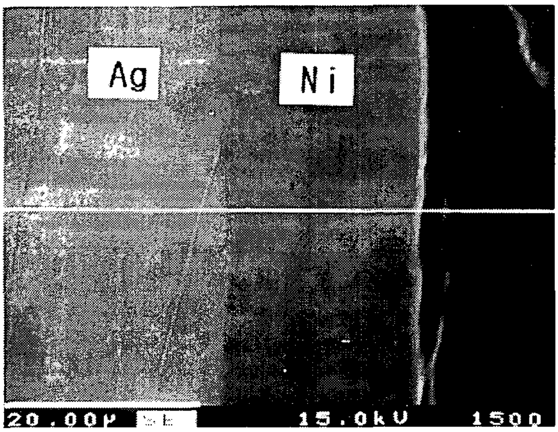

Fig.1 Cross-sectional SEM microstructure of the Ag/Ni bi-layer sheet which was cold rolled with ~94 % reduction and heat treated at 900℃ for 4h.

III. Results and Discussion

Fig.1 shows the cross-sectional SEM microstructure of the Ag/Ni bi-layer sheet which was cold rolled with a reduction amount of ~94 % and heat treated at 900℃ for 4h. The interface between the silver and nickel layers is clearly distinguished, which infers that the inter-diffusion of Ag and Ni atoms across the interface between Ag and Ni might be negligible.

Fig. 2 gives a (111) pole figure of the nickel surface of the Ag/Ni thin bi-layer sheet heat treated at 900℃ for 4h. The development of the cube texture, in which (100) plane is parallel to the sheet plane and <001> direction is aligned to the rolling direction is revealed. The cube texture of face centered cubic (FCC) sheets is known to be very sensitive to the presence of impurity atoms[4]. It was also observed that the development of the cube texture for a SS304(304 stainless steel)/Ni bi-layer sheet was clealy suppressed by the diffusion of Fe and Cr atoms into the nickel layer[5]. Therefore it is expected that the diffusion of silver atoms into nickel layer was not severe enough to suppress the development of cube texture in the Ni layer under this process

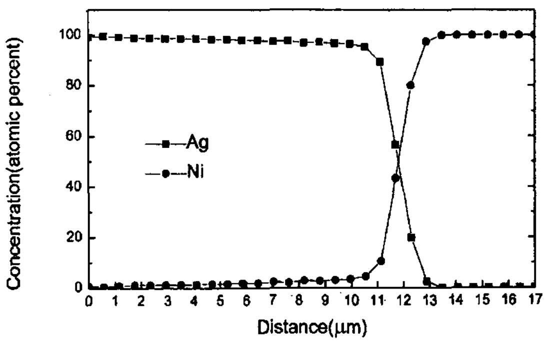

Fig.2 (111) pole figure of the nickel surface for the Ag/Ni thin bilayer sheet heat treated at 900℃ for 4h.

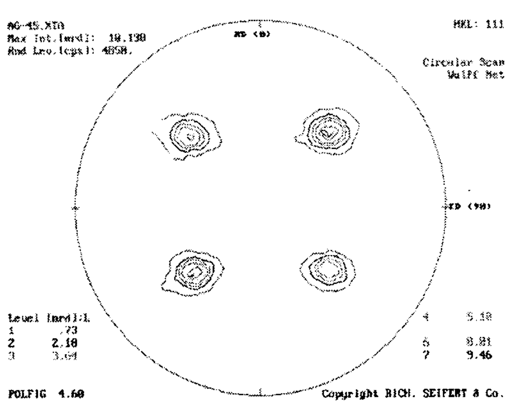

Fig.3 Concentration profiles of Ag and Ni atoms obtained from a line-scan across the Ag/Ni interface for a Ag/Ni bilayer sheet annealed at 900℃ for 4h.

condition.

Fig. 3 shows the concentration profiles of Ag and Ni atoms obtained from a line-scan across the Ag/Ni interface for the Ag/Ni bilayer sheet annealed at 900 ℃ for 4h. The concentration profiles of Ag and Ni atoms show sharp transition across the Ag/Ni interface, which means that the inter-diffusion of Ag and Ni atoms into each facing layer was very sluggish at the annealing condition of the development of cube texture in the severely cold deformed Ni layer. Therefore, it can be said that the presence of the Ag layer was chemically inert for the development of cube texture in the severely cold deformed Ni layer. The above results indicate that the Ag layer can be used as a chemical barrier for Ni and vice versa.

As described earlier, the joining of dissimilar materials leads to the modification of the properties of each of the joined materials. By varying the component and the volume fraction of the joined materials, the properties such as mechanical, electrical, magnetic, thermal etc. of the bilayered structure can be modified.

In general, the physical properties of a bilayer sheet can be expressed by a simple equation using the physical properties of the two components.

Choi et al.[6] reported that the tensile deformation behavior of a clad bilayer sheet followed the rule of mixture.

$$\sigma_u = \sigma_{uA} V_A + \sigma_{uB} V_B \qquad (1)$$

where σ_u and V indicate the uniaxial flow stress and volume fraction, respectively. Subscripts A and B stand for the components A and B of the bi-layer, respectively.

Magnetic hysteresis loss will also follow the rule of mixture because magnetic hysteresis loss is linearly proportional to the volume fraction of material component.

$$W_h = W_{hA} V_A + W_{hB} V_B \qquad (2)$$

where W_h and V indicate the magnetic hysteresis loss and volume fraction, respectively. Subscripts A and B stand for the components A and B of the bi-layer, respectively. However in the case of the electrical and thermal conductivity, we have to consider the anisotropy; the direction parallel or normal to the sheet plane. In the direction parallel to the sheet plane, electrical and thermal resistance of the bi-layer sheet shows series resistance of the components A and B.

In the direction normal to sheet plane, electrical and thermal resistance of the bi-layer sheet shows parallel resistance of the components A and B. Therefore, it can be said that the physical properties of a bi-layer sheet can be modified by the proper combination of different materials.

IV. *Conclusions*

Ag/Ni bi-layer sheet was fabricated by a combination of powder metallurgy, diffusion bonding, cold rolling and texture annealing processes. After heat treating the cold rolled thin Ag/Ni bi-layer sheet at 900℃ for 4h, excellent cube texture was developed on the nickel surface. Qualitative chemical analysis using EPMA showed that inter-diffusions of Ni and Ag in the Ag/Ni bi-layer composite were negligible. It shows that Ag can be used as a chemical barrier for Ni and vice versa. The development of cube texture in the Ag/Ni bi-layer sheet clearly showed a possibility for the enhancement of the physical properties of the cube textured metallic substrate which was used for a base material of RABiTS.

Acknowledgements

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