STUDY OF ELECTRIC AND OPTICAL PROPERTIES OF HIGH-T_c MATERIALS UNDER NEUTRON IRRADIATION AT DIFFERENT TEMPERATURES (30 AND 300 K) AND UNDER HIGH TEMPERATURE ANNEALING

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1. Cryogenic equipment and measuring system of a set were created which enable to carry out in situ an investigation of various electric and magnetic properties of HTSC-materials in WWR-M reactor through fast neutron ($E \geq 0.1\ MeV$) fluences region $10^{15} - 10^{19}\ n/cm^2$ at temperature range 20—30 K.

Investigating the variations of resistive and superconducting properties of $YBa_2Cu_3O_{6.95}$ — ceramics caused by low-temperature (30 K) neutron irradiation it is found, that the ordering action of irradiation dominates for $F<10^{18}\ n/cm^2$ (T_c increases from $92.3 \pm 0.2\ K$ to $95 \pm 0.3\ K$), but the disordering one dominates for $F>10^{18}\ n/cm^2$ (T_c decreases and ρ_{100} raises with degradation factors $\partial T_c/\partial F = -2.5 \cdot 10^{-18}\ Kcm^2$ and $\partial \rho_{100}/\partial F = 6 \cdot 10^{-23}\ Ohm \cdot cm^3$ respectively). Fig.1 represents the dose variation of T_c, which illustrates the "small dose" effect i.e. the T_c increasing for $F < 10^{18}\ n/cm^2$ and T_c degradation for $F \geq 10^{18}\ n/cm^2$.

2. The variation of the temperature behaviour of the high-T_c ceramics resistivity in the region of transition to superconducting state has been analysed by means of percolation theory. This transition is described with the use of transport coefficients whose behaviour near the transition is universal and can be represented in terms of critical indeces of the theory [1]. Assuming the temperature scale to be proportional to the scale of the fraction of the volume occupied by the superconducting phase, one can write for the conductivity $\sum$ for $T > T_c$: $(\sum - \sum_o)/\sum_o = [(T - T_c)/T_c]^{\tau}$, where τ is the critical index of percolation theory. The values of critical index for all the studied YBaCuO samples, both original and neutron-irradiated

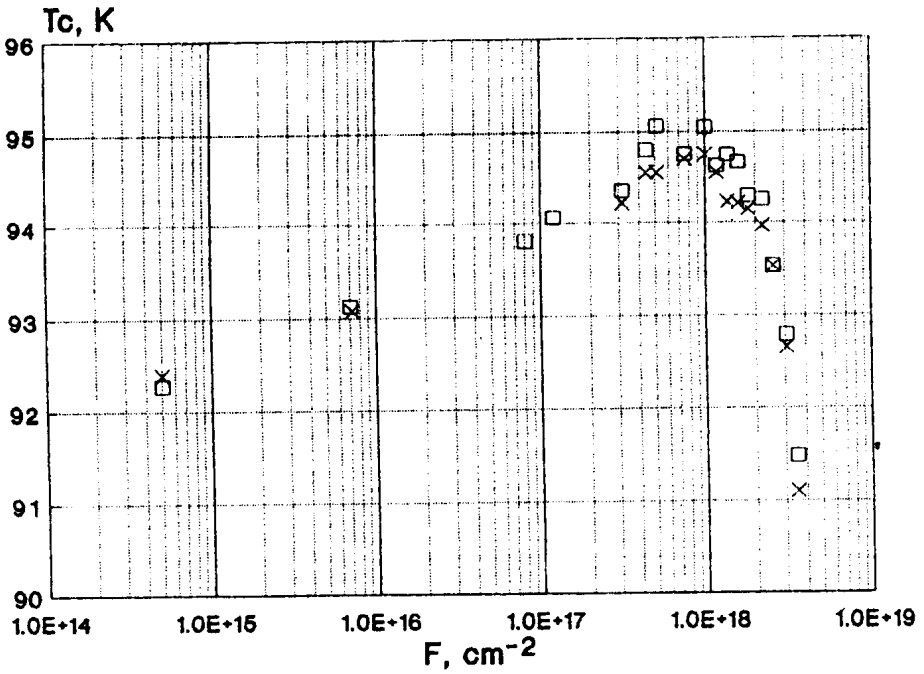

Fig.1. Temperature dependence T_c (onset) vs fast (E>0.1 mev) neutron fluence for $YBa_2Cu_3O_{6.95}$ ceramics. Irradiation temperature is ~ 30 K. Temperature variation speed during measuring SC-transition is 0.04 K/s. Π — heating; * — cooling

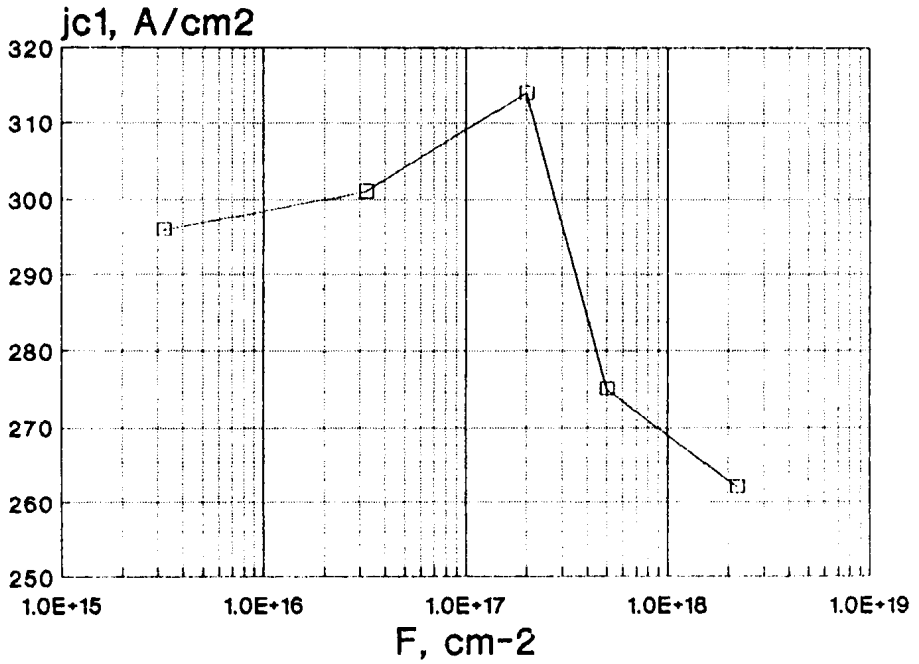

Fig.2. Dose dependence of critical current j_C vs neutron fluence for YBaCuO-ceramics

($F = 1.1 \cdot 10^{17} - 3.8 \cdot 10^{18}\ cm^{-2}$), have been found to lie in the range τ = (0.8—1.2), which corresponds to two-dimensional charge carrier transport for temperatures $T > T_c$.

3. High-temperature annealing of the original and reactor neutron-irradiated ceramic samples in the nitrogen environment and in air has been carried out in the range 100—950° C. The resistivity was observed to increase, with insreasing annealing temperature, and T_c, to decrease by 5 K at the annealing temperature of 400° C. The superconducting properties of the ceramics were found to recover (T_{ann} =700° C) after their degradation in the course of preliminary annealing. This effect has been observed on both the irradiated and original samples of the YBaCuO ceramics annealed at a slow rate (5° C/min) in dry nitrogen.

The oxygen atom concentration per unit cell was derived from a study of the products of 900 *keV* — deutons interaction with oxygen nuclei on a Van-de-Graaf accelerator. The temperature dependence of the resistivity and increasing superconductor transition temperature of the specimens consecutively annealed in model of local strained intermediable cluster has been qualitatively explained. The new phase created by these centers which has a $T_c \approx 90^\circ C$ and a relatively small volume apparently shunts the high resistivity regions and determines the superconducting properties of the samples.

4. Studies of IR optical reflectance of $YBa_2Cu_3O_{7-x}$ ceramics have shown that the transition from orthorombic to tetragonal phase in the course of annealing is accompanied by the appearence of the characteristic band near 640 cm^{-1} associated with oxygen vacancies [2]. Raman spectroscopy (RS) studies have been carried out in YBaCuO ceramics and films on various substrates ($SrTiO_3$, and MgO) which showed that neutron irradiation with (F=$3 \cdot 10^{17}\ cm^{-2}$) $YBa_2Cu_3O_{7-x}$ ceramics changed intensity of the RS spectrum near 590 cm^{-1} due to an increase of the oxygen vacancy concentration.

5. The magnetic properties of high-T_c superconductors are studied by microwave contactless method. The temperature dependencies of microwave absorbtion in YBaCuO-ceramics are obtained in the range 77—95 K. The values of critical magnetic fields H_{c1}=13.5—16.5 *Oe* and H_{c2}=260—340 *kOe* are determined which permits to calculate the London penetration depth Λ = 660—740 *nm* and the length of coherency ξ=0.66—0.74 *nm*. The critical currents J_{C1}=215—260 A/cm^2 and J_{C2}=4300—5200 kA/cm^2 are estimated. The value of critical current J_{C1} (T = 77 K, H = 13—20 *Oe*) of neutron-irradiated ($F = 3 \cdot 10^{15} - 2 \cdot 10^{18}\ cm^{-2}$) YBaCuO — ceramics reveals maximum which is connected with radiation - induced defects which seem to act as the pinning centers (fig.2).

References

1. Kirkpatrik S. //Rev.Modern Phys., 1973. V.45. P.574.
2. Chen J. et al. //Phys.C. 1989. V.159. P.317.