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Dissipative Effects near the Transition Temperature of High T_c Supeconductor

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The complex magnetic susceptibility of oxide superconductors near the transition temperature has been computed as a function of temperature and frequency by numerical solution of the non linear, flux diffusion equation. For field values much lower than the upper critical field, a description of dissipative effects in terms of the conventional flux creep and flux flow pictures is not able to reproduce experimental data.

1. INTRODUCTION

Dissipative effects in the high T_c have been extensively investigated in the last years [1,2]. In particular, the imaginary part (χ'') of the AC susceptibility measures both the hysteretic losses and the frequency dependent losses due to resistive effects [3]. In presence of large DC magnetic field, in the KHz-MHz frequency range, as the frequency increases, a shift toward T_c of the bell-shaped χ'' vs T curve is observed. In YBCO samples, in absence of DC fields, in the 10-1000Hz range, the leading edge of the bell near T_c is almost frequency independent compared with the drop-off at temperatures below the χ'' peak[4].

Hysteretic losses can be predicted by critical state models. Less attention has been devoted to the solution of the non linear diffusion equation [5] for the magnetic induction (B) in the sample, which is governed by the I-V characteristics and determines the frequency dependence[6]. In this paper we numerically evaluate the temperature and frequency dependence of the AC susceptibility, from the solution of the diffusion equation for B.

2. NUMERICAL METHOD

We considered a long cylindrical sample; in fields parallel to the axis the non linear diffusion equation for the induction B(r,t) has the form:

$$\partial B/\partial t = r^{-1}\partial/\partial r\,[r\,(\rho(B,J)/\mu_0)\,\partial B/\partial r] \qquad 1)$$

where r is the radial coordinate, J(r,t) is the current, and r(B,J) the resistivity: $\rho(B,J)=E(B,J)/J$. Since the total time for fluxon motion is the sum of the creep and flow time [7], the resistivity is the parallel of the creep (ρ_{cr}) and of the flux flow (ρ_{ff}) resistivities: $1/\rho = 1/\rho_{cr} + 1/\rho_{ff}$. Equation (1) has been numerically solved by means of FORTRAN NAG library routines, using sinusoidal boundary conditions, determined by the applied field $B_a(t)$: $B_a(t)=B_a \sin\omega t$, with B_a=2 mT. The stationary magnetization loops are calculated from the volume average $\langle B(r,t)\rangle$. Finally, the fundamental susceptibility $\chi'+i\chi''$ was calculated as Fourier coefficients of the magnetization cycle.

3. RESULTS AND DISCUSSION

In order to investigate the effect of different pinning mechanisms on fluxon dynamics, we have calculated χ' and χ'' for different frequencies. Following Brandt [8] the creep electric field is :

$$E_{cr}(J) = 2r_c \exp(-U_p(B,T)/K_BT)\cdot \sinh[JU_p(B,T)/(J_c(B,T)K_BT)] \qquad 2)$$

where $U_p(B,T)$ is the pinning potential, $J_c(B,T)$ the critical current density and we assume $\rho_c=\rho_{ff}$ For the flux flow electrical field we use the Bardeen-Stephen model [8] :

$$E_{ff}(J)=J\,\rho_n B/B_{c2}(T) \qquad 3)$$

where $B_{c2}(t)=B_{c2}(0)\,(1-t^2)/(1+t^2)$, and t=T/Tc.
The material parameters are referred to an YBCO sample [8,9,10,11]of radius R = 1cm, T_c =92.28 K, $\rho_n = 1.1\cdot10^{-8}\,(\Omega m/K)\cdot T + 2\cdot10^{-6}\,\Omega m$, $B_2(0)$=112T, $U_o(0)/K = 2\cdot10^4 K$, $J_o(0) = 10^{10} A/m^2$.

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Two pinning models have been considered. In the first (denoted as TM) U_p is estimated by taking the condensation energy times the volume ξa_o^2, where $a_o^2=\phi o/B$ [12] and ξ is the coherence length. The elementary pinning force f_p is given by $f_p=U_p/\lambda$, where λ is the penetration depth. The macroscopic force Fp results from a direct summation procedure (J_c = Fp/B). The resulting temperature dependences are:

$$U_p(B,t)=U(B,0)\ (1-t^2)^{3/2}(1+t^2)^{-1/2} \qquad 4a)$$

$$J_c(B,t)=J(B,0)\ (1-t^2)\ (1+t^2) \qquad 4b)$$

In the second model (denoted as CP) U_p and J_c are described within the collective pinning model, suitable for randomly distributed weak pinning centers. In the single vortex regime the temperature behavior has the form [13]:

$$U_p(B,t)=U(B,0)\ (1-t^4) \qquad 5a)$$

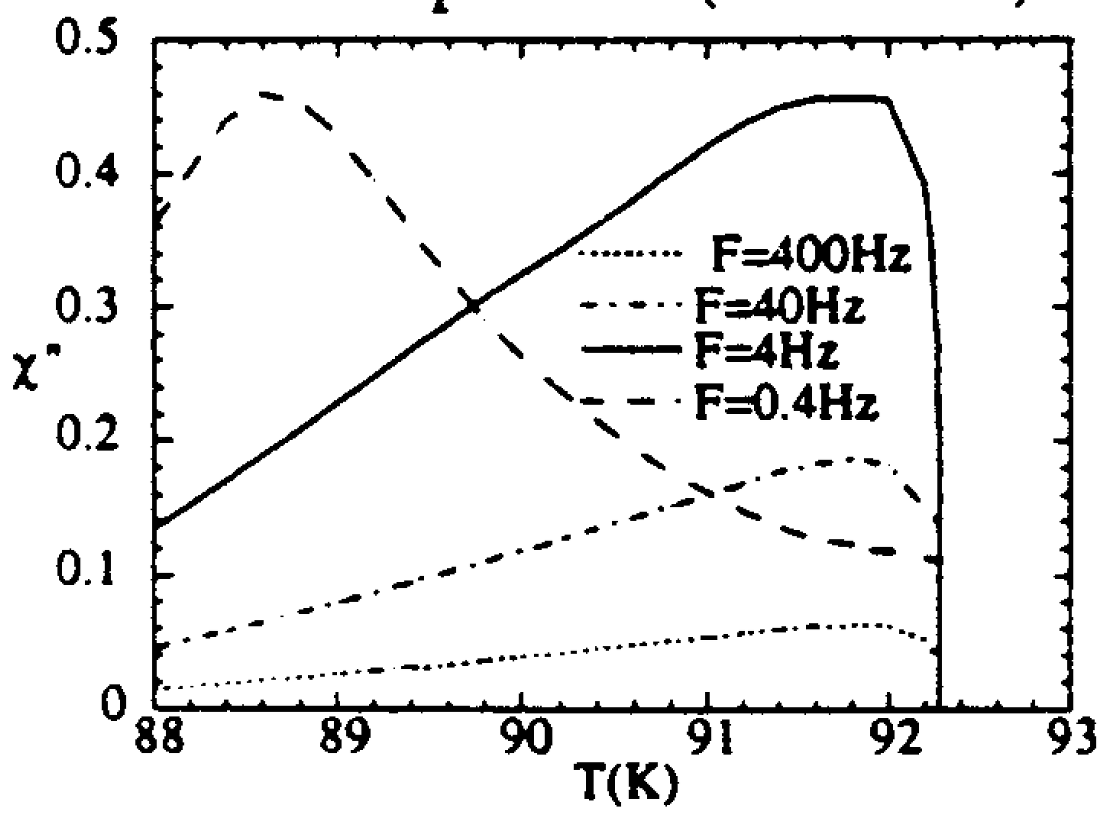
$$J_c(B,t)=J(B,0)\ (1-t^2)^{5/2}\ (1+t^2)^{-1} \qquad 5b)$$

For the magnetic field dependence of U_p (B,t) and J_c(B,t) we assume a Kim form with B_0=0.1T:

$$U_p(B,t)=U_0(t)\ B_0/(B_0+B) \qquad 6a)$$

$$J_c(B,t)=J_0(t)\ B_0/(B_0+B)$$

The temperature dependence of χ" is shown in fig.1 at different frequencies (0.4-400Hz)



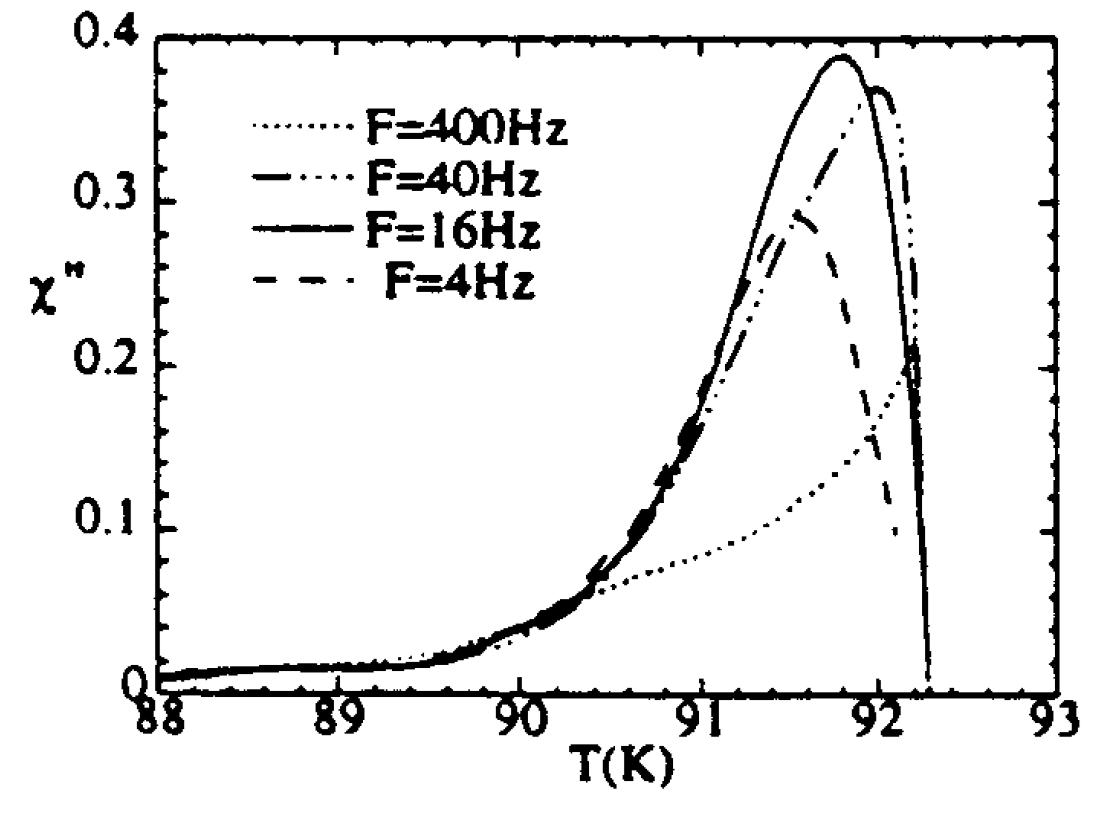


Fig.1 Temperature dependence of χ" at different frequencies. (a) : TM pinning; (b): CP pinning

For both models, common features of the computed curves are:

- the increase of the peak temperature with the frequency,

-at higher frequencies a sharper leading edge near Tc and a broader drop-off at lower temperatures.

Both these dependences are less pronounced in the CP model compared with the TM pinning model. Moreover a remarkable difference between the models is that for the CP model the peaks develop in a narrower temperature range compared with the TM case. At a first look the CP model shows a better agreement with the experimental behavior. However, for the chosen set of parameters, the simulated dependences are more pronounced compared with the measured ones [4,14,15]; in particular the quite large frequency dependence of the leading edge near Tc seems to not reproduce low field and low frequency experimental data.

REFERENCES

1) T.T.M. Palstra et al. Phys.Rev.Lett. 61 (1988) 1662; A.P.Malozemoff, et al. Phys.Rev.B 38 (1988)7203; P.Kes et al. Super.Sci.Tech.1 (1989)242

2) R.B.Goldfarb et al. Magnetic Susceptibility of Superconductors and other Spin System, p.49 Plenum press, New York (1991)

3)J.R.Clem *Magnetic Susceptibility of Superconductors and other Spin System*, p.177 Plenum press, New York (1991)

4) M.Polichetti, S.Pace, A.M.Testa, et all Solid State Comm,Vol.97,No.12,pp1055-1057 1996

5) C.J. van der Beek et all Physica C 197 (1992) 320-336

6) A. Gurevich Int.Jour.Mod.Phys.B9(1995)1045

7)S.Gjolmesli,K.Fosseim,T.Laegreid,*Transport Proprierties of Superconductors*,p.135 Vol.25,(1990)

8)E.H.Brandt *Transport Proprierties of Superconductors* , p.97 Vol.25,(1990)

9)Mark W.Coffey and J.R.Clem Phys.Rev.B Vol.45, No.17, p.9872-9881(1992)

10)M. Tinkham, Helvetica Physica Acta 61, 443 (1988)

11) Civale, *Magnetic Susceptibility of Superconductors and other Spin System*, p.313s Plenum press, New York (1991)

12)M.Thinkham *1989 Fall Meeting-Symposium*

13)R.Griessen,et al s Phys. Rev. Let. Vol.72, No.12, p.1910-1913 (1994)

14) C.Y.Lee,Y.H.Kao Physica C 256 (1996) 183-190

15) N.Savvides,A.Katsaros,C.Andrikidis and K.-H Muller Physica C 256 (1992) 267-273.