ELSEVIER

Physica C 341–348 (2000) 1615–1616

PHYSICA C

www.elsevier.nl/locate/physc

Anomalous Zero-bias Behavior in Co/BiSrCaCuO and Au/BiSrCaCuO Tunnel Junctions

Takayuki Ishibashi, Kazushige Sato and Katsuaki Sato *

Faculty of Technology, Tokyo University of Agriculture and Technology, Koganei, Tokyo 184-8588

Co/$Bi_2Sr_2CaCu_2O_x$(BSCCO) and Au/BSCCO tunnel junctions have been fabricated in order to study effects of the spin injection into the superconductors. The junction with $100 \times 100\,\mu m^2$ was fabricated on the cleaved BSCCO single crystal. In both cases, gap structures were clearly observed in dI/dV spectra. The gap energy of Co/BSCCO junction (28 mV) was smaller than that of Au/BSCCO junction. The zero-bias conductance peak (ZBCP) was observed clearly for the Au/BSCCO junction. It is considered that these differences between Co and Au junctions are due to the spin-polarization in the current flowing through the junctions.

1. Introduction

Recently, spin-polarized current flowing through a tunnel barrier between high-Tc superconductors and magnetic materials has become an important issue for understanding non-equilibrium state or symmetry in the high-Tc superconductivity. A substantial suppression of superconductivity by injection of spin-polarized current was reported [1–3]. For theoretical approach, the conductance spectra of F/I/S junctions have been calculated, where d-wave superconducting has been taken into consideration [4,5].

In this study, effects induced by spin-polarized current are investigated using Co/BSCCO tunnel junctions. The Co metal is chosen as a spin injector, because it is a ferromagnetic material having a spin polarization of 35 %, and its physical properties are well known. The BSCCO is a high-Tc superconductor having a critical temperature of 80-90 K (for 2212 phase) and is one of the most stable materials in the high-Tc superconductors.

2. Experimental

Figure 1 shows a schematic drawing of the Co/BSCCO and Au/BSCCO tunnel junctions used in this experiment. The junction is prepared on the cleaved surface, which is the $a-b$ plane, of a BSCCO single crystal grown by traveling solvent floating zone (TSFZ) method [6]. The chemical composition of Bi : Sr : Ca : Cu is determined as 2.1 : 1.9 : 1.0 : 2.0. The junction area of $100 \times 100\,\mu m^2$ was patterned using the conventional photolithography method. The junction area was formed by using a lift-off technique with 500 nm-thick CaF_2. A Co or a Au metal of 50 nm in thickness was deposited on the lift-off area by an RF magnetron-sputtering technique at room temperature. In the case of Co/BSCCO junction, Au with a thickness of 50 nm was deposited on the Co and the BSCCO as electrodes.

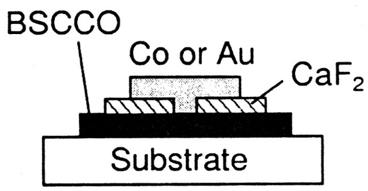

Figure 1. A schematic drawing of Co/BSCCO tunnel junctions.

*We thank Dr. G. Gu and Dr. N. Koshizuka of Superconductivity Research Laboratory for providing BSCCO single crystals.

0921-4534/00/$ – see front matter
PII S0921-4534(00)01479-9

3. Results and discussion

Figure 2 shows dI/dV spectra of a Co/BSCCO junction measured at 30 K and Au/BSCCO junction at 33 and 55 K. The junction resistance of these junctions is 0.6 and 0.3 Ω for Co/BSCCO and Au/BSCCO junctions, respectively. Clear V-shaped gap structures with gap energies of 28 mV is observed in the Co/BSCCO junction. However no peaks of DOS at just above the gap are observed in our junctions. The energy gap of the Co/BSCCO junction is about half of that of the Au/BSCCO junction, although junctions were made from the same single crystal. This result suggests that the superconductivity of the BSCCO is suppressed by the spin-polarized current flowing through the junction. On the other hand, the gap structure with zero-bias conductance peak (ZBCP) is clearly observed only in the Au/BSCCO junction.

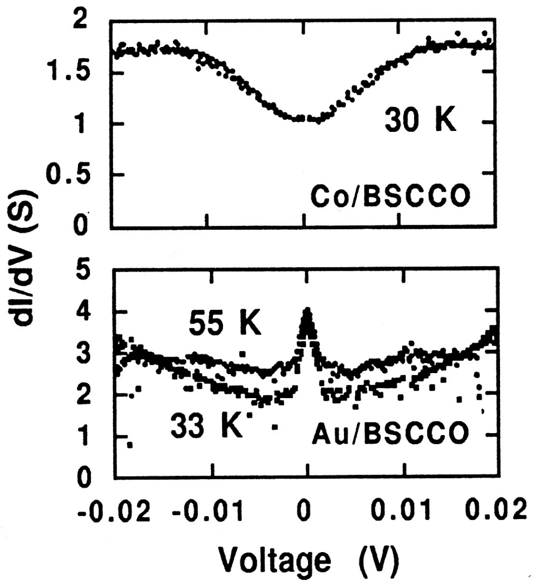

Figure 2. V - dI/dV of the Co/BSCCO junction measured at 30 K and Au/BSCCO junction at 35 and 55 K.

We consider that the suppression of the superconducting gap and the ZBCP is due to the spin polarized current flowing through the junction. The suppression of supercurrent has been reported by other groups and our group as the suppression of the critical current by the injection of the spin-polarized current [1-3]. The suppression of the ZBCP is consistent qualitatively with the result of a theoretical calculation about the spin polarization dependence of the conductance in ferromagnet/insulator/superconductor tunnel junction by Kashiwaya et al. [4].

4. Summary

The effects induced by spin-polarized current were investigated using Co/BSCCO and Au/BSCCO tunnel junctions. The V-shaped gap structures were observed for all Co/BSCCO junctions. The size of the gap was about half of that of Au/BSCCO junction. The ZBCP was not observed for Co/BSCCO while it was clearly observed for Au/BSCCO. These suppressions in the gap and the ZBCP were caused by the spin-polarized current flowing the tunnel junctions.

REFERENCES

1. V. A. Vas'ko, V. A. Larkin, P. A. Kraus, K. R. Nikolaev, D. E. Grupp, C. A. Nordman and A. M. Goldman, Phys. Rev. Lett. **78** (1997) 1134.
2. D. Koller, M. S. Osofsky, D. B. Chrisey, J. S. Horwitz, R. J. Soulen, Jr., R.M. Stroud, C. R. Eddy, J. Kim, R. C. Y. Auyeung, J. M. Byers, B. F. Woodfield, G. M. Daly, T. W. Clinton and M. Johnson, J. Appl. Phys. **83** (1998) 6774.
3. K. Lee, W. Wang, I. Iguchi, B. Friedman, T. Ishibashi and K. Sato, Appl. Phys. Lett. **75** (1999) 1149.
4. S. Kashiwaya, Y. Tanaka, N. Yoshida and M. R. Beasley, Phy. Rev. **B60** (1999) 3572.
5. I. Žutić and O. T. Valls, Phys. Rev. **B60** (1999) 6320.
6. G. D. Gu, K. Takamuku, N. Koshizuka and S. Tanaka, J. Crystal Growth **130** (1993) 325.