ANALYSIS PHASE TRANSITIONS HIGHER TEMPERATURE FORMATION OF COOPER PAIR (T*) $CdBa_2Cu_3O_6$ HTSC MATERIAL

V.M. ALIEV[1], J.A. RAGIMOV[2], R.I. SELIMZADE[1], G.A. ALIEVA[3]

[1]Institute of Physics Ministry of Science and Education of Azerbaijan, AZ 1073, Baku, G. Javid Ave., 131

[2]Azerbaijan Medical University, Baku, AZ 1022, st. Bakikhanova, 23

[3]Institute of National HP Ministry of Science and Education of Azerbaijan AZ 1025, Baku, Khojaly Ave., 30

The experimentally discovered minima in the ρ(T) dependence, within the framework of classical theories of superconducting fluctuations, in our opinion, directly indicates the possibility of the formation of fluctuation Cooper pairs in the studied $CdBa_2Cu_3O_6$ SC sample at $T > T_{min} >> T_c$. This allows us to say that in $CdBa_2Cu_3O_6$ an attempt at a superconductive phase transition is observed at T_{min}.

For the first time, based on experimental data on conductivity, the formation of a pseudogap in $CdBa_2Cu_3O_6$ with T_c = 86.6 K was confirmed and its temperature dependence was assessed.

Keywords: superconductivity, fluctuation conductivity, resistivity, critical temperature.
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1. INTRODUCTION

More than 35 years have passed since the discovery of HTSC. The number of articles devoted to HTSC is huge, but the reason for the high superconducting transition temperature T_c still remains an unsolved problem. The so-called pseudogap phase in HTSC (an anomalous “normal” state) turned out to be as difficult a problem as high-temperature superconductivity itself. In works devoted to the pseudogap phase in HTSC, only key experimental work is discussed and an attempt is made to relate to the nature of this unique phenomenon.

The number of works devoted to pseudogap effects in HTSC materials is extremely large (see, for example, [1–7] and references therein). As noted in these works, the pseudogap is a unique phenomenon observed in HTSCs. It manifests itself when studying the phenomena of tunneling, photoemission, heat capacity and other properties of HTSC. It is believed that at a certain temperature T* > Tc the density of states on the Fermi surface is redistributed: on a part of this surface the density of states decreases. Below temperature T* the connection is in a state with a pseudogap.

There are dozens of papers [8] where the authors “observed a transition to a superconducting state” at temperatures much higher than the record T_c. In this case, the samples are always heterogeneous, non-single-phase, and, as a rule, have a high resistivity. The effect disappears after some time. No one (including the authors themselves) can reproduce the results. The effect disappears after some time. No one (including the authors themselves) can reproduce the results. Even a special name has been invented for such samples: “irreproducible HTSCs.” Fig. 1 shows an example of such an irreproducible transition obtained for the $YBa_2Cu_3O_7$ film.

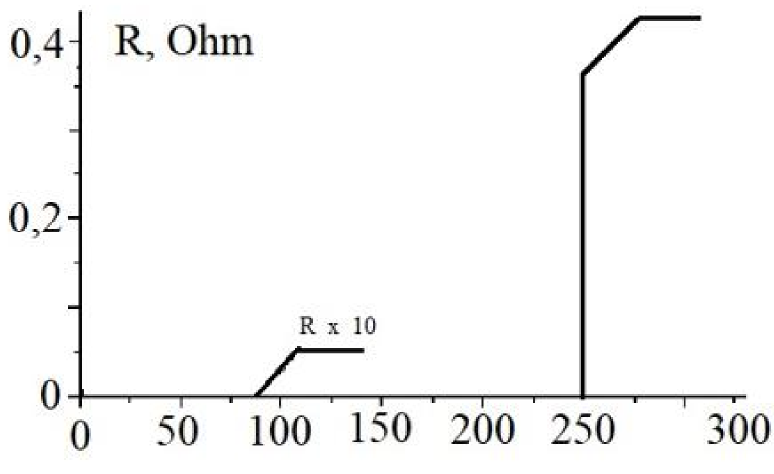

Fig.1. An irreproducible transition at T = 250K, observed in a non-single-phase, heterogeneous YBaCuO film. The arrow shows the usual transition to superconducting state at T=90K HTSC $YBa_2Cu_3O_7$ [9].

131, H.Javid ave, AZ-1073, Baku
Institute of Physics
E-mail: jophphysics@gmail.com

Recently, work [10] appeared devoted to the study of the pseudogap state in the material $Pb_{0,55}Bi_{1,5}Sr_{1,6}La_{0,4}CuO_{6+\delta}$ (Pb-Bi2201). A series of Pb-Bi2201 single crystals was obtained, on which a wide range of studies were carried out to identify the pseudogap state. The results of studies using three different experimental techniques indicate that the appearance of a pseudogap at T ≈ 132 K should be perceived as nothing other than a phase transition. Thus, the authors confirmed the conclusions of a number of experimental studies [11, 12] that as the HTSC temperature decreases, the material should experience two phase transitions: first, the appearance of a pseudogap, and then the transition to the superconducting state.

Previously, in [13, 14], we partially replaced yttrium with cadmium in the Y–Ba–Cu–O system.

It has been established that when yttrium is replaced by cadmium in the $Y_{1-x}CdxBa_2Cu_3O_{7-\delta}$ composition up to x = 0.8, the superconducting transition (SC) is maintained at Tc ~ 86–90 K. By completely replacing Y with Cd in the $YBa_2Cu_3O_{7-\delta}$ composition, high-resistivity samples were obtained, having SP at lower temperatures [15]. However, the nature of the curves predicted the possibility of obtaining a superconducting state in lower-resistivity $CdBa_2Cu_3O_6$ samples by changing the technological regime.

This work sets the task of obtaining superconducting ceramics $CdBa_2Cu_3O_6$ by changing the technological regime of synthesis.

2. EXPERIMENTAL RESULTS

The initial components (CdO, $BaCO_3$ and CuO) with the composition $CdBa_2Cu_3O_6$ in a stoichiometric ratio were mixed, pressed and annealed in a platinum crucible in air at 1193 K for 22 hours. Upon completion of heating, the resulting material was ground again, pressed and kept at this temperature for another five hours. The temperature was then raised to 1273 K and the material was held at this temperature for one hour. Then the temperature was lowered to the previous level, after two hours of exposure the material was slowly cooled to room temperature.

Using the method described above, a new superconducting ceramic material consisting of $CdBa_2Cu_3O_6$ was obtained. It has been established that when yttrium is completely replaced by cadmium in the Y–Ba–Cu–O system ($CdBa_2Cu_3O_6$ sample), a superconducting transition is observed at T_c ≈ 86.6 K.

In order to determine the phase composition of the resulting HTSC materials, the $CdBa_2Cu_3O_6$ sample was subjected to X-ray phase analysis. The result of the analysis is presented in Fig. 2.

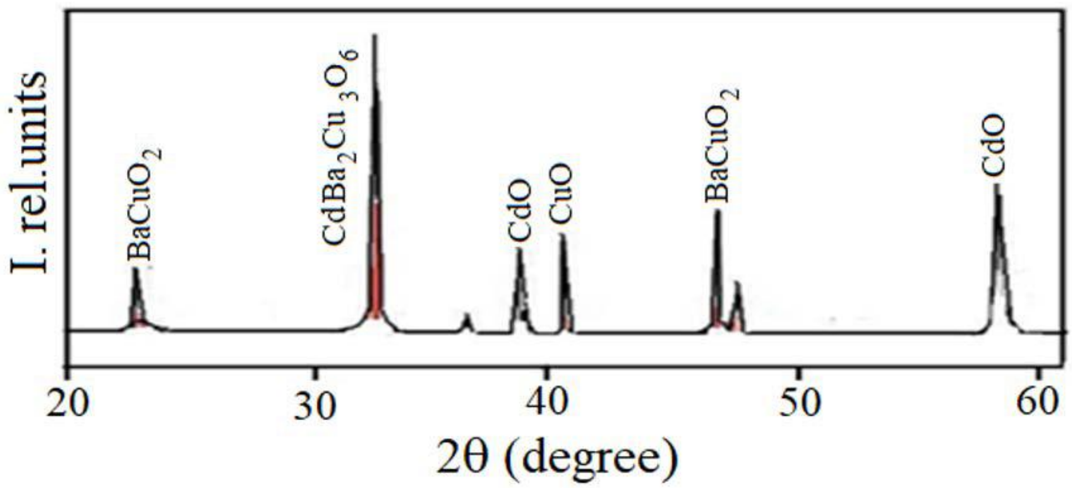

Fig. 2. X-ray diffraction pattern of a $CdBa_2Cu_3O_6$ sample.

Based on the X-ray diffraction pattern, it was revealed that when Y is replaced by Cd, all identified peaks coincide with slight shifts in the diffraction angles. Thus, we have obtained superconducting ceramics with the composition $CdBa_2Cu_3O_6$.

When studying the temperature dependence of the resistivity (ρ) of $CdBa_2Cu_3O_6$ in the temperature range 300–70 K, it was found that at T_{min} (*a*) ≈ 275 K the dependence ρ(T) passes through a deep minimum (Fig. 3, curve *a*). When repeated (after 72 hours), the minimum shifts towards low temperatures (T_{min} ≈ 252 K) (Fig. 3 curve *b*), and in the third measurement (after another 24 hours) the minimum disappears completely (Fig. 3 curve *c*).

It can be assumed that during the manufacturing process of $CdBa_2Cu_3O_6$, a certain crystallographic structure is realized with its own distribution of electrons throughout the volume of the sample and its own percolation paths for the flow of current through the polycrystal, in which the SC transition begins at T_{on} ≈ 280 K. Examination of the sample by X-ray diffraction analysis before the start of measurements and after the third measurement showed that the crystal structure of $CdBa_2Cu_3O_6$ remains unchanged and the identified peaks coincide. This gives grounds to believe that the formation of another crystallographic structure in the composition of $CdBa_2Cu_3O_6$ during synthesis is excluded. Therefore, the appearance of a minimum in the ρ(T) dependence can be explained by the specifics of percolation processes in $CdBa_2Cu_3O_6$, and its shift to lower temperatures and subsequent complete disappearance can be explained by a change in the percolation paths of current flow through the polycrystal during measurements (Fig. 3).

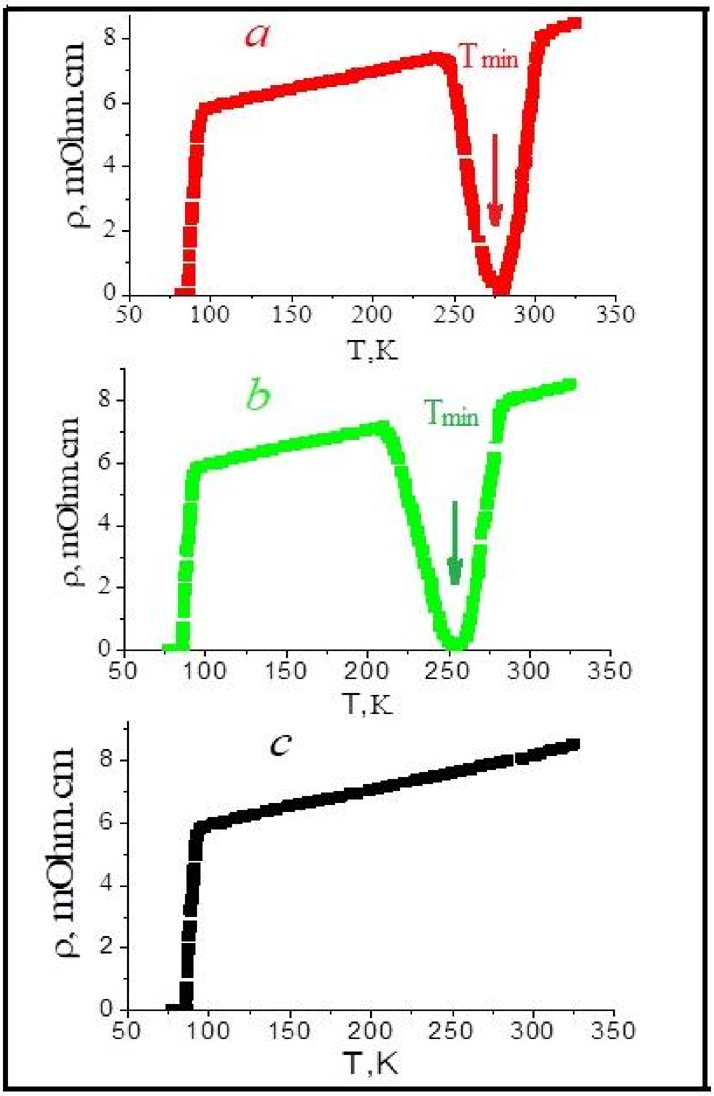

Fig. 3. Temperature dependences of the resistivity of optimally doped $CdBa_2Cu_3O_6$: a - first measurement (T_{min} = 275 K); c - measurement after 72 hours (T_{min} = 252 K); c - curve without minima, measured after another 24 hours. At all times cases T_c = 86.6 K.

Examination of the sample by X-ray diffraction analysis before the start of measurements and after the third measurement showed that the crystal structure of $CdBa_2Cu_3O_6$ remains unchanged and the identified peaks coincide.

This gives grounds to believe that the formation of another crystallographic structure in the composition of $CdBa_2Cu_3O_6$ during synthesis is excluded.

Therefore, the appearance of a minimum in the ρ(T) dependence can be explained by the specifics of percolation processes in $CdBa_2Cu_3O_6$, and its shift to lower temperatures and subsequent complete disappearance can be explained by a change in the percolation paths of current flow through the polycrystal during measurements (Fig. 3).

CONCLUSIONS

The experimentally discovered minima in the ρ(T) dependence, within the framework of classical theories of superconducting fluctuations, in our opinion, directly indicates the possibility of the formation of fluctuation Cooper pairs in the sample under study at $T>T_{min}>>T_c$. This allows us to say that in $CdBa_2Cu_3O_6$ an attempt at a superconductive phase transition is observed at T_{min}. This conclusion seems to us the most interesting and significant result of our research. At the same time, the question of why the resistance of the sample is restored with a further decrease in temperature remains open.

For the first time, based on experimental data on conductivity, the formation of a pseudogap in $CdBa_2Cu_3O_6$ with T_c = 86.6 K was confirmed and its temperature dependence was assessed.

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