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# FLUX DISTRIBUTION IN POLYCRYSTALLINE $YBa_2Cu_3O_7$

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The spatial distribution of the magnetic flux in polycristalline films and sinter pellets has been measured. Pronounced symmetric structures on a mm scale are observed in a field range of a few Gauss.

## INTRODUCTION

The magnetic behaviour of polycrystalline high $T_c$ superconductors is to a large extent governed by the weak links between the individual grains. As a result, magnetic flux penetrates into these samples already at very low fields on the order of a few Gauss. Numerous investigations have been performed concerning the magnetization and hysteresis curves of such samples (1). As to the spatial distribution of the flux most of these studies rely on assumptions like the Bean model (2); only in very few cases the actual distribution has in fact been measured. We present here results for polycrystalline $YBa_2Cu_3O_7$ which show examples for a flux distribution in good accord with the Bean model; others, however, display pronounced deviations from this model, both for sintered pellets and for thin polycristalline films.

## EXPERIMENTAL

The films used here were obtained by deposition of laser-ablated material on $ZrO_2$ ($10 \cdot 10$ $mm^2$); the pellets were prepared by the usual sintering process with a diameter of 12 mm and a thickness of about 2 mm. For some runs these discs were ground to a height of less than 0.5 mm to study the influence of the sample thickness. The magnetization was measured with a small vibrating pick-up coil as described earlier (3), which was scanned across the sample at a distance of about 0.3 mm. The spatial resolution of this device was $1 \cdot 3$ $mm^2$, much too coarse to detect the grains, but sufficient to resolve, for example, the ring currents induced in the sample by variations of the external field. Most of the measurements were performed under zero field cooling (ZFC) conditions at 77 K. Both shielding effects and the remanent state were studied by first scanning the sample exposed to a certain magnetic field and afterwards measuring the magnetization with the external field being turned off. Field-cooling (FC) the sample in a constant magnetic field yielded additional information.

## RESULTS AND DISCUSSION

Fig. 1 shows results for the flux distribution in a sintered pellet. For this sample the data, which were taken under ZFC conditions, are in qualitative agreement with the Bean model. With a magnetic field being applied (Fig. 1a), shielding currents along the pellet perimeter prevent the flux from entering the sample (B=3 Gauss, lowest trace). For higher fields a critical current density $j_c$ is reached, and flux penetrates from the edge in a roughly linear way. The field distribution found for 12 Gauss was similar to the one obtained with a

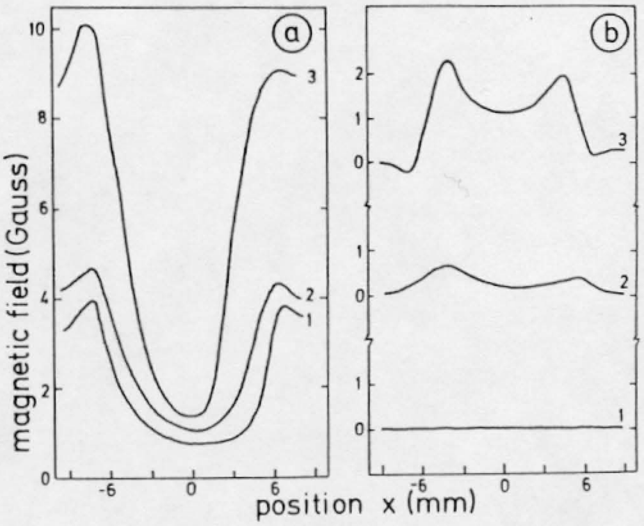

Fig. 1: Magnetic field at a distance of 0.3 mm above the surface of a sinter pellet (12 mm diam., 1.8 mm thickness). a) Shielding signal, with externally applied fields for trace 1: 3 G; 2: 4 G; 3: 8 G. b) Remanent signal. Traces 1-3 were each taken immediately after the corresponding trace in Fig. 1a.

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"model sample" consisting in a flat coil wound in the form of a spiral, thereby simulating ring currents with a constant current density. This suggests that also in the sinter pellets ring currents with $j=j_c$=const were flowing at $B=12$ Gauss throughout the whole disk.

For the same sample, Fig. 1b shows the remanent magnetization after turning the field off. Above a threshold of about 3 Gauss trapped flux was observed, which did not change no-ticeably on a time scale of minutes. (Also the other curves in Figs. 1 and 2 were constant on this time scale).

As already mentioned, field distributions qualitatively different from those given in Fig. 1 were found for some sintered pellets as well as for polycrystalline films. In order to demonstrate that this is not simply due to sample inhomogeneities, but is an inherent property depending on critical currents and pinning forces, we have reduced the thickness of the pellet of Fig. 1 by grinding it to 0.45mm and repeated the measurement of shielding (Fig. 2a) and remanent magnetization (Fig. 2b). In contrast to Fig. 1a the signal of the thinned sample in an applied field developes a pronounced maximum rather than a minimum at the center of the disk, with a field strength being approximately as large as the externally applied field itself. Likewise the remanent magnetization signal displays additional structure, showing (for $B \geq 3$ G) a sharp central minimum and altogether four maxima which tend to coalesce to two as the field to which the sample had been exposed is increased.

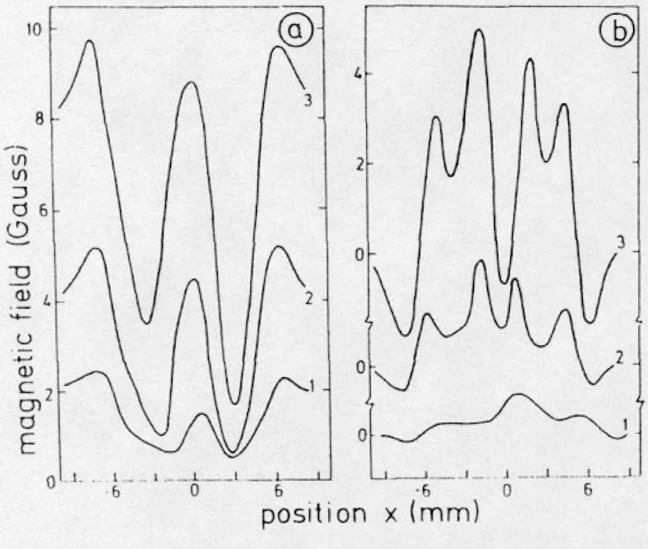

Fig. 2: Shielding (a) and remanent field (b) for the same sample as in Fig. 1, but with the thickness reduced to 0.45 mm. Trace 1: 2 G; 2: 4 G; 3: 8 G.

Results complementary to Fig. 2 were obtained for the same sample under FC conditions. With the cooling field still applied at 77 K the flux penetrated the sample nearly homogeneously (no macroscopic Meissner effect). When the external field was removed, a flux distribution with a central minimum developed, closely resembling an inverted image of Fig. 2a. Increasing the field back again to its original value yielded a "four minima" structure, again in close similarity to inverted traces of Fig. 2b. The magnetic structures shown above apperently result from the forces due to macroscopic ring currents and flux pinning. They bear resemblance with patterns well-known from discs of conventional type 1 superconductors (4).

## CONCLUSIONS

The data presented here demonstrate that in polycristalline high $T_c$ superconductors pronounced deviations from the widely accepted Bean model can occur. This is an effect interesting in itself, but it also has implications for the interpretation of integral magnetization measurements, like the derivation of critical current densities from ac susceptibility data.

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