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Effect of SnO, MgO and Ag_2O mix-doping on the formation and superconducting properties of Bi-2223 Ag/tapes

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Abstract

The Ag/tapes with the composition $Bi_{1.8}Pb_{0.4}Sr_{1.9}Ca_{2.1}Cu_{3.5}O_y$ + x wt% SnO + y wt% MgO + z wt% Ag_2O (x = 0, 0.2, 0.4; y = 0, 0.2; z = 0, 0.2) were prepared by sintering at 835℃ for 120 h after partial−melting at 845℃ for 1 h. The individual SnO doping, SnO and Ag_2O mix-doping, and SnO and MgO mix-doping all decrease the conversion of Bi-2212 phase to Bi-2223 phase. The tape with individual 0.4 wt% SnO doping shows the lowest conversion and the lowest critical current density. However, the SnO, MgO and Ag_2O mix-doping increase the conversion of Bi-2212 phase to Bi-2223 phase. The tape with 0.2 wt% SnO, 0.2 wt% MgO and 0.2 wt%Ag_2O mix-doping shows the highest proportion of Bi-2223 phase and the highest critical current density.

Keywords: Bi-2223; Superconductors; SnO doping; MgO doping; Ag_2O doping; Critical current density

1. Introduction

Among all the high-temperature superconductors discovered to date, Bi-2223 oxide superconductor is the most promising material for tapes and wires for high-current applications. However, critical current density (J_c) is strongly influenced by the presence of pinning defects and their possible matching with the cores of the vortex lines [1]. The defect structure is essential for flux pinning enhancement, which is in particular, the most important problem for the

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Bi-based superconductors [2,3]. In order to increase flux pinning, the Bi-2212 phase was doped by Al, Pb or rare earth elements to produce point defects [3,4], while in the Bi-2223 phase, Sr was partially substituted by Ba [5] or Sn [6] for the same purpose. In previous work [7,8], we reported the effect of MgO, Ag_2O, PtO_2 particles on the microstructure and pinning properties of Ag sheathed Bi-2223 tapes. The flux pinning was not clearly improved by the individual doping of MgO, Ag_2O or PtO_2 particles, respectively. However, MgO doping did not affect the formation rate of Bi-2223 phase, and could suppress the growth of secondary phases. Ag_2O or PtO_2 additions resulted in coarse secondary phases, and slowed the formation rate of Bi-2223 phase. Recently, we reported effect of MgO and Ag_2O mix-additions on the formation and superconducting properties of the bulk Bi-2223 superconductors. MgO and Ag_2O mix-additions can increase the proportion of Bi-2223 phase and improve the flux pinning [9]. In the present work, we studied effect of SnO, MgO and Ag_2O mix-doping on the formation and superconducting properties of Bi-2223 phase of Ag-sheathed tapes in the partial-melting and sintering process.

2. Experimental

The precursor with a nominal cation ratio Bi:Pb:Sr:Ca:Cu=1.8:0.4:1.9:2.1:3.5 was prepared by high purity (＞99.9%) Bi_2O_3, PbO, $SrCO_3$, $CaCO_3$ and CuO powders. After a calcination at 800℃ for 12 h, the powder was divided into six batches in which one was taken as the pure sample. 99.99% purity SnO, 99.9% MgO and 99.8% Ag_2O powders with an average size of 0.5 μm were added to the other five batches in five different mixture of x wt% SnO + y wt% MgO + z wt% Ag_2O (x = 0, 0.2, 0.4; y = 0, 0.2; z = 0, 0.2). The bulk samples were made by cold pressing a pellet to the size of $2\times3\times15mm^3$ at a pressure of about 233MPa. These samples, which were placed on a silver sheet, were partially melted in air at 850℃ for 1 h, then furnace-cooled to room temperature. In this work, a specific method for the preparation of the Ag-sheathed tapes was used. First, the bulk samples were cut into $1\times1\times15mm^3$ sizes, and then wrapped with three rotations of 0.1 mm thick Ag sheets. The wrapped samples were rolled to tapes with an overall thickness of 0.2 mm and a width of 3 mm. Finally, the resultant tapes were sintered at 835℃ for 120 h after partial−melting at 845℃ for 1 h. The AC susceptibility measurements were performed with a sumitomo susceptometer at a frequency of 313 Hz and a current of 50 mA in the temperature range 15-125 K. The critical current I_c was measured at 77 K in self-field using standard four-probe technique with the criterion of $1\mu Vcm^{-1}$. The critical current density J_c was determined from I_c and a cross-section of the oxide core. The formation of the Bi-2223 phase were analysed by XRD with Cu Kα radiation. In this study, the volume fraction of Bi-2223 phase (Q_{2223}) is defined as

$$Q_{2223} = H(00\underline{10})/(H(00\underline{10}) + L(008)) \tag{1}$$

where $H(00\underline{10})$ is the integral of the $(00\underline{10})$ peak of Bi-2223 phase, respectively, and $L(008)$ is the integral of the (008) peak of Bi-2212 phase.

3. Results and discussion

Fig. 1 shows the temperature dependence of the susceptibility of tapes un-doped, 0.2% SnO doped, 0.4% SnO doped and 0.2% SnO + 0.2% MgO + 0.2% Ag_2O mix-doped. It can be seen that for all tapes, changes in susceptibility occur in two steps, i.e. one change at 108 K due to the diamagnetic of the Bi-2223 phase and another change at 80 K due to the diamagnetic of the Bi-2212 phase, are observed. With an increase of the individual SnO doping amount, the diamagnetic height of the Bi-2223 phase decreases. However, the tape with 0.2% SnO + 0.2 % MgO + 0.2 %Ag_2O mix-doping shows the highest diamagnetic height of the Bi-2223 phase.

Fig. 2 shows XRD patterns of superconducting core of the tapes un-doped (a), 0.2% SnO doped (b), 0.4% SnO doped (c), 0.2% SnO + 0.2% Ag_2O mix-doped (d), 0.2% SnO + 0.2% MgO mix-doped (e), and 0.2% SnO + 0.2% MgO + 0.2% Ag_2O mix-doped (f). In Fig. 2, Bi-2223 phase and Bi-2212 phase are the main constituents of the tapes. And nearly all diffraction peaks are (00l) peaks of Bi-2223 and Bi-2212 phases, which indicates that the texture degrees of grains of the tapes are excellent.

Fig. 3 shows the volume fraction of Bi-2223 phase of the tapes. The individual SnO doping (b and c), SnO and Ag_2O mix-doping (d), and SnO and MgO mix-doping (e) all decrease the conversion of Bi-2212 phase to Bi-2223 phase by comparison with the un-doping (a). The tape with individual 0.4% SnO doping shows the lowest conversion. However, the tape with 0.2% SnO, 0.2% MgO and 0.2%Ag_2O mix-doping shows the highest proportion of Bi-2223 phase.

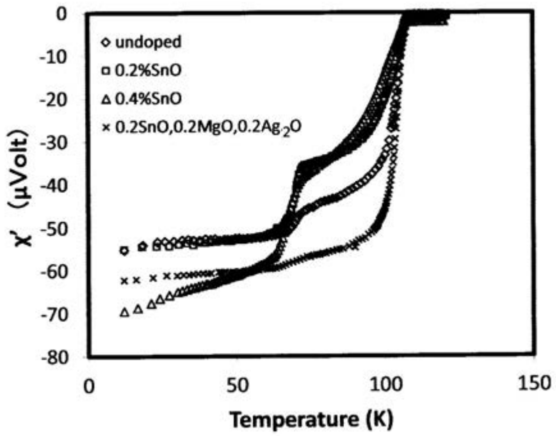

Fig. 1. The temperature dependence of the susceptibility of tapes un-doped, 0.2% SnO doped, 0.4% SnO doped and 0.2% SnO + 0.2% MgO + 0.2% Ag_2O mix-doped.

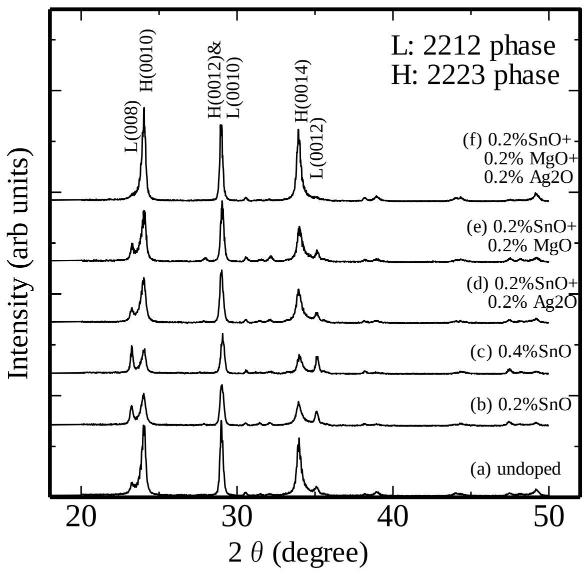

Fig. 2. XRD patterns of superconducting core of the tapes: (a) un-doped, (b) 0.2% SnO, (c) 0.4% SnO, (d) 0.2%SnO + 0.2%Ag_2O, (e) 0.2% SnO + 0.2% MgO, (f) 0.2% SnO + 0.2% MgO + 0.2% Ag_2O.

Fig. 4 shows the J_c of tapes un-doped (a), 0.2% SnO doped (b), 0.4% SnO doped (c), 0.2% SnO + 0.2% Ag_2O mix-doped (d), 0.2% SnO + 0.2% MgO mix-doped (e), and 0.2% SnO + 0.2% MgO + 0.2% Ag_2O mix-doped (f). The tape with individual 0.4 % SnO doping shows the lowest J_c value, and the tape with 0.2% SnO, 0.2% MgO and 0.2%Ag_2O mix-doping shows the highest J_c value. However, the SnO and MgO mix-doped tape (e) shows higher J_c

value than the un-doped tape (a) and the SnO and Ag_2O mix-doped tape (d) although the volume fraction of Bi-2223 phase in SnO and MgO mix-doped tape (e) is lower than that in the un-doped tape (a) and the SnO and Ag_2O mix-doped tape (d) as shown in Fig. 3. It is suggested that the MgO doping in the Bi-2223 superconductors can increase J_c due to improving the flux pinning.

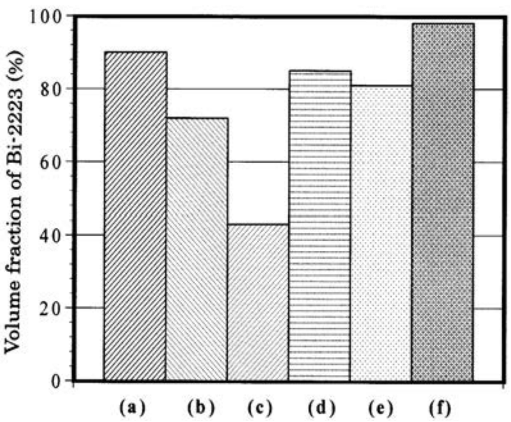

Fig. 3. The volume fraction of Bi-2223 phase of the tapes. (a) un-doped, (b) 0.2%SnO, (c) 0.4% SnO, (d) 0.2%SnO + 0.2%Ag_2O, (e) 0.2% SnO + 0.2% MgO, (f) 0.2% SnO + 0.2% MgO +0.2% Ag_2O.

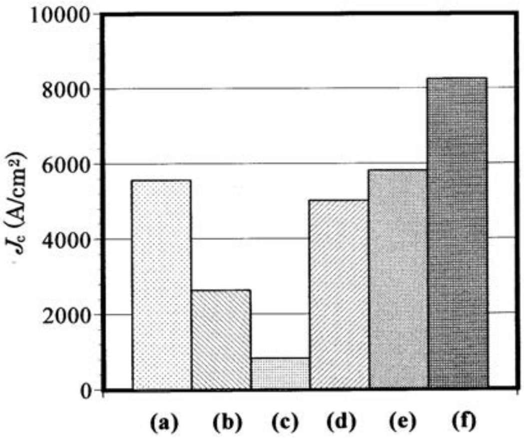

Fig. 4. The J_c of tapes un-doped (a), 0.2% SnO doped (b), 0.4%SnO doped (c), 0.2%SnO+0.2%Ag_2O mix-doped (d), 0.2% SnO + 0.2% MgO mix-doped (e), and 0.2% SnO + 0.2% MgO + 0.2% Ag_2O mix-doped (f).

4. Conclusion

The Ag/tapes with the composition $Bi_{1.8}Pb_{0.4}Sr_{1.9}Ca_{2.1}Cu_{3.5}O_y$ + x wt% SnO + y wt% MgO + z wt% Ag_2O (x = 0, 0.2, 0.4; y = 0, 0.2; z = 0, 0.2) were prepared by sintering at 835℃ for 120 h after partial−melting at 845℃ for 1 h. The individual SnO doping, SnO and Ag_2O mix-doping, and SnO and MgO mix-doping all decrease the conversion of Bi-2212 phase to Bi-2223 phase. The tape with individual 0.4wt% SnO doping shows the lowest conversion and the lowest critical current density. However, the SnO, MgO and Ag_2O mix-doping increase the conversion of Bi-2212 phase to Bi-2223 phase. The tape with 0.2wt% SnO, 0.2wt% MgO and 0.2wt%Ag_2O mix-doping shows the highest proportion of Bi-2223 phase and the highest critical current density. However, the SnO and MgO mix-doped tape shows higher J_c value than the un-doped tape and the SnO and Ag_2O mix-doped tape although the volume fraction of Bi-2223 phase in SnO and MgO mix-doped tape is lower than that in the un-doped tape and the SnO and Ag_2O mix-doped tape. It is suggested that the MgO doping in the Bi-2223 superconductors can increase J_c due to improving the flux pinning.

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