THE FLUCTUATION CONDUCTIVITY IN $Bi_{1,7}Pb_{0,3}Sr_2Ca_2Cu_3O_y$

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The mechanism of formation of excess conductivity in cuprate HTSC $Bi_2Sr_2CaCu_2O_x$ and $Bi_{1.7}Pb_{0.3}Sr_2Ca_2Cu_3O_y$ was considered in the framework of the Ginzburg-Landau theory model, with the Varlamov and Livanov correction. The temperature transition T_0 from the 2D fluctuation region to the 3D region (the temperature of the 2D-3D crossover) was calculated. The values of the coherence length $\xi_c(0)$ along the axis c Cooper couples and their interplanar coupling constant (J) have been calculated.

Keywords: superconductivity, pseudogap, excess conductivity, coherence length, composition.
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INTRODUCTION

Although more than thirty years have passed since the discovery of bismuth-containing high-temperature superconducting materials, their synthesis is an unsolved problem. The main disadvantages of traditional production of HTSC materials methods of this homologous series are low speed, incomplete completion of the solid-phase reaction, and also the complexity of directional formation of the real structure of the final material, which determines its structure-sensitive properties [1,2]. To date, three superconducting phases with the general formula $Bi_2 (SrCa)_{n+1} Cu_nO_x$ (n = 1,2,3), abbreviated as Bi Sr Ca Cu, are found in the Bi-Sr-Ca-Cu-O system as 2201, 2212, 2223. The critical temperature T_c increases with increasing Ca and Cu content and reaches 10K-35K, 80K-90K and 100-110K for phases 2201, 2212 and 2223, respectively [1-4].

It is known that the HTSC ceramics on Bi-based are of great interest in connection with the existence in it of a phase with T_c>100 K. However, the synthesis of this phase is a complex problem, since along with the $Bi_2Sr_2Ca_2Cu_3O_X$ phase, for which T_k>100K, a $Bi_2Sr_2CaCu_2O_X$ phase with T_c≈80K is formed, as well as non superconducting phases [1].

We note that $BI_{1,7}Pb_{0,3}Sr_2Ca_2Cu_3O_y$ is a convenient object for studying the formation mechanism of excess conductivity in cuprate compounds. We note that the partial substitution of bismuth by lead in the composition $Bi_2Sr_2Ca_2Cu_3O_x$ leads to an increase in the volume fraction of 2223 in the polycrystal [5,6]. Also, the presence of lead in polycrystals $Bi_2Sr_2Ca_2Cu_3O_x$ (B1) and $Bi_{1,7}Pb_{0,3}Sr_2Ca_2 Cu_3O_y$ (B2) promotes an increase in the ratio of Cu^{3+} / Cu^{2+} and, correspondingly, an increase in the critical temperature T_c, as well as decrease in the specific resistivity. This means that such a substitution leads to an increase in the state density of charge carriers [7-10].

It is known that the longitudinal and transverse coherence lengths in HTSC materials are very small [1, 2]. Short coherence lengths lead to a rather small volume of coherence. As a result, thermodynamic fluctuations play an important role in these systems. The study of the fluctuation conductivity above Tc is directly related to the formation of coupled electrons and also it considers the mechanisms of their occurrence. The method of fluctuation conductivity is an effective method of obtaining information about the behavior of a superconductor in the region of a phase transition. Substitution in HTSC leads to a change in the electronic system and, as a consequence, to a change in the microscopic parameters of the superconductor.

The aim of this work is to determine the effect of partial substitution of bismuth by lead in Bi-Sr-Ca-Cu-O on parameters of fluctuation conductivity.

EXPERIMENTAL RESULTS AND DISCUSSION

The procedure for obtaining $Bi_2Sr_2Ca_2Cu_3Ox$ (B1) and $Bi_{1,7}Pb_{0,3}Sr_2Ca_2 Cu_3Oy$ (B2) compounds is described in our work [11]. The powdered oxides and carboxyls of Bi_2O_3, PbO, $SrCO_3$, $CaCO_3$, and CuO of purity of 99.99% have been used in the synthesis of samples B1 and B2. The ratio of the initial components corresponded to the 2: 2: 2: 3 phase. The solid-phase reaction was carried out in two stages: first, at the temperature 1223K for 10 h, the intermediate products $Sr_2Ca_2Cu_3O_x$ and $Pb_{0.3}Sr_2Ca_2Cu_3Oy$ have been synthesized. The cooled mixture was triturated, the required amount of Bi_2O_3 was added to it and mixed well. Then the mixture was pressed into a tablet, sintering was carried out at 1123K for 48 hours, followed by quenching in air. Thus, $Bi_2Sr_2Ca_2Cu_2O_x$ polycrystals (containing up to (70-80)% phase 2212 with a mixture of 2202 and 2223 phases) and $Bi_{1.7}Pb_{0.3}Sr_2Ca_2Cu_3O_y$ (the content of the 2223 phase in the polycrystal was about 90%) were obtained.

The X-ray phase analysis was carried out for polycrystalline B1 and B2 samples [11]. On the basis of the radiograph, the percentage of 2212 and 2223 phases was calculated and the present additional was determined. The content of the 2212 phase in polycrystalline B1 was 70-80%, whereas the content of phase 2223 in polycrystalline B2 was already about 90%.

The temperature dependences of the resistivity of the B1 and B2 specimens are shown in Fig1. The critical temperatures of the SC transition T_c were determined from the maximum dρ/dT, obtaining by differentiating the curve ρ(T) fig.2.

As seen from Fig.1, partial substitution of Bi by Pb in the Bi-Sr-Ca-Cu-O system leads to an increase in the critical temperature from Tc_1 = 90.5K (sample B1) to Tc_2 = 100.09K (sample B2).

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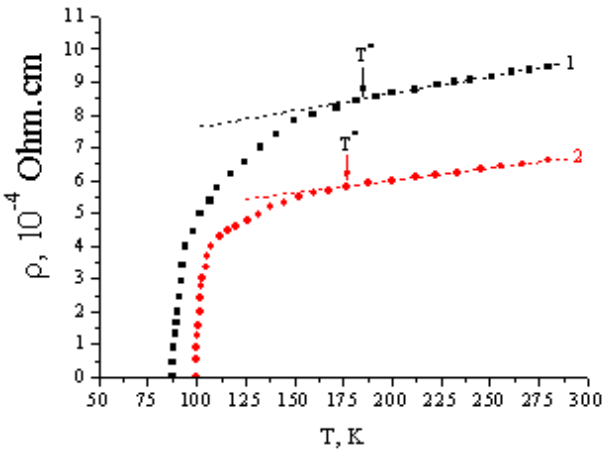

Fig.1. Temperature dependence of specific resistivity in B1 and B2, correspondingly 1 and 2.

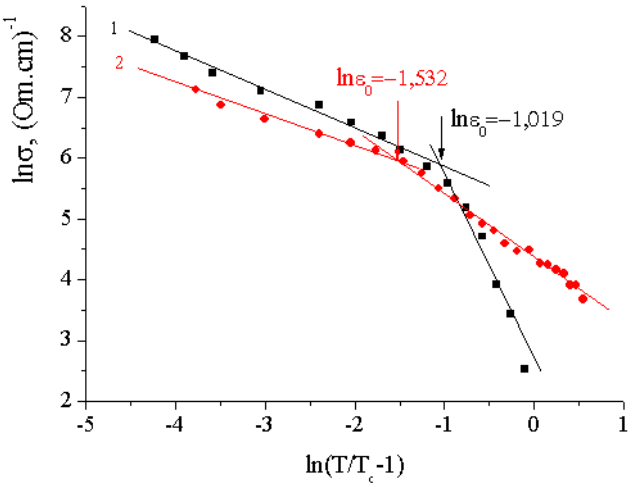

Fig.3. Dependence of excess conductivity logarithm from $\ln(T/T_c-1)$ in composition B1 and B2, correspondingly 1 and 2.

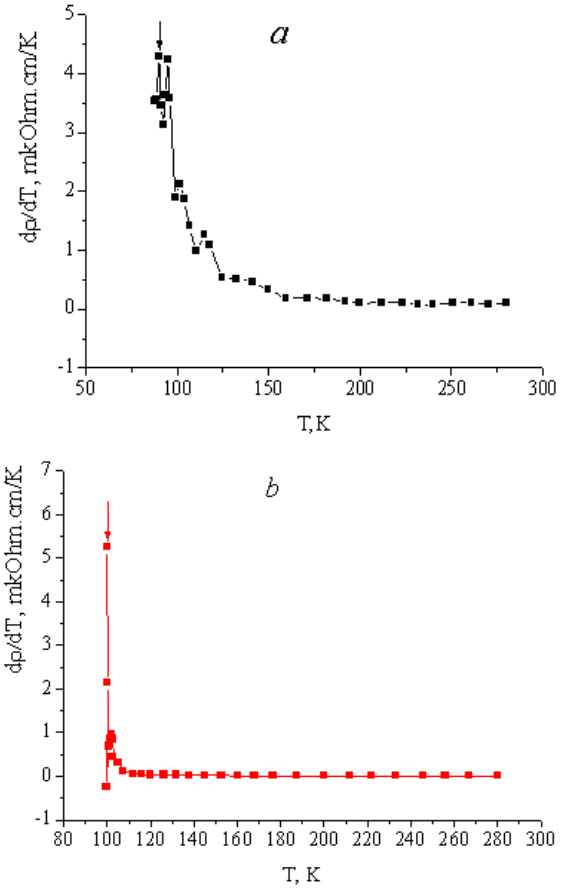

Fig.2. Temperature dependence of $d\rho/dT$ in the area of HS in composition B1 and B2, correspondingly *a* and *b*.

In this case, the resistivity ρ of the sample $Bi_{1.7}Pb_{0.3}Sr_2Ca_2Cu_3O_y$ in the normal phase decreases by almost 1.5 times in comparison with $Bi_2Sr_2Ca_2Cu_3O_x$.

It is known that there are two fluctuation contributions to the conductivity. A direct contribution, theoretically substantiated by Aslamazov and Larkin (AL) [12], arises as a result of spontaneous formation above T_c of Cooper couples created by fluctuations. The additional contribution introduced by Maki and Tompson (MT) [13, 14] to the development of AL theory is interpreted as the result of the interaction of already existing fluctuation couples with normal charge carriers and is determined by the processes of ancoupling in a particular sample. The contribution of the MT contribution depends on the lifetime of the fluctuation couples and it dominates in the region of two-dimensional 2D fluctuations in the case of weak ancoupling. The AL mechanism dominates in the three-dimensional 3D region of the phase transition near T_c. Thus, as the temperature approaches Tc, a change in the fluctuation mechanisms must be observed experimentally. In the layered structures, including HTSC, the AL contribution is usually determined by the Lawrence-Donijah (LD) model, which predicts a smooth dimensional crossover from 2D to 3D fluctuation behavior at $T \rightarrow T_c$.

In the framework of the Ginzburg-Landau theory, the fluctuation correction to conductivity in HTSC materials was calculated by Varlamov and Livanov [15]. According to this theory, the additional conductivity has the form.

$$\Delta\sigma = \left(\frac{e^2}{16\hbar d}\right)\left(\frac{T}{T_c}-1\right)^{-1}\left[1+J\left(\frac{T}{T_c}-1\right)^{-1}\right]^{-1/2} \qquad (1)$$

Where $J=(2\xi_c(0)/d)2$ – the constant of interlayer coupling, d –distance between layers.

It can be seen from equation (1) that at high temperatures, $T >> T_c$ (where $J<<\varepsilon$; $\varepsilon=(T/T_c-1)$, $\Delta\sigma$ is proportional to ε^{-1} (2D-conductivity), and when

approaching the transition temperature T_c (where J>>ε), Δσ varies to proportion $\varepsilon^{-1/2}$ (3D – conductivity).

The Figure 3 shows the dependence of the reduced electrical conductivity on temperature in the studied samples. This dependence shows a transition from 2D to 3D conductivity. The temperatures of the 2D-3D crossover (T_{cr}) of the studied samples are determined from the condition ε=4γ; where $\varepsilon=(T-T_c)/T_c$ and $\gamma=(\xi_c(0)/d)^2$, i.e.

$$T_{cr}=T_c\{1+4(\xi_c(0)/d)^2\} \qquad (2)$$

For the bismuth system, d (2212) = 15 Å and d (2223) = 19 Å [16].

The interlayer coupling constant J (0.377-$Bi_2Sr_2Ca_2Cu_3O_x$ and 0.21274-$Bi_{1.7}Pb_{0.3}Sr_2Ca_2Cu_3O_y$), the coherence length $\xi_c(0)$ (4.606Å-$Bi_2Sr_2Ca_2Cu_3O_x$, and 0.442- $Bi_{1.7}Pb_{0.3}Sr_2Ca_2Cu_3O_y$) are also estimated.

As seen from these experimental data, the partial substitution of bismuth by lead in $Bi_2Sr_2Ca_2Cu_3O_x$ leads to an increase in the volume fraction of 2223 in the polycrystalline and also leads to a decrease in both the constant interlayer coupling and the coherence length of Cooper couples.

CONCLUSION

The influence of the partial substitution of Bi by Pb on the mechanism of excess conductivity in the Bi–Sr–Ca–Cu–O system is studied. It was found that partial substitution of Bi for Pb leads to an increase in the critical temperatures of the sample $Bi_{1.7}Pb_{0.3}Sr_2Ca_2Cu_3O_y$ (B2) in comparison with $Bi_2Sr_2Ca_2Cu_3O_x$ (B1) (T_c(B2) = 100.09 K and T_c (B1) = 90,5 K, respectively). Simultaneously, the resistivity ρ of $Bi_{1.7}Pb_{0.3}Sr_2Ca_2Cu_3O_y$ in the normal state decreases and is a factor of ≈ 1.5 smaller than that found for $Bi_2Sr_2Ca_2Cu_3O_x$.

The mechanism of formation of excess conductivity in cuprate HTSC $Bi_2Sr_2Ca_2Cu_3O_x$ and $Bi_{1.7}Pb_{0.3}Sr_2Ca_2Cu_3O_y$ was considered within the framework of the model in the framework of the Ginzburg-Landau theory, with the Varlamov and Livanov correction. The T_0 transition from the 2D fluctuation region to the 3D region (i.e., the temperature of the 2D-3D crossover) was calculated.

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