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MAGNETIC MEASUREMENTS OF MAGNITUDE AND TIME STABILITY OF INDUCED CURRENTS IN THE Y-Ba-Cu-O DOPED WITH Cd AND Mg[1]

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Superconducting doped ceramic materials $YBa_2Cu_3M_xO_y$ (M = Cd, Mg) were prepared using Cu_2O instead of CuO with average size of grains close to 20 μm. Nominal doping concentration x of Cd and Mg was between 0 and 0.075 and 0.025 and 0.20, respectively. The effect of x on both magnitude and time stability of critical currents was studied from magnetic hysteresis loops recorded with different rates of field sweep. We have observed increase of induced currents with increasing content of Cd by about 15 to 40 % for 0.075 of Cd while the relaxation rate $Q = d\ln j/d\ln(dB/dt)$ was nearly independent on the Cd doping. The fish-tail effect (increase of superconducting currents with magnetic field) was observed in the Mg doped samples which is consistent with decreasing Q with increasing field at temperatures up to about 60 K.

Doping of ceramic YBaCuO with other atoms may improve significantly the superconducting properties. Cd and Mg doped YBaCuO systems has been investigated in various laboratories [1-3]. Contradictory results of these investigations were caused probably by different way of sample preparation and by different level of doping. Aim of this work is magnetic study of the effect of Cd and Mg doping on the magnitude and time stability (flux pinning) of induced currents in these materials at various temperatures and fields.

Our samples were prepared using Cu_2O as one of precursors [3,4] instead of commonly used CuO. This results in different temperature of oxygen uptake during the annealing. Nominal doping concentration x of Cd and Mg was between 0 and 0.075 and 0.025 and 0.20, respectively. The as-grown pellets were cut into slices and annealed at 970 K for 30 min and let to cool for about 10 hours to the room temperature.

Average size of the grains was determined from the statistical analysis of the distribution of the grain size values (see figure 1) obtained with an optical microscope. The

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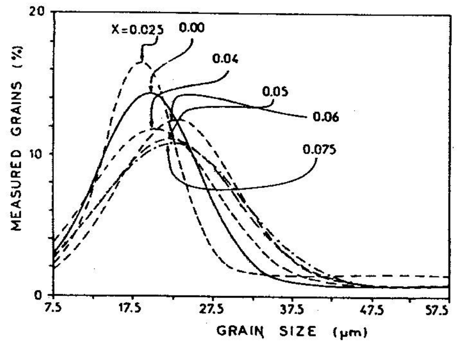

Fig. 1. Distribution of the grain size of the ceramic samples for different Cd doping x.

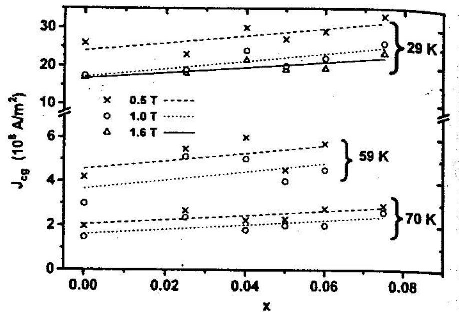

Fig. 2. The induced currents J_{cg} plotted as a function of doping concentration x for selected values of B and T.

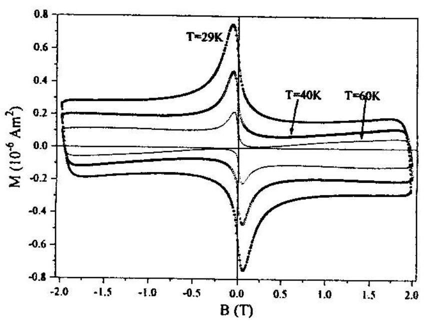

Fig. 3. Typical magnetic hysteresis loops measured at various temperatures on sample doped with 0.2 Mg. Note increasing height of the loops with increasing field corresponding to larger induced currents in larger fields.

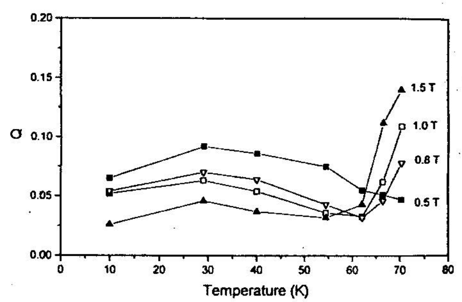

Fig. 4. The rates of relaxation $Q = d\ln j/dln(dB/dt)$ at different fields and temperatures for the sample doped with 0.2 Mg.

average grain size slightly increased with x being between 18.8 and 23.2 μm for the Cd doped samples. Transport properties and positron annihilation measurements made on these samples were published in [5].

The magnetic moment induced by changing external magnetic field B was measured using a vibrating sample magnetometer [6]. Magnetic hysteresis loops were recorded with various rates of field sweep dB/dt which enables to evaluate both magnitude [7,8] and time stability [6] of induced currents.

Changing magnetic field induces in ceramic superconductors two types of currents. The inter-grain currents flowing through all volume of the ceramic sample are relatively low limited mainly by the weak contacts between grains. Much larger intra-grain curents J_{cg} flow inside of each grain with radius close to the dimension of grains. Consequently

T[K]	0.5 T	1 T	1.6 T
29	0.075	0.058	0.042
59	0.055	0.038	0.025
70	0.055	0.041	0.032

Table 1: The rates of relaxation $Q = d\ln j/dln(dB/dt)$ evaluated at several fields and temperatures for the Cd doped samples. The Q values are nearly independent on the Cd doping up to $x = 0.075$.

the total measured induced magnetic moment m in ceramic superconducting samples is the sum of these two contributions [7,9] and it is in general difficult to distinguish between them. However, based on extensive experience with such materials [7,9] one can often assume which type of currents is dominant in particular range of fields and temperatures.

The induced currents J_{cg} for the Cd doped samples are plotted in figure 2 as a function of x for selected values of B and T. The J_{cg} values were evaluated using the measured avarage grain size for x. There is an increase of J_{cg} with Cd concentration by about 15 to 40 %.

The rate of relaxation $Q = d\ln j/dln(dB/dt)$ was evaluated from sets of hysteresis loops recorded with different rates of field sweep (the dynamic relaxation): the larger the difference between loops recorded with high and low field sweep is the larger is the relaxation of induced currents [6]. We observed considerable dependence of Q on both T and B on the Cd concentration x (see Table 1), but there was no clear dependence on x.

The relaxation of currents (flux creep in vortex system) in HTS materials like our ceramics takes place mainly inside grains (the relaxation of J_{cg}) due to very short coherence length of these materials so that the observed Q values reflect more the vortex pinning in the material inside grains than flux pinning on large imperfections due to granular structure of material [7].

Magnetic hysteresis loops on the Mg doped YBaCuO exhibit often larger magnetic moments in field of 2 T than in 1 T (see figure 3) indicating larger superconducting currents at higher magnetic fields (the "fish-tail" effect) which has been so far observed mainly on bulk single crystals [10]. It is explained by anomalous field dependence of relaxation processes in vortex systems when current relaxes faster in lower magnetic fields. The shape of our hysteresis loops is consistent with the temperature and field dependence of the relaxation rate Q where Q decreases with increasing magnetic field in wide range of temperatures up to about 60 K (see figure 4).

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