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Preparation of Cube-textured Nickel-alloy Tape using Metal Powders

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Abstract

Ni-13%Cr and Ni-70%Cu alloy tapes were prepared by using high purity metal powders as starting materials. The Ni-13%Cr and the Ni-70%Cu mixtures were isostatically pressed, sintered, rolled and texture-annealed. SEM EDS analysis showed that copper and nickel atoms were completely mixed, while the alloying between the chromium powders and the nickel powders was incomplete. In spite of incomplete alloying between nickel and chromium powders, sharp cube-texture was developed for the Ni-13%Cr tape as well as the Ni-70%Cu tape.

Keywords : powder, sintering, cold rolling, cube-texture, alloying

I. Introduction

Pure Ni is characterized by demonstrating a sharp cube texture and high resistance to oxidation. Sharp cube texture of Ni has made the Ni used as a metallic substrate for high Jc YBCO tape conductor by depositing ceria, YSZ and YBCO film on the Ni epitaxially[1].

For commercial application of textured nickel metal substrate, it is needed to fabricate the nickel tape in long length. Fabrication of the nickel rod or sheet may include the melting and casting processes at high temperature during which there are a lot of possibilities of the impurity incorporation into nickel metal from crucible and so on. It is known that the impurity contamination of nickel metal may result in the degradation of texture of nickel substrate. Poor texture of nickel substrate due to the presence of impurities might be inherited to the degradation of superconducting properties of the coated conductor with the structure of YBCO/buffer layers/Ni.

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Considering the impurity contamination during the melting and the casting processes, the powder metallurgy is one of the promising process for the fabrication of long-length nickel textured tape. Powder metallurgy is economical process, especially when the metal is produced cheaply as a powder directly during the extraction process, i.e. nickel. It should be also emphasized that the powder rolling method is well established process for the production of nickel strip. Very recently, Lee and Hong[2] successfully fabricated a sharp cube textured nickel strip by compaction, sintering, cold rolling and texture annealing process by using 99.99% fine nickel powder as starting material.

For practical use of high purity nickel substrate, it is desirable to increase the mechanical strength and to decrease the magnetization force. To accomplish these requirements, Ni-70%Cu alloy, Ni-13%Cr alloy and Ni-11%V alloy[3,4,5] have been developed. Those alloys show relatively strong mechanical strength and low magnetization at 77 K. However, work hardening of these alloys makes it difficult to

reduce the thick gauged rod or slab into the thin gauged strip. Therefore multiple intermediate anneal is necessary to relieve the stress. Powder metallurgy has an advantage for control of initial thickness and it is possible to get thin gauged strip directly without intermediate stress relief annealing process.

In this work, we report the preparation of Ni-13%Cr and Ni-70%Cu alloy tapes having a sharp cube-texture by compaction, sintering, cold rolling and texture annealing process by using high purity metal powder as starting material.

II. Experimental

The mixtures of high purity nickel(4N)-copper(3N) and nickel(4N)-chromium(3N) powders were compacted into a rectangular bar with the size of 2 cm x 2 cm x 5 cm and pressed cold iso-statically with a pressure of 170 MPa. Green compact was sintered at 1000 ℃ and 1200 ℃ in a mixture of 4% H_2 and 96% Ar for the Ni-70%Cu and the Ni-13%Cr compact, respectively. Sintered compacts were cold rolled with a reduction amount of 97%. Rolled strip was cut into small piece for the texture anneal. Texture anneal was performed by heating to 1000 ℃ with a rate of 1000 ℃/h, holding for 1h(Ni-70%Cu) and 4h(Ni-13%Cr)and furnace cooling in a mixture of 4% H_2 and 96% Ar.

X-ray diffraction(XRD) was made using CuK_α radiation. In order to investigate the in-plane and the out-of-plane deviation from exact cube orientation, (100)<001>, the rocking curve and the scan were

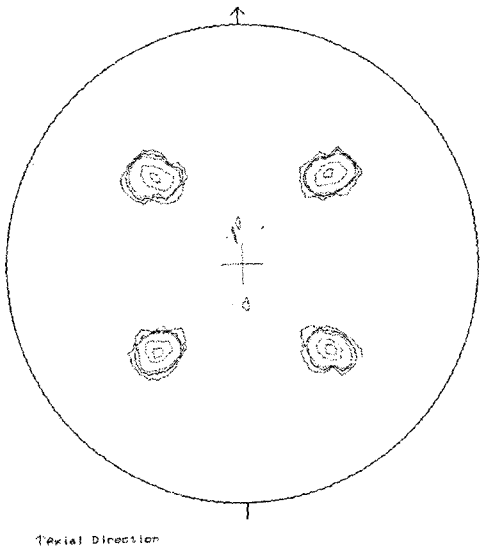
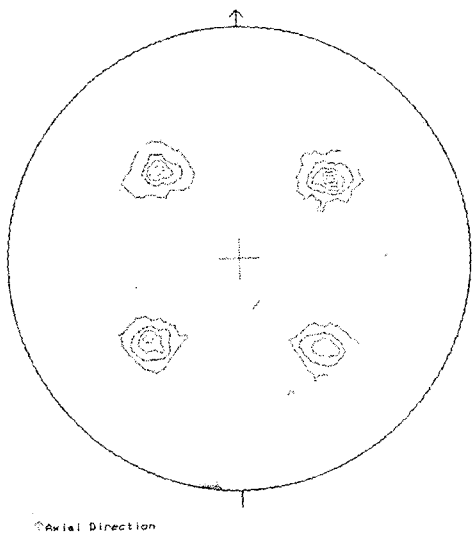
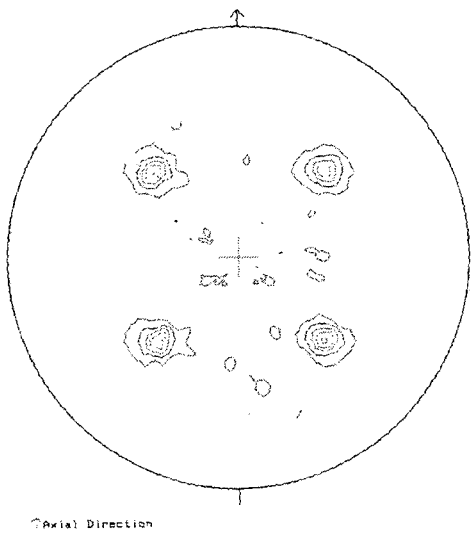


Fig. 1. (111) pole figure of Ni-13%Cr specimen.



(a) 800℃



(b) 1000℃

Fig. 2. (111) pole figure of Ni-70%Cu specimens. Texture anneal was performed at (a) 800 ℃ and (b) 1000 ℃.

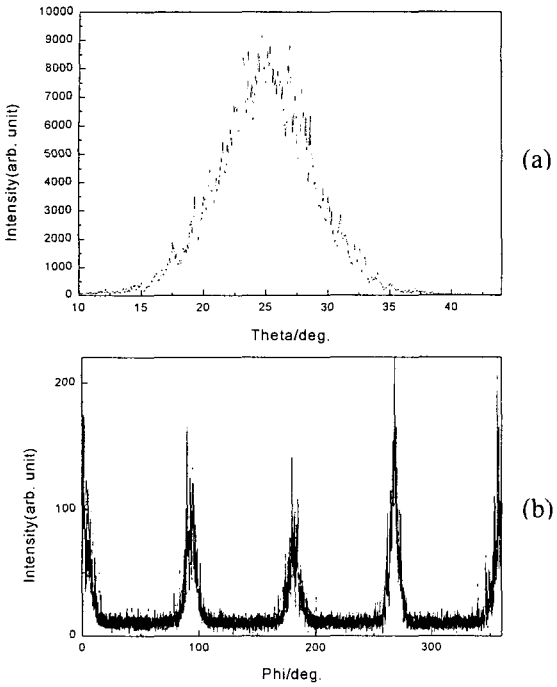


Fig. 3 XRD rocking curve and scan showing the out-of plane and the in-plane texture of the Ni-13%Cr specimer Texture anneal was made at 1000 ℃ in $4H_2$/96Ar atmos phere.

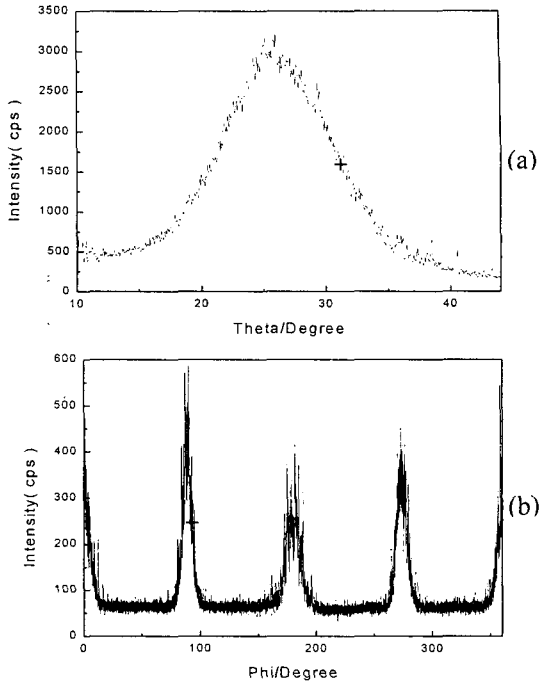


Fig. 4. XRD rocking curve and scan showing the out-of-plane and the in-plane texture of the Ni-70%Cu specimen. Texture anneal was made at 1000 ℃ in $4H_2$/96Ar atmosphere.

obtained using four circle goniometer. The alloying behavior between the mixed powders was investigated by scanning electron microscope(SEM) and wave-length dispersive spectroscopy(WDS) analysis.

III. Results and Discussion

Figure 1 shows the (111) pole figure of the texture annealed Ni-13%Cr specimen. Texture anneal was made at 1000 ℃ for 4h in a mixture of 4% H_2 and 96% Ar. It can be seen that (100)<001> cube orientation was sharply developed.

Figure 2 shows the (111) pole figures of the texture annealed Ni-70%Cu specimens which were heat treated at 800 ℃ and 1000 ℃ for 1h in a mixture of 4% H_2 and 96% Ar. It can be seen that (100)<001> cube orientation was sharply developed. Some minor components are also present for the specimen annealed at 1000 ℃ while these minor components were disappeared for the specimen annealed at 800℃.

Figure 3 shows the rocking curve and the scan of the texture annealed Ni-13%Cr specimen which was heat treated at 1000 ℃ for 4h in a mixture of 4% H_2 and 96% Ar. Full width half maximum(FWHM) of the rocking curve through the (002) peaks and the phi scan through the (202) peaks was measured as 7.6° and 11° , respectively. The FWHM of the out-of-plane and the in-plane texture are relatively higher than those of the pure nickel specimen prepared by the same technique[2].

Figure 4 shows the rocking curve and the scan of the texture annealed Ni-70%Cu specimen. Texture anneal was made at 1000 ℃ for 1h in a mixture of 4% H_2 and 96% Ar. FWHM of the rocking curve through the (002) peaks and the phi scan through the (202) peaks was measured as 10° and 11.4° , respectively. The FWHM of the out-of-plane and the in-plane texture are relatively higher than those of the pure nickel and the Ni-13%Cr specimens prepared by

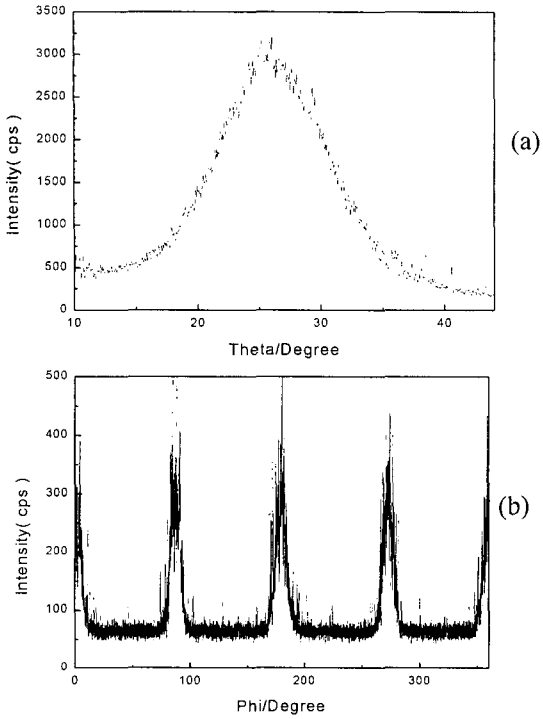


Fig. 5 .XRD rocking curve and scan showing the out-of-plane and the in-plane texture of the Ni-70%Cu specimen. Texture anneal was made at 800 ℃ in $4H_2/96Ar$ atmosphere.

the same technique.

Figure 5 shows the rocking curve and the scan of the texture annealed Ni-70%Cu specimen. Texture anneal was made at 800℃ for 1h in a mixture of 4% H_2 and 96% Ar. FWHM of the rocking curve through the (002) peaks and the phi scan through the (202) peaks was measured as 9.8° and 14° , respectively. The FWHM of the out-of-plane texture was not much changed due to the low annealing temperature, while that of the in-plane texture was increased.

Figure 6 shows the microstructure and the SEM EDS analysis for the sintered Ni-70%Cu specimen. Sintering was performed at 1000 ℃ for 4h in a mixture of 4% H2 and 96% Ar. It is seen that the pores, which is the characteristics of the sintered specimen, are existed. From the Cu mapping of the annealed specimen, it can be said that Cu and Ni powders were successfully alloyed. The complete alloying of the Cu and Ni powders was also con-

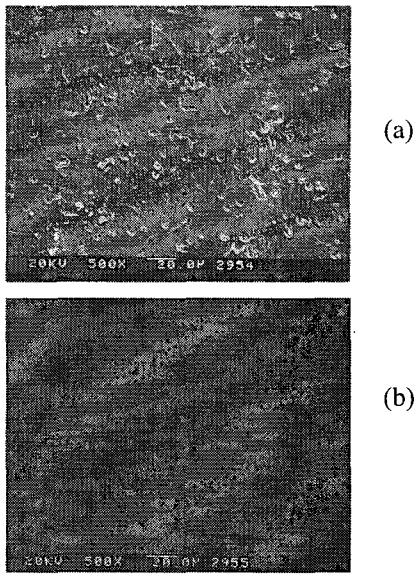


Fig. 6. (a) SEM micrograph of the sintered Ni-70%Cu and (b) Cu mapping by WDS analysis.

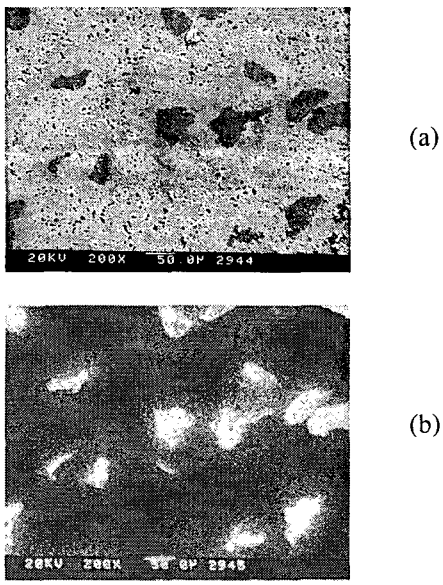


Fig. 7. (a) SEM micrograph of the sintered Ni-13%Cr and (b) Cr mapping by WDS analysis.

firmed by testing the magnetic property of the specimen at 77 K. There was no response when a Sm-Co magnet was approached to the specimen immersed in the liquid nitrogen. The disappearance of the ferromagnetic property of the pure Ni tells that the Cu and Ni powders were completely mixed in atomic scale.

Figure 7 shows the microstructure and the SEM EDS analysis for the sintered Ni-13%Cr specimen. >From the Cr mapping of the annealed specimen, it is seen that the alloying of the Ni and Cr powders was not complete. Incomplete alloying of the Cr and Ni powders was also confirmed by testing the magnetic property of the specimen at 77 K. The Ni-13%Cr specimen was responded to a Sm-Co magnet at the liquid nitrogen temperature. From the SEM EDS analysis, it is considered that incomplete alloying of the Ni-13%Cr mixture is due to the low interdiffusivity between Ni and Cr.

IV. Conclusions

Ni-13%Cr and Ni-70%Cu alloy tapes were prepared by using high purity metal powders. The Ni-13%Cr and the Ni-70%Cu mixtures were isostatically pressed, sintered, rolled and texture-annealed. SEM EDS analysis showed that copper and nickel atoms were completely mixed, while the alloying between the chromium powders and the nickel powders was incomplete. In spite of incomplete alloying between nickel and chromium powders, sharp cube-texture was developed for the Ni-13%Cr tape as well as the Ni-70%Cu tape. Ni-70%Cu alloy tape showed a non-magnetic property at 77 K, while Ni-13%Cr alloy showed a magnetic property at 77 K due to the incomplete alloying at the processing condition.

Acknowledgements

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