Surface analysis of shocked Bi-Pb-Sr-Ca-Cu-O (BPSCCO) particles by CCD/SEM

Hiroshi Kezuka **1**, Nakagawa Yuta **1,** Hiroyuki Fujita **2**, Mineo Ito**2**

Hitoshi Matsumoto **3,** Hiroaki Kishimira **3 ,** Tamio Endo **4**, Kazuhiro Endo **5**

Tokyo Univ. of Technology 1, Interdisci. Grad. School of Kinki Univ. 2

National Defense Academy 3, Mie University 4, Kanazawa Inst. of Technology 5

The BPSCCO powder was formed into pellets by using a compressor under pressures ranging from 200 to 300 MPa. The pellets were then subjected to a shock pressure of around 2-4 GPa for approximately 1 μsec, using the shock compaction system. The average size of the crystal grain for the shocked BPSCCO is about 15.3 μm after the annealing of 48 hours by CCD/SEM-observation.The sensitivity of the sensor made with the shock compaction method is about 13 %/(10^{-4} T) over the range of measurement of the magnetic field B_{meas}, which is about 13 times greater than that of a giant magnetoresistance (GMR) sensor.

1. Introduction

A magnetic sensor, constructed of bulk Bi-Pb-Sr-Ca-Cu-O(BPSCCO)[(1)-(4)] 、was fabricated by use of the shock compaction method,employing a propellant gun-system, and then sintered under through use of an electronic furnace. The specimen as a magnetic sensor was maintained in the superconducting state at 77.4K, under a current density of approximately 40 A/cm^2 in the absence of an excitation magnetic field. The superconducting state was then broken and the specimen exposed to a value of 40×10^{-4} T. That is, the resistance of the specimen occurred when exposed to 40×10^{-4} T under a constant J of 40 A/cm^2. The magnetic sensitivity of the specimen is measure over the range of measurement of the magnetic field from 0 to $\pm5\times10^{-4}$ T,under a constant 40×10^{-4}T.

Also, the size distribution of the crystal grain for the surface of shocked BPSCCO is measured by CCD/SEM-images.

2. Experimental

The particle size distribution of BPSCCO powder was measured by a laser diffraction size analyzer, which employed laser diffraction and scattering methods. The average size of the particles was found to be approximately 3 μm, such as reported in . Ref.(5).For the fabrication of the bulk BPSCCO specimen to be used as the magnetic sensor, the BPSCCO powder was formed into pellets by using a compressor under pressures ranging from 200 to 300 MPa. The pellets were then subjected to a shock pressure of around 2-4 GPa for approximately 1 μsec, using the shock compaction system as illustrated in Fig.1. The pellet specimens were annealed under a temperature of 845 °C for 48 hours, by heating in dry air at the rate of 14 °C/min, cooled in dry air to a temperature of 300 °C at the rate of 5 °C/min, and cooled to room temperature by natural cooling. The pellets measuring 0.5 mm in thickness and 10 mm in diameter, were cut into rectangular-shaped test specimens as magnetic sensors, measuring 9.4 mm in length and 1.7 mm in width, using a diamond saw at low cutting rate to limit the effects of heat.

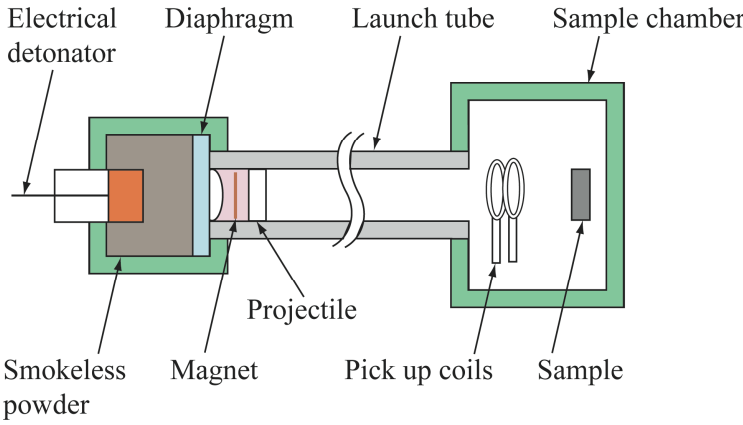

Fig.1. The shock compaction system

3. Results and Discussion

Figure 2 shows the typical dependence of the resistance $R(T$=77.4 K), without an application of a B_{bias}, on the excitation magnetic flux density B_{ex} for values of 0 to $\pm50\times10^{-4}$ T, under a temperature of 77.4 K. In this figure, curves (a) and (b) represent the magnetic characteristics of sensors with (solid circles) and without (open circles) the shock compaction method, under a constant J of 40 A/cm^2, respectively.

Temperature characteristics of curve (a) are shifted toward higher temperatures, than those of curve (b), and demonstrate the effect of the shock compaction method, as can be seen in this figure. Namely, the critical temperature $T_c(R$=0) of the sensor with the shock compaction method increases, quite evidently, from a T_c

of 101 K for the sensor without the shock compaction method to 105 K.

It can be seen in this figure that no hysteresis characteristics are observed over the range of B_{ex} values from 0 to $\pm 50\times10^{-4}$ T. In the addition, the characteristics of both sensors exhibit symmetry with respect to B_{ex}=0 during the application and withdrawal of B_{ex}.

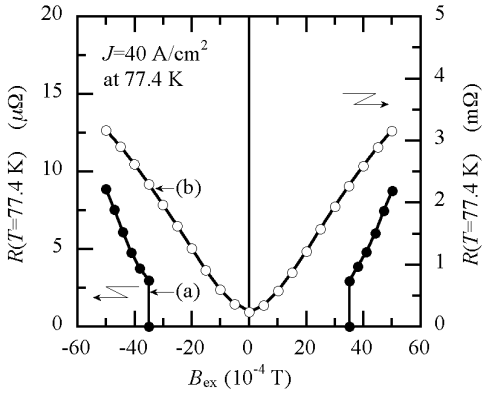

Fig. 2. Typical dependence of the resistance $R(T=77.4\ \mathrm{K})$ on the excitation magnetic flux density B_{ex} for the sensors, under temperature conditions of 77.4 K. Here, (a) and (b) represent the characteristics of sensors constructed with (solid circles) and without (open circles) the shock compaction method, respectively.

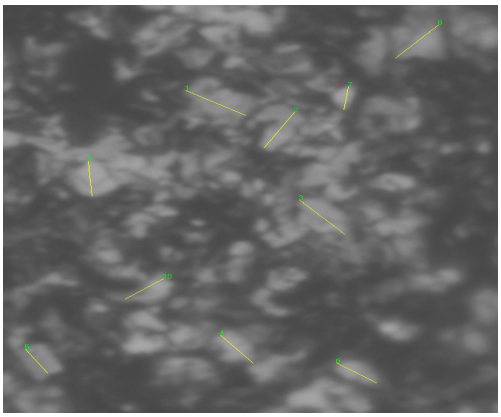

Fig. 3. The measurement of the size of crystal grain using CCD-image.

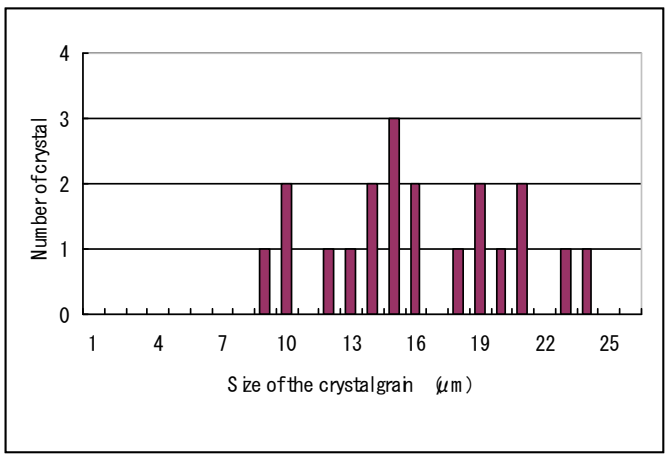

Fig.4. The size og crystal grain

From the typical plots of the dependence of resistance $R_{meas}(B_{meas})$ for the sensors on the measurement of magnetic flux density B_{meas} between 0 T to $\pm5\times10^{-4}$ T, the values of $R_{meas}(B_{meas})$ have been normalized by the value of $R_{meas}(B_{meas}=0\ \mathrm{T})$. The solid and open circles are the results of magnetic sensors constructed with and without the shock compaction method, respectively. The sensitivity of the sensor made with the shock compaction method is about 13 %/(10^{-4} T) over the range of measurement of the magnetic field B_{meas}, which is about 13 times greater than that of a giant magnetoresistance (GMR) sensor. It was, furthermore, found that the magnetic sensors exhibited directional and linear characteristics to the values of B_{meas}. In addition, no evidence of hysteresis was found in the characteristics. From the measurement of grain size distribution by CCD/SEM-observation, the average size of the crystal grain for the shocked BPSCCO is about 15.3 μm after the annealing of 48 hours as shown in Fig.3 and Fig.4.

4. Conclusions

The magnetic sensitivity of the specimen was approximately 13%/(10^{-4}T) over the range of measurement of the magnetic field from 0 to $\pm5\times10^{-4}$ T,under a constant 40×10^{-4}T for the value of, being approximately 13 times greater than that of a giant magnetoresistance sensor. It was, consequently, determined that it was possible to apply the bulk BPSCCO specimen as a highly sensitive magnetic sensor. The average size of the crystal grain for the shocked BPSCCO is about 15.3 μm after the annealing of 48 hours by CCD/SEM-observation.

References

(1) M. Itoh, K. Yamagata, A. Omura, M. Ishidoh, and T. Minemoto: “Highly sensitive magnetic sensor constructed with a YBCO thick film” , Advances in Cryogenic Engineering, Vol. 45, pp. 1739-1745, Kluwer Academic/Prlenum Publishers, NY (2000)

(2) K. Yamagata, A. Omura, M. Itoh, M. Ishidoh, and T. Minemoto: “Highly magnetic sensor made with a superconducting Y-Ba-Cu-O thick film”, *IEEE Trans. Appl. Supercon.*, Vol.11, No.1, pp.2383-2386 (2001)

(3) K. Yamagata, N. Hayashi, H. Kezuka, and M. Itoh: “Characterisitics of a highly sensitive magnetic sensor made from a thick BPSCCO film”, *Solid State Science*, Vol.5, No.4, pp.441-444 (2003)

(4) H. Kezuka, K. Yamagata, M. Itoh, T. Suzuki, M. Kikuchi, T. Atoh, M. Kawasaki, and K. Fukuoka: “Shock-compaction of Bi-Pb-Ca-Cu-O particles”, *Trans. MRS of Japan*, Vol.29, No.4, pp.1393-1395 (2004)

(5) K. Yamagata, Y. Maeji, H. Kezuka, and M. Itoh: “Magnetic sensor constructe of a thick BPSCCO film: Relationship between magnetic sensitivity and the quenching process”, Proc. IEEE Sensors 2004, pp.1078-1081 (2005)