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LOW FIELD MAGNETIC PROPERTIES OF SUPERCONDUCTING $Tl_2Ba_2Ca_2Cu_3O_{10}$ SINGLE CRYSTALS*

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Low Field Magnetic Properties of Superconducting $Tl_2Ba_2Ca_2Cu_3O_{10}$ Single Crystals

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Low field characterization of single crystals of $Tl_2Ba_2Ca_2Cu_3O_{10}$ using shielding, Meissner, and flux trapping measurements in fields of 0.2 to 40 Oe are presented. The highest inductive onset observed is 124 K. It is found that the shielding signal is highly non-linear in the applied field down to the lowest temperatures. The Meissner effect is found to be about 15 % of the shielding effect.

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Superconductivity has been discovered in the Tl-Ba-Ca-Cu-O system with a variety of transition temperatures and compositions [1-8]. One of the problems in studying the superconducting behavior of these materials is the difficulty of obtaining single phase samples. In this paper we report on the low field magnetic properties of single crystals, thus minimizing second phase contamination. We find small single crystals with fairly sharp superconducting transitions as high as 124 K. While the general magnetic behavior is qualitatively similar to that in the $YBa_2Cu_3O_{7-\delta}$ compounds, there are significant differences in the size of the Meissner effect, the strength of the flux pinning, and the sensitivity of the transition curves to the applied magnetic field.

Single crystals of $Tl_2Ba_2Ca_2Cu_3O_{10}$ were prepared by a self-flux technique, ranging in size from 0.3x0.3x0.5 mm^3 to 2x1x0.1 mm^3. X-ray measurements on the smallest crystals gave sharp reflections with a lattice constant in the c direction close to 36 Å, consistent with the 2223 composition [2]. Magnetic measurements on four crystals were performed in a low field SQUID magnetometer in fields as low as 0.2 Oe.

The Meissner effect was measured after cooling in an applied field to 4.2 K, then taking data on warming in the field. Shielding data were obtained after cooling in zero field, then applying a field and taking data on warming. Flux trapping data were obtained after cooling in the applied field, removing the field and taking data on warming in zero field.

Figure 1 shows shielding data taken in a field of 10 Oe along the **c** direction for the crystal with the highest T_c (124 K). This crystal was one of the smallest investigated, with a total moment of 6×10^{-6} emu in 10 Oe at 100 K. The transition temperature of this crystal is as high as any reported in the literature [4]. The inductive transition width of about 20 K (onset-completion) is typical of the smaller crystals with the exception of one which had a T_c of 120 K and a width of only 4 K in the same applied field. The magnitude of the signal in both of these crystals was too small for any systematic investigation.

Data for a larger crystal (with a magnetic moment about 100 times larger than that of the two crystals discussed above) is shown in Figures 2 and 3. This sample consisted of two subcrystals of slightly different orientation

imbedded in a finely crystallized matrix. Figure 2 shows how the inductive transition is affected by the applied field in the range 0.2 to 40 Oe. In the lowest field the inductive onset temperature is 119 K. The very broad transition observed in even the smallest field suggests that this crystal is rather inhomogeneous with a range in T_c down to at least 20 K. There is a systematic depression of the magnetic moment normalized to the applied field as the field is increased. This behavior is unlike that in $YBa_2Cu_3O_{7-\delta}$ crystals where the normalized magnetic moment curves in low fields rapidly approach the same value as the temperature is lowered below T_c. The observed non-linear behavior of the moment with applied field suggests low values of the lower critical field in $Tl_2Ba_2Ca_2Cu_3O_{10}$. Field-dependence measurements on a small, more homogeneous crystal similar to that of Figure 1 also indicate a rather small value for H_{c1}. In all four crystals investigated in this study, the inductive onset is considerably more strongly suppressed by applied fields of less than 100 Oe than is observed in $YBa_2Cu_3O_{7-\delta}$.

Figure 3 shows shielding, Meissner, and flux trapping measurements in a field of 2 Oe

performed on the same crystal as that used for Figure 2. For temperatures below 100 K, the Meissner signal amounts to about 15 % of the shielding signal independent of temperature. This value is three times larger than that typically observed in $YBa_2Cu_3O_{7-\delta}$ crystals. Above 100 K the fraction of Meissner to shielding increases to nearly 100 % just below T_c. This is consistent with the observation in Figure 3 that the flux trapping signal goes to zero at about the same temperature where the Meissner and shielding signals become equal. Qualitatively similar behavior is seen for the other three crystals. Over the whole temperature range the sum of the magnitudes of the Meissner and flux trapping signals equals the magnitude of the shielding signal to within a few per cent, similar to observations in $YBa_2Cu_3O_{7-\delta}$.

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Figure Captions

Figure 1. Magnetic shielding data in 10 Oe versus temperature for a small single crystal of $Tl_2Ba_2Ca_2Cu_3O_{10}$.

Figure 2. Normalized magnetization M/H versus temperature for a large crystal of $Tl_2Ba_2Ca_2Cu_3O_{10}$. The numbers labelling the curves are the applied fields in Oe.

Figure 3. Flux trapping, Meissner and shielding signal in 2 Oe versus temperature for the same sample as in Figure 2.

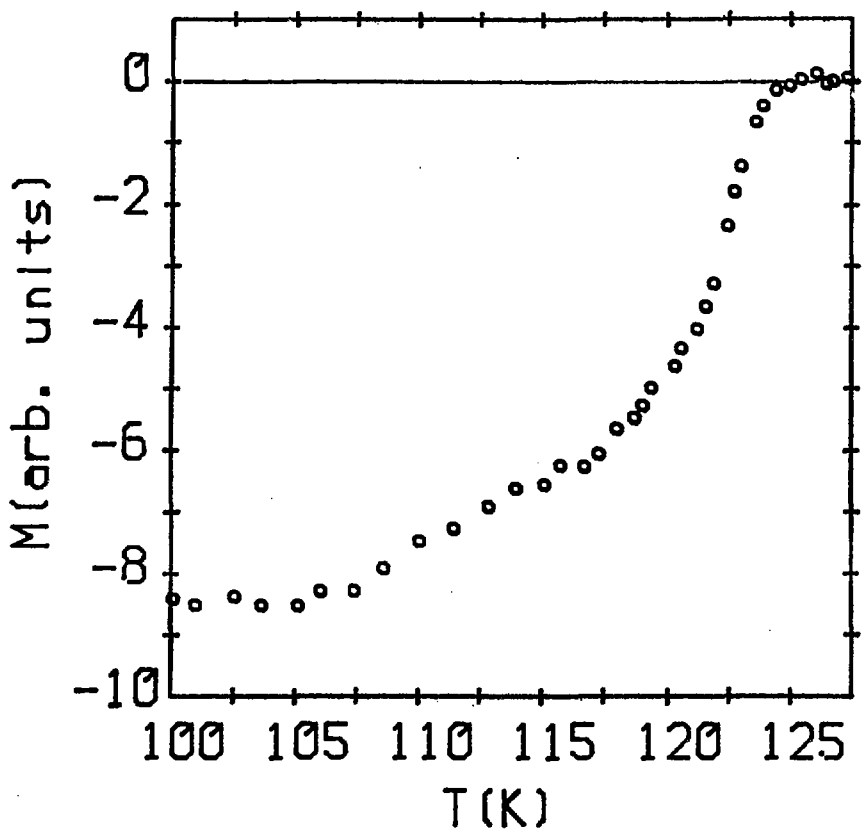

Fig. 1

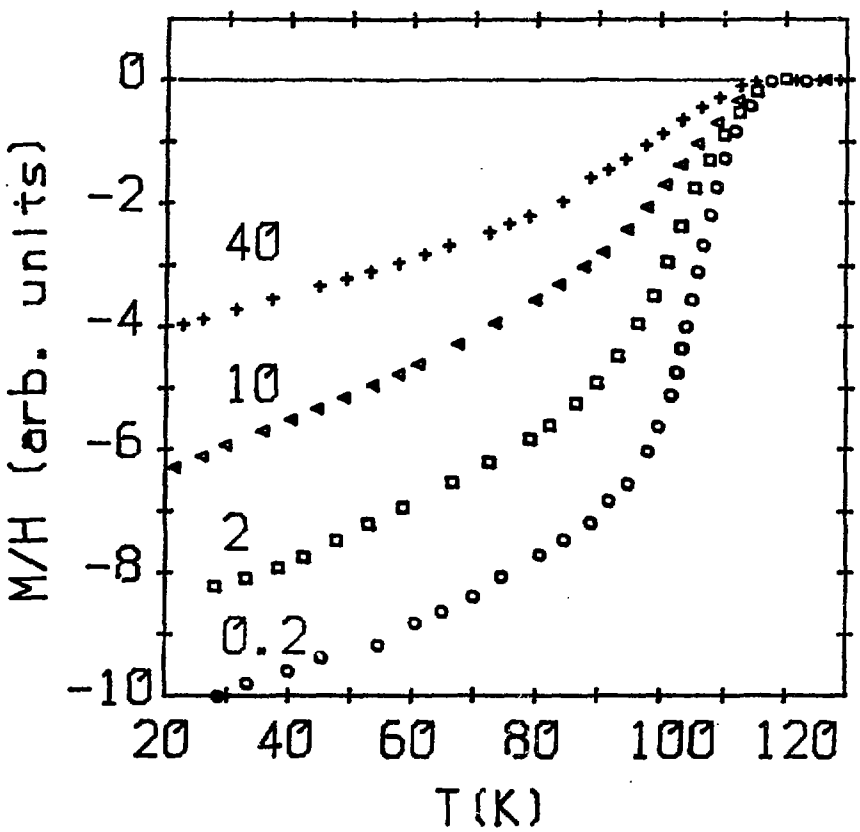

Fig. 2

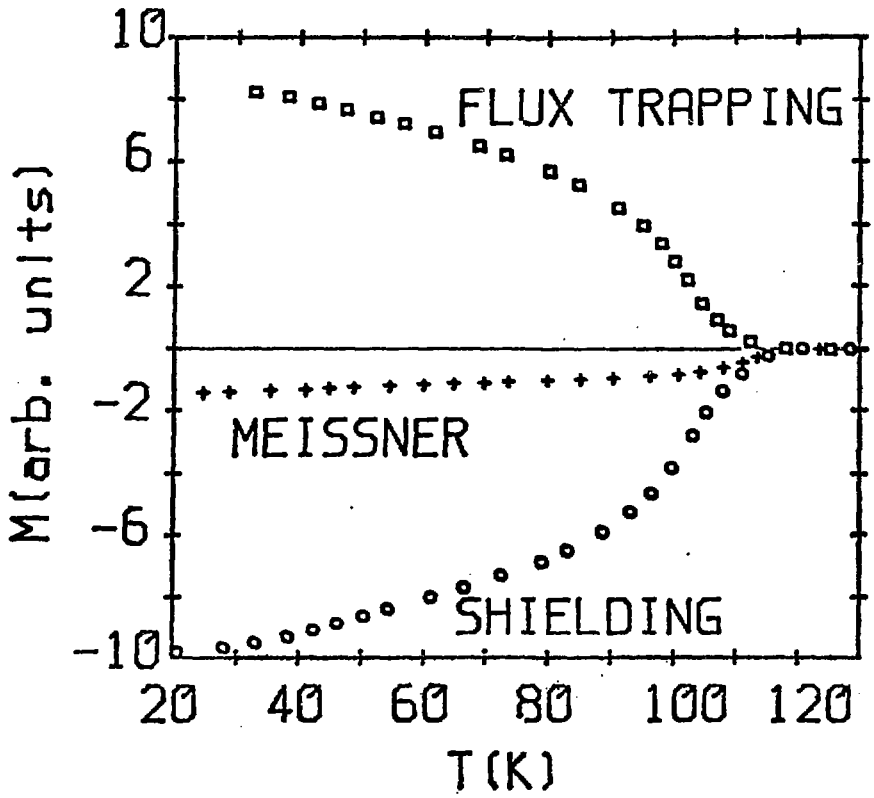
FLUX TRAPPING
MEISSNER
SHIELDING
M(arb. units)
T(K)
10
6
2
-2
-6
-10
20
40
60
80
100
120

Fig.3