Superconductivity of YBCO/(Sr,Ca)-Cu-O/YBCO system

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Abstract

The dependence of Tc on oxygen content and (x) of $Sr_xCa_{0.1-x}CuO_z$ films sandwiched with $YBa_2Cu_3O_{7-\delta}$ were examined. The Tce at x=0.1 ranged from 55K to 91K concerning the variation of oxygen pressure (0.1-1.0Torr). The dependence of Tco on (x) ranged over that of YBCO electrodes and revealed an optimal Tc (Tco=95K, Tce=91K) at x=0.05.

Key words: sandwiched thin films; compound cuprate;YBCO

1. Introduction

Superconductivity with high Tc's of 80-110K have been reported on high pressure synthesized complex-cuprates (A-Cu-$O_{2-\alpha}$) related with the alkaline-earth A=(Sr,Ca) for instance ref. [1]. On A-CuO_y films with A=Sr, the properties of A=Sr_1 and Sr_2 have been reported on microstructures [2] and superconductivity of high quality thin films with -75K by MBE [3], respectively. We have reported the electrical conductivity of Sr_xCuO (x=0-1.0) in a sandwiched structure $YBa_2Cu_3O_{7-\delta}/Sr_xCuO/YBa_2Cu_3O_{7-\delta}$ that $Sr_{0.1}CuO$ of x=0.1 has been Tce= 93.8K over that of YBCO electrodes [4]. Here we describe the superconductivity and the dependence of Tc on oxygen and compound ratios (x) of $Sr_xCa_{0.1-x}CuO_z$ films in $YBa_2Cu_3O_{7-\delta}/Sr_xCa_{0.1-x}CuO_z/YBa_2Cu_3O_{7-\delta}$ system (YBCO/$Sr_xCa_{0.1-x}CuO_z$/YBCO).

2. Experimental

YBCO/(Sr,Ca)CuO_z/YBCO was sputter-deposited on $SrTiO_3$(STO) substrates oriented (100) in an apparatus with two DC magnetron-sputtering- sources. YBCO electrodes were fabricated on STO at 800°C in flowing oxygen gas at pressure of 1.0Torr [4], [5]. The thickness of each YBCO film was 1500Å[4]. Above sputtering process for YBCO electrodes was followed by annealing for the orthorhombic c-axis orientation film with the lattice constant c=11.68Åunder conditions of a substrate temperature (Ts) of 515°C for 30minutes in the oxygen atmosphere at 300Torr. (Sr,Ca)CuO_z thin films were sputter-deposited to the thickness of 2200Åat the deposition rate of 110-220Å/min. Powders of SrO, CaO and CuO were mixed in various ratios (x) of Sr and Ca to prepare the discoidal press-forming targets which were synthesized in an air atmosphere by sintering at 930°C for 12 hours. Optimum values for both Ts=500°C and the flowed sputtering oxygen partial pressure Po=0.3Torr, which were due to the dependence of Tc in the (Sr,Ca)CuO_z thin films (x=0.1), were set for the Ca substitution. The area of the YBCO/(Sr,Ca)CuO_z/YBCO sandwich was 1 mm square as shown in Fig.1 (a). The electrical resistance (R) was measured with a constant dc electric current of 3mA/cm^2 passing along the cross section from YBCO-L3 to YBCO-L1 in Fig. 1 (a). The constancy of electric current was verified by the voltage drop of the standard resistor connected in a series. Details of the measurement are given in ref. 4,5.

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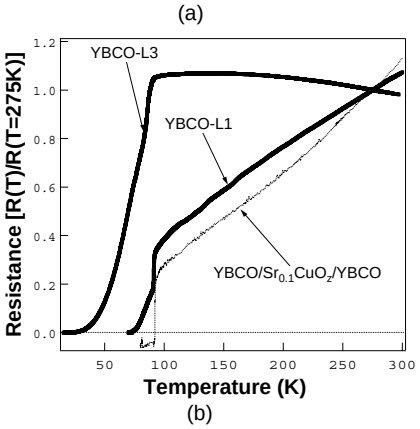

Fig. 1. Schematic of the cross section of YBCO/(Sr,Ca)CuO_z/YBCO (a), and electrical resistance, normalized at 275K, plotted against temperature, on YBCO electrodes and along the cross section in YBCO/$Sr_{0.1}CuO_z$/YBCO fabricated at the optimum Po (=0.3Torr) (b).

3. Results

Figure 1 (b) shows the superconductive transition of the horizontal direction of YBCO electrodes as L1 and L3 in this tri-layered system. The Tce of YBCO-L1, -L3 were 72K and 19K for L1 adhered to the substrate and the top layer L3, respectively. A transition in Fig. 1 (b) along the cross section (shown in Fig. 1 (a)) in YBCO/ $Sr_{0.1}CuO_z$/YBCO has higher Tc compared with that of YBCO electrodes. A clear dependence of Tc and R at normal state of YBCO/$Sr_{0.1}CuO_z$/YBCO on the oxygen pressure (Po) were observed. The Tce was found to range from 76K to 91K with a corresponding variation in (Po) of between 0.2-1.0Torr. A value of Po=0.3Torr gives the optimum composition of oxygen with the highest Tco of 97K with Tce=92K. Utilizing the optimized oxygen composition (Po=0.3Torr), the variation of the Tce value against (x) of $Sr_xCa_{0.1-x}CuO_z$ ranged from 85K to 91K over that of YBCO electrodes as shown in Fig. 2 (a). The Tc at the optimum composition (x=0.05) reached Tco=95K with Tce=91K. In Fig. 2 (b), R at 273K decrease with a corresponding increase of (0.1-x), the substitution of Ca. A (002) peak of CuO was confirmed in the XRD pattern on $Sr_xCa_{0.1-x}CuO_z$ films. The $Sr_{0.5}Ca_{0.5}CuO_z$ film with the higher R had the c-axis orientation with lattice constant of $c \approx 3.4\mathring{A}$, as evidenced by the (001) and (002) peaks in the XRD pattern, illustrating an infinite layer $SrCuO_{2-\beta}$ as opposed to $Sr_xCa_{0.1-x}CuO_z$. This transition of crystal structure is not unexpected

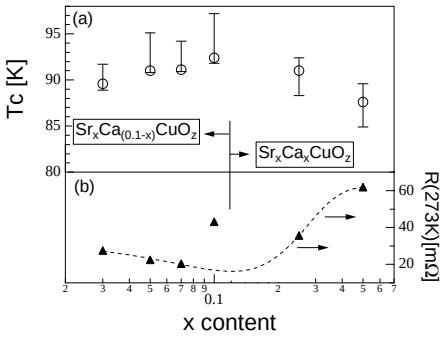

Fig. 2. Variations of both Tc and the electrical resistance in YBCO/(Sr,Ca)CuO_z/YBCO against (x) of $Sr_xCa_yCuO_z$ (with y=x or 0.1-x) in YBCO/$Sr_xCa_yCuO_z$/YBCO. (a) variations of Tc with Tc-middle (open symbols), Tco (upper bars) and Tce (under bars), (b) values of the electrical resistance at 273K.

considering the small quantity of both (Sr, Ca) and Ca which are intercalated in CuO and $SrCuO_{2-\beta}$ respectively. However, the dependence of both Tc and R on the value of (x) in YBCO/$Sr_xCa_{0.1-x}CuO_z$/YBCO shows a carrier doping effect with the intercalation in base insulators as CuO and $SrCuO_{2-\beta}$.

4. Conclusion

On the dependence on oxygen at x=0.1 in sandwiched system, the Tce ranges from 76K to 91K. The dependence of Tc on (x) of $Sr_xCa_{0.1-x}CuO_z$ ranged over that of YBCO electrodes and revealed an optimal Tc at x=0.05 with Tco at 95K and Tce at 91K.

References

[1] Z. Hiroi, M. Azuma, M. Takano, Y. Takeda, Physica C **208** (1993) 286.

[2] S. Takeno, S. Nakamura, Y. Terashima, T. Miura, Physica C **206** (1993) 75. C **213** (1993) 345.

[3] S. Karimoto, H. Yamamoto, T. Greibe, M. Naito,Jpn. J. Appl. Phys. **228** (1994) 129.

[4] S .Koba, R. Nagata, M. Onishi, Y. Ozono, K. Shibata, S.Higo, I.Kawano,T. Kushida, Y. W. Kim, T. Ogushi, Physica C**282-287** (1997) 707.

[5] T. Ogushi, M. Hirose, S. Koba, S. Higo, I. Kawano, Mod.Phys.Lett.B **40** (1995) L127.