금속분말이 첨가된 MgB_2 선재의 제조 및 특성

Fabrication of MgB_2 tape with metal powder addition

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Abstract: The MgB_2 tapes with several metal powder addition were fabricated by PIT method with or without heat treatment. The J_c value of 5,600 A/cm^2 and 16,000 A/cm^2 at 4.2 K and 5 T were obtained for the MgB_2 tape and 10 vol. % of Cu added MgB_2 tape without heat treatment respectively. The J_c value of 8,000 A/cm^2 and 35,000 A/cm^2 at 4.2 K and 5 T were obtained for the MgB_2 tape and 10 vol. % of Al added MgB_2 tape with heat treatment, respectively. The J_c-B curve shows enhancement in J_c under magnetic field, which suggests enhancement in workability and grain connectivity with several metal powder addition.

Key Words: MgB_2 tape, PIT method, J_c-B property.

1. Introduction

Since the discovery of superconductivity at 39 K in MgB_2 compound by Akimitsu *et al.*[1], many research groups in the world have been studied to find out new possibilities of practical application. Experiments in MgB_2 bulk and tape indicate that MgB_2 system shows no weak coupling of grains and that grain alignment is not necessary conditions for obtaining large current transfer across grains[2-3]. Recently, MgB_2 tapes with high transport currents using Ni, Cu and stainless steel sheath were obtained without any heat treatment[4-6]. These are very advantageous for practical application compared to high T_c superconductors.

Considering superconductivity at 39 K, one of possible applications of MgB_2 compound is a crycooler cooled magnet operated at 20 K. In view of practical applications, superconducting parameters such as upper critical field, H_{c2}, critical current density, J_c, and irreversibility field, H_{irr}, are very important factors. The upper critical field, H_{c2} of MgB_2 at 20 K was about 12 T[7], which was higher than that of Nb- Ti wire at 4.2 K [8]. However, J_c under magnetic field at 20 K of MgB_2 is still low, which does not reach to the practical level. Furthermore, H_{irr} at 20 K is also not high enough for magnet application.

In this paper, we report transport property of several metal powder added MgB_2 tape under magnetic field at liquid helium temperature and propose the possibility of enhancement in transport properties under magnetic field.

2. Experimental

Commercially available Alpha Aesar MgB_2 powder with various amounts (1,3,10 vol.%) of metal powders (Cu, Al, In, Pb) was packed into stainless steel tubes. These tubes were drawn and rolled into tapes. The final size of tapes was about 4 mm in width and about 0.6 mm in thickness. Some tapes were heat treated at 200°C for 30 minutes. These tapes were cut into short pieces with a length 4-5 cm, and current leads and voltage taps were directly soldered to the sheath materials of the tapes.

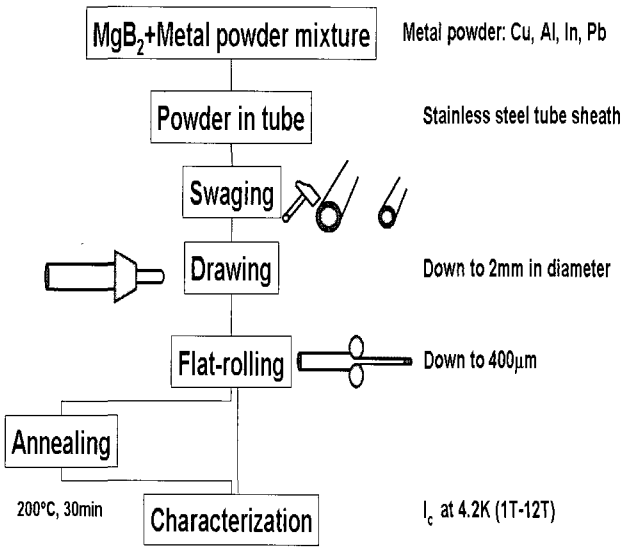

Fig. 1. Experimental procedure.

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A magnetic field was applied parallel to the tape surface. The critical current I_c was measured by a standard four-probe resistive method at 4.2 K in magnetic fields with a 1 μV/cm criterion. The detailed experimental procedures are shown in Fig. 1. The microstructure of the specimens was also studied using an optical microscope.

3. Results and discussion

Fig. 2 shows the typical cross section of the stainless steel sheathed MgB_2 tape. Densified microstructure was obtained without any heat treatment. For stainless steel sheathed tapes with pure MgB_2 powder, no apparent evidence of sausaging was observed, but for Cu added MgB_2 tape, sausaging was important. The MgB_2 with Cu achieved high packing density and work hardening of stainless steel sheath during cold working process, which produced the sausaging.

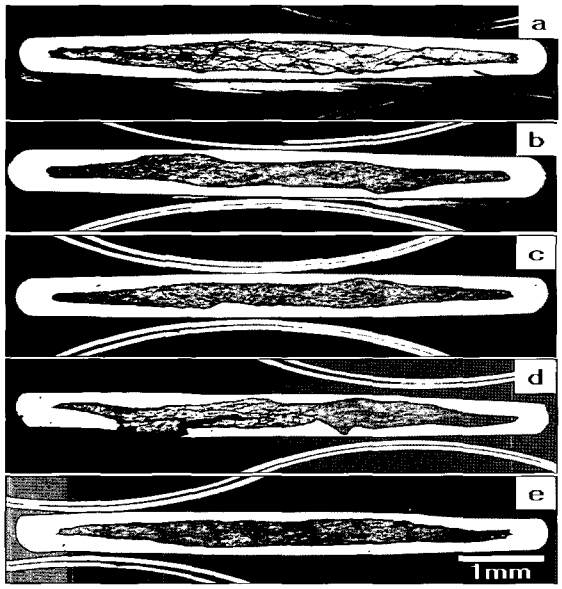

Fig. 2. Optical micrograph of cross section for MgB_2 tape (a) MgB_2, (b) 10%Cu (c) 10% Al, (d) 10% In, (e) 10% Pb.

Fig. 3 shows the X-ray powder diffraction pattern for Cu added MgB_2. Comparing Cu peaks with MgB_2, it is obvious that the peak intensity of Cu is higher than that of MgB_2. Insufficient MgB_2 intensity can be an indication of small crystallite size or high sample absorption.

Fig. 4 shows J_c versus magnetic field curves of several metal powder added MgB_2 tapes before annealing. The J_c values of Cu added MgB_2 tapes were much higher than that of the MgB_2 tape under magnetic field. The J_c value in 5 T of MgB_2 was about 5,600 A/cm^2 and 16,000 A/cm^2 for 10 vol. % of Cu added MgB_2 tape. The J_c value of 8,000 A/cm^2 and 35,000 A/cm^2 at 4.2 K and 5 T were obtained for the MgB_2 tape and 10 vol. % of Al added MgB_2 tape with heat treatment respectively. Enhancement in J_c under magnetic field for several metal powder added MgB_2 tape can be explained by the high packing density of MgB2 with soft metal powder addition associated with the hard sheath material. Thus the improvement in grain connectivity seems to be the probable origin for the enhancement in J_c by Cu addition.

The annealing at 200°C for 30 minutes produces enhancement in $J_c(B)$ as shown in Fig. 5 Compared with the result without annealing (Fig. 4), $J_c(B)$ was improved largely for 10 vol.% of Cu added MgB_2 tape. This result suggest that the annealing process makes grain connectivity better.

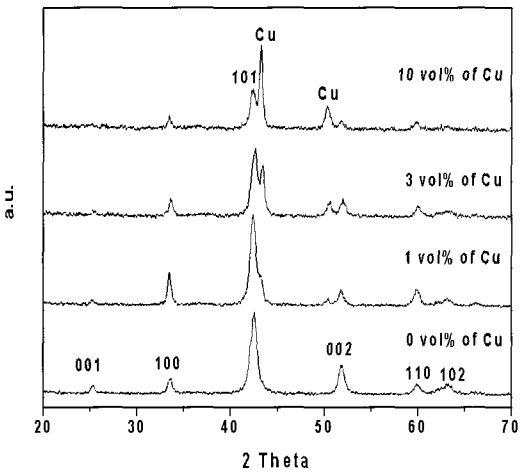

Fig. 3. X-ray powder diffraction patterns for Cu added MgB_2 extracted from as-rolled tape.

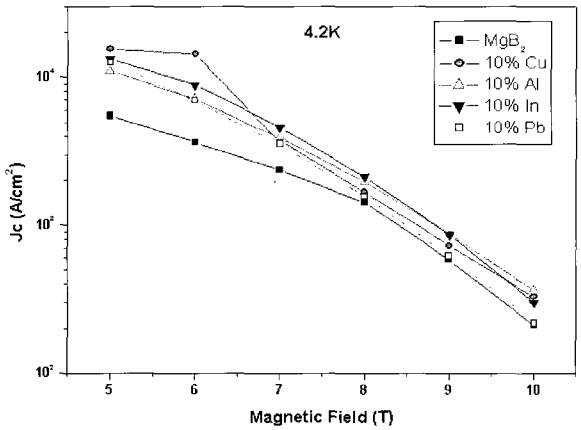

Fig. 4. J_c-B characteristics at 4.2K of MgB_2 tapes with several metal powder before annealing.

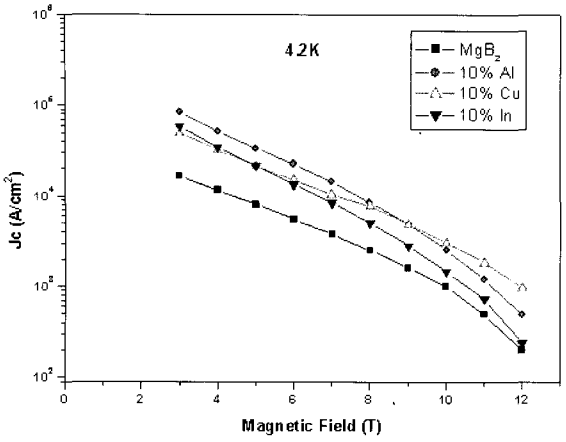

Fig. 5. J_c-B characteristics at 4.2K of MgB_2 tapes with several metal powder after annealing. (200℃, 30mins.)

4. Conclusions

We fabricated MgB_2 tape and several metal powder added MgB_2 tapes by PIT method without and with heat treatment. The J_c value of 5,600 A/cm^2 and 16,000 A/cm^2 at 4.2 K and 5 T were obtained for the MgB_2 tape and 10 vol. % of Cu added MgB_2 tape respectively. The J_c value of 8,000 A/cm^2 and 35,000 A/cm^2 at 4.2 K and 5 T were obtained for the MgB_2 tape and 10 vol. % of Al added MgB_2 tape with heat treatment, respectively. The J_c-B curve shows enhancement in J_c under magnetic field, which suggests enhancement in workability and grain connectivity with several metal powder addition.

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