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CRITICAL CURRENTS IN YBaCuO-CERAMICS

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Introduction

Starting from the [1] a great attention was attracted to physical properties of Josephson medium study. In our work we propose the new method of the measurement of the critical current density of the Josephson medium (i.e. of the ceramics transport currents) and their dependences versus field and temperature. Beside this, the temperature dependence of the first critical Josephson field was found.

Experimental

For the measurements the SQUID-magnetometer with high resolution ($10^{-12} A \cdot m^2$) was used. The experiments were carried out at T_c = 90.5 K, on the superconducting YBaCuO ceramic prepared by the standard technology of solid state synthesis. The sample was treated mechanically to give it the cylinder shape 3.7 mm height and 1.5 mm in diameter.

The magnetization measurements were carried out by the next procedure. The sample was cooled from 95 K down to 5 K at magnetic field < 10^{-2} Oe. Then at 5 K the external magnetic field H was switched on. The introduced field magnitude was controlled through the signal from the superconducting sample (Pb) placed into the same container with the sample under examination. The accuracy of magnetic field measurements ≈ 0.1 % was attained. After that the YBaCuO sample was placed into one of the magnetometer receptive loops and the temperature elevated up to 95 K. Each 0.1 K the magnetic moment M of the YBaCuO sample was controlled. This method gives the accuracy of magnetic moment measurement not worse than 0.1% in fields ≥ 5 Oe.

The obtained curves are plotted in fig.1a. Such a behavior of magnetic susceptibility χ was already observed (for example [2]) and has a traditional interpretation. At low fields and temperatures the sample screens the magnetic field by its whole volume. At temperature increasing the ceramic weak links begin to destroy, and the field penetrates into the sample until the main signal is determined by the screening of the magnetic field by separate grains. Now the susceptibility signal has a plato. At the more elevated temperatures the field penetrates into the grains and superconducting transition stops at Tc .

Thus, we can mark out two areas: the Josephson medium area and the grain area. Using critical state model, we found the Josephson critical current density j_c and its dependence on field and

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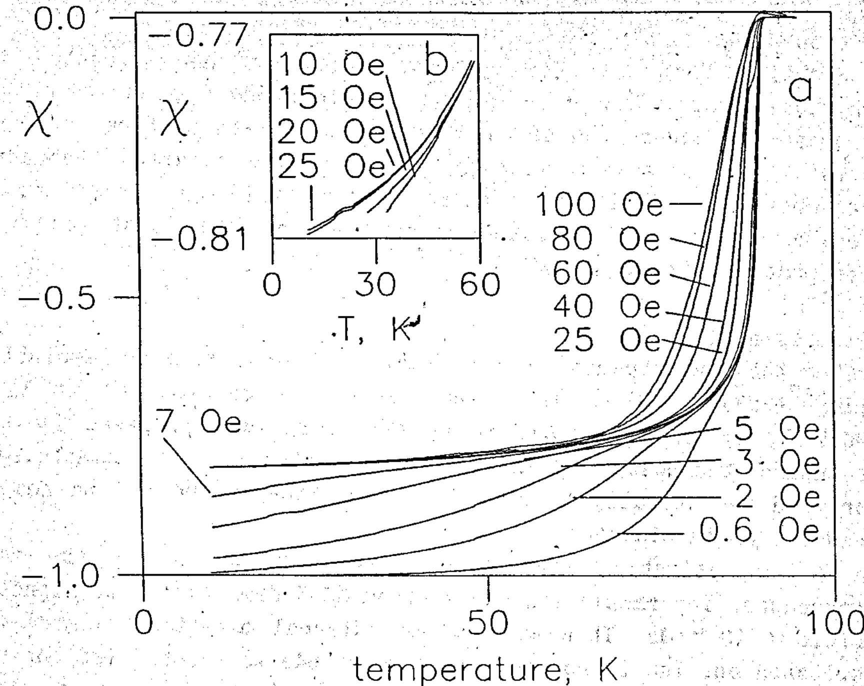

FIGURE 1 a,b

The ZFC susceptibility temperature dependence in various fields

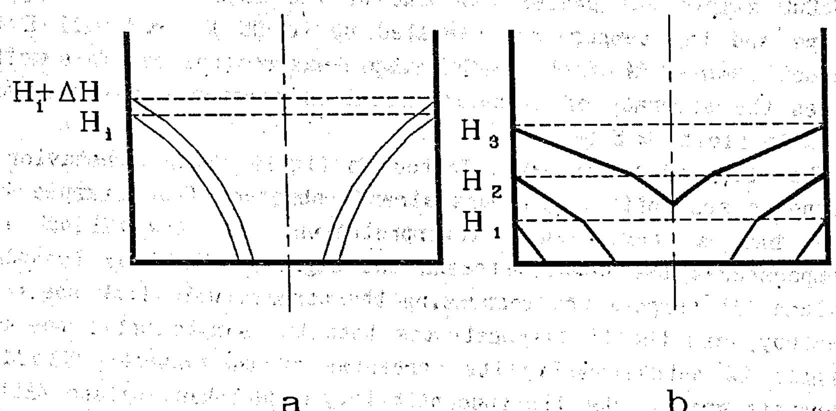

FIGURE 2 a,b

Penetration of the magnetic field into the sample

temperature for Josephson area. Critical current was determined by the following procedure. Let us exclude the grain signal χ_g. To this end we introduce the Josephson susceptibility χ_j:

$$\chi_j = -\frac{\chi-\chi_g}{1-\chi_g},$$

here χ is the magnetic susceptibility of the sample. Curve $\chi(T)$ at $H = 25$ Oe was selected as the χ_g level (see fig. 1b) in a temperature range of T = 10K - 70K. The grain shielding signal χ_g depends significantly on temperature. It may be connected either with the London penetration depth dependence, or with the fact that the transition temperature T_c of some grains is lower than 90.5 K.

Now from the series of curves $\chi_j(T)$ at different fields we will go to the set of points $\chi_j(H_i)$ at given temperature, i = 1...N, where N is the quantity of the curves regarded. To evaluate the $J_c(H)$ dependence the following speculation was used: if at the external field H_i it penetrates into the sample by a certain profile (see fig 2 a) then being increased the external field by ΔH the new profile can be considered the linear one from $H_i + \Delta H$ to H_i, and starting from H_i it repeats exactly the former. By the experimental points $\chi_j(H_i)$, assuming that the critical current density is constant between the fields from H_{i-1} to H_i and is equal to $J_c(H_i)$ (see fig.2 b), the $J_c(H_i)$ is evaluated from 1 to N. These evaluations claim high accuracy of χ and H measurements due to large shielding signal.

The evaluation results are shown in fig.3. It must be emphasized that the region of small fields and critical current high densities cannot be examined within the frame of the Josephson medium only, since the depth of the field penetration into the sample $d = H/J_c$ can became smaller than one grain linear size. Therefore the region of possible H and J_c must be limited by the straight line $J_c = H/d_{min}$, where d_{min} is the minimum size of the system. In fig. 3 the $J_c = H/d_{min}$ is represented by solid line for $d_{min} = 100$ μm.

Discussion

The $J_c(H)$ dependence can be roughly approximated by the 1/H dependence. It has no saturation at low fields within the limit of d_{min}.

High values of critical current density at low fields, i.e. at the surface of the sample, indicate the possibility of the surface

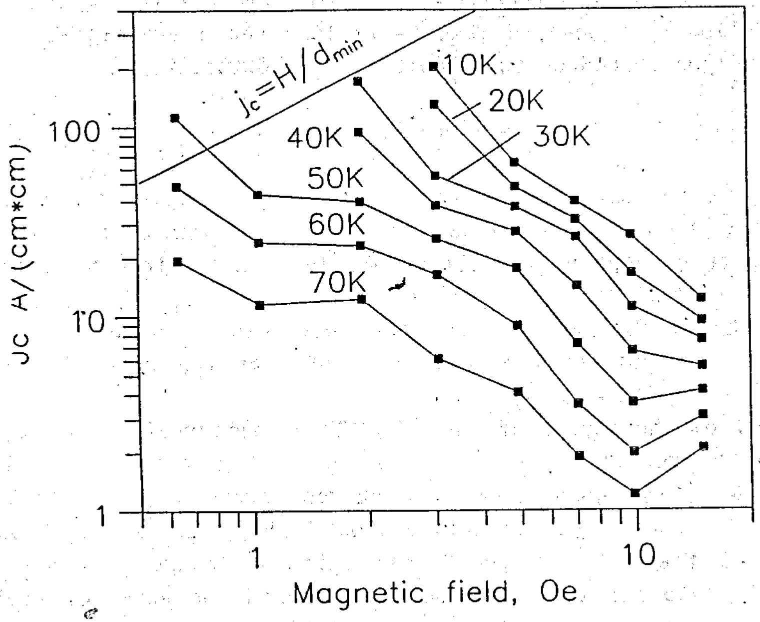

FIGURE 3

Critical current density dependences versus field at various temperatures

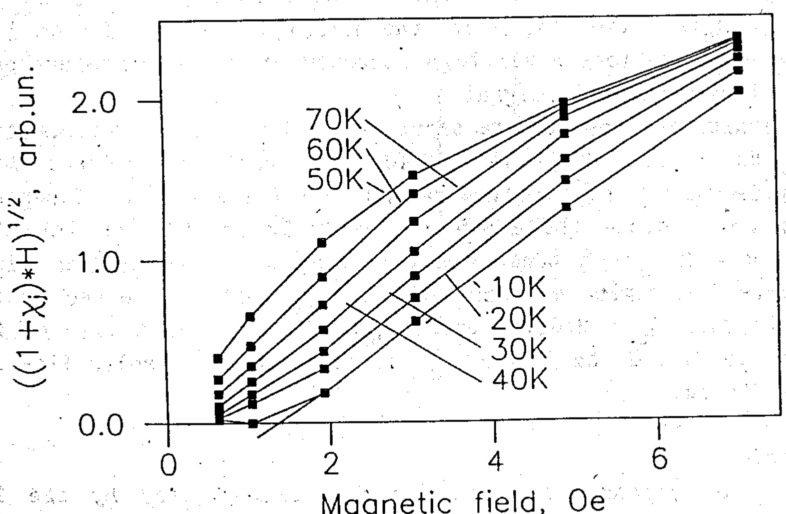

FIGURE 4

$\sqrt{(\chi_j+1)\cdot H}\rightarrow 0$ **extrapolation gives** H_{j1}

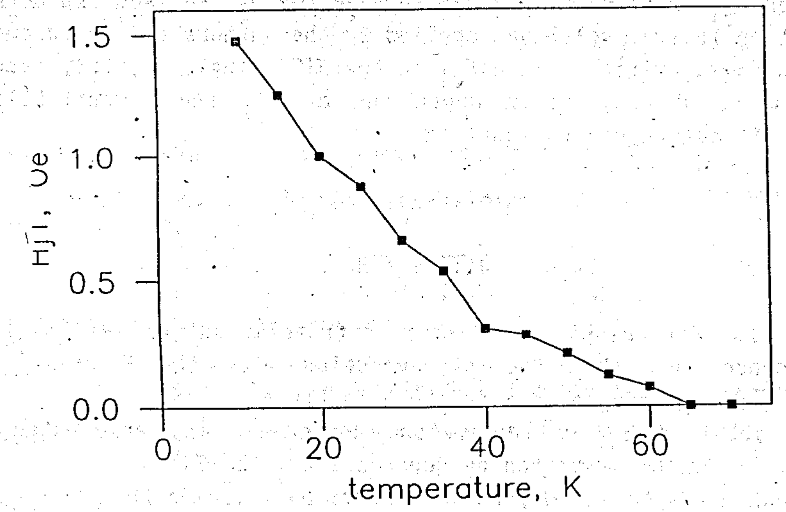

FIGURE 5

H_{j1} **temperature dependence**

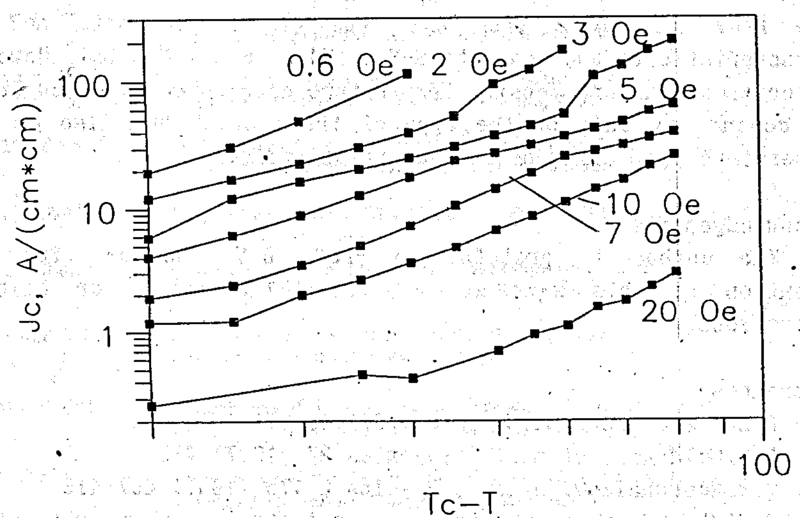

FIGURE 6

Critical current density dependence versus temperature in various magnetic fields

barrier H_{j1} existence. In order to find the H_{j1} we used the method described in [3], which was applied by the authors for measurement of the first critical field H_{c1} in the HTSC single crystal, namely at low field penetration depth and at H_{j1} the susceptibility signal is determined by equation

$$1 + \chi_j = (H-H_{j1})^2/(j_c \cdot R \cdot H), \text{ or}$$

$$H-H_{j1} \simeq \sqrt{((1+\chi_j) \cdot H)}.$$

H_{j1} is determined by linear extrapolation of $\sqrt{((1+\chi_j) \cdot H)}$ dependence from H to the intersection with the H axis. The $\sqrt{((1+\chi) \cdot H)}$ dependence on H is shown in fig.4.

The obtained $H_{j1}(T)$ temperature dependence is represented in fig.5. It can be described by dependace $H_{j1} \propto (T_c-T)^3$.

We can derive $j_c(T)$ dependences at various fields from the $j_c(H)$ dependences. They are shown in fig.6 and are well approximated by $j_c \propto (T_c-T)^2$ dependence. Similar dependence was observed for example for granulated YBaCuO films [4].

If we consider isolated Josephson contact temperature dependence we can see that it obeys the $j_c \propto (T_c-T)^n$ dependence, where n can vary from 1/2 to 2 with the type of the contact. $n \simeq 2$ is characteristic to the contacts S-N-S [5] or S-N-I-N-S [6]. However the critical current density temperature dependence obtained above can depend not only on the type of the contact but also on the temperature properties of the Josephson medium.

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