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Magnetic hysteresis of Re-doped HBCCO polycrystals

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We have performed a study of the magnetic hysteresis of $(Hg_{1-x}Re_x)Ba_2Ca_2Cu_3O_{8+\delta}$ samples with two "extreme" Re-substitutions in a temperature interval close to T_c. We observe a strong asymmetry of the magnetization loops that can be associated with grains surface barriers or reversible magnetization. We also determined the temperature dependence of the first penetration field and the irreversibility field of the grains, and the field dependence of the magnetization curve width. The results suggest that the optimum pinning level is located at $0.09<x<0.24$.

1 INTRODUCTION

The ceramic superconductors of the Hg family have focused a growing interest, due to their high critical temperature (135K [1]) and low anisotropy, if compared with Bi- and Tl-based HT_c's. It has been shown that the partial substitution of Hg for Re increases the stability and pinning strength of Hg-1223 phase [2]. In this paper a systematic study of magnetization loops at various temperatures is performed for two "extreme" substitutions of Hg1223 ceramics, and the temperature dependence of the penetration and the irreversibility fields are reported.

2 EXPERIMENTAL

The samples of nominal composition $(Hg_{1-x}Re_x)Ba_2Ca_2Cu_3O_{8+\delta}$ were obtained by the conventional ceramic route [2]. We only report here results for the substitutions x=0.09 and x=0.24, which we will call "Re0.09" and "Re0.24", respectively. While the first one corresponds to a very low Re content, the second is close to the nominal solubility limit (x=0.25) [3], so we are examining two "extremes" of the series. The measurements were performed in a MPMS-5S Quantum Design SQUID, in DC mode, using a scan length of 1cm to minimize magnetic field inhomogeneities, and 10 scans per measurement to diminish the noise. The field was applied along the longest dimension of the bars cut from the pellets, at a mean rate of ±1 Oe/s after zero field cooling (ZFC). The resistive transition onset for Re0.24 was 133K [4], and 4K wide.

3 RESULTS AND DISCUSSION

Figure 1 shows the magnetization curves for samples Re0.09 and Re0.24.

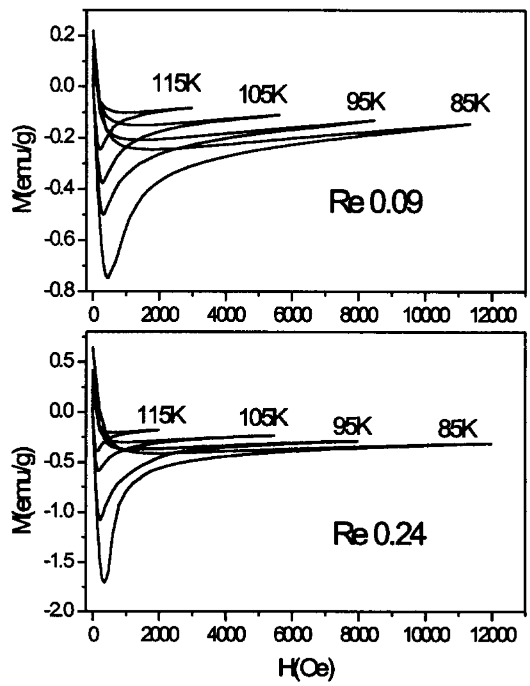

Figure 1. ZFC magnetization curves at different temperatures for samples Re0.09 and Re0.24. Straight lines as eye guides connect the experimental points. These lines overlap with the error bars.

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We should first remark that, considering the poor transport critical current density observed in these samples [4], we are assuming in the following analysis that all the features observed above a few oersteds, are *intra*-granular [5]. The strong asymmetry of the magnetization curves with respect to M=0 can be associated either to surface barriers and/or to a large reversible magnetization [5].

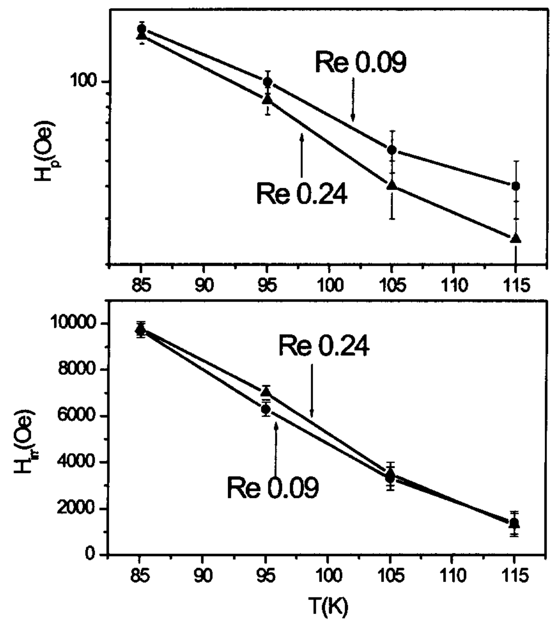

Figure 2. Temperature dependence of the first penetration field (upper graph) and of the irreversibility field (lower graph) of the grains.

The upper graph of Figure 2 reports the first penetration field of the grains, defined as the field at which the virgin curve abandons the linear behavior [5]. The approximate exponential temperature decay of H_p suggests that vortices move as weakly coupled pancakes [5] for both samples. The "better performance" of Re0.09 must be seen with caution, given the error bars. The lower graph of Figure 2 shows the temperature dependence of the irreversibility line (IL) defined as the point at which the field-increase and field-decrease branches of the magnetization start to overlap, considering our error bars. No sizable differences between the two samples are detected. Figure 3 displays the width of the magnetization curves (ΔM) for T=85K. Within a bulk pinning model [5], ΔM is proportional to the intragrain critical current density, J_c^{bulk}. Both curves display a quite similar

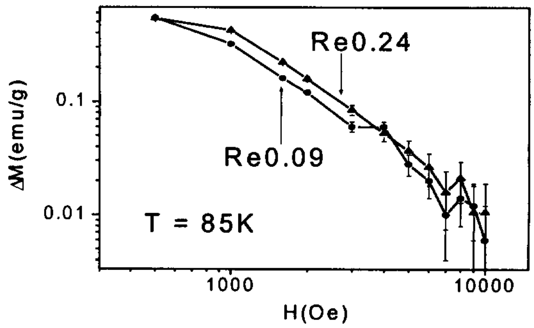

Figure 3. Field dependence of the width of the magnetization loops for T=85K

decay above 1kOe of the type $J_c^{bulk} \propto H^{-\beta}$, with $\beta \approx 1.5$ (a power law is also found in [6] close to T_c, but for a FC/ZFC regime). This fact, plus the similarities in the IL behavior indicate that no sizable differences in pinning strength exist between our two "extreme" Re substitutions. Considering that in [3] it is suggested that the formation of various defects favor pinning for Re contents below the theoretical solubility limit ($x \approx 0.25$) one may expect a pinning improvement for $0.09 < x < 0.24$.

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