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Role of silver on phase formation and texture development in Ag/BSCCO composites

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Abstract

Phase formation and texture development of BSCCO grains were investigated in Ag/BSCCO/MgO/Ag composites. Ag/BSCCO/MgO/Ag composites were fabricated using the powder-in-powder method. It was observed that the BSCCO powder was almost fully converted into the 2223 phase at the Ag/BSCCO interface whereas partially at the MgO/BSCCO interface. Strong texture with the *c*-axis of the 2212 and 2223 phases normal to the tape surface was developed at the interfaces of Ag/BSCCO and MgO/BSCCO. It was considered that the formation of the 2223 phase is closely related with the interaction between silver and BSCCO core. The results of this research seem to suggest that silver did not play a significant role in texture development of BSCCO grains.

1. Introduction

Among high-T_c oxide superconductors ($T_c > 77$ K), (Bi,Pb)SrCaCuO superconductor has several advantages such as high T_c, high J_c, moisture resistance, grain alignment by deformation, etc. Oxide materials are hard to fabricate in appropriate form due to their high brittleness. Therefore, there were many intensive investigations to develop a fabrication method for the application of this oxide superconductor.

Since Hikata et al. [1] succeeded in fabricating a high critical current density (J_c) Ag/Bi-2223 superconducting wire, intensive research has been made to increase its J_c value by controlling the processing parameters such as chemical composition, phase content, particle size of the starting powder, density, orientation of 2223 crystallites, size, volume fraction and the distribution of the various impurity phases, fabricating method, heat treatment, etc. Recently, several groups reported some fascinating results using Ag/Bi-2223 composites. Sato et al. [2] fabricated prototypes of coils and current leads using Ag/Bi-2223 composites. More recently, Yamada et al. [3] reported a high $J_c > 60\,000$ A/cm^2 and Li et al. [4] reported a similar $J_c > 70\,000$ A/cm^2 using the same material and the same processing technique. This J_c value is high enough to apply this composite for superconducting coils, current leads, power cable, etc at 77 K. However, there has been little effort to elucidate the effect of each of the above processing parameters on the superconducting behavior.

Silver metal was selected as a sheath material due to the low reactivity with BSCCO superconductor. It has also been known that the addition of silver to Bi-2212 and Bi-2223 core materials improves the strain tolerance of Ag/BSCCO composite [5]. It has been reported that the processing temperature of Ag/BSCCO composite is relatively lower than bulk

BSCCO. Fluekiger et al. [6] reported that the 2223 grains are more highly textured adjacent to the Ag/BSCCO interface than at the center. They suggested that the Ag/BSCCO interface was the main current path because 2223 grains were aligned well. Recently, Singh et al. [7] suggested that the grain alignment of Ag/BSCCO composites was improved due to the interaction between Ag/BSCCO core material. However, the role of silver regarding microstructure development in Ag/BSCCO composites is still unclear.

In this work, Ag/BSCCO/MgO/Ag composites were prepared in order to investigate the effect of Ag on phase formation and texture development of the 2223 grains in Ag/BSCCO composites.

2. Experimental

(Bi,Pb)SrCaCuO (Bi-2223) powder was prepared by mixing high-purity powders of Bi_2O_3, PbO, $SrCO_3$, $CaCO_3$ and CuO with a composition of Bi:Pb:Sr:Ca:Cu = 1.8:0.4:2:2.2:3 and calcining three times at 810°C for 24 h in air. The Ag/BSCCO/MgO/Ag composites were prepared by the powder-in-powder (PIP) method substituting silver powder for a silver tube [8]. The BSCCO pellet was pressed with a load of 1 ton/cm^2 and covered using high-purity MgO powder with a thickness of 2 mm. The BSCCO/MgO pellet was embedded in the silver powder using a rectangular-shaped stainless steel die. The Ag/BSCCO/MgO/Ag green pellet was obtained by pressing the complete powder compact with a load of 1 ton/cm^2.

The Ag/BSCCO/MgO/Ag green pellet was slowly heated to 800°C, held for 24 h and then furnace cooled. Silver powder sintered during the heat treatment and it was possible to fabricate the composite into a 250 mm thick tape by cold rolling. Intermediate annealing at 500°C was conducted to release the internal strain due to the cold deformation. Fig. 1 shows a schematic drawing of the Ag/BSCCO/MgO/Ag composite. After

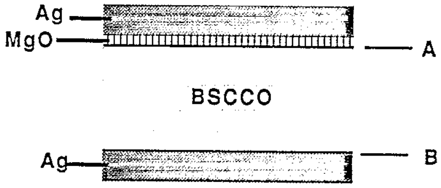

Fig. 1. Schematic drawing of the Ag/BSCCO/MgO/Ag composite.

annealing at 840°C for 50 h in air, the tape was cold-pressed with a load of 10 ton and then final heat treatment was made at 840°C for 100 h in air. The final thickness of the tape was 200 μm.

X-ray diffraction (XRD) measurements were carried out to investigate the structure and texture development of the BSCCO grains. Microstructures were examined using scanning electron microscopy (SEM).

3. Results and discussion

Fig. 2 shows XRD patterns of the BSCCO core at the Ag/BSCCO (B in Fig. 1) and MgO/BSCCO (A in Fig. 1) interfaces. Heat treatment was conducted at 840°C for 150 h with an intermediate pressing with a load of 10 ton after pre-annealing for 50 h. The Ag/MgO interface was weakly bonded whereas the MgO/BSCCO and Ag/BSCCO interfaces were strongly bonded. For XRD, silver metal at the Ag/BSCCO

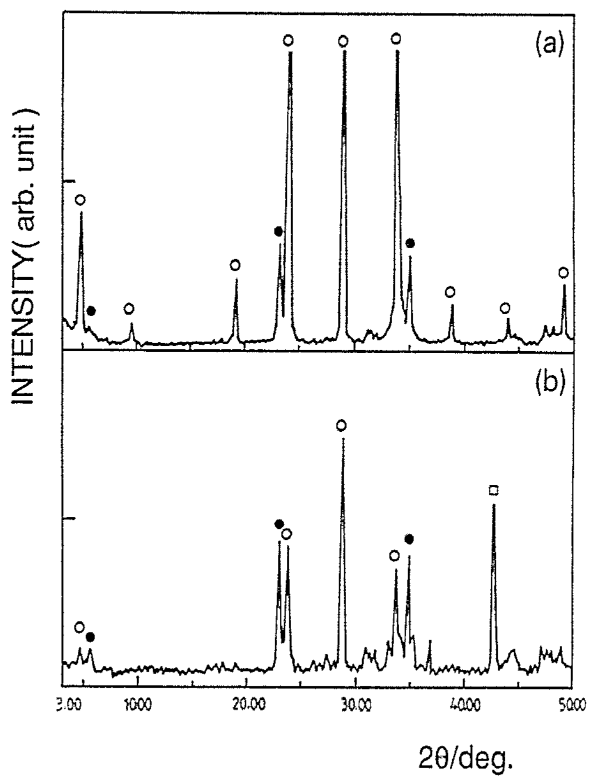

Fig. 2. XRD patterns of the BSCCO core at (a) Ag/BSCCO and (b) MgO/BSCCO interfaces. Open and filled circles denote the (00l) planes of 2223 and 2212 phases respectively and the open square is a diffraction peak for MgO.

interface was removed by using 50% H_2O_2 + 50% NH_3 but MgO was not removed so that XRD peaks from MgO also appeared in Fig. 2b. XRD peaks marked in Fig. 2 were those from the (001) planes of the 2212 and 2223 phases. Therefore, it can be said that the *c*-axes of the 2212 and 2223 phases aligned well normal to the pressing plane. It can also be recognized that the BSCCO core was almost fully converted into the 2223 phase at the Ag/BSCCO interface whereas the 2212 phase was partially transformed at the MgO/BSCCO interface. It has been reported that the formation of the 2223 phase was promoted in the Ag/BSCCO composite compared with the bulk specimen at low processing temperatures. Joo [9] suggested that the formation of low melting phases, resulting from the eutectic reaction between the 2212 phase and silver, enhanced the sintering kinetics at low temperature. From the above results, it appears that the formation of the 2223 phase is closely related with the interaction between the silver sheath and BSCCO core. It can be clearly noticed that the (001) texture was well developed not only at the MgO/BSCCO interface but also at the Ag/BSCCO interface. Therefore it can be said that silver did not strongly influence the development of (001) texture of the 2223 grains.

Fig. 3 shows a surface SEM photograph of the MgO layer at the Ag/MgO interface. It was observed that MgO layer with a thickness ranging from 2 to 2.5 μm covered the whole BSCCO surface. Microcracks also appeared in the MgO layer. The thickness of the BSCCO core and Ag sheath were measured as 100 and 50 μm, respectively, and were very uniform along the rolling direction. Therefore it is considered that the mass flow of the MgO powder was uniform along with BSCCO and silver sheath and that the MgO powder separates completely the BSCCO core from the silver sheath; i.e. there was no reaction between Ag and BSCCO core at the Ag/MgO/BSCCO side.

Fig. 4 reveals SEM photographs of the longitudinal cross section at the interfaces of Ag/BSCCO and MgO/BSCCO. It can be seen that the BSCCO grains at the MgO/BSCCO interface are well aligned along the rolling direction as well as at the Ag/BSCCO interface. The data coincide well with the XRD data in Fig. 2. The grain alignment at the center was also observed but it is rather weak when compared with the Ag/BSCCO and MgO/BSCCO interfaces.

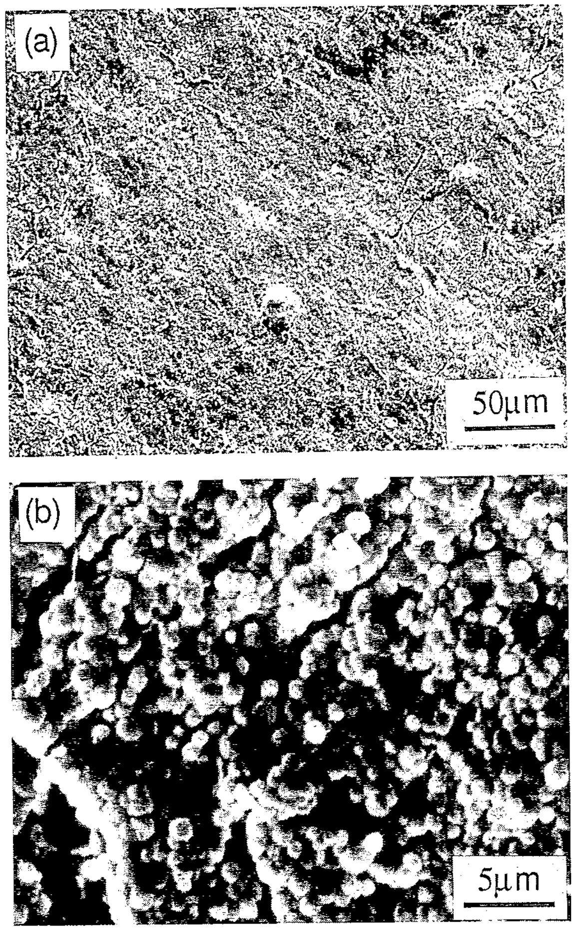

Fig. 3. Surface SEM photographs of the MgO layer in the Ag/BSCCO/MgO/Ag composite.

Singh et al. [7] recently proposed that grain alignment is also closely related to the interaction between the silver sheath (or additives) with the BSCCO grains as well as with the formation of the 2223 phase. But it is clear that the alignment of BSCCO grains has little relationship with the interaction between Ag and the BSCCO core because the alignment of BSCCO grains also occurred at the MgO/BSCCO interface. Therefore it can be said that silver itself does not influence the development of the (001) texture that is crucial for obtaining a high J_c Ag/BSCCO composite. This suggests that texturing of the BSCCO core in the Ag/BSCCO composite should be explained in terms of other reasons (e.g., mechanical or geometrical).

Summarizing, the phase formation and texture development of BSCCO grains were investigated in a Ag/BSCCO/MgO/Ag composite fabricated using the

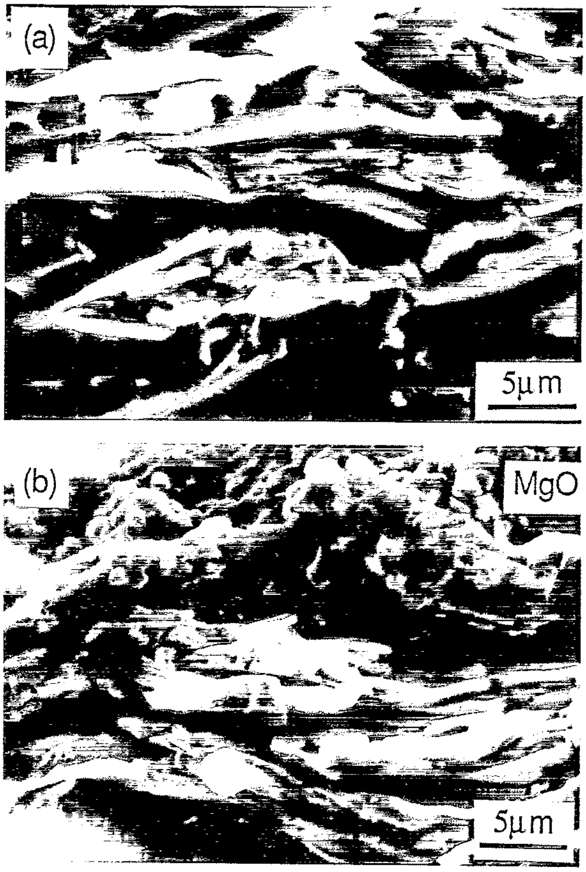

Fig. 4. Cross sectional photograph of the BSCCO core at (a) Ag/BSCCO and (b) MgO/BSCCO interfaces.

PIP method. It was clearly shown that the presence of silver enhanced the formation kinetics of the 2223 phase at low temperature (840°C) due to the interaction between silver and BSCCO core. However, it is considered that the presence of silver does not play a significant role in the texture development of BSCCO grains in Ag/BSCCO composites.

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References

[1] Hikata, K. Kase and H. Hitotsuyanagi, Japan J. Appl. Phys. 28 (1992) L82.
[2] K. Sato, T. Hikata, H. Mukai, M. Ueyama, N. Shibuta, T. Kato, T. Masuda, M. Nagata, K. Iwata and T. Misui, IEEE Trans. Mag. 27 (1991) 1231.
[3] Y. Yamada, M. Satou, S. Murase and T. Kimura, 6th International Symposium on Superconductivity, October 26–29, Hiroshima, Japan (1993).
[4] Q. Li, K. Boderson, H.A. Hjuler and T. Fleltoft, Physica C 217 (1993) 360.
[5] T.A. Miller, J.E. Ostenson, Q. Li, L.A. Schwarzkopf, D.K. Finnemore, R. Righi, R.A. Gleixner and D. Zeigler, Appl. Phys. Letters 58 (1991) 2159.
[6] R. Fluekiger, T. Graf, M. Decroux, C. Groth and Y. Yamada, IEEE Trans. Mag. 27 (1991) 1258.
[7] J.P. Singh, J. Joo, N. Vasanthamohan and R.B. Poeppel, J. Mater. Res. 8 (1994) 2458.
[8] H.G. Lee, Cryogenics, submitted for publication.
[9] J.H. Joo, J.P. Singh, T. Warzynski, A. Grow and R.B. Poeppel, preprint.