High T_c Superconducting Thick Film for Applications

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Abstract

The YBaCuO thick film was deposited by the electrophoresis in the solution with different dimension particles. The morphology of the films deposited from different particles size was compared. The powder made by sol-gel method has the submicron particles, which deposit the most smooth film, and without microcracks after sintering. After sintering of the deposited film, the zone-melting process was carried out in low oxygen partial pressure (100 Pa) and Ag was used as substrate. And the zone-melting was carried out in air and Ag-Pd alloy was used as substrate also. The orientation of the zone-melted YBaCuO was studied by XRD.

Key Words : YBaCuO, thick film, Electrophoresis, Zone-melting

1. Introduction

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 magnets which could be used for magnetic levitation of transportation vehicles, separation of some mines and polluted water, as well as energy storage[1].

BiPbSrCaCuO system is well known developed in making superconducting tape nowadays in the world, but its critical current decreases very fast with the increasing magnetic field, it is the main drawback to be overcome difficultly. Therefore scientists make efforts to find effective flux pinning center in $(BiPb)_2Sr_2Ca_2Cu_3O_y$, meanwhile $YBa_2Cu_3O_x$ superconductor which has good superconductivities under higher magnetic field, are being tried to fabricate wire or tape by many methods[2,3,4,5,6]. In the paper the combination of electrophoresis deposition and zone-melting technique was proposed for preparing the YBaCuO thick film. Because the melting temperature of $YBa_2Cu_3O_x$ (1010℃) is about 50℃ higher than that of silver. Therefore either the substrate for zone-melting has the melting point higher than 1010℃, or the melting point $YBa_2Cu_3O_x$ is reduced to lower than 961℃. An Ag-alloy with small amount of high melting point metal was designed, its melting point could be increased over 1010℃. The other way is to reduce the melting temperature of YBaCuO compound below 961℃, which may realize when zone melting process is in the low oxygen partial pressure.

2. Experiment

The YBaCuO thick film was deposited by the electrophoresis, of which the experimental details was described in the previous paper[7]. 20 mg of iodine and 2 mg of fine YBaCuO powder per 100 mℓ acetone were used in the Pyrex beaker under which a magnetic stirrer stirred 5 minutes before each deposition in order to make homogeneous suspension of the YBaCuO powder in the electrophoresis solution.

A 40~50 ㎛ thickness of YBaCuO film on Ag plate could be deposited in about three minutes. After deposition the film is rolled in order to increase the density and the adhesion of the film to the Ag plate.

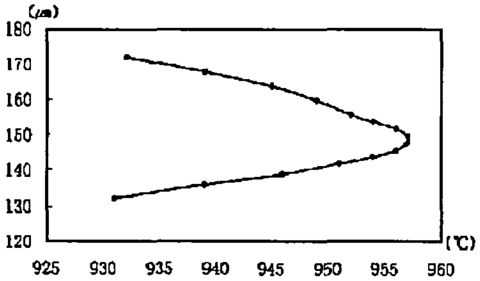

Fig. 1. Temperature distribution of the zone-melting furnace

A special furnace was designed with very narrow high temperature zone, the FeCrAl alloy wire was used as the heating element. The temperature distribution is shown in figure 1. The wideness of high temperature zone in the furnace is 4 ㎜ and the temperature gradient at the interface of liquid and solid is about 20℃/㎝. The large temperature gradient is benefit to the preference oriented growth of YBaCuO. The zone-melting process was carried out in low oxygen partial pressure (100 Pa) and Ag was used as substrate, and in air and Ag-Pd alloy was used as substrate respectively. The sample moved at a rate of 1~2 ㎜/hour in the zone-melting process.

3. Results and Discussions

3.1 Deposition of YBaCuO thick film by electrophoresis

The optimum parameters in electrophoresis process described in reference[7,8] were used in the experiment. In order to improve the quality of the deposited thick film the effect of YBaCuO particle size was compared. The particle sizes of normal sintered YBaCuO by powder metallurgy distribute from 1~40 ㎛, while the thickness of the deposited film is about 40~50 ㎛ only, therefore some cracks occurred in the film. In order to produce flat film surface and to compress the cracks in the experiment the fine YBaCuO powder, diameter less than 1 ㎛, made by Sol-gel method was used in the electrophoresis solution. In the experiment four samples of YBaCuO powder with different size were used in the solution respectively. The first three samples were selected from YBaCuO powder made by sintering and grinding. Their diameters were (1) 61~100 ㎛, (2) 45~61 ㎛ and (3) <45 ㎛ respectively. Sample (4) was made by Sol-gel method and the particles were 0.2~1㎛.

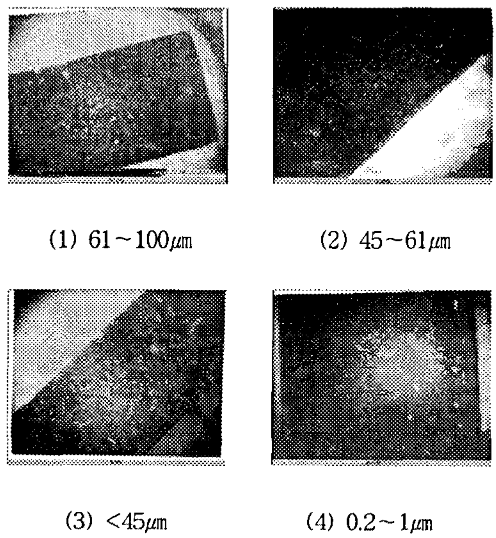

Fig. 2. Microscopy photos of electrophoresis films deposited from different sized powders

The Four samples were used to deposit YBaCuO films on the Ag plate by electrophoresis under the same electrophoresis parameters. The morphology pictures from the microscopy observation are shown in fig. 2. It can be seen that the surface of sample (1) is very rough and the adherence of the film on the Ag substrate is pure, and after sintering cracks appeared in the film. The surface of electrophoresis deposited film becomes smoother with the decreasing of particle diameters. The surface of sample (4) appears the most smooth and glorious.

3.2 Zone melting of YBaCuO thick film on Ag in low oxygen partial pressure

YBaCuO melts and decomposes based on following formula :

$$2YBa_2Cu_3O_{6.5+\delta} = Y_2BaCuO_5(s) + 3BaCuO_2 + 2CuO(\,l\,) + \delta O_2(g)$$

From the thermodynamic principle when oxygen partial pressure reduces the melting and decomposing temperature of YBaCuO will be reduced. Lindemer et al[9] studied the relation of oxygen partial pressure and the melting point for NdBaCuO system. In previous work[10] the zone-melting method in low oxygen partial pressure was used for the preparation of oriented NdBaCuO superconductor. Here the same equipment is used for the preparation of YBaCuO superconductor. 0.1% O_2 and 99.9% Ar were mixed in a plastic bag. First, the quartz tube of which one end was sealed, was evacuated for 5 minuets to make the tube vacuum and then the tube was connected to the plastic bag. The mixture of O_2 and Ar would fill the quartz tube. It was estimated that when oxygen partial pressure was 100 Pa, the melting point of YBaCuO may decrease to 930℃. After the zone-melting there are cracks and microcracks observed by microscopy on the surface of YBaCuO. The X-ray diffraction pattern (XRD) of a typical sample is shown in fig. 3. There are some diffraction peaks from other crystal planes, for example (013), (016) and (112) and Y_2BaCuO_5 (Y211 phase) besides the (001) planes diffraction peaks. The different orientation of grains would decrease the critical current density(J_c). The J_c value of a typical sample is 160 A/㎠ (0T, 77K).

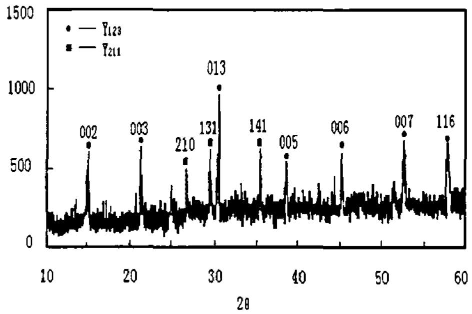

Fig. 3. XRD of YBaCuO made by zone-melting in low oxygen partial pressure

3.3 Zone melting of YBaCuO thick film on Ag-Pd alloy in air

The orientation of YBaCuO should be formed in the process from the partial melted state slowly cooling down to condensed state. The melting temperature of YBaCuO is about 1010℃ in air, therefore Ag (961℃ of melting point) can not be used as substrate. In the experiment fragments of Ag-Pd alloy was used as substrate of YBaCuO. When Pd content is 20 wt%, the melting point of Ag-Pd alloy is 1060℃. In the experiment zone melting temperature was selected to 1040℃, and moving speed of the sample was 2 ㎜/hour. The deposited YBaCuO tape was rolled before sintering, which could make the film dense. The XRD pattern of zone-melted sample is shown in fig. 4, which indicates that the grains in the sample are not oriented. The diffraction peaks are from different planes. Therefore the critical current density is smaller than 100 A/㎠. The reason of the small

J_c may be due to the low temperature (1040℃) for zone-melting in air. In order to make YBaCuO tape in air by zone-melting it is suggested that, the first a cheaper metal alloy with high melting point is needed or, the second, the melting point of YBaCuO is reduced by additives. For the former, the high melting point metals Ni and Cr were selected as alloy elements to add in the Ag powder. The attempt of preparing Ag-Ni and Ag-Cr alloys was not succeeded because of the very small solubility of Ni or Cr in Ag. For the latter, Ag ang PbO powders were selected for the additives into YBaCuO powder. When 10 wt% Ag and 10 wt % PbO were added in YBaCuO, the melting point of YBaCuO was reduced to 943℃. It was proved that the additives in that percentage could not reduce the superconductivity after T_c measurements.

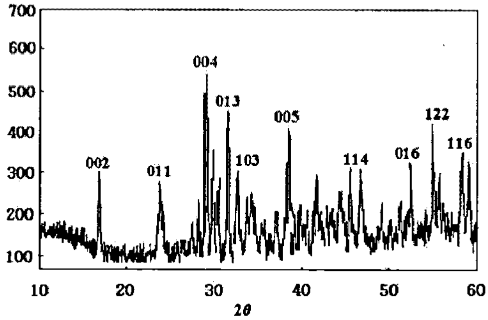

Fig. 4. XRD of zone-melted YBaCuO in air

4. Conclusions

The combination of Electrophoresis deposition and zone-melting was proposed to prepare the YBaCuO thick film. In the first step of the combination the film of about 50 ㎛ thickness was deposited, and the fine YBaCuO powder with <1 ㎛ in diameter made by sol-gel has advantage of smooth surface and less cracks as well as better adherence to the substrate. The zone-melting process was studied in low oxygen partial pressure for YBaCuO deposited on Ag substrate and in air for YBaCuO deposited on Ag-Pd alloy. The selection of substrates for YBaCuO deposition and the technique of zone-melting has to be improved.

Acknowledgements

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References

[1] James D. Doss, Engineer's Guide to High Temperature Superconductivity, John Wiley & Sons, New York, 1989

[2] K. Hasegawa, K. Fujimo, H. Mukai, et al, Appl. Supercond., Vol. 4, p. 487. 1998

[3] M. Fukutomi, S. Aoki, et al, Physica C, Vol. 219, p. 333, 1994

[4] A. Goyal, D.P. Norton, et al, J. Mater. Res. Vol. 12, p. 2924, 1997

[5] K. Onabe, H. Akata,...... in : T. Yamashita, Eds., Adv. Superconductivity VII, Springer, Tokyo, p. 598, 2000

[6] H. Yoshino, M. Yamazaki,...... in : T. Yamashita Eds., Adv. Superconductivity VII, Springer, Tokyo, p. 583, 2000

[7] D. W. Soh, Y. Q. Shan, J. C. Park, et al, Physica C, Vol. 337, p. 44, 2000

[8] F. H. Li, J. Wang, D, W. Soh, Z. G. Fan, J. Chinese Rear Earth, 2002

[9] T. B. Lindemer, E. D. Specht, P. M. Martin, M. L. Flitcroft, Physica C, Vol. 225, p. 65, 1995

[10] Z. G. Fan, W. Y. Gao, D. W. Soh, Preparation of NdBaCuO superconductor by zone-melting under oxygen partial pressure, Physica C, Vol. 386, p. 241, 2003