Specific heat of the noncuprate oxide superconductor $Ba_{0.6}K_{0.4}BiO_3$ in magnetic fields

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The specific heat of a single-phase polycrystalline sample of $Ba_{0.6}K_{0.4}BiO_3$ has been investigated in the temperature range 2–50 K in zero field and in magnetic fields up to 16 T. The coefficient of the linear term of the specific heat $\gamma \approx 6.4$ mJ/mole·K^2 has been determined experimentally for the first time, as well as the density of electronic states at the Fermi level $N(\varepsilon_F)$. The jump ΔC in the specific heat corresponding to the superconducting transition has been observed, which indicates the bulk nature of the superconductivity. The value of $\Delta C/\gamma T_c \simeq 1.8$. On the basis of the experimental values of γ and $\Delta C/T_c$ using the phonon model we have calculated the electron-phonon coupling constant λ and the characteristic phonon frequency ω_{ph}, the magnitude of the effective mass, the Fermi energy ε_F, the group velocity of the carriers V_F, the order parameter $\Delta(0)$, and the coherence length. We have found that the value of the effective mass of the electron $m^*/m \simeq 7.7$. We have shown that the value of T_c in $Ba_{0.6}K_{0.4}BiO_3$ is connected with the high characteristic phonon frequency and the relatively large density of electronic states $N(\varepsilon_F)$. The value $\lambda \simeq 0.9$ here corresponds to intermediate coupling.

INTRODUCTION

The study of the specific heat of high-temperature superconductors (HTSC) is aimed at shedding light on the mechanism of their superconductivity. One of the most important characteristics that can be obtained from the temperature dependence of the specific heat is the density of electronic states at the Fermi level $N(\varepsilon_F)$. In the regard, an interesting object of study is the superconductor $Ba_{1-x}K_xBiO_3$, whose critical temperature is quite high. The compound $Ba_{1-x}K_xBiO_3$ is a perovskite analog with a cubic rather than a layered structure like the other HTSC's, and does not contain copper or any magnetic ions. The $Ba_{1-x}K_xBiO_3$ system is very similar in its structure and chemical properties to the known superconducting material $BaPb_{1-x}Bi_xO_3$.

The low-temperature specific heat of $Ba_{0.6}K_{0.4}BiO_3$ has been investigated in a number of papers.[1–4] On the basis of those experiments it was concluded that the density of electronic states in this compound is low and the electron-phonon coupling weak. At the same time, the magnitude of the critical temperature is $T_c \sim 30$ K, which is uniquely high for cubic compounds, for which reason the agreement of these data on the basis of the electron-phonon mechanism of superconductivity raises certain difficulties. There are other data, at first glance contradictory, for example, the significant isotope effect[5,6] and anomalous temperature dependence of the upper critical field in fields up to 8 T.[7]

Of special interest is the temperature coefficient of the electronic specific heat γ. Reliable data on it can be obtained at low temperatures in strong magnetic fields, when the superconductivity is suppressed. However, for $Ba_{1-x}K_xBiO_3$ such measurements have not been carried out.

In the present paper we report a study of the behavior of the specific heat of $Ba_{1-x}K_xBiO_3$ ($x = 0.4$) in the temperature interval $T = 2$–50 K in zero magnetic field and in fields up to 16 T. A jump in the specific heat was observed at the superconducting transition temperature T_c and the magnitude of this jump ΔC was determined. The Sommerfeld parameter γ in the limit $T \to 0$ was estimated, and the experimental values of γ and $\Delta C/T_c$ thus obtained were used to estimate the density of electronic states at the Fermi level $N(\varepsilon_F)$ and the electron-phonon coupling constant λ. Measurements of the magnetic susceptibility were carried out simultaneously, which also allowed us to estimate the density of electronic states at the Fermi level. Then, using the standard electron-phonon model we discuss the parameters of the normal and superconducting states, the understanding of which is very important for an understanding of the pairing mechanism in this cubic perovskite superconductor. A comparison is also made of the main parameters of $Ba_{0.6}K_{0.4}BiO_3$ with the parameters of the HTSC $La_{1.8}Sr_{0.2}CuO_4$ and those of ordinary superconductors.

SAMPLES

The compound $Ba_{1-x}K_xBiO_3$ possesses superconducting properties only in the cubic phase near the boundary of the metal-insulator transition ($x \approx 0.37$). Superconductivity disappears at the transition to the insulator (semiconductor) phase as the potassium concentration decreases. In the cubic phase near the metal-insulator transition in the normal

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state the resistance of the sample has an essentially metallic character.

Samples of $Ba_{0.6}K_{0.4}BiO_3$ were prepared by the nitrate method[7] in which a finely grained starting mixture of Bi_2O_3, KNO_3, and $Ba(NO_3)_2$ powders was baked without pressing at a temperature of 715 °C in a nitrogen atmosphere. The baking time depends on the quantity of material (for two grams of mixture it is approximately one hour). Then the temperature was abruptly lowered and the quenched sample was annealed for 30 minutes at 450 °C in a stream of oxygen. At the end of the cycle the temperature was slowly lowered and after 5 hours was brought to 150 °C. The mixture was ground and the entire process was repeated anew. After the fifth cycle the powder was pressed into a pellet, baked and annealed one more time. X-ray diffraction analysis demonstrated that the samples obtained in this manner were single-phase. The period of the cubic unit cell a was found to be equal to 4.285 Å.

It is possible to judge the single-phase character of the sample also from the magnitude of the magnetic susceptibility χ, since impurity phases differ substantially in the paramagnetic component of the susceptibility.[8,9] The temperature-independent part of χ is in good agreement with the data of Ref. 8 and indicate that all the initial components reacted, and the small Curie–Weiss contribution to the susceptibility can be explained by the presence of traces of potassium dioxide,[9] containing less than 1% of the potassium.

The superconducting transition temperature T_c, determined resistively, is equal to 29.6 K, the width of the transition being equal to 2 K. From the inductive measurements (at a frequency of 1.5 kHz) we find $T_c = 29$ K.

The small value of the first critical field and strong pinning make it difficult to determine the fraction of superconducting phase by measuring the ratio of the magnitude of the Meissner effect to the magnitude of the effect of screening by the magnetic field: Thus the value of this ratio, measured with the help of a vibrational magnetometer in a field of 2 Oe, is 0.5, while the Meissner effect, measured by a SQUID magnetometer in a field of 30 Oe, contributes only 2% of the screening effect. The reason for the change in this ratio is the small value $H_{c1} \sim 10$ Oe of the lower critical magnetic field.[10] Thus, we can confirm that the superconducting phase makes up at least 50% of the bulk of the sample.[1)]

EXPERIMENTAL TECHNIQUE

The specific heat of the sample in the interval 2–50 K in zero field and in fields up to 16 T was measured by the adiabatic method[10] with an error less than 2%. The contribution of the sample holder to the measured heat capacity in the investigated temperature range was less than 50% and was measured independently in zero field and in fields up to 16 T.

The temperature dependence of the magnetic susceptibility in the temperature interval 4–300 K was determined by the Faraday method in a magnetic field with an induction of 5 T and with the help of a string magnetometer.[12]

The superconducting transition temperature of the sample was determined by the inductive method (at a frequency of 1.5 kHz) as well as the four-contact resistive method.

RESULTS AND DISCUSSION

Results of our study are presented in Figs. 1–3 and in Table I. Figure 1 presents experimental data on the low-temperature specific heat in the temperature range $T = 2$–7 K in zero field and in fields 8, 12, and 16 T plotted as C/T vs T^2. It can be seen that at low temperatures the specific-heat data are well described by the dependence $C/T = \gamma^* + \beta T^2$, which is characteristic of normal metals. The phonon specific heat, which is cubic in the temperature, as can be seen from the figure, is practically the same in zero field and in fields up to 16 T. The corresponding value of the Debye temperature is 296 K and is practically independent of the magnetic field H.

In the investigated sample the value of the coefficient of the linear term of the specific heat γ^* at low temperatures is close to zero in the measurements in zero field. This proves convincingly that the entire metallic part of the sample is the superconducting state. In fields from 8 to 16 T, when the sample is in the mixed state, the coefficient satisfies $\gamma^* = 1.6$ mJ/mole·K^2 in a field of 8 T, 2.2 mJ/mole·K^2 in a field of 12 T, and 2.5 mJ/mole·K^2 in a field of 16 T.

The straight line for $H = 16$ T in Fig. 1 does not pass through all the experimental points. For extrapolation we chose that temperature interval where $C(T)/T^3 \sim$ const (see Fig. 3), i.e., where the magnetic (T^{-2}) and phonon (T^5) contributions are minimal. To correctly determine the dependence of γ^* on H in the intermediate state in the HTSC, it is necessary either to subtract the magnetic contribution from the total specific heat or estimate the extrapolation coefficient out of the temperature range where this contribution is insignificant. Therefore, for the measurements in a field of 16 T the extrapolation was made from the region 6–8 K, and for zero field, from the region 2.5–7 K.

It has been established both theoretically and experimentally that in type-II superconductors, to which $Ba_{0.6}K_{0.4}BiO_3$ in the mixed state belongs, the electronic contribution to the specific heat (the linear term) depends on the magnetic field H, reaching the value of the Sommerfeld parameter γ at $H = H_{c2}(0)$ [here $H_{c2}(0)$ is the upper criti-

TABLE I.

Property	Ordinary metals	$Ba_{0,6}K_{0,4}BiO_3$	$La_{1,8}Sr_{0,2}CuO_4$
T_c, K	< 24	30	40
m^*/m	1 — 15	7,7	5
ε_F, eV	5 — 10	0,23	0,15
V_F, cm/s	$(1-2)\cdot 10^8$	$9{,}9\cdot 10^6$	$8\cdot 10^6$
ξ_0, Å	$10^3 - 10^4$	43	20
$H_{c2}(0)$, T	< 40	≥ 20	90

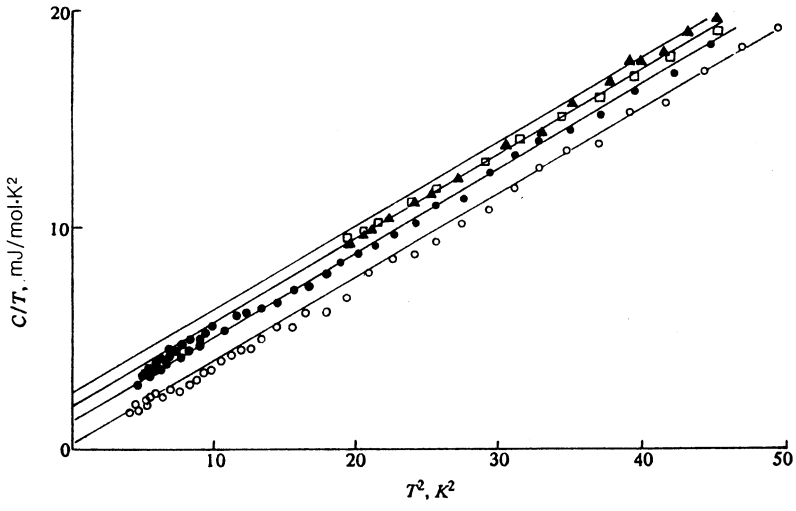

FIG. 1. Temperature dependence of the specific heat of $Ba_{0.6}K_{0.4}BiO_3$ in the low temperature region plotted as C/T vs T^2 in magnetic fields $H = 0$ (○) (the different symbols correspond to different experiments), $H = 8$ T (●), $H = 12$ T (□), $H = 16$ T (▲).

cal field at $T = 0$]. Thus, the value of γ can be obtained by extrapolating the field dependence $\gamma^*(H)$ to $H_{c2}(0)$. To estimate the coefficient of the electronic term γ, we used the relation $\gamma = H_{c2}(0) \cdot d\gamma^*/dH$. Figure 2 plots the dependence of C/T on T for the investigated sample in the vicinity of T_c. The jump in the specific heat at $T = 27$ K can be clearly observed, as can the variation in the slope of the temperature dependence of C/T after the jump. From the magnitude of the jump $\Delta C/T_c \approx 6$ mJ/mole·K^2 it follows that superconductivity in the sample is a bulk phenomenon.

A magnetic field of $H = 8$ T has a marked effect on the specific heat for $T \leqslant T_c$, as a result of which the jump ΔC vanishes in this temperature range.

From the observed jumps in the specific heat and the variations in the slope of the dependence of C/T on T corresponding to such jumps, and also the jump in the magnetic susceptibility χ in a field of $H = 5$ T it is possible to construct the dependence of $H_{c2}(T)$ shown in the inset to Fig. 2. From this dependence it is possible to estimate the lower limit $H_{c2}(0) = 20$ T. The extrapolation line passing through the low-field points (down to 7 T) (for data on which see the review in Ref. 1) also yields this value of $H_{c2}(0)$. This value was used in the other estimates.

The derivative $d\gamma^*/dH$ was determined from the dependence of γ^* on the magnetic field H. According to our estimates[2] $\gamma = 3.2$ mJ/mole·K^2. Thus, we get $\Delta C/\gamma T_c \approx 1.8$, which is characteristic of superconductivity. Note that the value of γ, experimentally obtained in this way (like the magnitude of the jump ΔC) is only half of the true value. The point here is that the investigated sample of $Ba_{0.6}K_{0.4}BiO_3$ is only 50% superconducting phase, as was noted above. Taking this fact into account, it may be asserted that in $Ba_{0.6}K_{0.4}BiO_3$ the parameter γ at low temperatures is equal to 6.4 mJ/mole·K^2.

As we just noted, the parameter $\Delta C/\gamma T_c \approx 1.8$ exceeds the value 1.43 given by BCS theory. In other words, the compound $Ba_{0.6}K_{0.4}BiO_3$ does not belong to the class of superconductors with weak coupling, but is rather a system with intermediate coupling, for which $\lambda \approx 1$. Therefore in determining the density of electronic states from γ it is necessary to take into account its renormalization due to electron-phonon coupling.

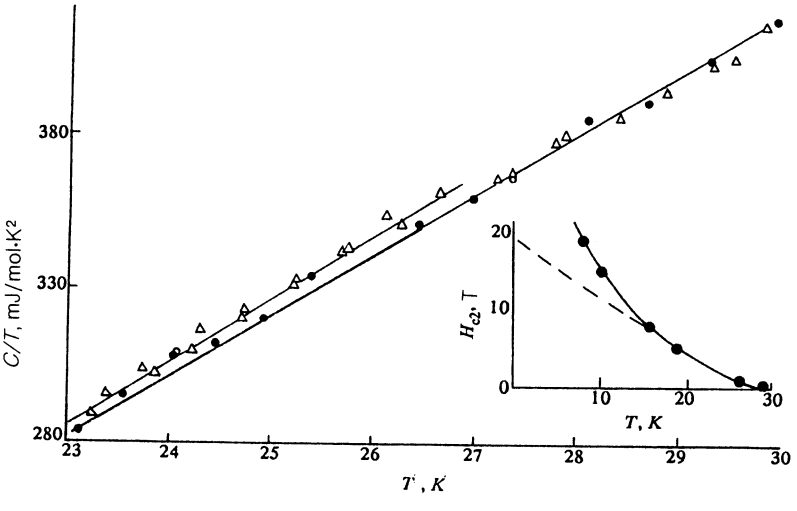

FIG. 2. The specific heat of $Ba_{0.6}K_{0.4}BiO_3$ in the vicinity of T_c plotted as C/T vs T: $H = 0$ (●) and $H = 8$ T (△). The inset shows the dependence $H_{c2}(T)$, obtained from the specific heat and magnetic susceptibility (the dashed line is an extrapolation of the low-field data to $T = 0$).

Using independent experimental values of γ and the magnitude of the specific-heat jump $\Delta C/T_c$, it is possible within the framework of the phonon model to calculate the main parameters of the electron-phonon coupling, i.e., the coupling constant λ and the characteristic phonon frequency ω_{ph} averaged over the coupling spectrum. Toward this end, we first apply the standard formula for the jump in the specific heat at T_c. It is well known[13] that in the case of strong coupling the deviation of the ratio $\Delta C/\gamma T_c$ from the value given by BCS theory is given by the expression

$$\frac{\Delta C}{\gamma T_c} = 1{,}43\left(1 + \alpha\left(\frac{k_B T_c}{\hbar\omega_{ph}^2}\right)\ln\frac{\hbar\omega_{ph}}{\beta k_B T_c}\right).$$

According to Ref. 12 the quantities α and β are 18 and 3, and according to Ref. 13, $2.56\pi^2$ and $e = 2.71$.[14] Note that $\Delta C/\gamma T_c$ depends only on the ratio T_c/ω_{ph}. Knowing ΔC, γ, and T_c, we can determine the value of the characteristic frequency. We obtain $\omega_{ph} = 450$ K. (We used the numerical values of the coefficients α and β from Ref. 14.) This latter fact means that the coupling of the electrons with the optical modes associated with the oxygen atoms is responsible for their pairing.

In the case of intermediate coupling the critical temperature T_c is related to the electron-phonon coupling constant λ and the phonon frequency ω_{ph} by the simple expression:[15]

$$T_c = \frac{\hbar\omega_{ph}}{7{,}45k_B}(\lambda - 0{,}48).$$

Hence we find $\lambda \simeq 0.9$. An analogous result follows from using a more accurate formula, e.g., that of MacMillan.[16] This estimate confirms the conclusion that in $Ba_{0.6}K_{0.4}BiO_3$ we are dealing with a superconductor with intermediate coupling.

Knowing the value of the parameter λ, we can immediately find the band density of electronic states at the Fermi level. Noting that

$$\gamma = \frac{2}{3}\pi^2 k_B N(\varepsilon_F)(1+\lambda),$$

we find $\gamma_{band} = \gamma/(1+\lambda) = 3.4$ mJ/mole·K^2, which corresponds to a density of electronic states at the Fermi level $N(\varepsilon_F) = 0.72$ states/eV·spin·atom.

Let us turn our attention to the results presented in Fig. 3, which displays the temperature dependence of the specific heat in the region 2–50 K plotted as C/T^3 vs T. This dependence contains information about the energy density of the phonon states in the low-energy region ($\omega \sim 9$ mV), which is confirmed by neutron measurements of the phonon spectrum.[17] In this figure the variation of the specific heat with the magnetic field is plainly visible.

Results of measurements of the magnetic susceptibility in the region 2–300 K are displayed in Fig. 4. Over a wide temperature range the susceptibility is negative and depends only weakly on temperature. Since the measurements of $\chi(T)$ were made in a field ~ 5 T, the observed transition is displaced toward lower temperatures and the onset of the transition is observed at 19 K. At temperatures in the range 250–300 K the value of $\chi(T)$ stands at $5.7\cdot10^{-5}$ emu/mole, which agrees with the results of Ref. 8. These latter results are presented in Fig. 4 for comparison.

To estimate the density of electronic states at the Fermi level from the data we assume that besides the spin paramagnetism, only the diamagnetism of the filled electronic shells χ_{core} contributes to the temperature-independent part of the magnetic susceptibility $\chi = 6\cdot10^{-5}$ emu/mole, i.e., $\chi_0 = k\chi_{Pauli} + \chi_{core}$, where k is the concentration of the metallic phase in the sample. Using tabulated values of the radii of the filled shells,[18] we obtain a value for the contribution of the filled electronic shells: $\chi_{core} = -7.8\cdot10^{-5}$ emu/mole. We assume that the quantity of metallic phase in the sample is equal to the quantity of superconducting phase, i.e., $k = 0.5$. Then for the Pauli paramagnetism we estimate $\chi_{Pauli} = 3.6\cdot10^{-5}$ emu/mole. Since the density of electronic states $N(\varepsilon_F)$ is expressed directly in terms of the Pauli susceptibility, we have $N(\varepsilon_F) = (2\mu_B^2)^{-1}\cdot\chi_{Pauli} = 0.54$ states/eV·spin·atom (here μ_B is the Bohr magneton).

It should be emphasized that the two values of the elec-

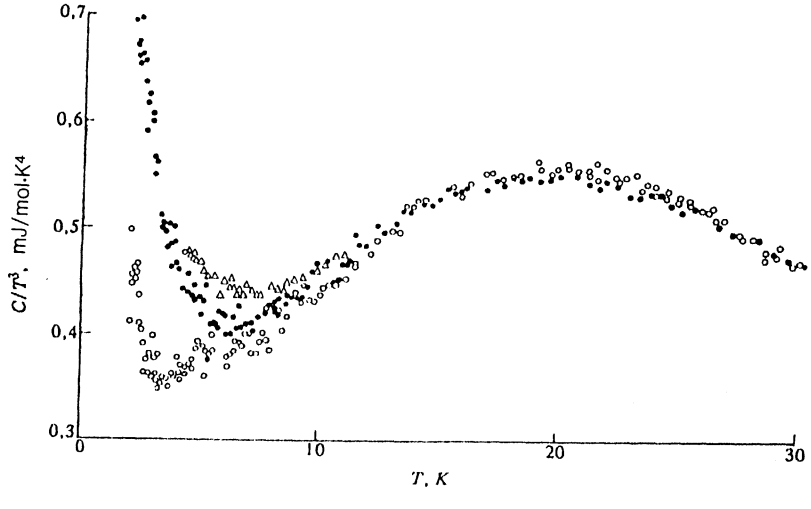

FIG. 3. Temperature dependence of the specific heat in the region 2–30 K plotted as C/T^3 vs T: $H = 0$ (○), $H = 8$ T (●), $H = 16$ T (△).

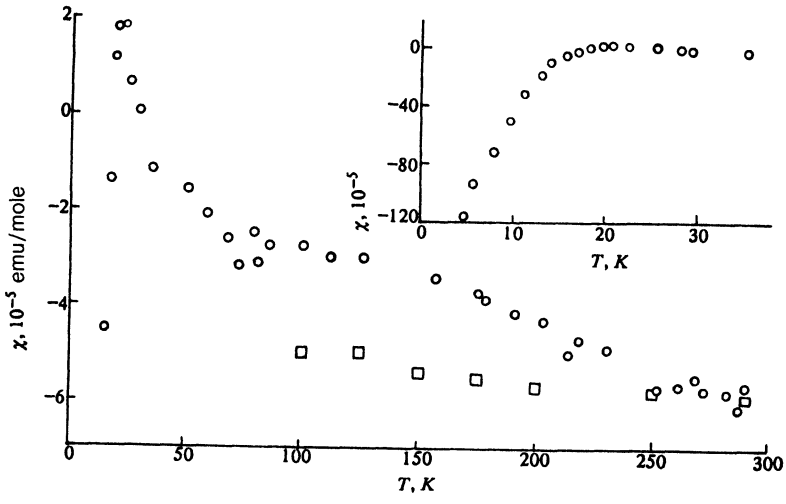

FIG. 4. Temperature dependence of the magnetic susceptibility of $Ba_{0.6}K_{0.4}BiO_3$ in the temperature range 4–300 K: ○—present work, □—Ref. 8. The inset shows the superconducting transition in a field of 5 T.

tronic density of states at the Fermi level $N(\varepsilon_F)$ obtained by two different methods from measurements of the specific heat and the magnetic susceptibility turn out to be close. Using these experimental results in the quasifree electron approximation, we also estimated other fundamental normal and superconducting parameters of the cubic perovskite $Ba_{0.6}K_{0.4}BiO_3$. Knowing the value of the coefficient of the electronic contribution to the specific heat γ and assuming that the dispersion law is quadratic $\varepsilon = p^2/2m^*$ and that the electron volume concentration n coincides with the volume concentration of the potassium atoms $n = x/a^3$ (i.e., each alloying atom of potassium gives up one charge carrier to the conductivity band), we can estimate the effective mass of the electron m^* by making use of the following relations:

$$n = \frac{x}{a^3} = \frac{g}{(2\pi\hbar)^3}\frac{4\pi}{3}p_F^3,$$

$$\gamma = \frac{\pi^2 k_B^2}{3}\frac{\partial n}{\partial \varepsilon}N_A \cdot a^3 = m^* \frac{g k_B^2 a^2 N_A}{\hbar^2}\left(\frac{\pi^2 x}{36g}\right)^{1/3},$$

where g is the spin degeneracy (in a system with a strong Hubbard potential $g = 1$), k is Planck's constant, p is the quasi-momentum, p_F is the Fermi momentum, x is the concentration of the alloying element, a is the lattice constant in the cubic structure, k_B is the Boltzmann constant, N_A is Avogadro's number, and ε is the electron energy. For $x = 0.4$ we find that $m^*/m = 7.7$. Thus, in $Ba_{0.6}K_{0.4}BiO_3$ the mass of the electron turns out to be approximately eight times greater than the mass of the free electron m.

The Fermi energy can be estimated from the formula

$$\varepsilon_F = \frac{\pi^2}{2}\frac{xN_A k_B^2}{\gamma} = 1800\ \text{K} = 0{,}23\ \text{eV}.$$

Consequently, $\mathscr{E}_F$ for $Ba_{0.6}K_{0.4}BiO_3$ is much smaller than in ordinary metals, where it typically ranges from 5 to 10 eV. Estimating the Fermi velocity V_F and momentum P_F as well, we have

$$V_F = \frac{2\pi^2}{3}\left(\frac{3x}{4\pi}\right)^{2/3}\frac{aN_A k_B^2}{\gamma_z} = 9{,}9\cdot 10^6\ \text{cm/s},$$

$$p_F = \frac{2\pi\hbar}{a}\left(\frac{3x}{4\pi}\right)^{1/3} = 7\cdot 10^{-20}\ \text{g·cm/s}.$$

Note that the small value of the Fermi velocity is another feature of $Ba_{0.6}K_{0.4}BiO_3$ that contrasts with ordinary superconductors, for which V_F is ordinarily $(1.5\text{–}2)\cdot 10^8$ cm/s.

As to the coherence length, within the framework of the standard theory

$$\xi_0 = \frac{0{,}18\hbar V_F}{k_B T_c} = \frac{\hbar V_F}{\pi\Delta(0)} = 43\ \text{Å}.$$

The small value of the coherence length is due to the low Fermi velocity and relatively high T_c.

Finally, the gap energy at $T = 0$, $\Delta(0)$, is related to T_c as follows: $2\Delta(0) = \alpha k_B T_c$, where α depends on the coupling strength (for weak coupling $\alpha = 3.52$). Making use of the experimental results obtained for T_c and ω_{ph} for $Ba_{0.6}K_{0.4}BiO_3$, we calculate the value of $\Delta(0)$ from the formula (see, e.g., Ref. 15)

$$\Delta(0) = 1{,}76\left[1 + \pi\left(\frac{T_c}{\omega_{ph}}\right)^2 \ln\frac{1{,}13\hbar\omega_{ph}}{ek_B T_c}\right]k_B T_c$$

and find $\Delta(0) \simeq 60$ K (i.e., $2\Delta(0)/k_B T_c = 4$).

Let us turn our attention now to the fact that the ratio $\Delta(0)/\varepsilon_F$ in ordinary superconductors is $\sim 10^{-4}$, while in $Ba_{0.6}K_{0.4}BiO_3$ we have $\Delta(0)/\varepsilon_F \sim 10^{-2}$. The ratio $\Delta(0)/\varepsilon_F$ characterizes the number of electronic states near the Fermi level existing as Cooper pairs. The fairly large value of $\Delta(0)/\varepsilon_F$ for $Ba_{0.6}K_{0.4}BiO_3$ indicates a high density of Cooper pairs and a short coherence length.

Comparative estimates of the fundamental normal parameters of the high-temperature superconductors

$Ba_{0.6}K_{0.4}BiO_3$ and $La_{1.8}Sr_{0.2}CuO_4$ (Ref. 19) and ordinary metals are given in Table I.

As can be seen from the table, the main parameters of the cubic perovskite $Ba_{0.6}K_{0.4}BiO_3$ are very close in value to the same parameters for the layered cuprate and differ substantially from the values of those parameters for ordinary metals.

CONCLUSION

On the basis of these experimental results and estimates of the basic normal and superconducting parameters of $Ba_{1-x}K_xBiO_3$ that are important for understanding the physics of HTSC's, it is possible to draw the following conclusions:

1. The electronic specific heat coefficient $\gamma(0)$ has been determined for the first time from specific heat measurements in magnetic fields, which has allowed us to estimate the band density of states at the Fermi level $N(\varepsilon_F)$. This quantity was also determined independently from measurements of the magnetic susceptibility. The values of $N(\varepsilon_F)$ so obtained are close. It turns out that the density of electronic states of $Ba_{0.6}K_{0.4}BiO_3$ is relatively high and comparable to the density of states in ordinary superconductors.

2. The value of the ratio $\Delta C/\gamma T_c$ has been experimentally determined to 1.8, which is greater than the value given by BCS theory. The experimentally determined values of $\gamma(0)$ and the jump in the specific heat at T_c, $\Delta C/T_c$, has allowed us to calculate the main parameters of the spectrum of attractive coupling λ and ω_{ph} within the framework of the phonon model. We find that $\lambda \sim 0.9$, which corresponds to intermediate coupling. The characteristic frequency of the spectrum ω_{ph} is ~ 450 K and is close to the mean phonon frequency obtained by inelastic neutron scattering. In other words, electron pairing takes place as a result of the optical phonon modes associated with the oxygen atoms.

3. The effective mass of the electron in $Ba_{0.6}K_{0.4}BiO_3$ has been estimated. Because of the large value of $N(\varepsilon_F)$ and the simultaneously low electron concentration, the corresponding value of the effective mass turns out to be relatively large: $m^*/m \sim 7.7$.

4. On the basis of our estimates of the parameters of the electronic spectrum—the Fermi energy ε_F and the group velocity of the carriers V_F—we can say that a distinguishing feature of $Ba_{0.6}K_{0.4}BiO_3$ is the small value of both ε_F and V_F, which are an order of magnitude smaller than in ordinary metals.

5. Using the experimental values of T_c and ω_{ph}/T_c we have determined the order parameter $\Delta(0) = 60$ K. Consequently, the specific parameter $\Delta(0)/\varepsilon_F$ is two orders greater than in ordinary superconductors, as a result of which the coherence length is found to be small, equal to ~ 43 Å. We find $2\Delta(0)/k_B T_c = 4$.

6. The main physical parameters of the cubic perovskite $Ba_{0.6}K_{0.4}BiO_3$ are quite close to those of layered cuprate $La_{1.8}Sr_{0.2}CuO_4$ and differ substantially from the parameters of ordinary metals.

7. The observed value of T_c is due to the high value of the characteristic frequency of the phonon spectrum and the relatively high density of states $N(\varepsilon_F)$, with $\lambda \sim 0.9$, which corresponds to intermediate coupling. The combination of the small value of the current carrier concentration and the high density of electronic states $N(\varepsilon_F)$ leads to strong electronic correlations, which is a distinguishable feature of HTSC's.

In conclusion, we would like to express our gratitude to N. A. Chernoplekov and M. N. Khlopkin for useful and fruitful discussions.

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[1)] In order to be specific we will take the volume of the superconducting phase to be equal to 50% in what follows.

[2)] Although $H_{c2}(T)$ has an anomalous character and the real value of $H_{c2}(0)$ is undoubtedly greater than 20 T, this changes the estimate of γ only slightly, taking into account saturation of the dependence of $\gamma(H)$ at high H.

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