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"FISH-TAIL" IN THE MAGNETIZATION AND RELAXATION RATE CURVES OF $Tl_2Ba_2CaCu_2O_8$ CRYSTALS

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Magnetization curves have been measured for several $Tl_2Ba_2CaCu_2O_8$ crystals. For crystals with relatively low critical currents, an anomalous maximum is recorded over a wide range of temperatures. This maximum completely disappears after heavy ion irradiation. We interpreted the results in terms of a phase transition from different vortex phases.

Numerous recent reports [1-7] describe an anomalous increase in the width of the magnetization loops of high temperature superconducting oxides (HTS) with the increase of the external magnetic field. In particular, the dependence of the magnetization on the magnetic field exhibits an unusual bump ("fishtail") in fields larger than the penetration field H* (the first field for full penetration across the sample).

The fishtail behavior in these structures can be explained naturally by the assumption of a phase transition in the vortex system.

The investigations were carried out on TlBaCaCuO single crystals with T_c in the vicinity of 106 K. The crystals were grown from the melt in oxygen flow and their typical dimensions are 0.9x0.7x0.1 mm^3. X-ray studies of the crystals showed that they have a tetragonal symmetry with a=b=3.858 A, c=29.318 A. We present here the results for the most perfect crystal (sample No.1) that showed oxygen homogeneity. We also present magnetization curves for crystals with oxygen vacancies (sample No.2) and for a crystal irradiated with Pb(10^{11} cm^{-2}) (sample No.3). All the measurements of the magnetization, as a function of field , temperature or time, have been done with the "Oxford instruments" vibrating sample magnetometer (VSM).

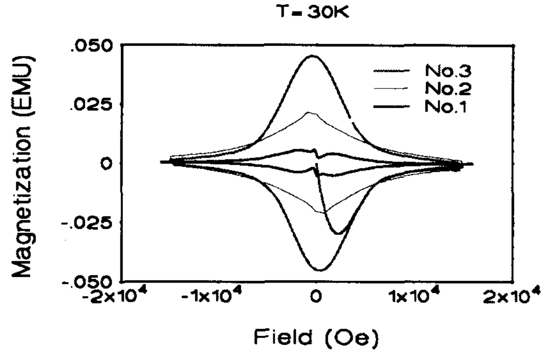

Fig 1. Magnetic hysteresis loops at T=30K for samples No.1,No.2,No.3.

We note that for sample No.1 the anomaly is observed at 20-65 K and for the second sample it observed only in the 35-65 K temperature range. For sample No. 3, the second maximum was not observed at all. What is clear from Fig.(1) is that the dip of the minimum on the magnetization loop decreases along with increase of the vortex interaction with the defects. Temperature increase results in depinning of the vortices (in the sample with a lot of oxygen defects) and result in "deepness" of the magnetization curve.

The maximum in the relaxation rate $S=d(M)/(d\ln(t)M_0)$ corresponds to the field higher than field of minimal magnetization which makes difficult to explain this phenomena

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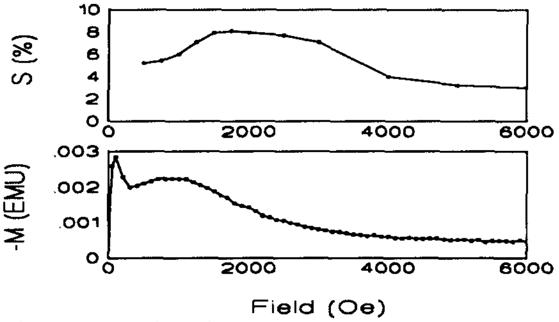

Fig 2 a) Relaxation rate vs magnetic field for sample No.1 at T=40K b) Typical magnetization curve for sample No.1 at 40K.

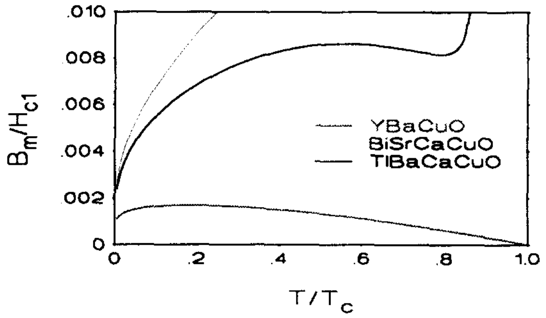

Fig 3. Numerical calculation $B_m(T)$ for different systems.

as a crossover between the different creep regimes with different relaxation rate. In the following we consider an explanation which is based on the concept of melting transition and then, we discuss its applicability.

From the Lindemann criteria [8] we get the melting line $B_m(T)$:

$$B_m(T) = \phi_0 x^2/\lambda_0^2$$

were x is defined via

$$\frac{\beta(1-t)^{11/4}}{t} = x^{7/2}\exp(\frac{\sqrt{1-t}}{x})$$

and: $x = \lambda(0)/a_0$, $t = T/T_c$, $\beta=0.5C_L^4\kappa^2\ln\kappa/Gi$, $Gi=8\pi^2\kappa^4T_c^2\xi_0^2/\phi_0^4$, C_L is the Lindemann parameter, a_0 is the period of the Abrikosov lattice, ϕ_0 is the unit of the flux. Clearly the shape of the melting curve strongly depends on the parameter β. On the other hand, this parameter strongly depends on set k, C_L but the quantities in Gi are not known accurately. Choosing $\kappa=50$, $C_L=0.1$, $Gi\approx1$ we obtain for this parameter $\beta \approx 0.5$. (For YBaCuO this estimation is about 2500, and for BiSrCaCuO $\beta\approx0.2$). Qualitatively this explains the low field fishtail phenomenon. The melting transition occurs at the field for which magnetization shown a minimum "dip". Simple estimation of the minimum point on magnetization curves yields induction $B\approx0.01H_{c1}$ (See Fig 3). From this estimation, the difference between the melting theory and the experiment can not be explained even if one involve either inhomogeneous distribution of magnetic induction inside the nonellipsoidal sample and by a large demagnetization factor. In any case B_m can not exceed 20 Oe. Moreover, due to the logarithmic character of relaxation at the dip point and essential width of magnetization loop in this region of the magnetic field, it seems, we are dealing with a new vortex phase. As a possible candidate to this vortex phase we propose the vortex-slush assumed by Worthington, Fisher and Huse [9]. They noted that there is no symmetry difference between vortex-slush phase and the usual vortex-liquid phase. The symmetry changes under transition from vortex-slush to vortex solid phase resulting in dramatic change of magnetic properties. It seems the same vortex phase can be detected in other high temperature superconductors [6,10] by the magnetic measurements.

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