MAGNETIC HYSTERESIS OF SUPERCONDUCTING GdBa2Cu3O7 DOWN TO 1.8 K

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MAGNETIC HYSTERESIS OF SUPERCONDUCTING $GdBa_2Cu_3O_7$ DOWN TO 1.8 K

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Abstract. – We report magnetization measurements on single-phase sintered $GdBa_2Cu_3O_7$ between 1.5 and 100 K and in fields up to 35 kG. The shape of the low-field diamagnetic loop at 4.2 K is typical of the high-T_c Y-Ba-Cu-O systems and is imposed by Josephson junctions. The high-field regime is influenced by the paramagnetic response of Gd-ions. Saturation effects are observed near the Néel temperature $T_N \sim 2.5$ K. The intra-grain magnetic critical current J_c is roughly the same ($\sim 10^6$ A/cm^2 at 4.2 K) as in Y-Ba-Cu-O systems either granular of single crystals.

One of the surprising features of the $YBa_2Cu_3O_7$ high-T_c superconductors is the insensitivity of the *transition temperature T_c to the substitution* of Y by the trivalent magnetic rare earth ions [1, 2]. A second question which will be emphasized here concerns the influence of the rare-earth elements on the critical curent densities and the associated diamagnetic cycles.

The sample investigated in this paper ($GdBa_2Cu_3O_7$) is granular with grain diametér probably of order 10-20 μm. The magnetic measurements were done with a vibrating sample magnetometer as described in reference [3, 4].

Figure 1 shows a set of magnetic cycles (*M vs. H*) at different temperatures ranging from 1.5 to 100 K and in fields up to 35 kG.

As in the case of $YBa_2Cu_3O_7$ [4] and $La_{1-x}Sr_xCuO_4$ [3] the *M vs. H* relationship of $GdBa_2Cu_3O_7$ exhibits several irreversibility regimes. First, at low enough field ($H \leq 100$ G at $T \ll T_c$) we observe (inset Fig. 1) a very small loop characterized by a lower threshold field (H_{c1}^{w}) below which the initial *branch of the curve is fairly linear* and reversible and by an upper threshold field (H_{c2}^{w}) above which the curve again becomes reversible and linear but with a strong reduction of the magnetic susceptibility χ, that is $\chi(H_{c2}^{w}) / \chi(H_{c1}^{w}) \sim 50$ % in the present case. the low-*H* cycle discussed above is ascribed to the penetration of the field within the sample through the weakly-superconducting links connecting more strongly superconducting grains [3, 4].

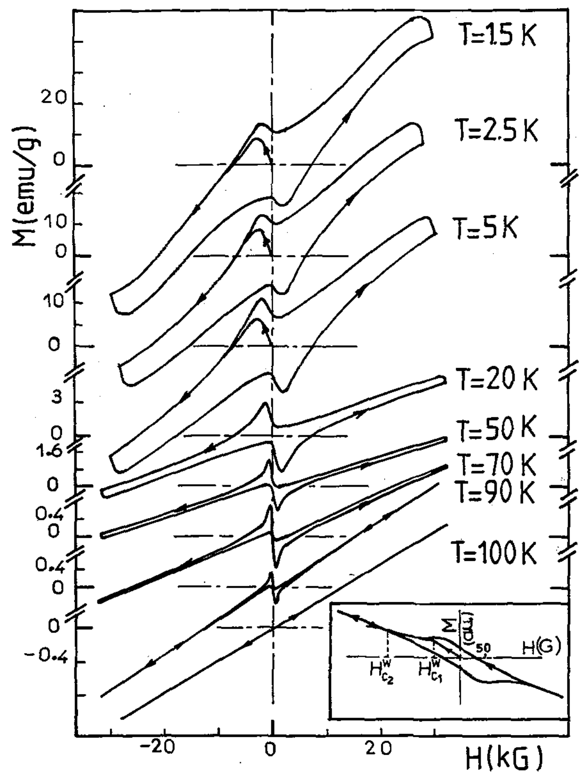

Fig. 1. – The magnetization as a function of field for $GdBa_2Cu_3O_7$ at various temperatures. The inset shows the magnetic heehaviour at very low fields.

As the field is further increased from H_{c2}^{w} we observe the onset of a regime of strong irreversibilities at a third critical field H_{c1} (~ 300 G at 4.2 K) identified as the first critical field of the grains. It can be seen (Fig. 1) that the shape of the high field cycle changes considereably with T : on the one hand, at the lowest temperatures (T = 1.5 and 2.5 K) there are some tendencies toward saturation at the highest field available (35 kG). However, the $M(H)$ curve hardly obeys a Brillouin function even in a limited field range (15-35 kG). On the other hand, at the highest temperatures (see isotherm 90 K) the curve once again becomes reversible above a fourth threshold field $H_r(T)$. It will be shown later (see formula 1) that $H_r(T)$ defines a line in the (H, T) plane above which the critical current density is zero (within the experimental uncertainties). Finally, the sample behaves like a perfect paramagnet at $T \geq 95$ K $\sim T_c$. All the above behaviour at $T < 95$ K is again very similar to that seen in $YBa_2Cu_3O_7$ except the large paramagnetic contribution which exceeds the diamagnetic one at $H \geq 2$ to 3 H_m where H_m is the value at which $M(H)$ passes by a maximum. The magnetic critical current density within a given grain of radius r_g is given by the critical state formula

$$J_c(T,H) = 15\,[M_+(T,H) - M_-(T,H)]\,/\,r_g \qquad (1)$$

where the units are: r_g in cm ($r_g \sim 10^{-3}$ cm here), M in emu/cm^3 and J_c in A/cm^2. $M^+(H) - M^-(H)$ is the distance between the direct and the returning branches of the magnetic cycles of figure 1. The temperature dependence of J_c is presented in figure 2 (note the semi-log scale) for $H = 9$ and 18 kG. The most striking features of this figure are the large value of the intra-grain current ($J_c > 10^6$ A/cm^2 at 4 K) and their abrupt drop with T. It is again remarkable that both the magnitude of J_c and its temperature dependence are quite similar to those of $YBa_2Cu_3O_7$ either granular or single-crystal when we use the appropriate radius (i.e. of the grain or of the single crystal) in each case.

Finally, from the variation of

$$M(\mathrm{Gd}) \sim (M_+(T,H) + M_-(T,H))\,/\,2$$

with T at 9 kG we find a Néel temperature $T_N \sim 2.5 \pm 0.4$ K and a Curie-Weiss temperature $\theta \sim -2 \pm 1$ K in agreement with previous results [5].

It must be stressed that because of the spurious effects associated with magnetic irreversibilities and the associated time effects and because of the flux jumpss which could cause local heatings the data should involve some inherent uncertainties which call for further investigations;

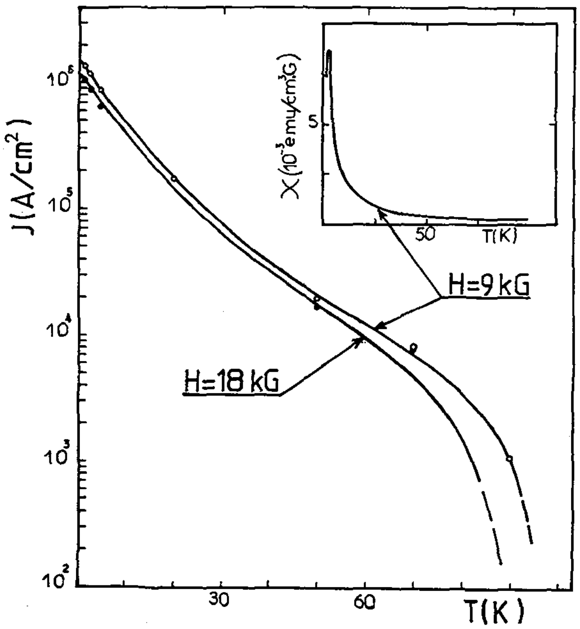

Fig. 2. – The magnetic critical current of $GBa_2Cu_3O_7$ as a function of temperature at 9 and 18 kG. Inset: the magnetization of Gd as a function of temperature at 9 kG.

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