MICROSTRUCTURE AND J_c OF Y-Ba-Cu-O SUPERCONDUCTOR AFTER P_{O_2}-ALTERNATIVE HEAT TREATMENT①

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ABSTRACT The effect of P_{O_2}-alternative heat treatment on the melting point, the microstructure and the J_c of $YBa_2Cu_3O_{7-\delta}$ superconductor has been investigated. It is found that the melting point of $YBa_2Cu_3O_{7-\delta}$ decreased to 900 ℃ when P_{O_2} decreased to 10 Pa. The texture of the $YBa_2Cu_3O_{7-\delta}$ polycrystal could occur at temperatures lower than 920 ℃ after P_{O_2}-alternative treatment.

Key words: ceramic superconductor $YBa_2Cu_3O_{7-\delta}$ preparation texture

1 INTRODUCTION

It is necessary to produce ceramic superconductor in available shapes, such as wire or tape for their applications. $YBa_2Cu_3O_{7-\delta}$ superconducting wire or tape can be easily fabricated by means of powder-in-tube technology, or drawing and rolling of $YBa_2Cu_3O_{7-\delta}$ powder sheathed with Ag tube[1]. However, critical current density of sintered $YBa_2Cu_3O_{7-\delta}$ tape or wire would deteriorate rapidly in weak magnetic field. Since the melting temperature of Ag is lower than that of $YBa_2Cu_3O_{7-\delta}$ in air, Ag-sheathed $YBa_2Cu_3O_{7-\delta}$ tape or wire can only endure sintering and not endure melt-crystallizing in air. Some available heat treatments should be developed to improve the field dependence of the critical current density of Ag-sheathed $YBa_2Cu_3O_{7-\delta}$ wire or tape. Based on the fact that the stability of $YBa_2Cu_3O_{7-\delta}$ depends on not only temperature but also P_{O_2}[2], the compacted $YBa_2Cu_3O_{7-\delta}$ pellets were heat-treated in a P_{O_2}-alternative atmosphere to search that the $YBa_2Cu_3O_{7-\delta}$ could melt and crystallize at a temperature lower than the melting temperature of Ag.

2 EXPERIMENTAL

2.1 *Melting Examination of the $YBa_2Cu_3O_{7-\delta}$*

$YBa_2Cu_3O_{7-\delta}$ powder was prepared by chemical reaction of solid state. The powder was treated at various temperatures and P_{O_2}. The treated powder was characterized by XRD to examine the decomposition of the $YBa_2Cu_3O_{7-\delta}$. Whether $YBa_2Cu_3O_{7-\delta}$ melts or not in the treatments was determined according to the adhensive strength between the particles in the treated powder. Furthmore, the rolled thick film of $YBa_2Cu_3O_{7-\delta}$ powder with Ag substrate was examined before and after melting treatment. In the present experiments, P_{O_2} was adjusted by the pressure of flowing air through the tube furnace.

2.2 *P_{O_2}-alternative Treatment of $YBa_2Cu_3O_{7-\delta}$ Pellet*

$YBa_2Cu_3O_{7-\delta}$ powder was compacted into

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pellets of d 10 mm × 0.1 mm at 2.5 GPa. The pellets were treated for 0.1 ~ 1 h at 850 ~ 920 ℃ and 1 ~ 100 Pa P_{O_2}, then held for 2 h at 850 ~ 920 ℃ and 0.1 MPa P_{O_2}. After cooled in furnace, the critical current densities of the treated pellets were measured in magnetic field by four-probe DC method with the criterion of 1 μV/cm, and their microstructures were characterized by SEM.

3 RESULTS AND DISCUSSION

Fig. 1 shows the results of the melting (decomposing) of $YBa_2Cu_3O_{7-\delta}$. It can be seen that $YBa_2Cu_3O_{7-\delta}$ would melt at a temperature lower than 920 ℃ under 20 Pa oxygen pressure. The surface of the $YBa_2Cu_3O_{7-\delta}$ thick film treated under the above condition exhibits molten status, as shown in Fig. 2. This result is inconsistent with Lay *et al*[3] who reported that $YBa_2Cu_3O_{7-\delta}$ would start to decompose at higher temperature under the same P_{O_2} in DTA study. $YBa_2Cu_3O_{7-\delta}$ is rather stable, as shown in Fig. 3. In Lay's DTA, the rate of temperature rising was 10 ℃/min and there was no duration at the measured temperature. It suggests that the difference in the decomposing or melting point of $YBa_2Cu_3O_{7-\delta}$ between the present study and the Lay's rises from the hysteresis of decomposing of $YBa_2Cu_3O_{7-\delta}$ measured in DTA.

It is obvious from Fig. 1 that the effect of P_{O_2} is similar to that of temperature for $YBa_2Cu_3O_{7-\delta}$. The microstructure evoluation of $YBa_2Cu_3O_{7-\delta}$ pellets in P_{O_2}-alternative treatment was shown in Fig. 4. After P_{O_2}-low treatment, $YBa_2Cu_3O_{7-\delta}$ pellet exhibits a

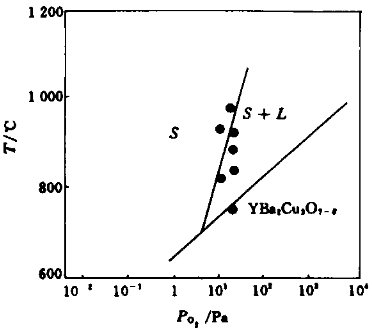

Fig. 1 The dependence of the melting (decomposing) point of $YBa_2Cu_3O_{7-\delta}$ on P_{O_2}, solid circles represent the exprimental conditions of P_{O_2}-temperature, L and S represent solid phase and liquid phase respectively

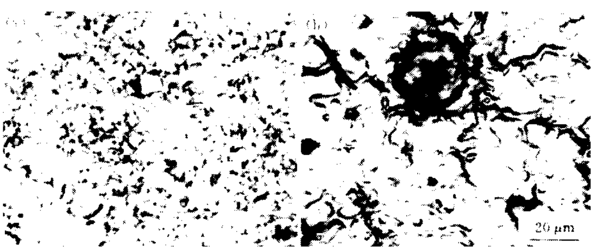

Fig. 2 The surface microstructures of the rolled thick films of $YBa_2Cu_3O_{7-\delta}$ powder with Ag substrate

The films treated at 900 ℃ for 0.5 h at (a)—0.1 MPa P_{O_2}; (b)—20 Pa P_{O_2}

dense and homogeneous microstructure, yet $YBa_2Cu_3O_{7-\delta}$ pellet treated at alternative P_{O_2} exhibits a locally-textured microstructure which is similar to that of melt-texture growth reported by Jin[4]. The mechanism of the microstructural evolution can be suggested as follows. In the P_{O_2}-alternative treatment, $YBa_2Cu_3O_{7-\delta}$ would melt in P_{O_2}-low treatment, then $YBa_2Cu_3O_{7-\delta}$ grains preferentially grow in the liquid state under P_{O_2}-high treatment. In other words, the mechanism is similar to the melt-texture growth reported by Salama *et al*[5].

The improved microstructure of the $YBa_2Cu_3O_{7-\delta}$ pellet treated in P_{O_2}-aternative atmosphere is responsible for the reduced field dependence of the J_c, as shown in Fig. 5. The J_c value of the sintered $YBa_2Cu_3O_{7-\delta}$ deteriorates exponentially in weak magnetic fields. On the contrary, J_c of the $YBa_2Cu_3O_{7-\delta}$ Pellet treated at alternative P_{O_2} is hardly affected by weak magnetic fields.

The microstructural evolution mentioned above and the J_c improvement of $YBa_2Cu_3O_{7-\delta}$

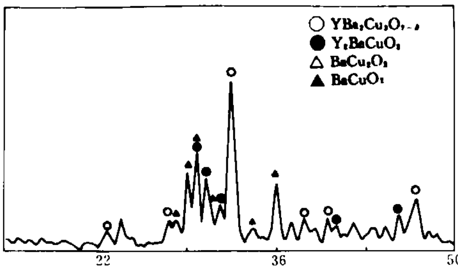

Fig. 3 The X-ray diffraction pattern of $YBa_2Cu_3O_{7-\delta}$ powder compact treated at 910 ℃ for 1 h at 20 Pa P_{O_2}

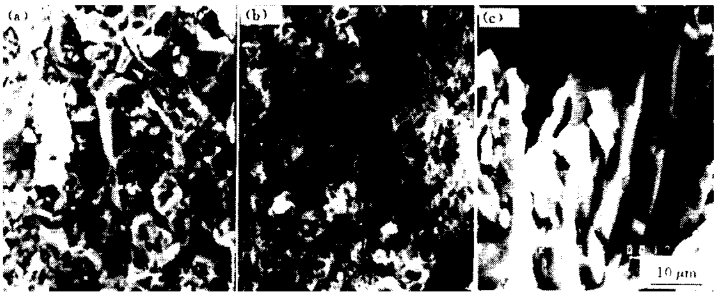

Fig. 4 The microstructure of $YBa_2Cu_3O_{7-\delta}$ pellets (×1 560)
(a)—untreated; (b)—treated at 900 ℃ and 20 Pa P_{O_2};
(c)—treated at 20 Pa P_{O_2} and retreated at 0.1 MPa P_{O_2}, at 900 ℃

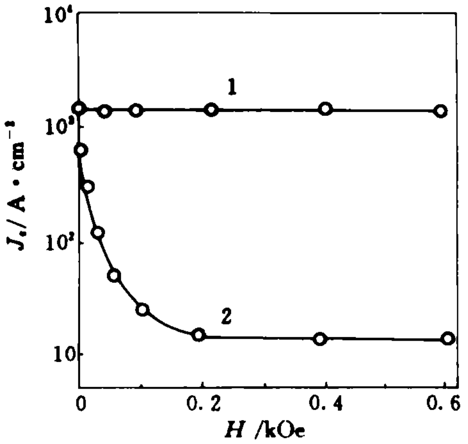

Fig. 5 The dependence of the J_c (77 K) of Y-Ba-Cu-O superconductor on magnetic field

(1)— P_{O_2} -alternatively treated; (2)—sintered

polycrystalline after P_{O_2} -alternative treatment show that the oxyen pressure can be controlled to decrease the temperature of melt-texture growth and improve the properties of $YBa_2Cu_3O_{7-\delta}$ superconductor.

4 CONCLUSION

The melting temperature of $YBa_2Cu_3O_{7-\delta}$ can be decreased by controlling P_{O_2} in the atmosphere. The P_{O_2} -alternative treatment would result in melt- growth of $YBa_2Cu_3O_{7-\delta}$ at a temperature lower than 920 ℃, and improve the field dependence of J_c.

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with experimental observation. However, the calculation shows certain difference with experimental data on the σ phase fraction at 800 ℃.

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