PROCESS CHARACTERISTICS OF $HoBa_2Cu_3O_{7-\delta}$ AND EFFECT OF MAGNETIC FIELD ON SUPERCONDUCTIVITY OF $REBa_2Cu_3O_{7-\delta}$(RE=Y, Ho)①

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ABSTRACT The relationship between preparing technological process and superconducting characteristic of the oxide superconductor was studied. Ho^{3+} was used instead of Y^{3+} in the oxide superconductor to raise the superconducting characteristic. Through the magnetic field treatment, some useful results were obtained.

Key words: superconductor $REBa_2Cu_3O_{7-\delta}$ magnetic field pressing magnetic field sintering

1 INTRODUCTION

In April, 1986, Bednorz and Müller found that the oxide $Ba_xLa_{5-x}Cu_5O_{3(5-x)}$ exhibits superconductivity at 35K. This surprising breakthrough has set off a new upsurge of superconductivity emulation. New results and new records are found every year. As one of the main parameters, cirtical electric current density (J_c) is the key which makes superconductor go into the industrial use. There are many ways to raise J_c, but most are very complicated, such as raising the sample's density, purity and content of oxygen.

In order to improve the crystalline grain's range, the paper chose Ho^{3+} (Ho_2O_3) with stronger paramagnetism and similar ion radius to Y^{3+} to replace Y^{3+} in the $YBa_2Cu_3O_{7-\delta}$ oxide superconductor system. Through the magnetic field pressing(MFP) and magnetic field sintering (MFS), superconductor of the $HoBa_2Cu_3O_{7-\delta}$ was obtained.

2 EXPERIMENTAL

The samples were prepared by solid phase reaction of analytically pure BaO, CuO and Ho_2O_3 of 99.99% purity. The electric resistance was measured by the standard four-point method and alternative magnetic susceptibility by mutual inductance bridge method. The critical electric current density was obtained by directly measuring the relationship between electric current and voltage by direct current four-point method.

The density of the samples was determined by the method described in Ref. [1]. The phase structure and the grain morphology were determined using X-ray diffraction and scanning electronic microscope(SEM).

3 RESULTS AND DISCUSSION

3.1 *Effect of Repeated Sintering on Superconducting Characteristics*

The sintering technological process is 940 ℃, 8h. After the sintering, the samples were mixed homogeneously in ceramic grinder, and were pressed under a pressure of 50~60MPa, then sintered once more.

From Table 1, it can be found that the repeated sintering is useful for obtaining high J_c superconductor. From the scanning electronic microscope observation(Fig. 1 and Fig.

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Table 1 Effect of repeated sintering
T_c (A/cm^2), J_c (K)

Sintering conditions	First sintering		Second Sintering		Third Sintering		Forth Sintering	
	J_c	T_c	J_c	T_c	J_c	T_c	J_c	T_c
920 ℃, 6 h	800	82.0	950	83.0	1 200	82.0	600	83.0
800 ℃, 6 h	—	—	1 000	82.5	1 000	84.0	—	—
700 ℃, 6 h	—	—	1 250	82.0	1 150	83.0	—	—

2), it is clear that the repeated sintering can make the sample's grains crystallize more perfectly and raise the sample's density.

3.2 *Effect of Sintering Temperature on T_c and J_c*

After the low temperature sintering (800 ℃, 6 h), the powder was pressed under a pressure of 50~60 MPa, and the disc samples

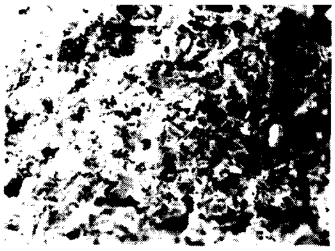

Fig. 1 SEM micrograph of sample after first sintering

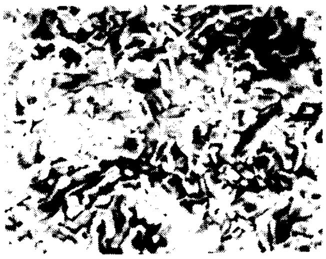

Fig. 2 SEM micrograph of sample after third repeated sintering

were sintered at different temperatures in air for 8 h. The T_c values and J_c values of the samples were listed in Table 2.

Table 2 Effect of sintering temperature on D(g/cm^3), T_c(K), J_c(A/cm^2)

Property	900 ℃	920 ℃	940 ℃	960 ℃
D	5.75	5.87	5.96	6.28
T_c	82.3	81.6	83.0	83.0
J_c	600	650	740	850

Table 2 shows that the higher the sintering temperature is, the higher the sample's density and J_c values are, but all of these samples have low T_c values.

3.3 *Effect of Magnetic Field Treatment* (MFP or MFS) *on Samples' Density*

Through the magnetic field (10^5 Oe) pressing (MFP) and magnetic field sintering, the superconductor of $HoBa_2Cu_3O_{7-\delta}$ has higher average body density, as shown in Table 3.

Table 3 Effect of MFP and MFS on samples' density (g/cm^3)

Method	1		2	
	A	B	A′	B′
Normal	5.37	5.36	5.42	5.41
MFS, MFP	6.31	6.31	6.32	6.33

These results can also be shown by SEM observation (Fig. 3 and Fig. 4).

From Figs. 3 and 4, it can be seen that the sample which commited magnetic field treatment (both MFP and MFS) crystallizes more perfectly and has less defects.

3.4 *Effect of Magnetic Field Treatment on Crystallization Grain's Range and Superconductivity*

It can be seen from Figs. 5~10 that to the $HoBa_2Cu_3O_{7-\delta}$ oxide superconducting system (Ho-S), the crystallize grain's range can be obviously improved by the magnetic field sintering, but the single magnetic field pressing is no use for improving the grain range, and that to the $YBa_2Cu_3O_{7-\delta}$ oxide superconducting system (Y-S), the magnetic field treatment(MFP or MFS) is no use for impro-

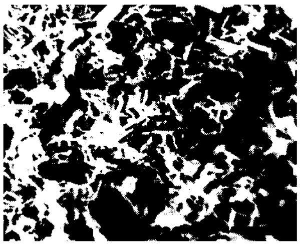

Fig. 3 SEM micrograph of sample after normal treatment

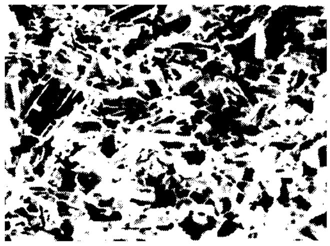

Fig. 4 SEM micrograph of sample after magnetic treatment

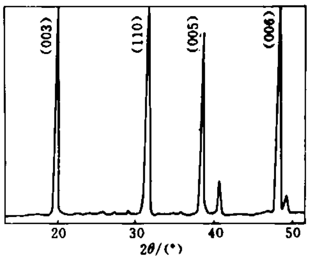

Fig. 5 X-ray diffration pattern of mormal treatment Ho-S superconductor

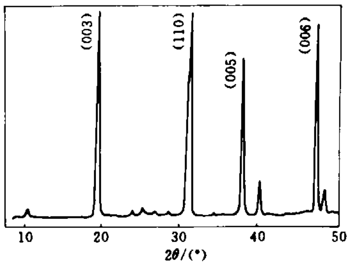

Fig. 6 XRD pattern of single MFP Ho-S superconductor

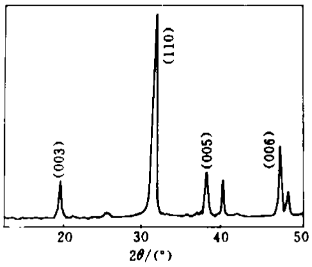

Fig. 7 XRD pattern of both MFP and MFS Ho-S superconductor

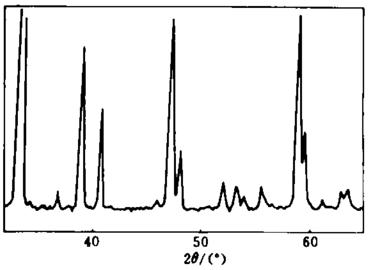

Fig. 8 XRD pattern of normal treatment Y-S superconductor

ving the grains's range. This can be attributed to the fact that the effective Bohr magnetion of Ho^{3+} and Y^{3+} ions are estimated to be 10.2 and 0 μB, respectively.

From Fig. 7, it can be seen that the Ho-S sample has [110] preferred orientation. Through the parameter's measure, it can also be known that the J_c values on the parallel and vertical orientations of the magnetic field are different, as shown in Table 4.

Table 4 T_c(K) and J_c (A/cm^2) of $HoBa_2Cu_3O_{7-\delta}$ values along different directions

Direction	1		2	
	T_c	J_c	T_C	J_c
Parallel	83.0	320	90.5	850
Vertical	83.0	110	90.5	520

The solid physics theory indicates that the magnetic field gives the magnetic matter (like Ho_2O_3) an additional energy or magnetic field acting on the atom and ion magnetic domains. The additional energy can be given by

$$-(\boldsymbol{u}_J)\cdot(u_0\boldsymbol{H}) = -\boldsymbol{u}_B\cdot\boldsymbol{B} = gu_B\cdot M_J\cdot B \quad (1)$$

Under the sintering temperature, the Ho^{3+} is paramagnetism in the magnetic field and the Ho^{3+} ion magnetic domain range is shown in Fig. 11 and Fig. 12.

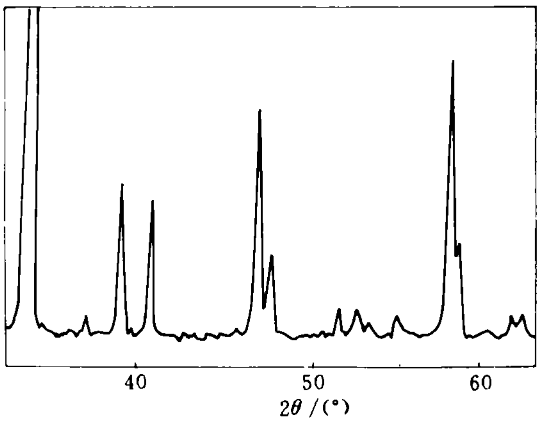

Fig. 9 XRD pattern of single MFP Y-S superconductor

The sample obtained from magnetic field sintering was treated by repeated sintering. The changes of J_c values are shown in Table 5. Table 5 shows that the repeated sintering has destroyed the existing preferred orienta-

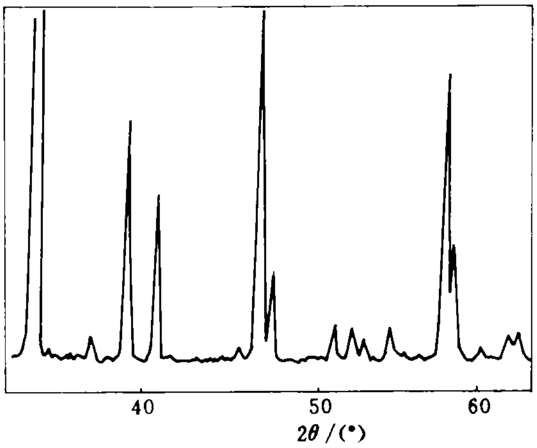

Fig. 10 XRD pattern of both MFP and MFS Y-S superconductor

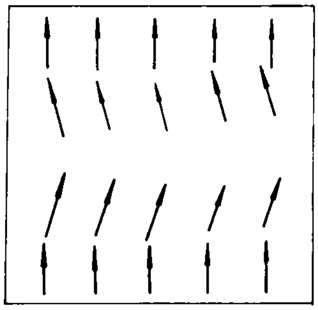

Fig. 11 Ho^{3+} magnetic domain range in additional magnetic field

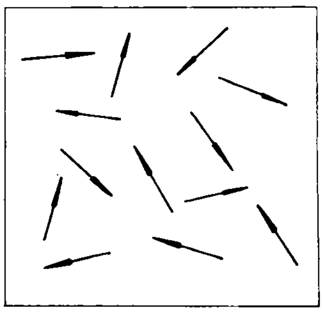

Fig. 12 Ho^{3+} magnetic domain range in no additional magnetic field

Table 5 J_c **values after repeated sintering** (A/cm^2)

Direction	First	Second	Third
Parallel MFS	326	1 300	1 250
Vertical MFS	116	1 000	1 250

tion, so the J_c values along different directions are similar or same at last.

4 CONCLUSIONS

(1) The repeated sintering is useful for the superconductors' grains to crystallize more perfectly and raise the sample's body density in $REBa_2Cu_3O_{7-\delta}$(RE=Y, Ho) systems.

(2) Within the temperature range 900 to 960 ℃, the higher the sintering temperature is, the higher the sample's body density and J_c values are.

(3) The magnetic field treatment can raise the $HoBa_2Cu_3O_{7-\delta}$'s body density and improving the superconductor crystallizing perfectibility.

(4) After the magnetic field treatment, $HoBa_2Cu_3O_{7-\delta}$ superconductor shows preferred orientation in [110], and its J_c values are different along different directions; but the $YBa_2Cu_3O_{7-\delta}$ superconductor does not have these phenomenon.

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layer. The plastic deformation can produce more defects such as dislocations and cracks in the matrix, which speed up the diffusion of the oxygen into the matrix, thus bringing about deep oxidation. The thickness of the oxide film is also related to whether there exist elements with strong affinities for oxygen. In addition, the bonding strength between the oxide film and the matrix and the wear rate also affect the thickness of the load-bearing oxide film. The thicker the load-bearing oxide film, the better the high-temperature wear resistance. At 600 ℃, the wear resistance of the Fe-25Re alloy with the maximum thickness of oxide film is better than that of the Fe-50Re alloy with relatively thicker oxide film; the wear resistances of the pure Fe and Fe-70Re alloy without appreciable thickness of oxide films are relatively poor.

The high-temperature wear of the Fe-Re alloys is a dynamic equilibrium process. After a long time of wearing, an oxide layer with stable thickness, composition, oxide types and corresponding proportions is obtained, thus the Fe-Re alloys can self-lubricate in a long term.

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