Study on Properties of Ag and PbO Doped $YBa_2Cu_3O_x$

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Abstract

A proposed way to prepare $YBa_2Cu_3O_y$ wires or tapes is that Ag is used as substrate and melting point of $YBa_2Cu_3O_y$ is decreased to lower than the melting point of silver (961℃). Therefore after the deposition of $YBa_2Cu_3O_y$ film on Ag substrate, the heat treatment can be carried out below the Ag melting point. Silver (Ag) and Lead oxide(PbO) were selected to be additives for $YBa_2Cu_3O_y$. Different Ag and PbO contents were added in $YBa_2Cu_3O_y$, the melting points of which were measured by DTA. In order to guarantee that the superconductivity of $YBa_2Cu_3O_y$ was not reduced after Ag and PbO added into $YBa_2Cu_3O_y$, their superconductivities were measured. It is proved that as additives, both Ag and PbO can reduce the melting point of $YBa_2Cu_3O_y$. For Ag doped $YBa_2Cu_3O_y$, T_c is about 93K and ΔT_c is 2~3K. For PbO doped $YBa_2Cu_3O_y$, T_c is 88K~92K and ΔT_c is 11~12K. When 10 wt% of Ag and 10 wt % PbO were added in $YBa_2Cu_3O_y$, the melting point of the mixture of $YBa_2Cu_3O_y$ (80 wt%), Ag (10 wt%) and PbO (10wt%) is 943℃. The transition temperatures (T_c) of the sample is 91.8 K.

Key Words : $YBa_2Cu_3O_x$, additives, melting point, superconductivity

1. Introduction

Because Ag is not oxidized in air and as an impurity it does not reduce the superconductivities of $YBa_2Cu_3O_x$, Ag still is a desirable substrate material for $YBa_2Cu_3O_x$ tape [1-4]. The fabrication of Ag-alloys with high melting points have been tested, the attempt did not succeed because the solubility of alloying elements Ni and Cr in Ag is too small to form an alloy [5], and the noble metals Pt, Pd are not suitable for the mass application due to their high price. Therefore the another way for making $YBa_2Cu_3O_y$ tape is studied, in which pure silver is used as substrate while the melting point of $YBa_2Cu_3O_x$ is reduced by additives. The melting point of $YBa_2Cu_3O_x$ superconductor must be reduced from 1010℃ to lower than the melting point of Ag (961℃).

The first of all is to find the agent (element or compound) which could reduce the melting point of $YBa_2Cu_3O_y$ when the agent was added in. The substances which would damage the superconductivities of $YBa_2Cu_3O_y$ could not be selected as additives although they could reduce the melting point of $YBa_2Cu_3O_y$. Here Ag and PbO were chosen as the additives for reducing the melting point of $YBa_2Cu_3O_y$. Ag as the additive was studied [6,7] in order to eliminated the micro-cracks in textured $YBa_2Cu_3O_y$ superconductors. The idea of chosen PbO was from the synthesis of $(BiPb)_2Sr_2Ca_2Cu_3O_y$ in which Pb substituted for some Bi sites and could benefit to stabilize of 110 K superconductive phase. The Differential Thermal Analysis (DTA) was used for the measurement of the melting points of solid solution of $YBa_2Cu_3O_y$ and Ag (or PbO). The transition temperatures(T_c) were measured by the standard four line method.

2. Experiments

The $YBa_2Cu_3O_y$ powder was prepared by solid state reaction and powder with particle size of less than 40 ㎛ was used in the experiment. The samples of $YBa_2Cu_3O_y$ with different Ag, PbO were prepared, and the contents of additives were shown in table 1.

Table 1. Superconductivities of $YBa_2Cu_3O_y$ doped Ag or PbO.

Samples	Contents of impurities (wt%)	Critical temperature (T_c, K)	Transition width (ΔT_c, K)
$YBa_2Cu_3O_y$		92.0	3
YBaCuO with	Ag 5	93.0	3
	Ag 10	93.5	2
	Ag 15	93.0	2
YBaCuO with	PbO 5	90.3	11.2
	PbO 10	92.6	11.5
	PbO 15	91.0	11.2
	PbO 20	88.2	11.6

Table 2. Superconductivities of $YBa_2Cu_3O_y$ double doped Ag and PbO.

Samples	Impurity contents(wt%)	Critical temperature (T_c, K)	Transition width (ΔT_c, K)
1	5 Ag + 5 PbO	88.0	14.0
2	5 Ag + 10 PbO	90.0	12.6
3	5 Ag + 15 PbO	91.8	11.6
4	5 Ag + 20 PbO	91.8	11.6
5	10 Ag + 5 PbO	91.2	7.5
6	10 Ag + 10 PbO	91.8	5.0
7	10 Ag + 15 PbO	92.0	5.0
8	10 Ag + 20 PbO	91.2	2.0
9	15 Ag + 5 PbO	90.5	12.0
10	15 Ag + 10 PbO	88.0	12.0
11	15 Ag + 15 PbO	89.8	10.0
12	15 Ag + 20 PbO	88.8	12.0

In reference [6], it was known that if Ag content was over 15 wt% when the sample was melted Ag would separated out from $YBa_2Cu_3O_y$, because the saturated solubility of Ag in $YBa_2Cu_3O_y$ was about 15 wt%. Therefore the maximum content of Ag added in $YBa_2Cu_3O_y$ was 15 wt%. The compositions of double doped (Ag + PbO) $YBa_2Cu_3O_y$ are list in table 2.

The mixtures of $YBa_2Cu_3O_y$ and additives were solidified after grinding and pressing at 900℃ in air. One gram of each sample was cut for the measurement of melting point by DTA, and the left samples used for the measurements of transition temperatures (T_c).

3. Results and Discussions

3.1 The melting points of $YBa_2Cu_3O_y$ with additives

The melting points of $YBa_2Cu_3O_y$ samples with different Ag or PbO contents were shown in figure 1.

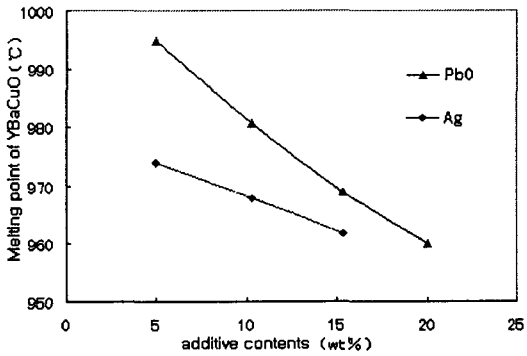

Fig. 1. The melting points of $YBa_2Cu_3O_y$ with different additive contents.

From the figures 1, it is known that both additives, Ag and PbO additives can reduce the melting point of $YBa_2Cu_3O_y$. The melting point of $YBa_2Cu_3O_y$ with 10 wt% Ag can reach 961℃. and that of $YBa_2Cu_3O_y$ with 20 wt% PbO can reach 959℃, both of which are very close to the melting point of Ag. Melting point of $YBa_2Cu_3O_y$ with 10 wt% Ag and 10 wt% PbO (sample 6) was 943℃. It was suggested that the melting points of samples 7 - 12 in table 2 should be

measured, and even considerable results may achieved.

3.2 Critical Temperatures (T_c) of $YBa_2Cu_3O_y$ with different additives Ag and PbO contents

In the experiment, critical temperatures (T_c) were measured by standard 4 line method in liquid nitrogen. The data in table 1 are for the samples of $YBa_2Cu_3O_y$ doped with Ag or PbO respectively. The relations of T_c and ΔT_c of $YBa_2Cu_3O_y$ with different Ag or PbO contents are presented in figure 2 and figure 3.

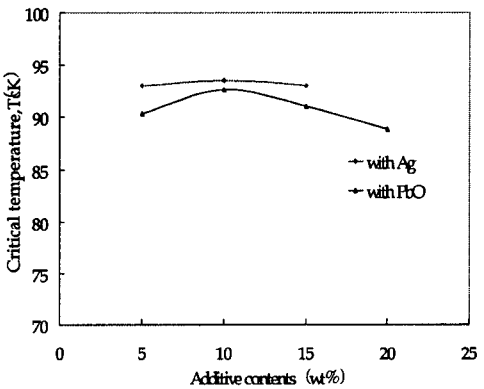

Fig. 2. T_c of $YBa_2Cu_3O_y$ with different Ag and PbO contents respectively.

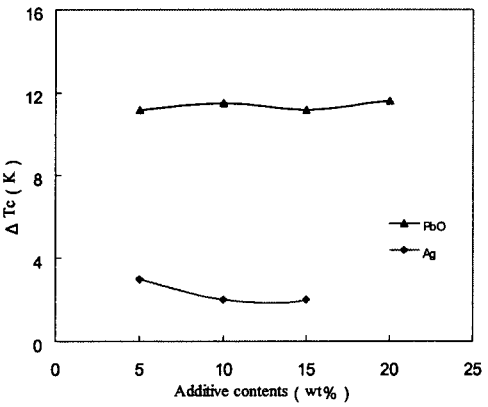

Fig. 3. ΔT_c changes with different Ag and PbO contents.

Comparing with pure $YBa_2Cu_3O_y$ sample the T_c and ΔT_c of Ag doped $YBa_2Cu_3O_y$ samples do not change obviously, which means Ag contents do not influence the superconductivities of $YBa_2Cu_3O_y$ superconductors. For the PbO doped samples when the content of PbO is less than 15 %, T_c does not change too much, while T_c of the sample with 20 % PbO reduced to 88.2K. The ΔT_c values for all PbO doped samples increased to about 11K, which means the superconductivities of PbO doped $YBa_2Cu_3O_y$ are not good as that of Ag doped samples.

3.3 The superconductivity of double doped $YBa_2Cu_3O_y$

The data in table 2 are for the samples of $YBa_2Cu_3O_y$ doped the two additives Ag and PbO at the same time.

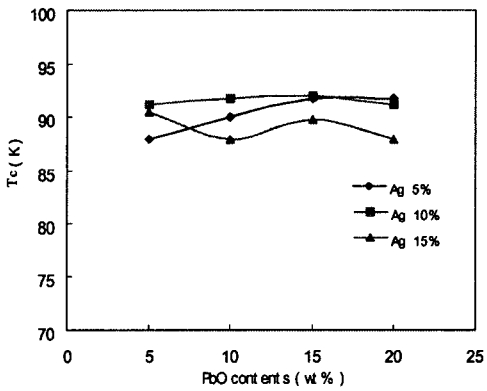

Fig. 4. T_c values of $YBa_2Cu_3O_y$ with double additives Ag and PbO.

For double doping (Ag + PbO) $YBa_2Cu_3O_y$ in table 2, the data of T_c and ΔT_c of 10 wt% Ag group are better than the other two groups, especially the ΔT_c data are obviously less than that of other two groups. In table 2 only the melting point of $YBa_2Cu_3O_y$ sample with 10 wt% Ag and 10 wt% PbO was measured by DTA and its melting point was 943℃. If the samples of $YBa_2Cu_3O_y$ with 10 wt% Ag and doped 15 wt% PbO and 20 wt% PbO were studied by DTA, their melting points would be even lower.

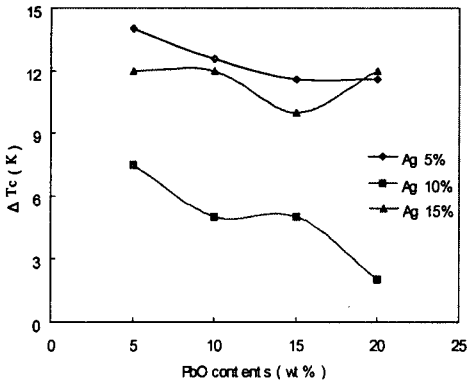

Fig. 5. ΔT_c changes with double additives Ag and PbO.

4. Conclusions

The additives of Ag and PbO are effective for reducing the melting point of $YBa_2Cu_3O_y$ superconductors. The melting point of $YBa_2Cu_3O_y$ sample with 10 wt% Ag and 10 wt% PbO was 943℃, which may suitable for the texture growth in the heat treatment of $YBa_2Cu_3O_y$ below Ag melting point. The measurements proved that Ag additive does not decrease the superconductivity of $YBa_2Cu_3O_y$, while the PbO content in $YBa_2Cu_3O_y$ is less than 15 wt%, the T_c value is about 90K, ΔT_c 11K. Ag and PbO could be the effective additives in $YBa_2Cu_3O_y$ when pure Ag is used as substrate for preparation of $YBa_2Cu_3O_y$ tapes.

Acknowledgements

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