$YBa_2Cu_3O_x$ Superconductor by Adding with Non-superconducting Additives

Soh Deawha*, Cho Yongjoon*, Natalya Korobova**
Myongji Uni.*, Kazak State National Uni.**

Abstract

The improvement of critical temperature (T_c), critical magnetic field (H_c), and critical current density (J_c) of superconductor is important for practical applications. In this study, the additives such as metal oxides were used to improve the preparation conditions of $YBa_2Cu_3O_x$ superconducting bulk samples and depending on additives the properties of $YBa_2Cu_3O_x$ superconductor were studied. The effects of additives to the density, grain alignment, and porosity of samples that affect the critical current density of superconductor also have been investigated.

Key Words : superconductor, additives, metal oxides, density, grain alignment

1. Introduction

After $YBa_2Cu_3O_x$ superconductor with 90 K zero resistance was found [1] many researches have been performed vigorously to improve its superconducting properties and their results have been applied to the fabrication of various film or bulk type superconductors. High T_c oxide superconducting materials can be used in liquid nitrogen. The cheap cryogenic medium makes the materials promise in many fields, especially the tapes (wires) are designable for power transmission, fault current limiter, and for high strong magnets which could be used for magnetic levitation of transportation vehicles, separation of some mines and polluted water, as well as energy storage [2]. As an attempt to improve the preparation conditions of $YBa_2Cu_3O_x$ superconducting powder or bulk samples the preparation methods such as MTG (Melt Texture Growth), LPP (Liquid Phase Processing), QMG (Quench Melt Growth), and MPMG (Melt Powder Melt Growth) etc. have been widely applied and studied [3,4]. As those kinds of methods have many drawbacks during preparing processes the studies to improve processes are being developed currently. For those the researches of an ambient gas, an oxygen pressure control, and a use of additives were performed [5,6].

2. Experiment

$YBa_2Cu_3O_x$ powder was synthesized by conventional solid-state reaction and sol-gel method (Fig. 1), showing a size distribution of 5 ㎛ and 0.2~1 ㎛, respectively and their critical temperatures of 89~93 K. The additives such metal oxides as Ag_2O, PbO, and both Ag_2O and PbO were added to promote grain growth and to decrease porosities and weak links between grain boundaries of $YBa_2Cu_3O_x$ superconductors.
In the first group samples 5 wt%, 10 wt%, 15 wt% of Ag_2O were added in $YBa_2Cu_3O_x$. In the second group samples 5 wt%, 10 wt%, and 15 wt% of PbO were added in $YBa_2Cu_3O_x$.

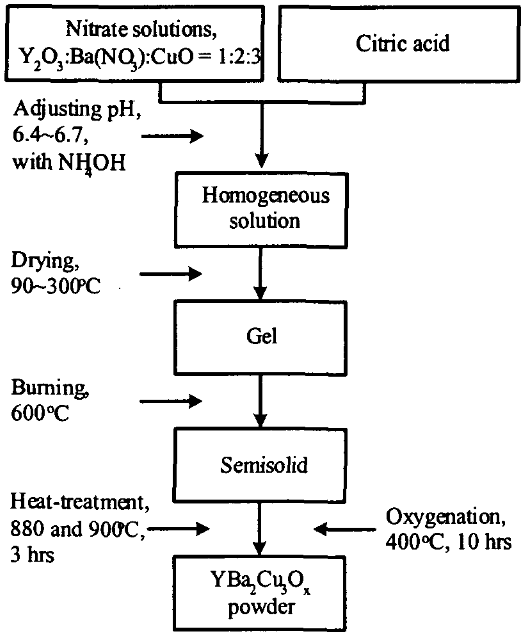


Fig. 1. Procedure of $YBa_2Cu_3O_x$ superconducting powder prepared by sol-gel method.

After packing to pellet with 20 mm diameter and 5 mm height, conventional heat treatment process was use to solidify samples at 920 °C for 8 hours. The properties of samples were investigated by using DTA, SEM, EDS, XRD, four point probe method.

3. Result and discussion

3.1 Melting temperature of samples with additives

The melting point of pure $YBa_2Cu_3O_x$ superconductor was 1015 °C. When additives were added it was shown that the melting points of samples were decreased. The relation of $YBa_2Cu_3O_x$ and additives, Ag_2O and PbO are shown in Fig. 2 and 3. The melting temperature of $YBa_2Cu_3O_x$ was decreased with the increasing Ag_2O, PbO contents. When 15 wt.% Ag_2O, 20 wt.% PbO, both 10 wt.% Ag_2O and 15 wt.% PbO were added the melting temperature of samples were decreased to 961 °C, 959 °C, and 920 °C, respectively.

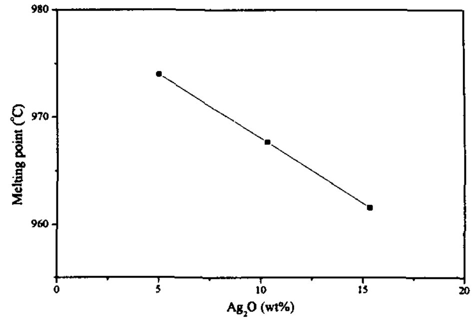


Fig. 2. Melting point of $YBa_2Cu_3O_x$ with different Ag_2O content.

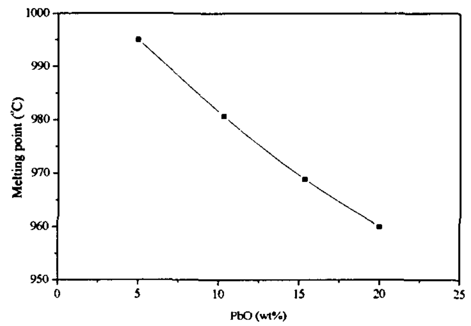
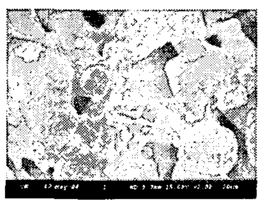


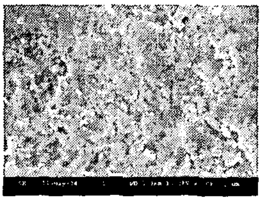
Fig. 3. Melting point of $YBa_2Cu_3O_x$ with different PbO content.

3.2 The Superconductivities of samples

Figure 4 was shown the samples prepared with solid and sol-gel synthesized powder. The surface structure of sample prepared with sol-gel synthesized powder appeared better densification since the connectivity and density of sample sol-gel synthesized powder was improved comparing with the sample prepared with solid state synthesized powder.



(a)



(b)

Fig. 4. Surface SEM photographs of $YBa_2Cu_3O_x$ superconductor prepared with solid state synthesized powder (a) and sol-gel synthesized powder (b).

In the measurement of critical current of pure $YBa_2Cu_3O_x$ superconductor sample, sol-gel synthesized powder showed 36 % higher current density than solid state synthesized powder.

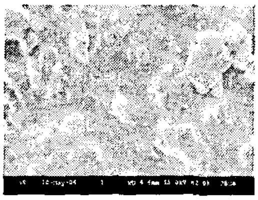
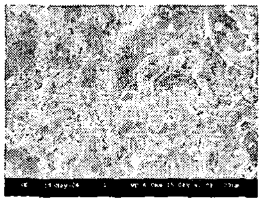


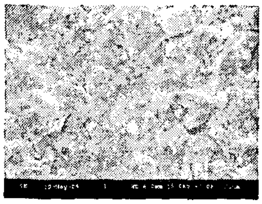
Fig. 5. Surface SEM photographs of $YBa_2Cu_3O_x$ superconductor prepared with sol-gel synthesized powder and 15 wt% Ag_2O.

In $YBa_2Cu_3O_x$ superconductor sample with the additive of Ag_2O, both samples prepared with sol-gel and solid state synthesized powder with 15 wt.% Ag_2O were found to improve the critical current by 6 % and 200 %, respectively. The samples prepared with sol-gel synthesized powder had better critical current property than those prepared with solid-state synthesized powder.

In the samples prepared by sol-gel synthesized powder with PbO addition of 5~20 wt.% (Fig. 6), as an increasing additives the melting temperature of $YBa_2Cu_3O_x$ sample was decreased and packing effect was also increased. But there is a reaction between PbO and $YBa_2Cu_3O_x$ and PbO is not an independent phase in $YBa_2Cu_3O_x$ matrix. The reaction and the result may have effect on the superconductivities of $YBa_2Cu_3O_x$.



(a)



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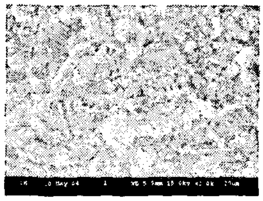

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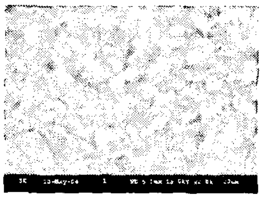

(d)

Fig. 6. Surface SEM photographs of $YBa_2Cu_3O_x$ sample prepared with sol-gel synthesized powder and 5 (a), 10 (b), 15 (c), and 20 wt% (d) PbO.

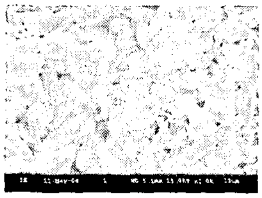

Fig. 7. Surface SEM photographs of $YBa_2Cu_3O_x$ samples prepared with sol-gel synthesized powder added with 10 wt% Ag_2O and 10 wt% PbO.

The sample with 5 wt.% PbO had the highest critical current of 4.15 A and the samples with both 10 wt.% Ag_2O and 10 wt.% PbO (Fig. 7) showed the highest critical current of 4.35 A.

4. Conclusion

Compared to conventional solid-state powder synthesis, the sol-gel synthesis was proved to reduce a powder preparation time and to get highly pure powder, and better superconducting properties. The preparation method of $YBa_2Cu_3O_x$ superconductor by using sol-gel synthesized powder as well as applying additives can increase grain growth and interconnections of grain boundaries so that it could effectively apply to the process of large sized $YBa_2Cu_3O_x$ superconductor.

As the results of the dissertation can be adopted to the preparation of $YBa_2Cu_3O_x$ superconductor, which has better superconducting properties, it is expected that they could be applied to electric and electronic fields such as superconductor fly wheel, permanent magnet, or magnet core etc..

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