

*S.L. Sidorov, A.I. Dyachenko, V.Yu. Tarenkov, V.F. Zavodovskii*

## DEMONSTRATION OF SUPERCONDUCTING FLUCTUATIONS IN CHARACTERISTICS OF ANDREEV CONTACTS IN Bi2223–Ag AT $T > T_c$

The most problematic issue of the physics of high-temperature superconductivity is the nature of the pseudogap  $\Delta_{PG}$  in electron spectrum of cuprates. In Brillouin zone, the pseudogap  $\Delta_{PG}(\mathbf{k})$  is localized in the neighborhood of the points  $\mathbf{k} = (0, \pm\pi/a_0), (\pm\pi/a_0, 0)$  where  $a_0$  is the lattice constant in the  $\text{CuO}_2$  plane. Within the same area, the energy gap of Cooper pairs  $\Delta(\mathbf{k})$  achieves the maximum. As a result, intrinsic bond can appear between two order parameters. The bond does not reduce to competition for the same areas of the Fermi surface. The solution of this problem requires experiments that are sensitive to the phase of the order parameter of a superconductor. One of these methods is Andreev reflection in normal metal–superconductor contacts, being immediately determined by the existence of Cooper pairs. At Andreev reflection, an electron injected from metal N to superconductor S forms Cooper pair in the neighborhood of NS boundary. The pair goes to condensate and a hole is reflected to the normal metal. Counter-flow of holes results in increase in the current through the contact in comparison to the current in the normal state (excess current). A singularity of conductivity of the contact  $dI/dV$  at  $V \approx \Delta(T)/e$  allows estimation of the value and the symmetry of the energy gap  $\Delta(\mathbf{k})$ . It is demonstrated in the present paper that excess conductivity and current are observed in Andreev contacts  $\text{Bi}_{1.6}\text{Pb}_{0.4}\text{Sr}_{1.8}\text{Ca}_{2.2}\text{Cu}_3\text{O–Ag}$  (Bi2223–Ag) at the temperatures  $T < T_{\text{pair}}$  where  $T_{\text{pair}}$  is above  $T_0 \sim 140\text{–}150$  K (that is the temperature of Nernst effect appearance) and substantially exceeds the temperature of superconducting transition  $T_c \approx 110$  K. This result agrees with detection of diamagnetic response and Nernst effect and does not contradict to recent results of photoemission spectroscopy with high angle resolution (ARPES) for Bi2223 cuprate.

**Keywords:** andreev spectroscopy, energy gap, excess current

**Fig. 1.** Conductivity of Andreev contact Bi2223–Ag ( $T_c = 110$  K) at the temperatures  $T$ , K: 1 – 78, 2 – 95, 3 – 101, 4 – 104, 5 – 110, 6 – 122, 7 – 146. On the insertion –  $R(T)$  dependence for Bi2223

**Fig. 2.** Current-voltage characteristic of contacts Bi2223–Ag ( $T_c = 110$  K) at the temperatures  $T$ , K: 1 – 77, 2 – 101, 3 – 110, 4 – 122, 5 – 146, 6 – 170, 7 – 182. On the insertion – a chart of process of Andreev reflection of electrons (filled mugs) with formation of Cooper pair and hole (empty group)

**Fig. 3.** Temperature dependence of excess current  $I_{\text{exc}}$  (at  $V \sim 200$  mV) (curve 1) and conductivity of contact  $dI/dV$  (at  $V = 0.01$  V) (curve 2)