CHANGES OF MAGNETIC PROPERTIES OF $YBaCuO$-CERAMICS UNDER LOW-TEMPERATURE REACTOR NEUTRON IRRADIATION

V. A. Chekanov, R. F. Konopleva, A. K. Pustovoit, B. A. Borisov

At present a modification of HTSC properties under the neutron irradiation is widely studied. The most part of the experimental works were carried out at irradiation temperature $T > 78$ K. The low-temperature ($T < 78$ K) irradiation may significantly modify properties of HTSC, in particular, magnetic properties. It is therefore of interest to investigate the changes of the magnetic properties of HTSC under low-temperature irradiation.

The investigation of the influence of the reactor neutron irradiation at $T = 25$ K on the magnetic properties (susceptibility χ) of HTSC was performed on $YBaCuO$-ceramics in the lowtemperature helium loop in the PNPI WWR-M reactor [2]. The samples were irradiated up to neutron fluences $\Phi = 2 \cdot 10^{18}$ cm^{-2} with temperature heating scans up to $T < 100$ K to registrate $\chi(T)$ dependences. The measurements were performed during the irradiation using the ac inductance connection bridge.

Fig.1 presents temperature dependences of the real χ' (Fig.1a) and imaginary χ'' (Fig.1b) parts of susceptibility for the unirradiated sample at different values of ac magnetic field H_{ac}. The superconducting transition temperature T_c and the temperature T_m corresponding to the maximum on the $\chi''(T)$ dependence were determined from this data. T_c was taken as a temperature at which $\chi'(T) = -0.05$. Two regions are revealed on the $\chi'(T)$ curves differing in sensitivity to the magnitude of H_{ac}. The behavior of $\chi'(T)$ is independent on H_{ac} (within the range of H_{ac} used in the experiment) and is due to the intragranular SC [3]. At $T < 89$ K $\chi'(T)$ depends on H_{ac}, which results from the weak link conductivity. The maxima on $\chi''(T)$ curves are shifted to lower temperatures with increase of H_{ac} (Fig.1b).

Fig.2 presents the dependences of χ (2a) and $\chi''(T)$ (2b) after neutron irradiation. The comparison between this data before (Fig.1) and after (Fig.2) irradiation showed, that the irradiation shifts T_c and T_m to lower temperature and decreases the part of $\chi'(T)$ curve, associated with intragranular SC. It is worth to point out the decrease of the absolute value of $\chi'(T)$ caused by the decrease of SC volume of the sample after irradiation.

Fig.3 shows changes of T_c with neutron fluence. The $T_c(F)$ dependence has maximum at $\Phi = 3 \cdot 10^{17}$ cm^{-2} that confirms increase of T_c obtained from the resistivity measurements observed earlier in our work. The theoretical model for explanation of this effect was proposed in [4]. As T_c is defined from the part of χ', associated with the intragranular SC, the increase of T_c at small Φ can be ascribed to the improvement of SC properties of grains. T_c degradation with neutron fluence Φ results from increase of the efficiency of influence of stable defects introduced by neutron irradiation on SC properties of ceramics [4]. The value and the temperature dependence of $j_c(T)$ can be obtained from the $\chi''(T)$ dependences for corresponding T_m and H_{ac} [3]:

$$j_c = 5 \cdot H_{ac}/(\pi R), \tag{1}$$

where R — radius of the specimen. Fig.3b presents a dependence of $j_c(\Phi)$ obtained by making the section of curve family $j_c(T)$ at $T = 70$ K for different neutron fluences. From Fig.3b it follows that value of j_c linearly decreases with increasing fluence with the rate $dj_c/d\Phi = 1.1 \cdot 10^{-16}$ A.

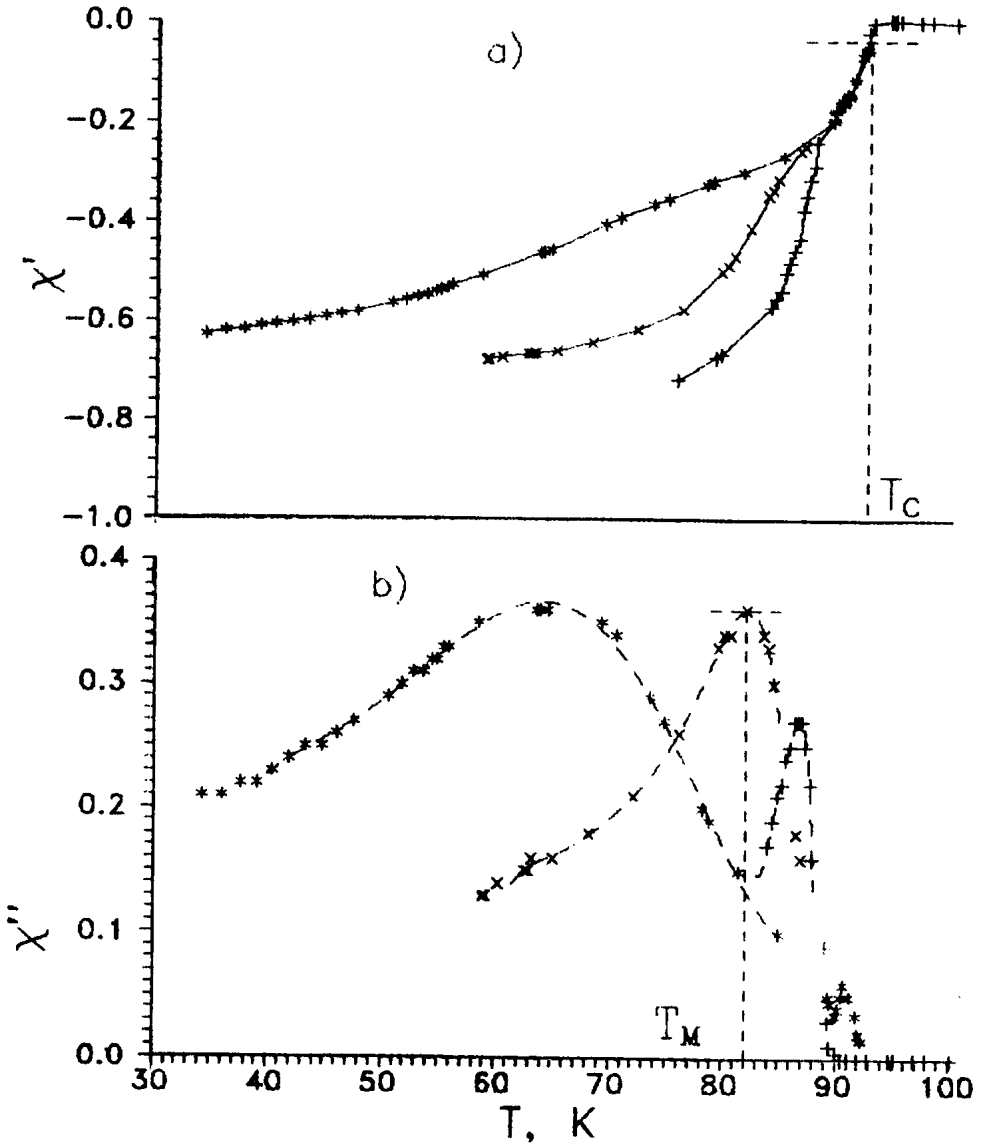

Fig.1. Temperature dependences of real (1a) and imaginary (1b) parts of susceptibility for unirradiated sample at different values of H_{ac}(Oe): + 1.3, × 4.2, * 13

The most of experimental data on neutron irradiation influence on j_c obtained from magnetic measurements, reveal the increase of j_c with neutron fluence in the range $\Phi \leq 10^{18}$ cm^{-2}. The discrepancy of our $j_c(F)$ dependences with results presented in [1] may be explained, if we take into account that j_c in [1] was determined at $H > H_{c1g} \sim 500$ Oe and so is related to the intragranular conductivity. In our experiment the value of j_c is determined by weak links as the value of $H_{ac} < 13$ Oe that is less than H_{c1g}.

The role of weak links can be estimated from the ratio of Josefson coupling energy J to the intragranular condensation energy Eg J/E_g using the value of j_c, calculated from Eq.(1) according to expressions presented in [3]:

$$J = \frac{H_{ac} \cdot a^2}{4\pi e} \cdot j_c, \quad E_g = \frac{H_{cg}^2}{8\pi} \cdot V_g, \tag{2}$$

where a — the radius of SC grain ($\sim 10^{-6}$ m), V — its volume, H_{cg} — thermodynamical critical grain field. If we accept for $j_c = 1.5 \cdot 10^{-3}$ A/cm^2 ($T_m = 91$ K), we can obtain

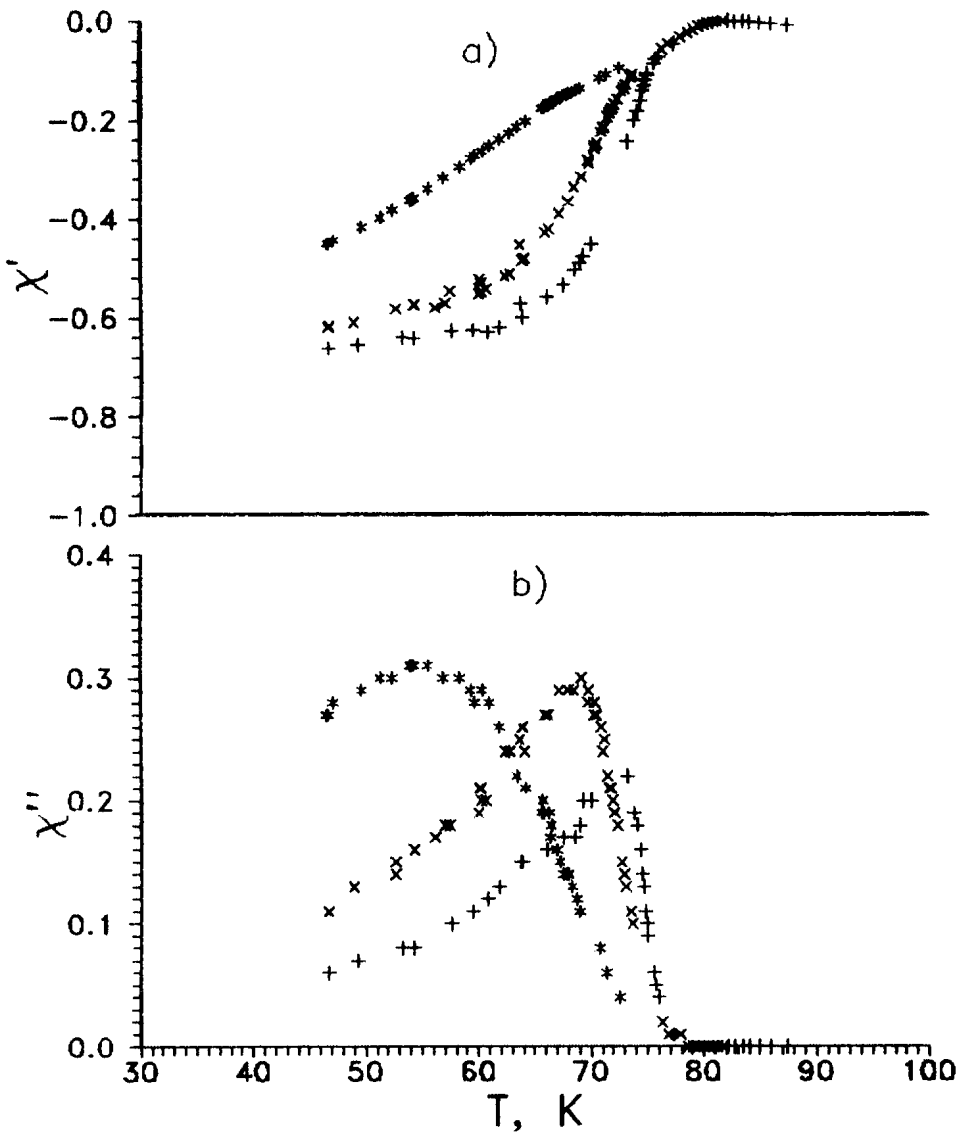

Fig.2. Temperature dependences of real (2a) and imagi-nary (2b) parts of susceptibility after neutron irradiation ($\Phi = 2 \cdot 10^{18}$ cm^{-2}) at different values of H_{ac}(Oe): + 0.42, × 1.3, * 4.2

$J/E_g \approx 10^{-11}$. It means that the effects related to the specimen granularity are dominant and magnetic properties of the specimen are determined by the weak links.

Thus, the performed investigations of magnetic properties of $YBaCuO$ ceramics in the course of neutron irradiation show, that the $T_c(\Phi)$ dependences have nonmonotonous character with the maximum at $\Phi = 3 \cdot 10^{17}$ cm^{-2}, that apparently is due to the improvement of the granular SC properties because of the increase of structure perfection resulting from low fluence irradiation. It is shown, that j_c determined by weak intergranular links and monotonous decrease of $j_c(\Phi)$ evidences for the destruction of these links at fluences $\Phi > 10^{17}$ cm^{-2}.

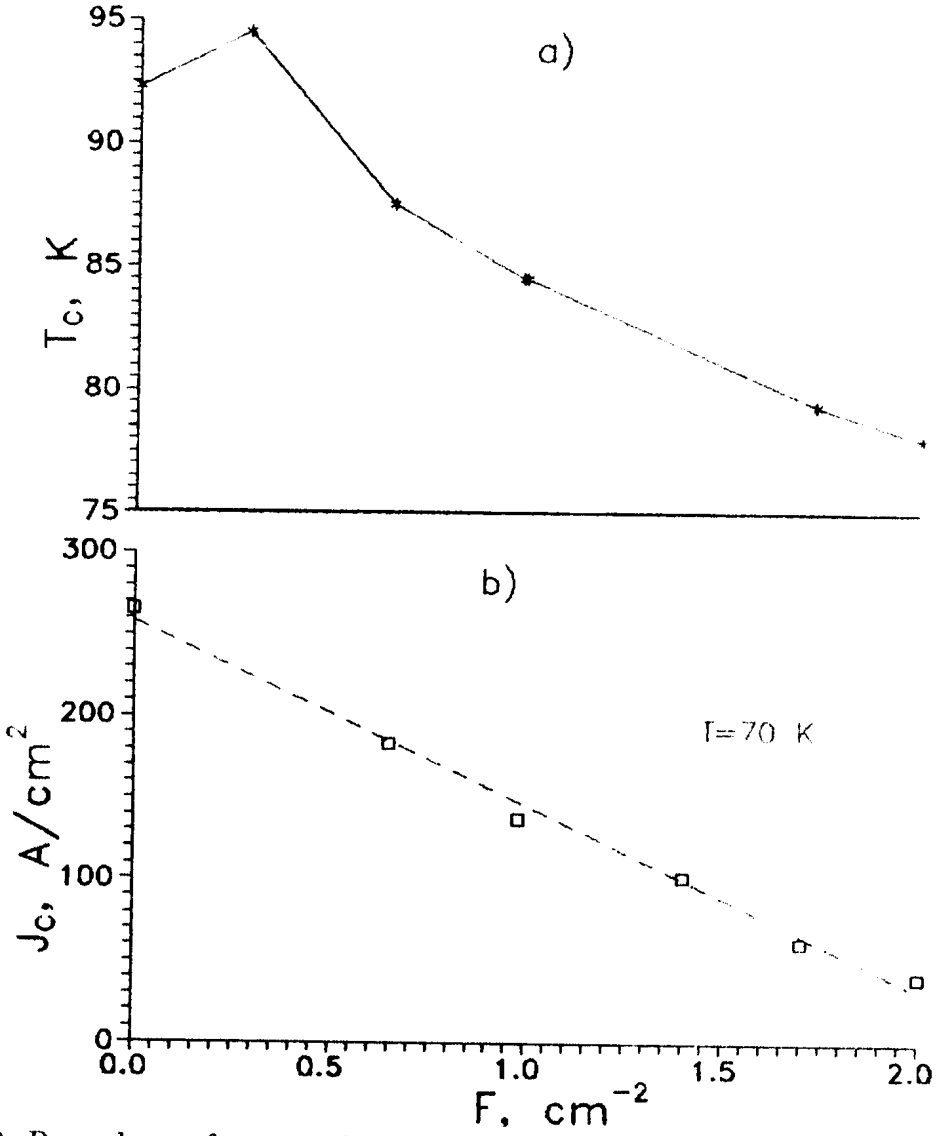

Fig.3. Dependence of superconducting transition temperature T_c (3a) and dependence of critical current for different neutron fluences (3b)

REFERENCES

1. *Weber H.W.* Studies of High Temperature Supercond., by Ed. Narlikar A.V., 1991. V.9.
2. *Pustovoit A.K. et al.* Preprint LNPI–1749, 1991. 30 p.
3. *Mejilichov E.Z.* //Superconductivity: Phys.Chemistry, Technique, 1989. V.2. P.5–29.
4. *Konopleva R.F. et al.* // Superconductivity: Phys.Chemistry, Technique, 1993. V.6. P.568–576.