LOW-FIELD hf-ABSORPTION IN IRRADIATED HTSC-MATERIALS

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At present a study of the magnetic flux vortex motion which determines the critical parameters of superconducting materials has a considerable scientific interest. The study of a vortex motion in HTSC with pinning centers (PC) introduced by cascade-formation particles-protons, neutrons or ions is of especial importance.

It is known [1] that such PC with size exceeding the coherence length ξ have the most vortex pinning force as compared to that in HTSC with a dislocation or point defects.

The aim of this work is the study of the magnetic flux kinetics under radiation PC introducing into HTSC. The measurements of hf-absorption were carried out at f = 120–140 MHz ($T > T_c$) on samples of $YBa_2Cu_3O_{7-x}$-ceramics with different density and "packet" quasicrystals $Bi_2Sr_2CaCu_2O_8$, placed into inductance coil of the parallel oscillatory circuit. Irradiation of HTSC-samples was performed at PNPI WWR-M reactor by fluences of fast ($E > 0,1$ MeV) neutrons 10^{15}–10^{19} cm^{-2}. The method of hf-absorption have been used both for the study of magnetic properties of HTSC in steady-state conditions and for research of dynamic critical state peculiarities. In this case hysteresis of hf-absorption vs magnetic field direction, regime of cooling (ZFC, FC), time and temperature have been measured. In quasistationary state the lower Josephson critical field H_{c1J} was determined from maximum of the dependence absorption intensity I_r vs magnetic field. The table presents values of critical field H_{c1J} of the investigated initial HTSC-materials. The observed correlation between density (ρ) of HTSC and values of H_{c1j} is explained by increasing volume part (with decreasing ρ) occupied by a week links, by increasing λ_J and decreasing of H_{c1J}, respectively:

$$H_{c1J} = \Phi_o \cdot \ln(2\lambda/a)/4\pi\mu\lambda_J^2$$

where μ is an effective magnetic permeability; λ_J is the Josephson penetration depth; Φ_o is a single flux quantum; $a \ll \lambda_J$ is an average grain's size.

Table

Type of HTSC	Density, ρ, g/cm^3	H_{c1J}, Oe
Ceramics $YBaCuO$	4,3	16
Ceramics $YBaCuO$	4,8	220
Quasicrystals Bi–2212	6,5	330

The experimentally obtained values of H_{c1J} for different HTSC have allowed to estimate a number of parameters of SC-junction: the area S and its temperature dependence $S(T)$; the London penetration depth λ, percolation length of coherence ξ_p [2] as well as values of the equivalent critical currents J_{cJ} for $YBCO$ and $BSCCO$ before and after irradiation. General result of irradiation for both type of HTSC consists in monotonous increase of J_{cJ} according to power law $J_{cJ} \sim \Phi^{\alpha}$ with neutron fluence from 10^{16} to $5 \cdot 10^{17}$ cm^{-2}. Such increase (or "enhancement") of the critical current vs dose of cascade-formatting irradiation can be connected with two reasons. Firstly, with vortices trapping by PC as radiation defect-cascades of atomic collisions or disordered regions, with size exceeding coherence length ξ. Secondly, observed rise of J_{cJ} can be connected with the ordering effect of irradiation, stimulate "building" of interstitial oxygen atoms ($O4$) into sites of HTSC lattice ($O5$).

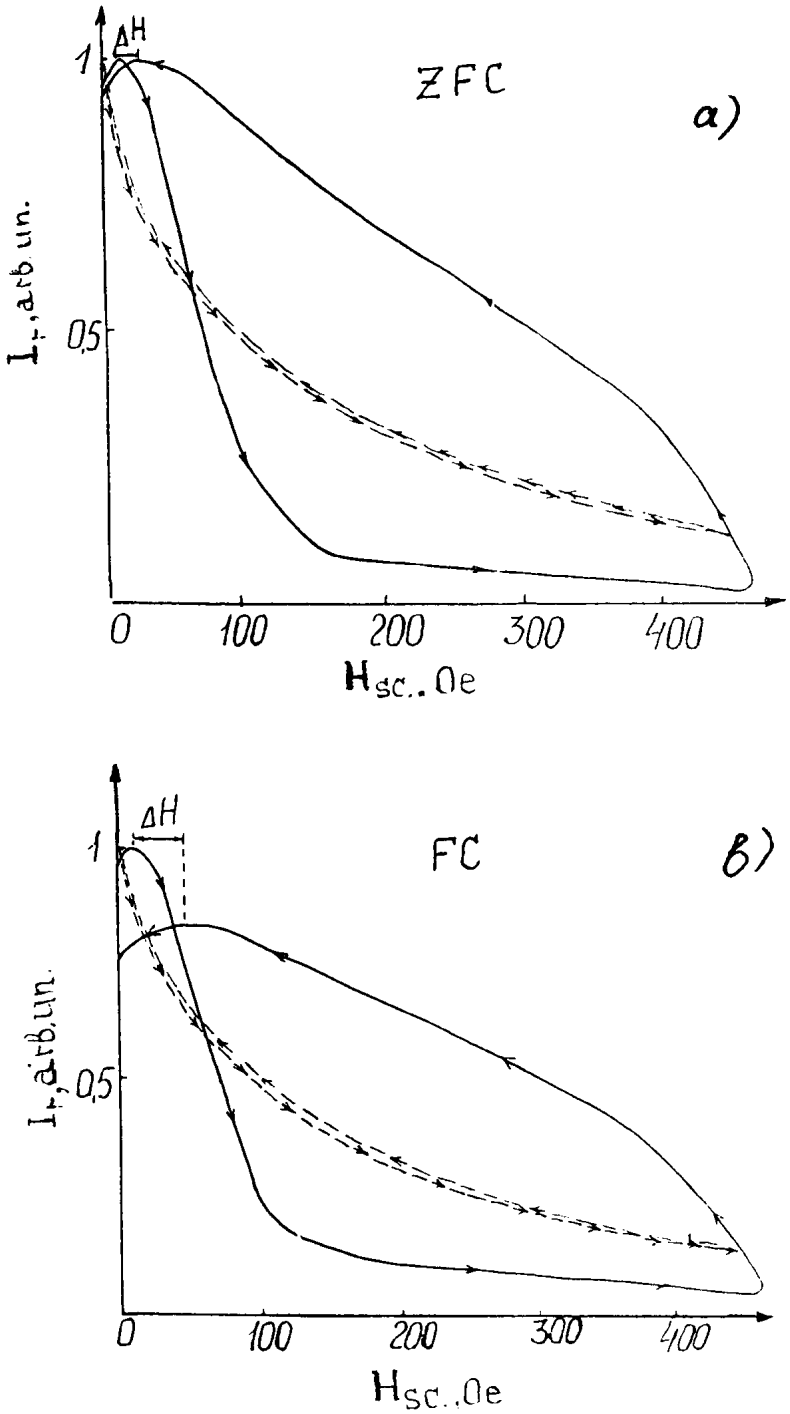

Fig.1. Hysteresis of rf-absorption in $YBCO$-ceramics (solid) and $BSCCO$-quasicrystals (dashed) under direct and reverse magnetic field scanning in regime ZFC and FC

The observed enhancement of J_{cJ} under fast neutron irradiation reveals more significant in $BSCCO$ (with initially higher $J_c^o = 10^5$ A/cm^2) as compared to $YBCO$ (with initially lower $J_c^o = 300$ A/cm^2). It can be supposed that the mentioned effect of J_c enhancement is rather connected with dominating vortex pinning than with radiation ordering since the latter effect reveals stronger in initially disordered HTSC (with low J_c). The enhancement maximum of J_c in investigated HTSC is observed at neutron fluence $\Phi_{max} = 5 \cdot 10^{17}$ cm^{-2}. At $\Phi > \Phi_{max}$ dependence $J_c(\Phi)$ falls down according to power law $J_c \sim \Phi^{-\alpha}$.

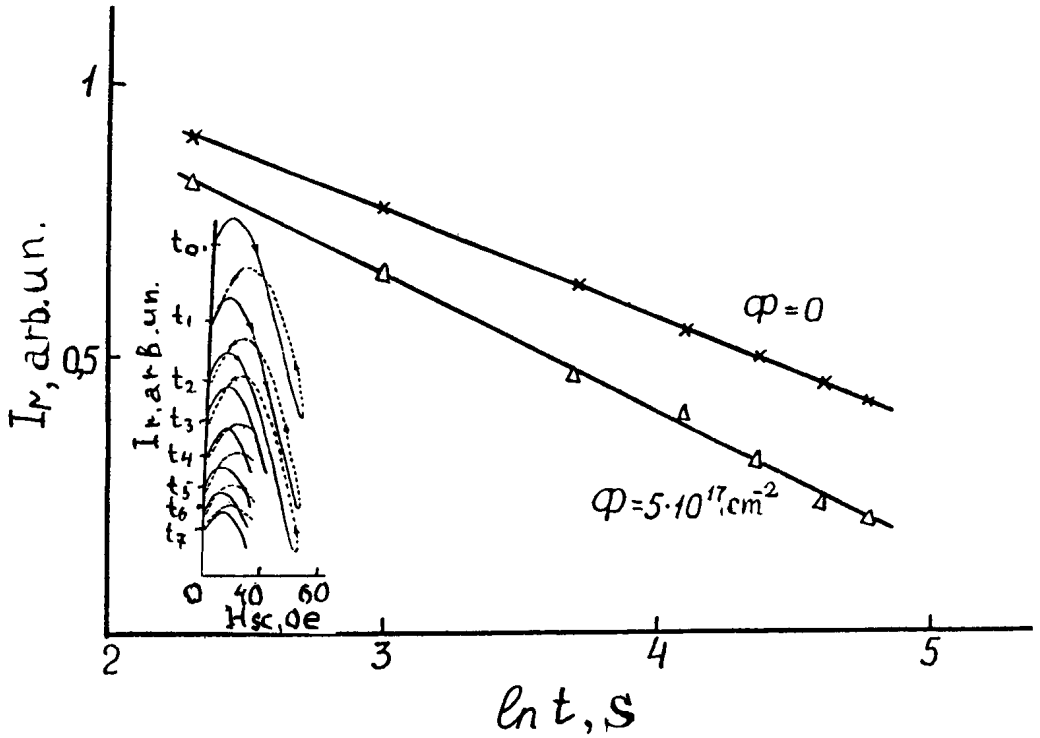

Fig.2. Magnetic flux creep determined from time dependence of hysteresis loop (the inset) for $YBa_2Cu_3O_{7-x}$-ceramics

The peak position of $J_c(\Phi)$ dependence permits to estimate the average distance L between PCs in assuming that the average size of RDs $-d = L$ in the peak of $J_c(\Phi)$. According to the known cross-section defect formation in HTSC $\sigma = 0,05$ cm^{-1} [3] and taking into account uniform RD's distribution in HTSC under neutron irradiation, the concentration of PC at $\Phi_{\max} = 5 \cdot 10^{17}$ cm^{-2}: $N_{pc} \sim \Phi \cdot \sigma = 2,5 \cdot 10^{16}$ cm^{-3} and the average distance between radiation PC$-L \sim N^{-1/3} = 34$ nm have been determined.

Thus, the measurements of quasistationary rf-absorption of irradiated HTSC allowed to estimate some parameters of HTSC and SC-transition: the area of transition S, the penetration depth λ_J,values of the critical current as well as the average distance between radiation PC.

To study the peculiarity of dynamic critical state the hysteresis signal of hf-absorption was measured *vs* a direction magnetic field, regime cooling, time and temperature. Fig.1 presents the experimental dependencies of hf-absorption $I_r(H)$ $YBCO$-ceramics and $BSCCO$-quasicrystals in which the hysteresis was observed under direct and reverse field scanning. It has following typical peculiarities:

- the value of hysteresis (area of the loop) depends on a degree of HTSC's granularity, namely, in ceramics the hysteresis is more than in Bi-quasicrystals;
- the hysteresis is revealed in two ways: in value and in the peak position;
- the value of hysteresis rises with the temperature lowering owing to more effective trapping of magnetic flux at low temperature;
- the hysteresis depends on regime of cooling: for ZFC it is more than for FC;
- the evolution of hysteresis *vs* time is observed (Fig.2) after trapping magnetic flux $H_{\max}$ by HTSC-samples and at successive scanning by field $H < H_{\max}$. This evolution is cha-

racterized by the flux movement and permits to estimate the creep rate of magnetic flux $S = dI_r/d[\ln(t)]$;
– from the fall-down of intensity $I_r(t)$ the value $S = 0,25$ was found and the pinning potential $U = 0,027$ eV $(T = 77K)$ in irradiated $YBCO$-ceramics was determined which showed week attachment of the vortices at PC.

The above — specified peculiarities of the hf — absorption hysteresis are explained in terms of phenomenological model of dynamical critical state [4], based on superposition of external applied field and inner fields (local inter grain, intra grain diamagnetic and paramagnetic field) under direct and reverse scanning of external field.

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