HIGH FIELD STUDIES OF SINGLE CRYSTALS OF CUPRATE SUPERCONDUCTORS BY CANTILEVER MAGNETOMETRY

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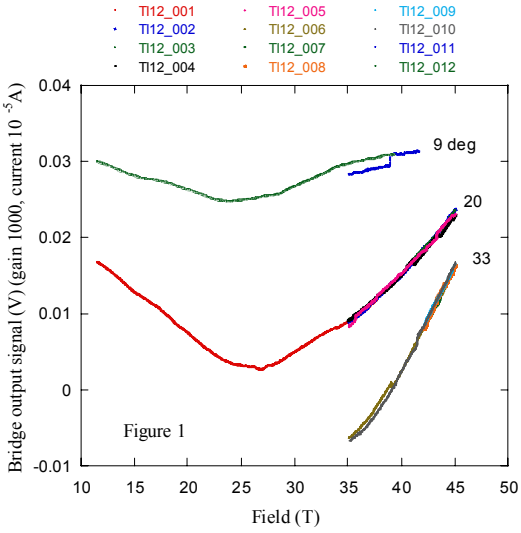
Introduction

One of the major outstanding problems in cuprate physics is that no definitive observations of de Haas van Alphen (dHvA) quantum oscillations have been reported. Optimally-doped cuprates have an upper critical field $B_{c2}(0)$ in excess of 100 T and although dHvA oscillations have been observed in the vortex state in some other superconductors down to say 0.3 to $0.5B_{c2}$, the signal is strongly attenuated. However this attenuation could be smaller in "d-wave" superconductors such as the cuprates where there are nodes in the order parameter. One prime candidate for such studies is the overdoped single layer cuprate $Tl_2Ba_2CuO_{6+\delta}$ (Tl:2201) where T_c can be reduced to below 15K by suitable oxygen treatment, thus reducing $B_{c2}(0)$. Another candidate is the naturally-underdoped, stoichiometric material $YBa_2Cu_4O_8$ (Y124) with T_c of 80 K. The aim of the present project is to search for dHvA oscillations in fields up to 45 T in these two materials using the same cantilever technique used successfully for small single crystals of MgB_2 at NHMFL in fields up to 32 T. Until now we have used two days of magnet time for this work, one day using a resistive magnet up to 32 T and the other using the hybrid magnet up to 45 T. The latter experiment was curtailed prematurely due to a power failure, but some interesting preliminary results were obtained.

Experimental Details and Results

Shortly before the hybrid experiment a new batch of Tl:2201crystals was prepared in Cambridge using a modified method aimed at reducing thallium loss during synthesis, AC susceptibility and SQUID measurements showed sharp superconducting transitions with T_c values of 8 K. After a test experiment at NHMFL to 32 T, data were obtained for one Tl:2201 crystal and one Y124 crystal immersed in liquid He^3 at 0.5 K, in fields up to 45 T. The results for Tl:2201 are summarized in Figs. 1 and 2. Generally no oscillatory structure was observed either by eye or in Fourier transforms, FT. On the final run the noise level was improved by changing the earthing arrangement for that cantilever and some slow oscillations that might correspond to a dHvA frequency of 1000 T, only 1/28 of the area of the Brillouin zone, were then seen.



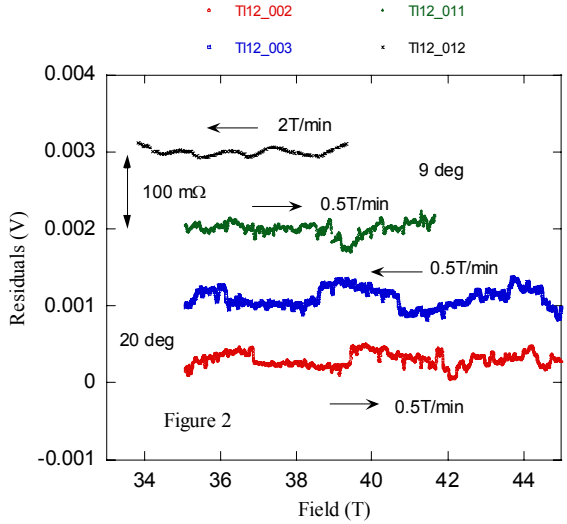


Fig.1 Raw torque data taken at various angles between the applied field and the c axis. There is evidence for a superconducting response below 25T. Fig.2. High field data after subtracting a 2nd order polynomial background. The sharp steps are probably noise. The final run (Tl12_012) had less noise and showed some slow oscillatory structure, giving a peak in the FT at 1000T.

Clearly the above results are promising and show that this work should be continued both on the presently available crystals and possibly on others with a lower residual resistivity.