# THE TIME DEPENDENCE OF POINT CONTACT RESISTANCE OBSERVED ON $YBa_2Cu_3O_x$/METAL AND $Bi_2Sr_2CaCu_3O_y$/METAL JUNCTIONS

Yu. Revenko**, M. Grajcar*, A. Plecenik, V. M. Svistunov**, S. Benacka

Institute of Electrical Engineering, Slovac Academy of Sciences, Bratislava, Slovakia

*Department of Radiophysics, Comenius University, 842 15 Bratislava, Slovakia

**Donetsk Physico-Technical Institute, Ukrainian Academy of Sciences, 72, R. Luxemburg Str., Donetsk, 340114, Ukraine

*A considerable time dependence of* $YBa_2Cu_3O_x$/In,Au *and* $Bi_2Sr_2Ca_2Cu_3O_y$/Ag *point contact resistance was experimentally observed. We explain the results in the frame of oxygen out-diffusion from upper layers of high-*$T_c$ *superconductor. Computer simulations of the oxygen diffusion in* $YBa_2Cu_3O_x$ *(*YBCO*) and* $Bi_2Sr_2Ca_2Cu_3O_y$ *(*BSCCO*) give good agreement with the experimental results. From the comparison of experimental curves with theoretical ones we conclude that* BSCCO *is more stable material than* YBCO*, however, the surface degradation process due to oxygen diffusion is significant for both materials in the room temperature range. Below 180 K no increase of point contact resistance was observed.*

**Introduction.** A large effort has been made to prepare well defined tunnel junctions of high temperature superconductor (HTS) with other metals or superconductors. In the case of HTS, extremely hard demands on the interface quality are required, as a consequence of very small coherent length [1,2].

Another very important new problem is chemical stability of the surface of HTS [3]. It is well known that concentration of oxygen strongly influences local properties of HTS [4,5]. *X*-ray photoemission spectroscopy [6], methods of surface analysis [7], as well as experiments on energy gap suppression [8] give evidence that these changes arise due to chemical interaction between electrodes and/or due to oxygen depletion on the surface of HTS [9,10].

In this paper we argue that temperature dependence of the time increase of the point contact resistance in YBCO/metal and BSCCO/metal junctions is a convincing proof of oxygen diffusion processes at the interface of HTS/normal metal. A comparison of the materials shows higher oxygen stability in BSCCO than in YBCO material.

**Experimental.** The stability of the tunneling resistance was studied on highly oriented YBCO thin films (*c*-axis perpendicular to the substrate) prepared by magnetron sputtering [11] on MgO single crystal substrates. The zero resistance critical temperature $T_c = 85$ K, critical current density $j_c = 10^5$ A·cm$^{-2}$, for films 100 nm thick. The other studied HTS material BSCCO ($T_c = 105$ K) was prepared by conventional technique. The direct point contacts (i. e. without any artificial layer on the surface of HTS) were prepared at temperatures ranging from 340 to 77 K. As an upper electrode bulk Au, Ag, and In were used in the form of sharp points. Measurement of time dependence of differential resistance was performed using standard low-frequency phase sensitive detection technique.

**Results and discussion.** The increase of point contact resistance in time was observed in both YBCO and BSCCO superconductors. From the obtained dependences (Fig. 1), the diffusion coefficients of oxygen motion were calculated using fitting procedure described in [12]. Similar fitting procedure was simultaneously elaborated by Zhou et. al. [13] for BSCCO with good agreement to experimental

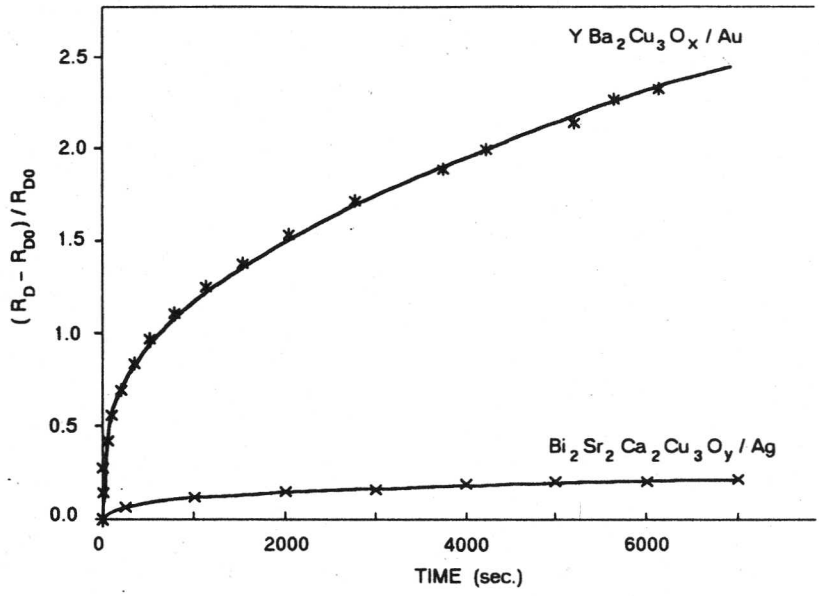


**Fig. 1.** A comparison of the time dependence of change of normalized differential resistance of zero voltage for $YBa_2Cu_3O_x$/Au and $Bi_2Sr_2Ca_2Cu_3O_y$/Ag point contact junctions

results. The fitting procedure is based on the model of oxygen diffusion in the CuO layers in YBCO or Bi2O2 layers in BSCCO. The diffusion equation is solved supposing the dependence of diffusion coefficient and resistivity on oxygen con-

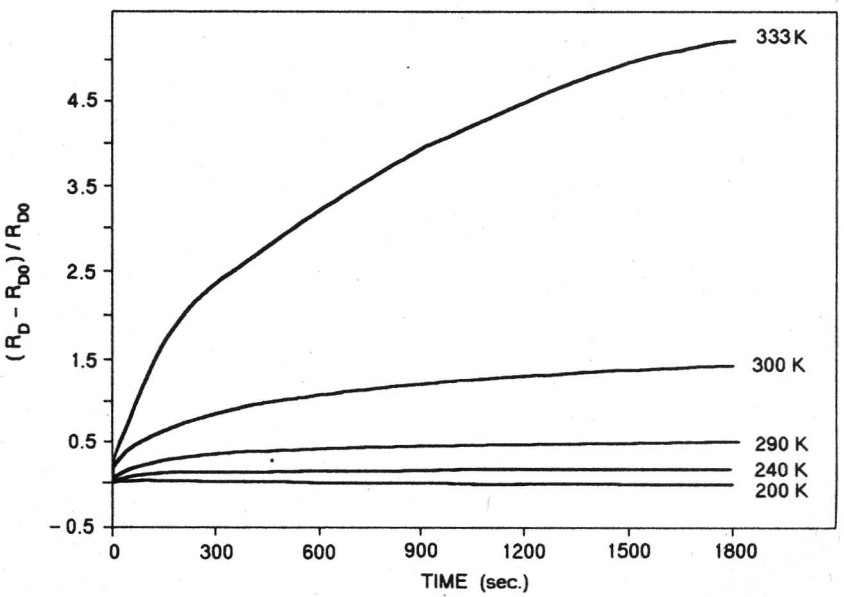


**Fig. 2.** The time dependence of change of contact resistance for $YBa_2Cu_3O_x$/Au junction at different temperatures

centration. The theoretical curves fit well the experimental data and yield the following diffusion coefficients at 300 K :

$D_{BSCCO} = 3.2 \cdot 10^{-19}\ cm^2/s$ and $D_{YBCO} = 3.7 \cdot 10^{-18}\ cm^2/s$.

The time dependence of contact resistance at various temperatures for both materials was also measured (Fig. 2,3). The temperature dependence of the effect observed for YBCO is typical for diffusion processes and no contact resistance changes were measurable at temperatures below 200 K. Much smaller temperature dependence in BSCCO material is evident (Fig. 3). In this case the increase of point contact resistance was still observable at 180 K, but further decrease of resistance still occurred at temperatures lower than 180 K. We believe there exist two counter-going processes causing the resistance change in bulk material. The first process is degradation of BSCCO by oxygen out-diffusion (increase of the resistance), and the second process originates from the penetration of the sharp tip into the material (decrease of the resistance). Moreover, another physical processes may play significant role. The higher oxygen stability of BSCCO resulting from our measurements is in contradiction to the fact that the increase of point contact resistance is stopped for BSCCO at a lower temperature than for YBCO. This may be explained by intrinsic disorder in both YBCO and BSCCO superconductors playing the role of source of mobile oxygen defects, effectively enhancing the oxygen diffusion [14]. The transition from disordered to more ordered state increases the activation energy of diffusion process with subsequent reduction of oxygen diffusion. But it means that the temperature of transition from disordered to ordered state is for BSCCO lower than for YBCO, what has been confirmed by our tunneling measurements [15] too. The details will be described in a forthcoming publication.

The presented results correlate with those obtained by other authors. Ong and co-workers cryogenically deposited counter-electrode on the surface of YBCO single crystal at low temperature. They observed that a tunneling barrier arises after the junction temperature is raised to 200 K [16]. The authors presume oxygen diffusion process, which agrees well with our temperature dependences of point contact resistance versus time (Fig. 2 — oxygen diffusion also stops below 200 K).

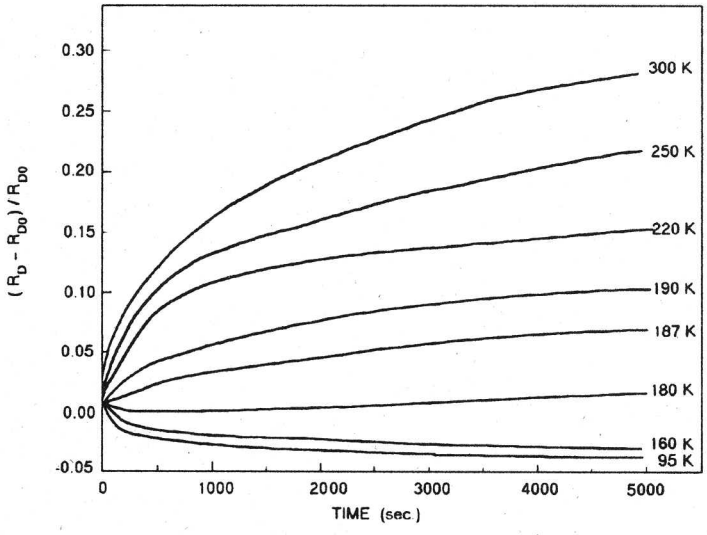


**Fig. 3.** The time dependence of change of contact resistance for $Bi_2Sr_2Ca_2Cu_3O_y$/Ag junction at different temperatures

The similar degradation processes were measured by non-contact method, using measurement of capacitance with one electrode made of HTS materials (both YBCO and BSCCO) [6,17]. All published results confirm higher oxygen stability of BSCCO in comparison to YBCO.

**Conclusions.** The experimentally observed time dependences of the $YBa_2Cu_3O_x$/In,Au and $Bi_2Sr_2Ca_2Cu_3O_y$/Ag point contact resistances were analyzed. The received experimental dependences were fitted by procedure based on the vacancy mechanism of oxygen diffusion in the CuO layers (YBCO) and Bi2O2 layers (BSCCO). The good agreement between fitted theoretical curves and experimental data enables us to obtain oxygen diffusion coefficient for BSCCO and YBCO: $D_{BSCCO} = 3.2 \cdot 10^{-19}$ cm$^2$/s and $D_{YBCO} = 3.7 \cdot 10^{-18}$ cm$^2$/s. The temperature dependence of the point contact differential resistance clearly shows that the degradation of BSCCO surface is stopped at lower temperature than for YBCO one. We suppose that this experimental fact is a consequence of higher oxygen diffusion in intrinsic oxygen disordered state. An increasing of contact resistance was not observed below 180 K.

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