THE INFLUENCE OF SYNTHESIS REGIME ON SUPERCONDUCTING PROPERTIES OF $Bi_2Sr_2Ca_1Cu_2O_X$

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It was investigated the temperature dependence of specific resistivity, thermal power and excess conductivity of $Bi_2Sr_2Ca_1Cu_2O_X$ in 77-300K temperature region. A superconducting transition was observed at 78K. It was analyzed the influence of fluctuations on the conductivity in the superconducting transition region. The 2D-3D crossover temperature T_{cr} was determined. The microscopic parameters such as dimensional crossover temperature (T_{cr}), interlayer coupling strength (J), and zero temperature coherence length along c axis (ξ_0) are estimated.

Keywords: superconducting material, specific resistivity, thermal power, excess conductivity, coherence length, temperature dependence.
PACS:74.62.Bf; 74.25.F; 74.40.-n

INTRODUCTION

Bi-based superconductors (BSCCO- Bismuth Strontium Calcium Copper Oxide) are the first high temperature superconductors, which did not contain a rare earth element. It is a cuprate superconductor, which shares a two-dimensional layered Perovskite structure with the superconducting copper oxide plane. It has general formula Bi_2Sr_2Can-1CunO2n+4+x with specific transition temperature ranging from T_c=20K (n=1, (2201) phase), 85K (n=2, (2212) phase), 110K (n=3, (2223) phase) and 104K (n=4, (2224) phase) [1].

It is well known that the superconducting properties of Bi-based compounds are very sensitive to the hole concentration, which depends on the atomic displacement. Substitutions into the BSCCO system affect strongly the carrier concentration and therefore lead to significant changes both on the electronic and superconducting properties [2-4].

The method of superconductor preparation and the sintering conditions greatly influence it. The electrical transport properties of HTSC are very sensitive to the chemical compositions, sintering temperature, sintering time, type and amount of substitutions [2-5].

The present work is devoted to study the transport properties of $Bi_2Sr_2Ca_1Cu_2O_X$ polycrystalline. It was investigated the influence of synthesis regime on the specific resistivity, thermal power and exsess conductivity of $Bi_2Sr_2CaCu_2O_X$ in the 77-300K temperature interval.

EXPERIMENTAL RESULTS AND DISCUSSION

The samples have been prepared by the solid state method by taking $CaCO_3$, $SrCO_3$,Bi_2O_3 and CuO as starting precursors and mixed in appropriate amount with a Bi:Sr:Ca:Cu cation ratio of 2:2:1:2. These materials were pressed and then sintered in air at 840^0C for 5 hours (sample-1) and 10 hours (sample-2) then quenched to room temperature.

The phase purity of the obtained samples was investigated by X-ray diffraction. The XRD analysis was performed using a Brucker -D8 advance diffractometer at room temperature with scanning mode with a step size $\Delta(2\theta)=0.05^0$ and $5^0\leq 2\theta \leq 80^0$. From the XRD data, various structural characteristics (such as, lattice parameter: *a*=5.39790A; *c*=30,68500A, system-tetragonal, space group (P4(75)), and grain size (465,7A) were deduced.

The resistivity and thermal power were measured using standard four-point probe technique with a 6-1/2-digit precision multimeter (8846A-Fluke). For taking the measurement, the sample is mounted in cryostat, and then four probes are electrically connected to the sample by indium.

The thermal power was measured by applying a longitudinal heat flux with a constant power released in the heater. The temperature gradient in the sample between probes varied from 0.5 to 2K. The thermal power of the sample was measured relative to copper. The thermal power sign is negative over the entire measured temperature range. This behavior indicates that the electron carriers are dominant. Thermal power value increases almost linearly with temperature decreasing. The temperature dependence of thermal power goes through a maximum *T*~117K then rapidly falls to zero below T_c for both $Bi_2Sr_2Ca_1Cu_2O_X$. The temperature dependence of thermal power is linear in the normal state of both investigated samples, and similar to that of the high-T_c cuprates. To interpret the measured data on thermal power, we take into consideration that this compound exhibits multiband superconductivity. Detail discussion is made elsewhere [5].

During the measurement, an interesting fact was revealed that the sign of the thermal power of both samples, unlike the other HTSCs, was negative. The reason for this is still difficult to explain, because the thermoelectric power sign of Bi-based HTSC is positive, especially if the critical temperature is above 50K [1,3,5].

The temperature dependences of the resistivity of $Bi_2Sr_2CaCu_2O_X$ samples are plotted on fiq.1. As can be seen, the ρ *(T)* dependences of samples have a metallic behavior above the T_c. The phase transition from normal metallic state to superconducting state happens at temperature T_c=78K, and T_c=78.5K respectively for samples-1 and sample-2 and calculated from the first order derivative plot.

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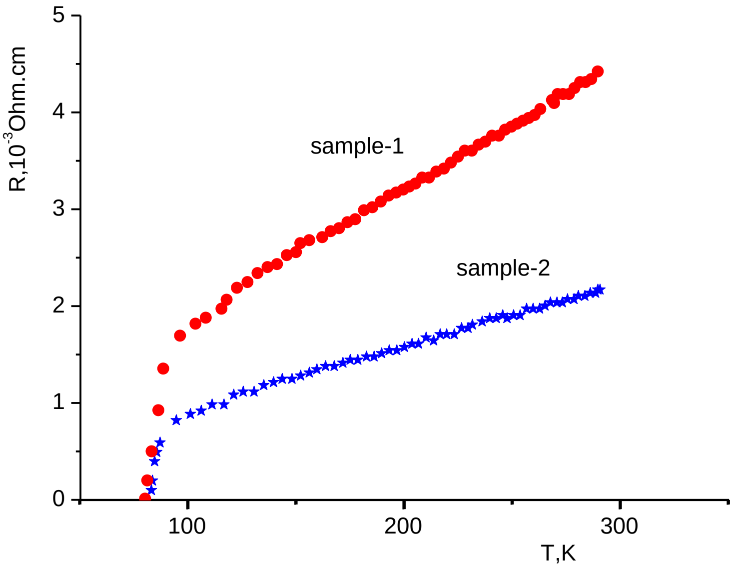


Fiq.1. The temperature dependencies of specific resistivity of $Bi_2Sr_2CaCu_2O_X$.

The temperature dependence of these samples is almost identical. However, the values of the resistivity of these samples differ by two times. Their annealing times are two times different also. As can be seen, the longer the annealing time reduce to the lower of their resistance.

The temperature dependence of the resistance deviates from linearity at 117K (sample-1) and 112K (sample-2). The deviation from the linearity of the temperature dependence of the resistivity is a common characteristic of HTSC materials. Starting from a certain temperature *T**, the resistance decreases more rapidly with decreasing temperature than at high temperatures. A sharper decrease in the resistance of the sample below *T** is a consequence of the formation of superconducting cooper pairs at these temperatures [6].

The phase diagram of high-temperature and low-temperature superconductors is very different. If in the low-temperature superconductors only the Meissner and normal parts take place, then in HTSC the picture becomes a little more complicated, there arises, in addition to everything else, an area with strong fluctuations. The reason for this is primarily due to the fact that the longitudinal and transverse coherence lengths in HTSC materials are very small. And this, in turn, leads to a rather small amount of coherence, where only a few Cooper pairs are contained.

As is well known, in the region of the phase transition (PT), the conductivity is significantly affected by superconducting fluctuations [6.7]. The resistivity $\rho(T)$ is affected by superconducting fluctuations resulting in noticeable deviation of $\rho(T)$ down from its linear dependence at higher temperatures and its analysis is one of the experimentally accessible methods just shedding light on the normal state transport properties of HTSC [6]. The Aslamasov and Larkin (AL) [8] and Lawrence and Doniach (LD) [9] models are used for description of fluctuations in intergrain and intragrain regions of HTSC cuprates. The excess conductivity is generally analyzed by using these two models. According to the LD model, the excess conductivity $\Delta\sigma$ due to superconducting fluctuations are expressed by [6]

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

where $J = (2\xi_c(0)/d)^2$ is interlayer coupling strength, $\xi_c(0)$ is zero temperature coherence length along c axis, and d-distance between layers.

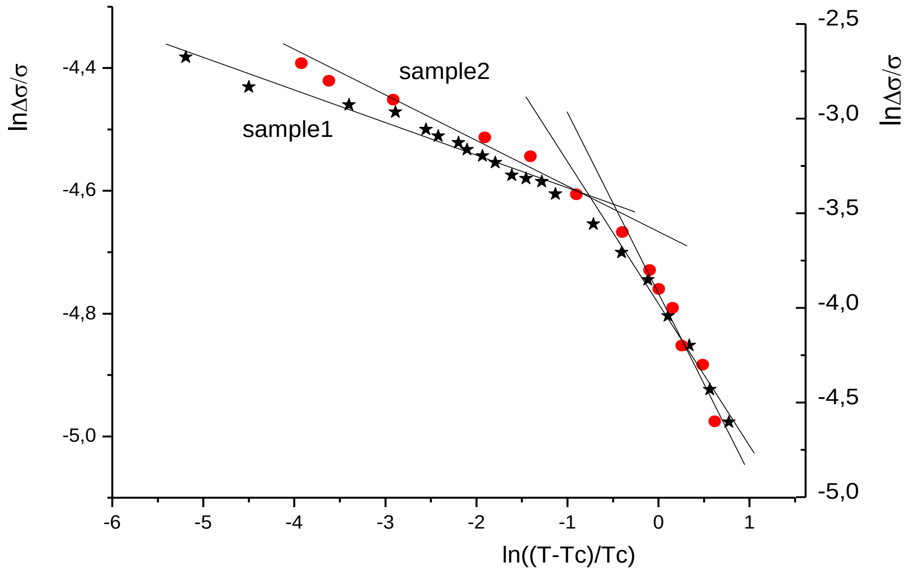
The physical reason for the appearance of excess conductivity is that, as a result of thermal fluctuations, Cooper pairs appear at a temperature above T_c, which creates an additional channel for the electric current.

As is seen from (1) at high temperatures $T \gg T_c$ (where $J \ll \varepsilon$; $\varepsilon = (\frac{T}{T_c}-1)$, $\Delta\sigma$ is proportional ε^{-1} (2D – conductivity), and nearly to transition temperature T_c (where $J \gg \varepsilon$), $\Delta\sigma$ is change as $\varepsilon^{-1/2}$ (3D – conductivity).

The 2D–3D crossover temperature T_{cr} was determined according to expression $\varepsilon = 4\gamma$, where $\varepsilon = (T-T_c)/T_c$ and $\gamma = (\xi_c(0)/d)^2$:

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

Fig.2 shows the dependence of $\ln\Delta\sigma/\sigma$ versus $\ln (T-T_c)/T_c$ for the investigated samples.



Fiq.2. The dependence of *lnΔσ/σ* versus *ln (T-T$_c$)/T$_c$*

Using experimental data (fig.2) and according to (2), the dimensional crossover temperature-the transition temperature of the 2D-3D fluctuation conductivity was calculated for the studied samples (T_{cr}(sample-1) =88K; and T_{cr} (sample-2) = 90K). The microscopic parameters such as interlayer coupling strength *J* (sample-1)=0,054; J(sample-2)=0,056, and zero temperature coherence length along c axis ξ_0 (sample-1)=4Å; ξ_0 (sample-2)=3,8Å are estimated. The value of *J* is characterized the degree of anisotropy of the system. The high values of *J* mean that the system is less anisotropic. It is known that Bi-based superconductors have a quasi-layered structure with CuO_2 planes in the unit cell [1.6] On the other hand Bi-based superconductors are quasi-two-dimensional superconductors with a weak interaction between copper-oxygen planes and strong anisotropy of resistance. The strong anisotropy of electronic properties is due to the weakening of the bond between the double CuO_2 layers.

CONCLUSIONS

The excess conductivity of two $Bi_2Sr_2CaCu_2O_X$ with different annealing times in the region of the superconducting phase transition is analyzed. It is obtained that an increase of the annealing time leads to an increase of microscopic parameters such as 2D-3D dimensional crossover temperature *(T_{cr})*, interlayer coupling strength (*J*) and decrease of resistivity.

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Recevied: 18.09.2017