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Influence of irradiation and impurity defects on the fluctuation conductivity of $YBa_2Cu_3O_{7-\delta}$ single crystals

G.Ya. Khadzhai[1], I. Goulatis[2], A. Chroneos[2,3], V.Yu. Gres[1], L.V. Bludova[4], A. Feher[5], R.V. Vovk[1,6]

[1]V.N. Karazin Kharkiv National University, 61022, Svoboda Sq. 4, Kharkiv, Ukraine
[2]Department of Electrical and Computer Engineering, University of Thessaly, 38333 Volos, Greece
[3]Department of Materials, Imperial College London, London SW7 2BP, United Kingdom
[4]B.Verkin Institute for Low Temperature Physics and Engineering of NAS of Ukraine, Kharkiv, 61103, Ukraine
[5]Centre of Low Temperature Physics, Faculty of Science,P.J. Safarik University, Park Angelinum 9, 041 54 Kosice, Slovakia
[6]Ukrainian State University of Railway Transport, 61050, Feierbakh Sq. 7, Kharkiv, Ukraine

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The effect of medium doses (from 10^{19} e/cm^2 to 10^{20} e/cm^2) of fast electron irradiation and the change in the praseodymium concentration in the range $0.0 \le z \le 0.5$ on the excess conductivity of optimally oxygen-doped $YBa_2Cu_3O_{7-\delta}$ single crystals has been investigated. It was determined that electron irradiation and an increase in the degree of doping with praseodymium leads to a significant expansion of the temperature interval of excess conductivity existence, thereby narrowing the region of the linear dependence $\rho(T)$ in the ab plane. It was determined that at doses $0 \le D \le 6.5 \cdot 10^{19}$ e/cm^2, the value of the transverse coherence length $\xi_c(0)$ increases with an increase of D by about 3 times and more than four times as the content of praseodymium in the sample increases to $z \approx 0.42$. In both cases, the 2D-3D crossover point shifts upward in temperature. In contrast to the case of irradiation with low doses ($D \le 10^{19}$ e/cm^2) and doping with praseodymium up to concentrations $z \le 0.39$, irradiation with medium doses and doping with praseodymium at higher concentrations leads to a nonmonotonic dependence of the transverse coherence length $\xi_c(0)$ on the irradiation dose, with characteristic maxima at $D \sim (7\text{-}8) \cdot 10^{19}\ e/cm^2$ and $z \approx 0.42$, which may be due to the general suppression of the superconducting characteristics.
Keywords: $YBa_2Cu_3O_{7-\delta}$ single crystals, excess conductivity, irradiation, fast electrons, 2D-3D crossover.

Вплив радіаційних і домішкових дефектів на флуктуаційну провідність монокристалів $YBa_2Cu_3O_{7-\delta}$. *Г.Я. Хаджай, І. Гулатіс, О. Хронеос, В.Ю. Гресь, Л.В. Блудова, О. Фехер, Р.В. Вовк*

Досліджено вплив середніх доз (від 10^{19} до 10^{20} cm^{-2}) опромінення швидкими електронами та зміни концентрації празеодиму в інтервалі $0.0 \le z \le 0.5$ на надлишкову провідність оптимально допованих киснем монокристалів $Y_1Ba_2Cu_3O_{7-\delta}$. Показано, що опромінення електронами та збільшення ступеня допування празеодимом приводить до значного розширення температурного інтервалу існування надлишкової провідності, тим самим звужуючи область лінійної залежності $\rho(T)$ у ab-площині. Встановлено, що при дозах $0 \le D \le 6.5 \cdot 10^{19}$ cm^{-2} значення величини поперечної довжини когерентності $\xi_c(0)$ збільшується зі зростанням D приблизно в 3 рази та більш ніж у чотири рази у міру підвищення вмісту празеодиму у зразку до z ≈0.42. При цьому в обох випадках зсувається за температурою 2D-3D точка кросовера. На відміну від випадку опромінення малими дозами ($D \le 10^{19}$ cm^{-2}) та допування празеодимом до концентрацій z ≤ 0.39, опромінення середніми дозами та допування празеодимом при більш високих концентраціях призводить до немонотонної залежності поперечної довжини когерентності $\xi_c(0)$ з характерними максимумами при D ~ 7-8 10^{19} cm^{-2} та $z \approx 0.42$, що може бути пов'язане із загальним пригніченням надпровідних характеристик.

1. Introduction

$RBa_2Cu_3O_7$ compounds (R = Y or rare-earth elements) are technologically important (due to their high current-carrying capacity) for the memory devices, ultrasensitive readout elements, and ultrafast communication lines. A characteristic feature of high-temperature superconductivity (HTSC) cuprates is the presence of a wide area of excess conductivity ($\Delta\sigma$) on the temperature dependences of the electrical resistivity $\rho(T)$ [1-11]. At temperatures $T^* > T >> T_c$, $\Delta\sigma$ is due to the manifestation of the so-called pseudogap (PG) anomaly [1,11]. At temperatures near the critical temperature $T \ge T_c$, $\Delta\sigma$ is determined by the mechanisms of fluctuation pairing of charge carriers (FC), described in detail in previous seminal studies [12-14]. In these conditions the composition and topology of the defect ensemble plays an important role [1,3,9,15], which determines the conditions for the flow of the transport current and the mechanisms of carrier scattering. Experimentally, irradiation [16,17] and praseodymium doping [18,19] are efficient ways to tune the composition and morphology of the defective ensemble in HTSC materials. These methods are advantageous as they preserve the stoichiometry of the material, the average number of electrons per atom, they maintain the macrohomogeneity of samples, and a controlled change in the concentration of radiation and impurity defects [19, 20].

The study of the effect of radiation on the FC in HTSC cuprates is fundamentally important to understand the microscopic nature of high-temperature superconductivity [21, 22], which remains unclear despite 37 years of intensive research [23]. Notably, despite the very extensive experimental investigations [1-10,15–20], the question regarding the effect of radiation exposure on various conduction regimes and, in particular, the fluctuation conductivity of HTSC compounds remains still not fully explained. Obviously, a certain role here is played the fact that the main amount of available experimental data was obtained on textured [24] and ceramic [1] samples with a high content of intergranular bonds, as well as from films [8] deposited on substrates of various types through very different technological processes.

The critical temperature of $RBa_2Cu_3O_{7-\delta}$ compounds (R = Y or rare-earth elements) optimally doped with oxygen is $T_c \approx 90$ K and weakly depends on the nature of R. In this case, $CeBa_2Cu_3O_{7-\delta}$ and $TbBa_2Cu_3O_{7-\delta}$ do not form an ORTO structure [25], $PmBa_2Cu_3O_{7-\delta}$ is radioactive, and for $PrBa_2Cu_3O_{7-\delta}$ there is no superconductivity ("praseodymium anomaly"), despite the presence of an orthorhombic unit cell of isostructural YBCO [25]. Compounds with a partial replacement of Y by Pr are interesting as there is partial suppression of superconductivity but the lattice parameters and oxygen stoichiometry of the compound remain practically unchanged [1,18]. The influence of Pr impurities on the conditions and regimes for the realization of fluctuation conductivity in such compounds [19,20] plays an important role not only in clarifying the nature of high-temperature superconductivity, but also in determining empirical ways to increase the critical parameters of HTSC compounds.

In previous studies [26-30], we investigated the effect of relatively low irradiation doses from 1.4 to $8.8 \cdot 10^{18}$ e/см^2, and the weak doping with praseodymium on the FC and excess conductivity in $YBa_2Cu_3O_{7-\delta}$ single crystals with stoichiometric composition. Here, we consider the effect of medium doses (up to $100 \cdot 10^{18}$ e/см^2) of irradiation with high-energy electrons and the effect of Pr impurities in a wide concentration range ($0.0 \le z \le 0.5$) on the fluctuation conductivity in $Y_{1-z}Pr_zBa_2Cu_3O_{7-\delta}$ single crystals during the flow of a transport current in basic ab-plane.

2. Experimental

The $YBa_2Cu_3O_{7-\delta}$ single crystals studied in this work were grown by the melt-solution method in a gold crucible [1,3,5]. The crystals were saturated with oxygen in an oxygen atmosphere at 430°C for four days. All crystals contained twins, and the twin planes had a block structure. The resistivity was measured by the standard 4-pin method. The corresponding crystal sizes for these measurements were (1.5...2)×(0.2...0.3)×(0.01…0.02) mm^3, where the smallest size corresponded to the c axis. To obtain crystals with partial replacement of Y by Pr, $Y_{1-z}Pr_zBa_2Cu_3O_{7-\delta}$, Pr_5O_{11} was added to the initial mixture in the appropriate percentage.

The modes of growth and oxygen saturation of $Y_{1-z}Pr_zBa_2Cu_3O_{7-\delta}$ crystals were the same as for undoped single crystals [19,20]. Y_2O_3, $BaCO_3$, CuO and Pr_5O_{11} compounds were used as initial components for crystal growth. A transport current of up to 10 mA was passed through the largest sample size, the distance between potential contacts was usually 1 mm.

The technology for obtaining experimental samples and carrying out resistive measurements, as well as the analysis of the transport properties of samples in the normal and superconducting states are described in detail in [1,3,5,19,20]. Irradiation with electrons with energies of 0.5 to 2.5 MeV was carried out for T < 10 K. The irradiation dose $D = 10^{18}$ e/cм^2 by electrons with an energy of 2.5 MeV corresponds to a defect concentration averaged over all sublattices of 10^{-4} displacement per atom [16,31]. The sequence of measurements was as follows: First, we measured the temperature dependences of the resistivity of the samples before irradiation. Then the temperature was lowered to 5 K and irradiation was carried out. The beam intensity was such that the temperature of the sample during irradiation did not exceed 10 K. After irradiating the sample with an appropriate dose, it was heated to a temperature of 300 K and, by gradually lowering the sample temperature, the resistivity temperature dependences were measured at T<300 K. A specially designed helium cryostat was employed to carry out resistivity measurements after irradiation in the temperature range 4.2<T<300 K. All resistivity measurements were carried out at a fixed temperature. The temperature was measured with a platinum resistance thermometer, and the temperature stability was about 5 mK.

3. Results and discussion

Figure 1(a) shows the dependences $\rho_{ab}(T)$ obtained before and after irradiation with fast electrons at doses from 0 (curve 1) to 86.3·10^{18} e/cm^2 (curve 8). Part of the curves in fig. 1(a) is not shown so as not to complicate the overall picture. The curves of these dependences are analyzed in previous work [32]. The resistivity curves of $Y_{1-z}Pr_zBa_2Cu_3O_{7-\delta}$ single crystals as the praseodymium content z changes from zero (curve 1) to z = 0.5 (curve 8) are shown in fig. 1(b). As can be observed from Fig. 1 in both cases, the curves are characterized by a quasi-metallic behavior of the resistivity with a characteristic linear portion of the ρ(T) dependence at high temperatures. Both at the maximum irradiation doses and at the maximum Pr content, the curves begin to acquire a characteristic S-shape, indicating the appearance of a thermally activated region on the ρ(T) dependences, which will be discussed in more detail below.

There are noticeable differences in the evolution of resistivity curves under irradiation and doping with praseodymium. As can be seen from fig. 1, radiation exposure leads to an anomalously strong (compared with the change in composition [16,33]) suppression of superconductivity (decrease in T_c) in $YBa_2Cu_3O_{7-\delta}$. However, the nature of the change in the electrical and superconducting properties of HTSC with a change in composition [33] and under the action of irradiation is somewhat different. The main difference is as follows: while with a change in composition, a decrease in T_c to 86 K, as a rule, is accompanied by a change in the shape of the ρ(T) curves from metallic to the so-called "S-shaped curve" with a characteristic thermally activated deflection [1,33], during irradiation, the same, in absolute value, decrease in T_c with a noticeable increase in ρ in the temperature range T_c – 300K is not accompanied by the appearance of an S-shaped dependence ρ(T). The thermally activated behavior of the electrical resistivity of irradiated samples appears only at sufficiently low values of T_c [32]. One of the reasons leading to a strong decrease in T_c in irradiated samples may be the appearance of dielectric inclusions under the action of irradiation due to the redistribution of oxygen between the O(4) and O(5) positions and the formation of local regions with a tetragonal structure.

As the dose increases, the critical temperature decreases from ~92 to ~24 K, and $\rho_{ab}(T)$ increases from ρ ~ 158 to 384 μOhm·cm, respec-

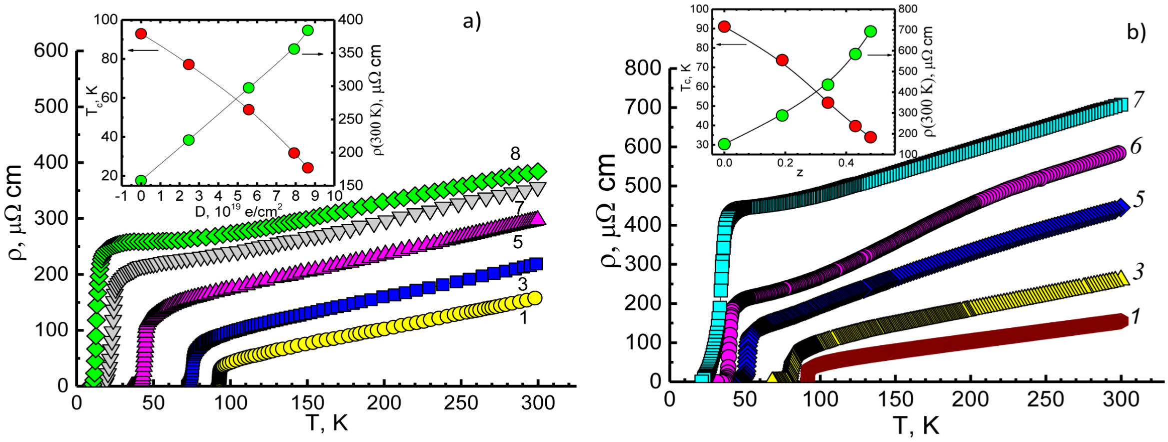

Fig. 1(a). Temperature dependences $\rho_{ab}(T)$ of $YBa_2Cu_3O_{7-\delta}$ single crystal for z = 0.0, 0.19, 0.34, 0.43, 0.48, curves 1;3;5;6;7, respectively. The inset show the concentration dependences of the critical temperature T_c (red circles) and the electrical resistivity at room temperature ρ_{300} (green circles) for all samples.

tively, which is consistent with the literature data [34,35]. Clearly similar effects are avoided when supplemented with praseodymium [1,18]. Dose and concentration dependences, $T_c(D,z)$ and $\rho_{300}(D,z)$, are shown in the insets to Fig. 1.

As follows from Fig. 1, when the temperature drops below a certain characteristic level, T*, in the basal plane, on the $\rho_{ab}(T)$ dependences in the region of relatively high temperatures, a fairly wide linear section is preserved even at significant irradiation doses. To explain such dependencies, a number of different theoretical models have been proposed, the most famous of which are the so-called RVB theory and the NAFL model [8]. According to the first, scattering in HTSC compounds occurs through the interaction of carriers with two types of quasiparticle excitations, spinons and holons [8]. Herewith, the temperature dependence of the electrical resistivity assumes, in addition to the linear in temperature term, the presence of an additional term, proportional to 1/T [8], in both cases, as in longitudinal and as in transverse electrical resistivity:

$$\rho(T) = AT^{-1} + BT \quad (1)$$

As it is observed from fig. 2, at radiation doses up to $\leq 70 \cdot 10^{18}$ см$^{-2}$ and at a low level doping of praseodymium $z < 0.25$, the temperature dependences $\rho_{ab}(T)$ becomes nearly linear in $\rho \cdot T - T^2$ coordinates.

However, for the case of medium and high doses $D > 100 \cdot 10^{18}$ см$^{-2}$ and in the case of medium and heavily praseodymium doped samples $z \geq 0.25$, the experimental curves $\rho_c(T)$ can no longer be well described by the dependence from Eq. (1). According to the NAFL model [8], carrier scattering in HTSC systems is determined by antiferromagnetic interaction. Herewith, the presence of a linear section in the $\rho(T)$ dependences serves as a reliable sign of the normal state of the system. Notably, none of the theoretical models explaining this behavior of the $\rho(T)$ curves in the region of relatively high temperatures could satisfactorily describe the deviation of the electrical resistivity from the linear dependence at temperatures below a certain characteristic value T^* corresponding to the opening temperature of the pseudogap [1].

The curves deviate downward from the linear dependence, which indicates the appearance of the so-called excess conductivity, $\Delta\sigma$, the temperature dependence of which can be obtained by the formula: $\Delta\sigma = \sigma - \sigma_{lin}$, where $\sigma = \rho_{ab}^{-1}$ is the experimental value of conductivity in the normal state at $T < T^*$, and $\sigma_{lin} = (\rho_{lin}^{-1}) = (AT + B)^{-1}$.

Near T_c, according to existing concepts [1,12-15], for the case of 2D and 3D fluctuations, $\Delta\sigma$ in polycrystalline systems can be described by the expressions:

$$\Delta\sigma_{2D} = 1/4\left\{\frac{e^2}{16d}\varepsilon^{-1}\left[1+\left(1+\frac{8\xi_c^4(0)}{d^2\xi_{ab}^2(0)}\varepsilon^{-1}\right)^{1/2}\right]\right\}, \quad (2)$$

$$\Delta\sigma_{3D} = \frac{e^2}{32\hbar\xi_p}\varepsilon^{-1/2} \quad (3)$$

where ξ_c and ξ_{ab} are the coherence lengths across and along the basal plane, d is the interplanar spacing, $\varepsilon = (T - T_c)/T_c$ is the reduced temperature, and $\xi_p(0)$ is the effective characteristic coherence length at T=0, which is given by the equation:

$$1/\xi_p(0) = 1/4[1/\xi_c(0) + (1/\xi_c^2(0) + 8/\xi_{ab}^2(0))^{1/2}] \quad (4)$$

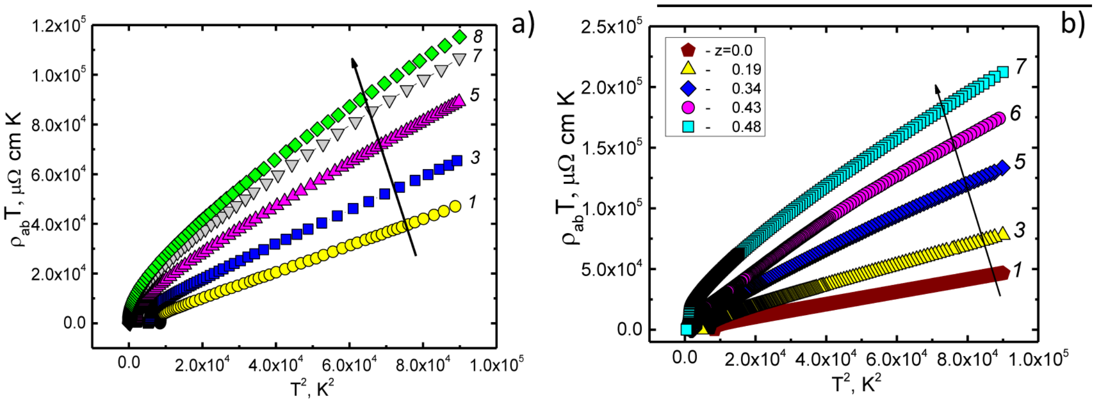

Fig. 2. Temperature dependences of electrical resistivity in ρ·T–T² coordinates in the ab plane. Curves' designations are the same as in Fig. 1.

In the case of single crystal samples, $\Delta\sigma$ is determined by the classical AL equation [12]: $\Delta\sigma = C\varepsilon^{\alpha}$, where

$$C = \begin{cases} \dfrac{e^2}{32\hbar\xi(0)} \text{ and } \alpha = -0.5 \text{ for 3D, (near } T_c \text{, at } \xi \gg d \text{ the interaction between fluctuating superconducting pairs is realized in the entire volume of the superconductor)} \\ \dfrac{e^2}{16\hbar d} \text{ and } \alpha = -1 \text{ for 2D, (far from } T_c \text{, at } \xi_A \ll d \text{ theinteraction is possible only in the planes of the conductive layers} \end{cases} \quad (5)$$

Figure 3 shows the temperature dependences $\Delta\sigma(T)$ in $\ln\Delta\sigma(\ln\varepsilon)$ coordinates. It can be seen that in the temperature range between T_c and $\leq 1.1T_c$ (depending on the oxygen content), these dependences are satisfactorily approximated by straight lines with a slope angle of $\alpha_1 \approx -0.5$, which indicates a three-dimensional character of fluctuation superconductivity in this temperature range. With a further increase in temperature, the rate of decrease in $\Delta\sigma$ increases significantly ($\alpha_2 \approx -1$), which, in turn, can be considered as an indication of a change in dimensionality of fluctuation conductivity (FC). This change corresponds to a 2D-3D crossover. Notably, in previous studies the FC in $YBa_2Cu_3O_{7-\delta}$ HTSC systems of various compositions using the Kouvel-Fisher method [4,6,10] a whole chain of crossovers was repeatedly recorded, and this was interpreted as a sequence of transitions 1D-2D, 2D-3D, 3D-critical fluctuations and intermediate types between them.

Taking into account these results, we can present the following picture of superconducting pairing in HTSC. Fluctuation pairs, apparently nucleated inside the CuO_2 planes at $T \leq T^*$, are leading to an increase in n_{sc}. Since at $T \gg T_c$ the value of n_{sc} and especially the $\xi_c(T)$ are very small, there is likely to be no interaction between the pairs. The corresponding electronic state of the fluctuation pairs can be considered as zero-dimensional, which is not described by the existing FC theories. At $T \leq T_{2D}$, fluctuation pairs begin to overlap, but still only within the CuO_2 planes, forming a 2D electronic state, which is described by the Mackie-Thompson regime (MT) contribution of the Hikami-Larkin (HL) theory [14]. At $T \leq T_{3D}$, the increasing $\xi_c(T)$ becomes greater than d and connects the conducting planes by paired tunnel interactions of Josephson type. Now, the fluctuation pairs interact throughout the entire volume of the superconductor, forming a 3D electronic state, which is well described by the 3D contribution of the Aslamazov – Larkin (AL) theory [12]. In fact, only now the system is entirely ready to complete the transition to the superconducting state.

Notably, for the dependences $\ln\Delta\sigma(\ln\varepsilon)$ obtained upon irradiation with maximum doses D=7.92 and 8.63 $\cdot 10^{19}$ e/cm², a nonmonotonic behavior of the curves is observed, characterized by an additional crossover at temperatures $\varepsilon \geq \varepsilon_0$ with a sharp decrease in the slope angle α. This feature has already been observed earlier in [8] and may indicate the presence of transition to the so-called Mackie-Thompson regime (MT) in the system [14] of the behavior of the temperature dependences of excess conductivity $\Delta\sigma$.

In the 2D-region, two-particle tunneling between layers is excluded, resulting to superconducting and the normal carriers being located directly in the planes of the leading layers. The dominant contribution to the FC in this regime is made by an additional contribution, justified by Mackie-Thompson [14] and determined as the result of the interaction of the fluctuation pairs with the normal charge carriers. This contribution depends on the lifetime of fluctuation pairs and is determined by the processes of pairing for each specific sample. In this case, it

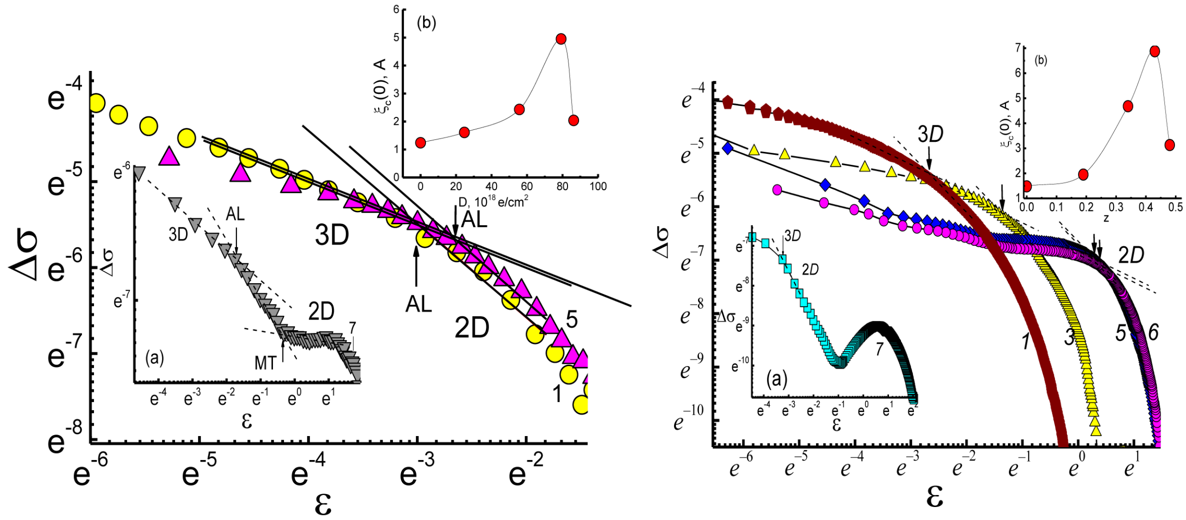

Fig. 3 (a) Dependences $\ln\Delta\sigma(T)$ on $\ln\varepsilon$ for fluences 0 (yellow circles), $55.7\cdot10^{18}$ e/cm^2 (magenta delta) and $79.2\cdot10^{18}$ e/cm^2 (gray delta, inset (a)). Inset (b) shows dependences of $\xi_c(0)$ on Φ.
(b) Temperature dependences of excess conductivity in the ***ab***-plane for $Y_{1-z}Pr_zBa_2Cu_3O_{7-\delta}$ single crystals in $\ln\Delta\sigma$-$\ln\varepsilon$ coordinates. Inset (a) shows the same dependence for $z = 0.48$. The inset (b) shows the dependences of $\xi_c(0)$ on z. The designation of the curves corresponds to the designations in Fig. 1

is important to take into account the degree of heterogeneity of the sample structure. According to [8] for samples of perfect structure:

$$\sigma_{MT} = \frac{e^2}{8\hbar d(1-\alpha/\delta)} \ln\left\{\left(\frac{\delta}{\alpha}\right)\frac{1+\alpha+(1+2\alpha)^{1/2}}{1+\delta+(1+2\delta)^{1/2}}\right\}\varepsilon^{-1} \quad (6)$$

Here,

$$\alpha = 2\left[\xi_c(0)/d\right]^2 \varepsilon^{-1} \quad \text{and}$$

$$\delta = 1{,}203\left(l/\xi_{ab}(0)\right)\left(16/\pi\hbar\right)\left[\xi_c(0)/d\right]^2 k_b T\tau_\varphi \quad (7)$$

are the communication and depairing parameters, respectively. Here l is the mean free path, ξ_{ab} is the coherence length in the ab-plane, and τ_φ is the existence time of fluctuation pairs. In the presence of inhomogeneities in the structure, the σ(T) dependence is determined by the Lawrence - Doniach (LD) model [13].

Considering Eq. 5 at the 2D-3D crossover point:

$$\varepsilon_0 = 4\left[\xi_c(0)/d\right]^2. \quad (8)$$

In this case, having determined the value of ε_0 and using the literature data on the dependence of T_c and interplanar spacing on δ [36-38], it is possible to calculate the value $\xi_c(0)$. The dependence of $\xi_c(0)$ on the irradiation dose is shown in the inset (b) to Fig. 3(a).

As can be seen from the figure, the value of $\xi_c(0)$, calculated according to Eq. 8, increases from 1.3 to more than 5Å and, after passing through the maximum, sharply decreases to values of about 2Å as the irradiation dose increases and T_c decreases, which qualitatively differs from the dependence of $\xi_c(0)$ on D obtained on $YBa_2Cu_3O_{7-\delta}$ single crystal samples [27] upon irradiation with low doses of fast electrons up to D= $8.8\cdot10^{18}$ e/cm^2. The dotted lines show the approximation of the experimental curves by straight lines with slopes $\alpha_1\approx-0.5$ (3D regime) and $\alpha_2\approx-1.0$ (2D regime).

Arrows show 2D-3D crossover points. Inset (a) shows the same dependences for samples K7 and K8. The inset (b) shows the concentration dependences of the coherence length $\xi_c(z)$.

Fig. 4 shows the dependences of $\xi_c(0)$ on T_c for all investigated samples. Dark squares show the data obtained previously for $YBa_2Cu_3O_{7-\delta}$ film samples at different volumes of δ [8]. As is known from the general theory of superconductivity (Bogoliubov-de Gennes – BdG [39]), the relationship between $\xi_c(0)$ and T_c in superconducting compounds obeys the relation:

$$\xi_0 \sim \hbar v_F/[\pi\Delta(0)], \quad (9)$$

where Δ(0) is the order parameter at T=0 K. Since for $YBa_2Cu_3O_{7-\delta}$ the value $2\Delta(0)/k_B T_c \approx 5$, then, taking $\xi_0 = \xi_c(0)$ this can be written as :

$$\xi_c(0) = G/T_c \quad (10)$$

where $G=2K\hbar v_F/(5\pi k_B)$ and the proportionality coefficient is K≈0.12. The dependence $\xi_c(0)$ as a function of T_c is shown in Fig. 4 with a solid line, which indicates that the pairing mechanisms in HTSC films, in this range of temperatures and praseodymium concentrations, obey to a large degree the general theory of superconductivity. Qualitatively similar behavior of analogous dependences is observed for $YBa_2Cu_3O_{7-\delta}$ (squares) and $Y_{1-z}Pr_zBa_2Cu_3O_{7-\delta}$ (circles) single-crystal samples at $T_c \geq 55$K and 75K, respectively. At lower T_c there is a qualitatively similar nonmonotonic behavior of the dependence $\xi_c(0)$ on D and the Pr concentration, obtained upon irradiation with medium doses of fast electrons and doping with praseodymium. This is associated with a general suppression of the superconducting characteristics of HTSC $YBa_2Cu_3O_{7-\delta}$ compounds at irradiation doses D $\geq 10^{20}$ e/cm^2 and praseodymium concentrations z ≥ 0.4 (also refer to [40,41]). The final answer to this question can be obtained by analyzing the effect of higher irradiation doses and high concentrations of praseodymium on the temperature dependences of electrical resistivity, up to the complete suppression of superconductivity in these compounds.

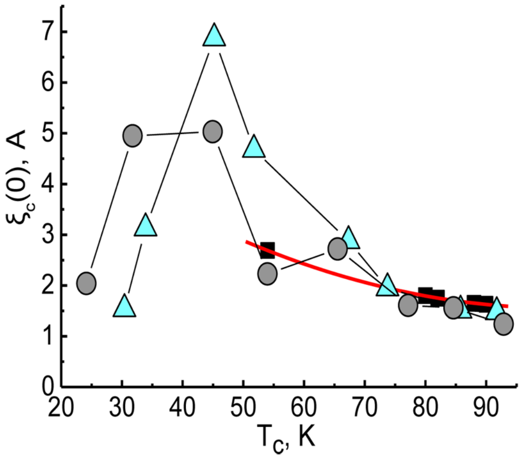

Fig.4. Dependences of $\xi_c(0)$ on T_c for $YBa_2Cu_3O_{7-\delta}$ (circles) and for $Y_{1-z}Pr_zBa_2Cu_3O_{7-\delta}$ (triangles). Squares – data [8] for $YBa_2Cu_3O_{7-\delta}$ films.

4. Summary

To summarize, irradiation with medium doses of high-energy electrons and an increase in the degree of praseodymium doping of optimally oxygen-doped $YBa_2Cu_3O_{7-\delta}$ single crystals leads to qualitatively similar changes in the temperature dependences of electrical resistivity ρ*(T)* in the ab-plane. In particular, there is a significant expansion of the temperature interval of excess conductivity Δσ(T) existence. In both cases, there is a multiple increase in the transverse coherence length ξc(0) and the 2D-3D crossover point significantly shifts by temperature. It was for the first time established that, in contrast to the case of irradiation with small doses of high-energy electrons (D$\leq 10^{19}$ cm^{-2}) and with praseodymium doping to concentrations z $\leq$ 0.39, irradiation with medium doses and praseodymium doping at higher concentrations, leads to a non-monotonic dependence of the transverse coherence length $\xi_c(0)$ from the critical temperature T_c with characteristic maxima at D~7-8$10^{19}$ cm^{-2} and z≈0.42, which may be associated with a general suppression of superconducting characteristics.

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