Superconducting energy gap in $\text{Ba}_{1-x}\text{K}_x\text{BiO}_3$: Temperature dependence

F. Szabó\textsuperscript{a}, P. Samuely\textsuperscript{a}, N.L. Bobrov\textsuperscript{b}, J. Marcus\textsuperscript{c}, C. Escribe-Filippini\textsuperscript{c}, and M. Affronte\textsuperscript{c}

\textsuperscript{a}Institute of Experimental Physics, Slovak Academy of Sciences, CS-04353 Košice, Slovakia
\textsuperscript{b}Institute for Low Temperature Physics and Engineering, Ukrainian Academy of Sciences, Kharkov, Ukraine
\textsuperscript{c}Laboratoire d’Etudes des Propriétés Electroniques des Solides CNRS, BP 166, F-38042 Grenoble Cedex 9, France

Email address: bobrov@ilt.kharkov.ua

(Dated: April 4, 2018; Published Physica C, 235-240, 1873 (1994))

The superconducting energy gap of $\text{Ba}_{1-x}\text{K}_x\text{BiO}_3$ has been measured by tunneling. Despite the fact that the sample was macroscopically single phase with very sharp superconducting transition $T_c$ at $32\, K$, some of the measured tunnel junctions made by point contacts between silver tip and single crystal of $\text{Ba}_{1-x}\text{K}_x\text{BiO}_3$ had lower transition at $20\, K$. Local variation of the potassium concentration as well as oxygen deficiency in $\text{Ba}_{1-x}\text{K}_x\text{BiO}_3$ at the place where the point contact is made can account for the change of $T_c$. The conductance curves of the tunnel junctions reveal the BCS behavior with a small broadening of the superconducting-gap structure. A value of the energy gap scales with $T_c$. The reduced gap amounts to $2\Delta/kT_c = 4 \div 4.3$ indicating a medium coupling strength. Temperature dependence of the energy gap follows the BCS prediction.

PACS numbers: 74.20.Fg; 74,45+c; 74.50.+r; 74.70.-b; 74.70.Dd

Bismuthate superconductors, in contrast to the cuprates with a quasi twodimensional lattice, are fully 3-dimensional with cubic symmetry and diamagnetism in the normal state. Their superconducting properties seem to be understood within the classical theory. Tunneling studies on $\text{Ba}_{1-x}\text{K}_x\text{BiO}_3$ have shown a full superconducting energy gap $\Delta$ with the reduced value $2\Delta/kT_c$ ranging from the weak coupling limit [1, 2] to the medium coupling [3]. It is generally accepted that the electron-phonon interaction plays a role in the superconductivity here [1, 3]. There is on the other hand some similarity with the cuprates. Both perovskites are near the metal-insulator transition triggered by doping. Namely, for $\text{Ba}_{1-x}\text{K}_x\text{BiO}_3$ the system becomes metallic (superconducting) at $x \sim 0.35$. The highest transition temperature $T_c = 32\, K$ is achieved near the metal-insulator transition and then it is decreased down to $20\, K$ for $x = 0.5$, the solubility limit. Asymmetric linear background of the tunneling conductance may indicate strong electronic correlations in the normal state.

The $\text{Ba}_{1-x}\text{K}_x\text{BiO}_3$ crystals used in this experiment were grown by electrochemical method [4]. They are characterized by the high and sharp superconducting transition at $T_c = 32\, K$. They are macroscopically single phase. The point-contact technique has been used to make the tunnel junctions with a silver single crystal as a tip.

![FIG. 1: Tunneling conductance at 4.2 K of the $\text{Ba}_{1-x}\text{K}_x\text{BiO}_3$ – Ag junction with $T_c = 32\, K$ and the fit by the BCS density of states.](image-url)
FIG. 2: Temperature dependence of the spectrum for the tunnel junction with $T_c = 20$ K.

FIG. 3: Temperature dependence of the superconducting energy gap. Dashed line - BCS curve.

by $E' + i\Gamma$ as the only extra parameter (Dynes formula). Actually, the superconducting energy gap $\Delta$ equals to $6 \text{ meV}$ and very small smearing factor $\Gamma = 0.35 \text{ meV}$, $T_c$ of the tunnel junction was $32 \text{ K}$.

We measured also the temperature dependence of the tunneling effect. In few cases we found the transition temperature of the tunnel junction different from the bulk $T_c$. As shown in Fig. 2, the transition $T_c$ was achieved at about $20 \text{ K}$. Lower local $T_c$ can be caused by a presence of microphases of different stoichiometry, e.g. by variation in the concentration of potassium and/or the oxygen deficiency. Local deviations in stoichiometry seem to be a general problem of the bismuthates. It is worth noticing that our sample does not show multiphase character in ac susceptibility and it has a high metallic conductance above $T_c$ [4]. We fitted the experimental data by the Dynes formula with resulting values: $\Delta_0 = 3.5 \text{ meV}$, $\Gamma = 0.5 \text{ meV}$.

In Fig. 3 the temperature dependence of the superconducting energy gap obtained from the data of three different junctions is displayed in the reduced coordinates to account for different $T_c$, resp. $\Delta_0$. In all three cases the data follow the BCS prediction.

The reduced superconducting energy gap $2\Delta/kT_c$ amounts to $4 \div 4.3$ for all junctions. Hence the gap scales with the $T_c$ in $\text{Ba}_{1-x}\text{K}_x\text{BiO}_3$. Presence of microdomains of different phases observed by our point-contact method may affect several physical properties measured in the system.

This work was partially supported by the Commision of the European Communities Contract No.CIPA-CT93-0183.

[1] Q. Huang, J. F. Zasadzinski, N. Tralshawala, K. E. Gray, D.G. Hinks, J. L. Peng, and R. L. Greene, Nature (London) 347, 369 (1990).
[2] F. Sharifi, A. Pargelis, R. C. Dynes, B. Miller, E. S. Hellman, J. Rosamiña, and E. H. Hartford, Jr., Phys. Rev. B 44, 12521 (1991).
[3] E. S. Hellman and E. H. Hartford, Jr. Phys. Rev. B 47, 11346 (1993).
[4] M. Affronte, J. Marcus, C. Escribe-Filippini, A. Sulpice, H. Rakoto, J. M. Broto, J. C. Ousset, S. Askenazy, and A. G. M. Jansen Phys. Rev. B 49, 3502 (1994).