BLUSHING OF PHASE TRANSITIONS $Y_{0,7}Cd_{0,3}Ba_2Cu_3O_{7-\delta}$ IN NTSC MATERIAL

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The effect of substitution of Y for Cd on the mechanism of the formation of excess conductivity in $YBa_2Cu_3O_{7-\delta}$ polycrystals is investigated. With the substitution of Cd for Y, the resistivity ρ of the $Y_{0,7}Cd_{0,3}Ba_2Cu_3O_{7-\delta}$ sample increases noticeably, and the value of the critical temperature of the transition to the superconducting state (T_c) decreases.

It is shown that superconducting phase transitions (PTS) in them have a diffuse character. The parameters of the blurring of the FP are determined: T_0, *a*, L_0 (T), and dL_0 / dT. It was found that in $YBa_2Cu_3O_{7-\delta}$ HTSC material, partial substitution of Y for Cd atoms significantly reduces the PT region and increases dL_0 / dT.

Keywords: superconductivity, phase transition, Y0,7Cd0,3Ba2Cu3O7-δ, transition rate.
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INTRODUCTION

Although more than thirty years have passed since the discovery of high-temperature superconducting materials, their synthesis is an unsolved problem. The main disadvantages of traditional methods for obtaining HTSC materials are low rate, incomplete completion of the solid-phase reaction, as well as the complexity of directional formation of the real structure of the final material, which determines its structure-sensitive properties.

The study of phase transitions (PT) is one of the topical and studied areas of solid state physics. This is due to the close connection between PT and many branches of solid state physics. One of the topical issues is to identify the classification of the studied FP, to what extent it is blurred, and how it is possible to influence the degree of blurring. For this, it is necessary to determine the parameters of the phase transition, which makes it possible to judge the degree of its blurring. An analysis of the temperature dependences of the electrical properties of high-temperature superconductors near and in the region of the phase transition shows that the phase transitions in them are of a diffuse nature and this follows from the features of type-II superconductors. But the study of blurring issues near and in the FP region reveals the mechanisms leading to blurring, with the help of which one can judge the quality of the object under study. This is especially true for new modified HTSC materials. The first studies of PT smearing in HTSCs were performed for bismuth ceramics and a polycrystalline sample [1, 2]. The results were interpreted within the framework of the theory of diffuse phase transitions [3]; therefore, this work is devoted to the determination of the parameters of phase transitions blurring in $Y_{0,7}Cd_{0,3}Ba_2Cu_3O_{7-\delta}$ HTSC material.

EXPERIMENTAL RESULTS AND THEIR ANALYSIS

The synthesis of $YBa_2Cu_3O_{7-\delta}$ and $Y_{0,7}Cd_{0,3}Ba_2Cu_3O_{7-\delta}$ was carried out in two stages [4, 5]. At the first stage, the initial components in a stoichiometric ratio were mixed and annealed in air at a temperature of 1120 K for 25 h. At the second stage, the resulting compositions were annealed in oxygen (P = 1.2–1.5 atm) at a temperature of 1190 K for 25 h and slowly cooled to room temperature.

Samples with dimensions 8 × 4 × 3 mm were cut from compressed tablets (diameter 12 mm, thickness 3 mm) of the synthesized polycrystals. The electrical resistance was measured according to the standard four-probe scheme. The current contacts were created by applying a silver paste with the subsequent connection of silver wires 0.05 mm in diameter to the ends of the polycrystalline to ensure uniform current spreading over the sample. Potential contacts were also created, which were located on the surface of the sample in its middle part. Then, a three-hour annealing was carried out at a temperature of 200 ° C in an oxygen atmosphere. This procedure made it possible to obtain a contact resistance of less than 1 Ohm and to carry out resistive measurements at transport currents up to 10 mA in the ab-plane.

RESULTS AND ITS DISCUSSION

The temperature dependences of the resistivity ρ (T) = ρab (T) of the synthesized polycrystals $YBa_2Cu_3O_{7-\delta}$ (1) and $Y_{0,7}Cd_{0,3}Ba_2Cu_3O_{7-\delta}$ (2) are shown in Fig. 1. The ρ (T) dependences of the $YBa_2Cu_3O_{7-\delta}$ sample (Fig. 1) have a shape characteristic of optimally doped HTSCs. The linear course of the temperature dependence of the resistivity of samples Y1 and Y2 in the normal phase is well extrapolated by the expression ρn (T) = $(\rho_0 + \kappa T + BT^2)$ (here B and k are some constants).

As seen from Fig. 1, the critical temperatures of samples Y1 and Y2 are T_c1 = 90.1K and T_c2 = 88K, respectively. In this case, the resistivity ρ (T) of the Y2 sample in the normal phase at 300 K in comparison with $YBa_2Cu_3O_{7-\delta}$ increases by almost 2 times. The critical temperature of samples Y1 and Y2 is T01 = 92.58K and T02 = 91.1K, respectively.

In papers [6-9], the questions of PT smearing in HTSC are investigated. It is shown that the

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determination of the PT parameters contributes to the identification of the law of the transition of the normal phase to the SC phase, the degree and region of its smearing, the influence of the magnetic field and various types of defects in ceramic samples. This becomes possible if the exact temperature of the FP-T_0, the temperature constant of the FP-a, the phase distribution function – L_0 (T) and the temperature rate of the FP-dL_0/dT are determined from the experimental data. The method for determining these parameters is based on the theoretical model of the RFP [3] and is described and tested in detail in [1, 2, 6-9].

The theory of diffuse phase transitions (RFP) in condensed systems is based on the introduction of the switch-on function L (T). It is assumed that if the thermodynamic potentials of the α and β-phases are denoted by Φ_α and Φ_β, then the total thermodynamic potential in the region of coexistence of the phases Φ (T) can be represented as:

$$\Phi(T)= \Phi_\alpha(T)-\Delta\Phi(T).L(T) \quad (1),$$

where its change is ΔΦ (T) = Φα(T) - Φβ (T). When FP occurs in the interval ΔT = T2-T1 (T2> T1), the switching function L must satisfy the conditions

$$L_0(T)= \begin{cases} 0 & T < T_1 \\ 0 < L < 1 & T_1 < T < T_2 \\ 1 & T > T_2 \end{cases} \quad (2)$$

According to the theory of the RFP, for L (T) in the zeroth approximation it was obtained

$$L_0(T)= \frac{1}{1+exp[a_0(T-T_0)]} \quad (3)$$

Taking into account that L0 (T) characterizes the relative fraction of phases in the region of their coexistence, it can be represented in a simple form

$$L_0(T)=\frac{m_\beta(T)}{m_\alpha(T)+m_\beta(T)}=\left[1+\frac{m_\alpha(T)}{m_\beta(T)}\right] \quad (4)$$

where mα and mβ are the masses of the α and β phases. From the joint solution of (3) and (4) it is obtained that

$$a = (T_0\text{-}T)\text{-}1.\ln m_\alpha/m_\beta \quad (5)$$

Since and is a constant, the factor $\ln(m_\alpha/m_\beta)$ in (5) must be a linear function of temperature. Therefore, from the temperature dependence of $\ln(m_\alpha/m_\beta)$, the temperature PT = T_0 is determined. The most informative is the derivative L_0 (T) with respect to temperature, which expresses the temperature rate of phase transformations of each phase:

$$\partial L/\partial T=-\frac{a}{2}\cdot\frac{1}{1+ch[a_0(T-T_0)]} \quad (6)$$

To quantitatively characterize the blurring of the PT, one can the half-width of the dL0/dT curve, i.e. temperature range

$$2\Delta T^*= -3,52/a. \quad (7)$$

In the case of superconductors, if the normal phase (n.f.) is taken as one phase, and the superconducting phase (s.p.f.) is taken as the other, then the proposed method can be applied to HTSC as well. Then the corresponding masses will take the value of mn and ms and they should be determined from the changes in the physical characteristics in the region of the SP FP. In this case, they are determined from the data ρ (T). From the temperature dependence ln (m_n / m_s), the temperature FP-T_0 (the point of intersection of straight lines with the abscissa axis) was found, and from the slope Δln (m_n / m_s) / ΔT (tangent of the angle) the temperature constant a (Fig. 2).

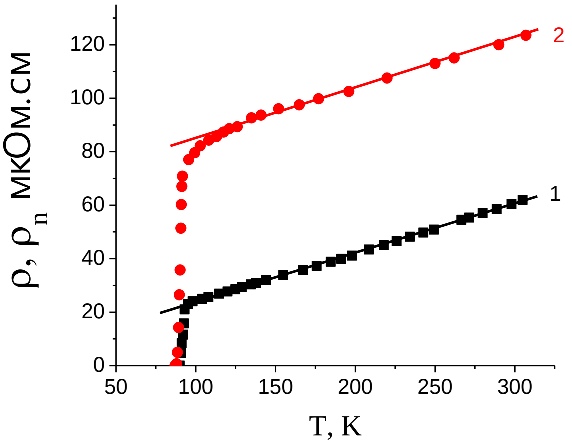

Fig. 1. Temperature dependences of the resistivity of the samples: 1- $YBa_2Cu_3O_{7-\delta}$, 2- $Y_{0,7}Cd_{0,3}Ba_2Cu_3O_{7-\delta}$. The straight lines represent $\rho_n(T)$, extrapolated to low temperatures.

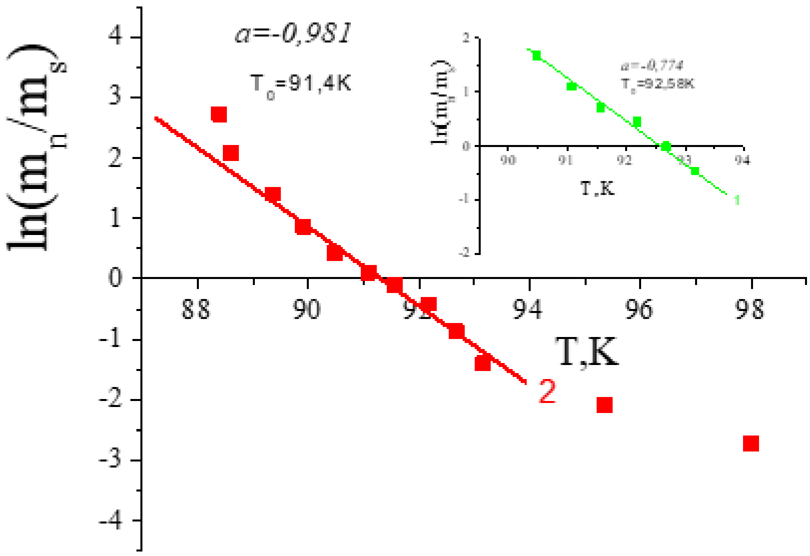

Fig. 2. Temperature dependences $\ln(m_n/m_s)$ for samples: 1- $YBa_2Cu_3O_{7-\delta}$, 2- $Y_{0,7}Cd_{0,3}Ba_2Cu_3O_{7-\delta}$.

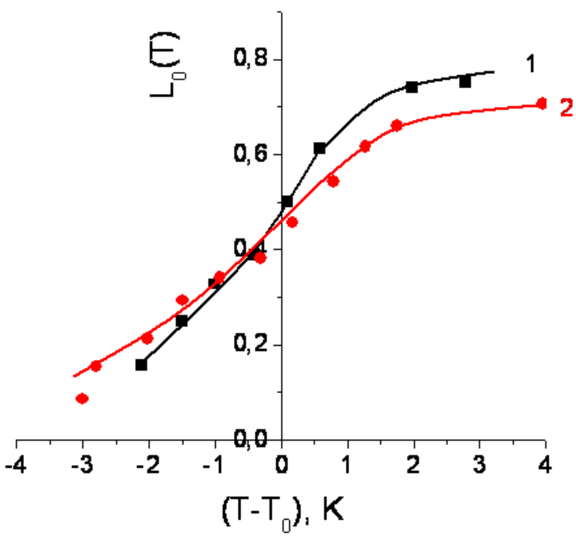

Fig. 3. Temperature dependences of the switch-on function L (T) for samples: 1- $YBa_2Cu_3O_{7-\delta}$, 2- $Y_{0,7}Cd_{0,3}Ba_2Cu_3O_{7-\delta}$.

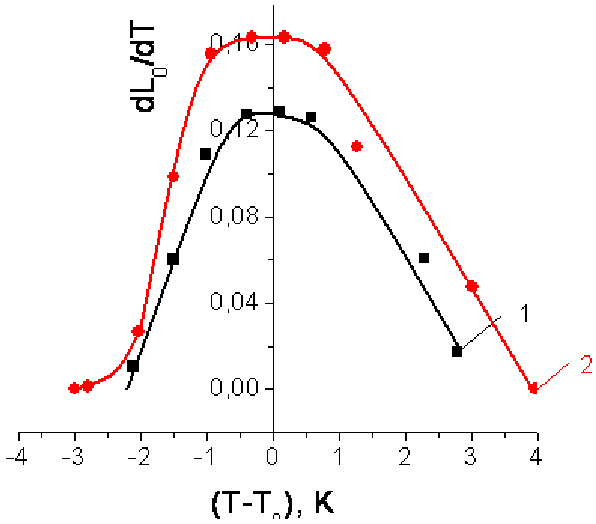

Fig. 4. Temperature dependences of the derivative of the switch-on function dL / dT for samples: 1- $YBa_2Cu_3O_{7-\delta}$, 2- $Y_{0,7}Cd_{0,3}Ba_2Cu_3O_{7-\delta}$.

These parameters made it possible to calculate the temperature dependence L_0 (T) using formula (3) (Fig. 3), and using (6) dL_0 / dT (Fig. 4). The results of calculations showed that with partial substitution of cadmium for yttrium in Y-Ba-Cu-O, the indicated PT parameters change, i.e. for $YBa_2Cu_3O_{7-\delta}$ SP material T_0 = 92.58K, *a*= -0.774, L_0 (T) = 0.5 and dL_0 / dT = 0.128, and for $Y_{0,7}Cd_{0,3}Ba_2Cu_3O_{7-\delta}$ was T_0 = 91.4K, *a* = -0,981, L_0 (T) = 0.44 dL_0 / dT = 0.162. Note that with the substitution of Cd for Y, the degree of blurring calculated according to equation (7) decreases and for Y1 and Y2 is 2.27K and 1.79K, respectively. In this case, the rate of phase transformations (dL_0 / dT) of sample Y2 in comparison with Y1 increases 1.26 times. Thus, we can conclude that the quality of yttrium ceramics improves upon partial substitution of Y atoms for Cd atoms. It can be assumed that, in this case, the concentration of defects decreases.

CONCLUSION

Studies and analyzes have shown that the substitution of Cd for Y leads to a slight decrease in the critical temperatures of the $Y_{0,7}Cd_{0,3}Ba_2Cu_3O_{7-\delta}$ sample in comparison with $YBa_2Cu_3O_{7-\delta}$ (respectively, T_c1 = 90.1K and T_c 2 = 88K). In this case, the resistivity ρ (T) of the Y2 sample in the normal phase at 300 K in comparison with $YBa_2Cu_3O_{7-\delta}$ increases by almost 2 times.

It is shown that superconducting phase transitions (PTs) in them have a diffuse character. The parameters of the blurring of the FP are determined: T_0, a, L_0(T), and dL_0/dT. It was found that the degree of smearing (ΔT*) of the $Y_{0,7}Cd_{0,3}Ba_2Cu_3O_{7-\delta}$ sample upon the substitution of Cd for Y in the Y–Ba–Cu – O system decreases three times.

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