A Study on the Electrical Characteristics of Renewable Electrical Energy Superconducting Precursor using Organic Metal Salts Method for Electrical Power Transmission

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We have fabricated superconductor ceramics by chemical process. A high Tc superconductor with a nominal composition of $Bi_2Sr_2Ca_2Cu_3O_y$ was prepared by the organic metal salts method. Experimental results suggest that the intermediate phase formed before the formation of the superconductor phase may be the most important factor. The relation between electromagnetic properties of Bi HTS and external applied magnetic field was studied. The electrical resistance of the superconductor was increased by the application of the external magnetic field. But the increase in the electrical resistance continues even after the removal of the magnetic field. The reason is as follows; the magnetic flux due to the external magnetic field penetrates through the superconductor and the penetrated magnetic flux is trapped after the removal of the magnetic flux.

Keywords : High Tc superconductor, Electric power, Chemical process, Bi HTS

1. INTRODUCTION

Since the discovery of high Tc oxide superconductors with transition above liquid nitrogen temperature[1-4], many efforts have been focused on improving the fabricability of ceramic superconductors and increasing the critical current density of the systems. Recently several effective methods, which could fabricate ceramic superconductors into a wire or a tape shape with high Jc, have been successfully developed for the BiSrCaCuO system. The discovery of superconductivity in the BiSrCaCuO system with two superconducting temperatures, significant effort has been directed towards developing high current superconducting wire technologies.

Compared with the earlier developed YBaCuO superconductor, this oxide system contains no rare earth element and has greater chemical resistance against moisture, but the critical current density, Jc, is lower and requires prolonged annealing to form the high Tc and other phase. So far, much effort has been devoted to the fabrication and application of this superconducting oxide system. Generally the preparation of superconducting oxides by conventional solid state reaction relies upon the repeated milling and sintering of an oxide and carbonate mixture, with such a process, the time required to obtain acceptable homogeneity is very expensive and serious contaminations may be introduced during the milling process. On the other hand, chemical solution methods are much more efficient in the production of mixtures of high homogeneity.

When a sufficiently strong current exceeding the critical current passes through a type II superconductor in the mixed state, the Lorentz force exceeds the pinning force between the flux line and the moving charge and the core lattice is set in motion against viscous drag force inducing a voltage drops in the sample[5,6].

The early works of Kim et. al.[7] showed that the voltage drop develops in the type II superconductor of the mixed state, and the flux flow resistivity remains zero up to the critical current. Above the critical current and the slope dv/di increases, the voltage drop increases with current until the liner flux flow region is attained.

We reported the fabrication of the BiSrCaCuO high Tc superconductor by the organic metal salts method, and the characteristics change of flux flow resistivity with external magnetic field and field polarity.

2. EXPERIMENTAL PROCEDURE

The high Tc superconductor of Bi system with the nominal composition of $Bi_2Sr_2Ca_2Cu_3O_y$ precursor was prepared from mixed powders of Bi_2O_3, $SrCO_3$, $CaCO_3$,

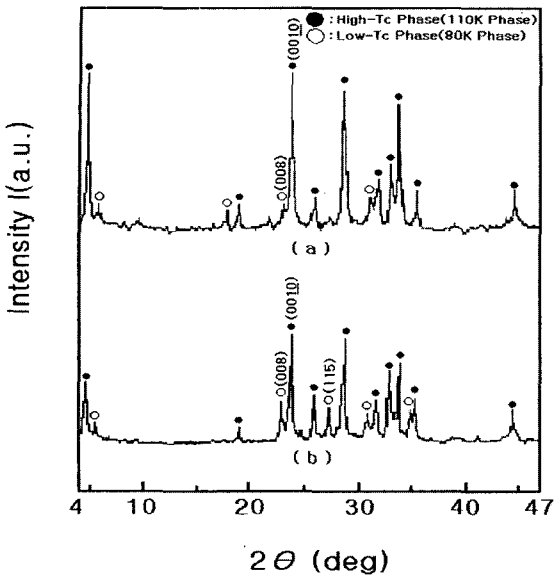

Fig. 1. The X-ray diffraction patterns of powered superconducting BiSrCaCuO superconductor, (a) is the case of Ag_2O doped superconductor, (b) is undoped superconductor ; • and ○ denote high Tc phase (110 K phase) and low Tc phase (80 K phase), respectively.

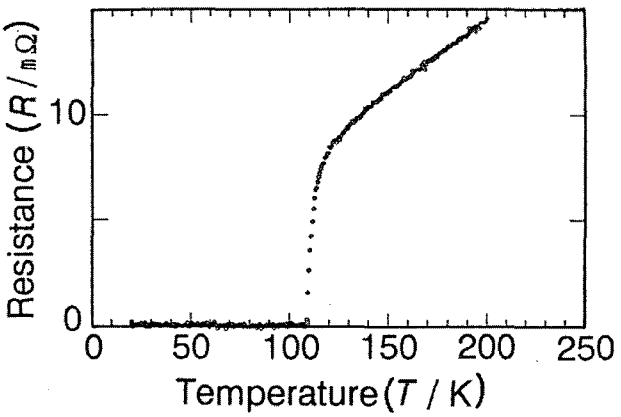

Fig. 2. The resistance-vs-temperature curves of the pellets sintered 850 ℃ for 50 hours.

and CuO by the organic metal salts method. A mixture of nitrate salts in a suitable molar ratio with total weight 50 gm was dissolved in 150 ml distilled water. The nitrate solution was then vigorously stirred with a few drops of 60 wt% HNO_3 solution added to assist the dissolution. After a clear solution was obtained, powered citric acid and ethylene glycol were added. The resulting solution of light blue was magnetically stirred and heated at 80 ℃. A vigorous reaction occurred and enormous amount of N_2 gas evolved during this procedure. When a vigorous liquid began to set into a gel, the gel was dehydrated at 120 ℃ for 12 hours, while the color of the gel changed from blue to green, and finally a solid precursor material of a brownish yellow color was obtained. The solid precursor was ground with mortar and pestle. The powered precursor was then transferred into an alumina crucible and placed in an air furnace. It was slowly heated to 400 ℃ for 10 hours. The furnace temperature was then slowly raised to 850 ℃, and calcination was performed at this temperature for 5 hours followed by furnace cooling to room temperature. The calcined powder was ground with mortar and pestle into powders. After grinding the calcined cake, the powder mixtures were pressed into pellets under 300 kg/cm^2, followed by sintering at 850 ℃ for 50 hours. The electrical transport properties of the BiSrCaCuO superconductors were measured by the conventional four probe method. The present author used a conductive silver paste to attach copper leads to the sample. The magnetic characteristics were evaluated with a magnetometer placed a dc magnetic field, applied perpendicular to the surface of the magnetometer. The phases formed after calcinations and sintering were analysed by X-ray powder diffraction (XRD) using $CuK\alpha_1$ radiation. The compositions of the sample were evaluated by electron probe micro analysis (EPMA). The U shaped superconductors was polarized by the field cooling at 77 K with a samarium cobalt rear earth permanent magnet of B = 0.15 T, 46 mm in length and 10 mm in thickness. The disk sample with a diameter of 8 mm and thickness of 1mm weighed 0.3 g.

3. RESULTS AND DISCUSSION

Figure 1(a) shows an XRD pattern of an 5 wt% Ag_2O doped BiSrCaCuO superconductor, while Fig. 1(b) is an XRD pattern of an undoped sample, where (•) and (○) denote the peaks of 110 K phase and 80 K phase, respectively. Figure 1 shows the structure of superconductor crystalline state. From XRD patterns, the presence of the superconducting low Tc phase (80 K phase) was confirmed in the undoped sample because of the presence of the (115) diffraction peak. In order to investigate the reaction between Ag_2O and the superconducting phases, powder X-ray diffraction analysis was carried out on the calcined powder. The high T_C superconducting phase ($Bi_2Sr_2Ca_2Cu_3O_{10}$, 2223 phase) is the main phase but a small amount the low T_C phase ($Bi_2Sr_2Ca_1Cu_2O_8$, 2212 phase) remained.

Figure 2 shows the R-T curves of the sintered pellets with their XRD patterns shown in Fig. 1. Their zero - resistance temperatures, Tc(0), was found to be 105 K. Transition temperature T_C of all specimens tested were

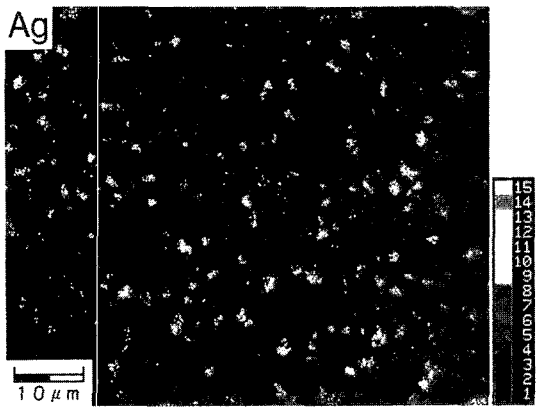

Fig. 3. EPMA image of the BiSrCaCuO superconductor with Ag_2O addition.

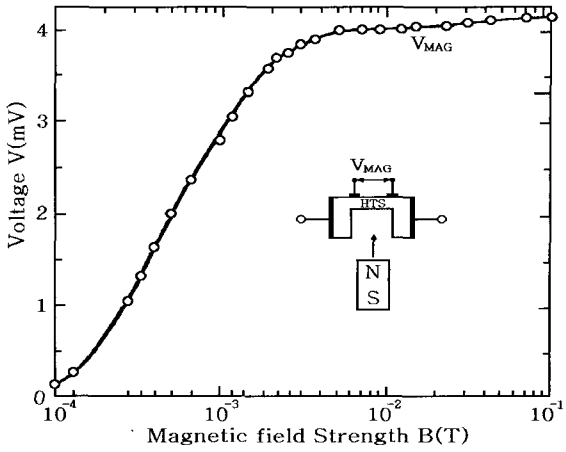

Fig. 5. Dependence of the voltage V_{MAG} on externally applied magnetic field at 77 K.

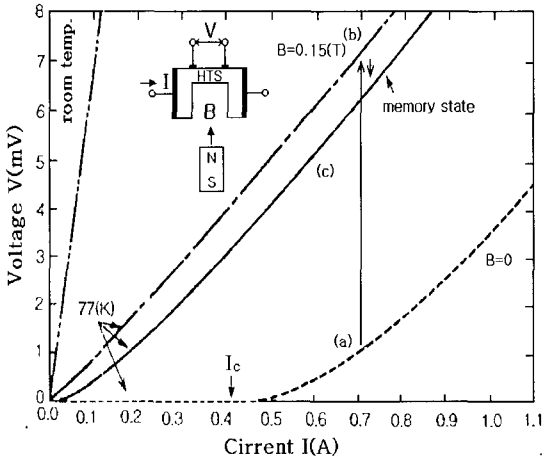

Fig. 4. Voltage–current characteristics of the superconductor.

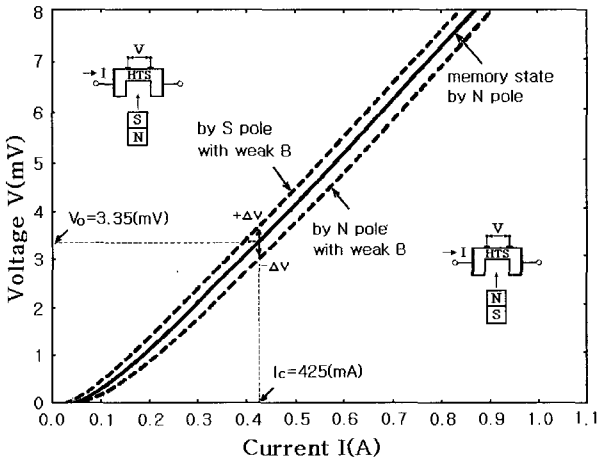

Fig. 6. Voltage – current characteristics of N polarized superconductor.

shown to be 105 K. The presence of Ag in the doped sample is attributed to the reduction of Ag_2O in oxide ceramics during reaction sintering, similar to those observed in the Ag_2O doped YBaCuO superconductor[4]. In our experiments, the Ag_2O doped samples were showed high T_C (about 105 K) as well as sufficient formation of the 2223 phase. The lattice parameters of the 2212 phase and the 2223 phase for our samples were calculated from the XRD patterens. At constant sintering time, the parameter is nearly constant at 0.55 nm, while the c parameter reduced from 3.10 nm to 3.09 nm. But this variation is very small. It means that the variation of the lattice parameter is not a function of Ag_2O content. The EPMA pattern in the 5 % Ag_2O doped sample in Fig. 3 showed a uniform dispersion of Ag particles.

The voltage–current characteristics of a doped Ag_2O BiSrCaCuO superconductor showed in Fig. 4. The curves(a) and (c) were obtained at external magnetic field at 77 K.

The curve(b) at 77 K, gradually approaches the curve(c) after the removal of the external magnetic field. If the voltage is applied again after returning to zero voltage, V–I characteristics are shown in curve(c). This means that the sample is in the memorized state. The voltage V_{MAG} appeared across the field cooled HTS sample increased with external magnetic field, showing a linear region in the range between 10^{-4} and 3×10^{-3} T, as in Fig. 5.

The voltage – current (V– I) characteristics of the field cooled by the N pole superconducting magnetometer in Fig. 6 shows that the positive and negative ΔVs are the increment and the decrement of voltage drop across the HTS sensor with respect to the initial voltage V_0, respectively.

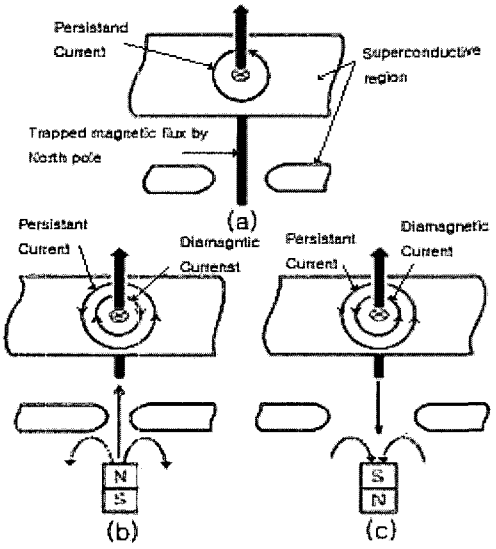

Fig. 7. Mechanism of change in electrical resistance caused by small external magnetic field.
(a) Memorized superconductor by North pole.
(b) With effect of external North pole.
(c) With effect of external South pole.

It is found that the superconducting device memorized by the north pole of a magnet detects the polarity of external weak magnetic flux of less than $2x10^{-3}$ T. This result is reasonably explained by the model as shown in Fig. 7.

Figure 7(a) shows the direction of persistent current and trapped magnetic flux of high Tc superconductor magnetized by the north pole. The trapped magnetic flux destroy some superconduction part and causes the appearance of voltage drop across the sample at each value of current I. Figure 7(b) shows the model of memorized sample by the north pole with the effect of applied external magnetic flux. Because the diamagnetic characteristics of superconducting material induce opposite magnetic flux against the applied external magnetic flux caused by the induced surface diamagnetic current with the clockwise direction as shown by dashed circle.

Due to two kinds of current with the opposite direction, the total magnetic flux which pass through the superconductor decreases the voltage drop across the sample at the same of current I is observed. In Fig. 7(c), for the south pole of the applied external magnetic flux, the direction of induced surface diamagnetic current is counterclockwise as shown by the dashed circle and both kinds of current have the same direction. The total magnetic flux passing through the superconductor are increased, the increasing the destroyed regions of superconduction part, that is, thus the voltage drop across the sample increases at the same of current I. By the similar mechanism as mentioned above, the south pole of the memorized superconducting device yields to weak magnetic flux and increases the voltage drop across the sample.

4. CONCLUSION

Although the precursor material prepared in this work was not in the amorphous state as expected, volume fraction of the high Tc phase was obtain at 850 ℃ for a short time. From the experiments, it has been found that the memorized superconductor can detect both magnitude and polarity of the coming magnetic flux. The knowledge from this principle shows that the same polarity of the coming external magnetic flux and the memorized magnetic flux will cause to decrease the resistance of the superconductor, that is, the voltage across the superconductor is decreased. Furthermore, the different polarity of the coming external magnetic flux and the memorized magnetic flux will cause to increase the resistance value of the superconductor, that is, the increasing of voltage across the superconductor.

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