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AC Magnetic Susceptibility Measurements Near the Superconducting Transition Temperature of YBCO Sintered Samples

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Abstract

The temperature dependence of the ac susceptibility of sintered YBCO pellets is experimentally analysed in detail few Kelvin below the transition temperature. The quite complex dependence of χ' and χ'' on the frequency and the amplitude of the ac magnetic field cannot be explained by an ohmic Flux Flow or Critical State models, so that intermediate regimes or different non linear phenomena are to be considered.

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1. INTRODUCTION

The temperature dependence of the ac susceptibility of ceramic superconductors have been studied by many autors. In particular the dependence of the real (χ') and the imaginary part (χ'') of the susceptibility on the field amplitude and frequency has been discussed[1–6] in different regimes (Normal state, Flux Flow and Critical State regimes). It has been pointed out that in the case of hysteresis of the magnetization produced by a critical state regime, the values of χ' and χ'' are independent of the field frequency. On the other hand, above the irreversibility line the pinning is ineffective, so that the magnetic behaviour should be dominated by a pure Flux Flow and the values of χ' and χ'' should be independent of the field amplitude.

In this paper the detailed behaviour of sintered pellets near the transition temperature T_C is examined by the ac susceptibility. In these granular systems, at temperatures well below T_C, the low field behaviour is dominated by the intergranular Josephson coupling between grains. As the temperature increases this coupling tends to disappear, so that the isolated grains determine the behaviour near T_C. In this temperature range the fluctuations effects are not negligible. Up to now these effects have been mainly studied by dc susceptibility measurements[7].

2. EXPERIMENTALS RESULTS

Measurements have been performed on YBaCuO sintered samples (5 x 3 x 15 mm^3) prepared with a modified citrate pyrolysis procedure. The experimental set–up is a non commercial 3 coils susceptometer, in the bridge configuration, in which the voltage induced in the 2 pick–up coils, in series and wrapped in opposite direction, is measured by a lock–in amplifier (EG&G 5302). The temperature is controlled by a thermoregulator (Lake Shore DRC 93 CA). All the experimental data are acquired by a computer HP 9000/300.

Measurements in the range 78–98 K have been performed for different ac fields (0.2, 5, 10 Gauss) at different frequencies (17,107, 1070 Hz). The range 89–94 K has been explored in detail with a rate of 0.04 K/min for the same fields and frequencies, with or without a superimposed dc field (5, 10, 50, 100 Gauss). The temperature dependence of χ' and χ'' near T_C is showed in Fig. 1 for a particular value of the frequency and of the ac field.

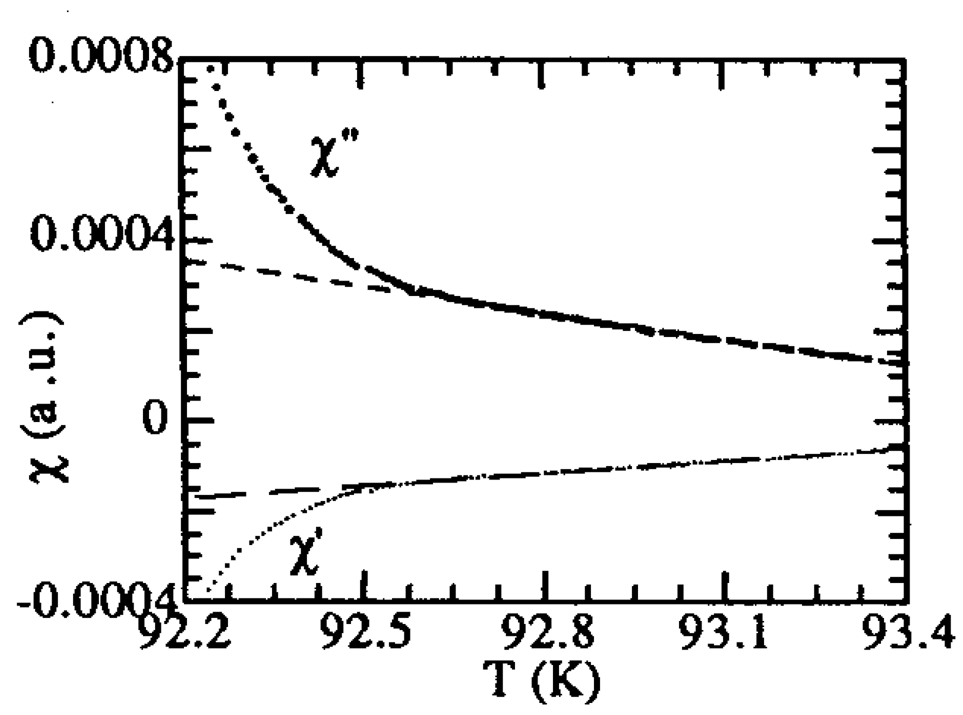

FIG. 1 – χ' and χ'' vs T at 10 Gauss – 1070 Hz.

At T > T_C the measured values of χ' and χ'' are nearly constant, with a weak linear temperature dependence (dashed line in Fig. 1). In order to analyse the onset region of the superconducting state, we can define the onset temperature T_{on} as the temperature at which the difference between the measured signal and the linear temperature dependence is higher than the noise. We have also verified that such definition does not depend on errors in the phase setting of the lock–in amplifier, at least for errors smaller than 20 degrees.

In general, a difference ΔT between the onset temperature of χ' and χ'' exists; such difference is measured with an error smaller than the error of single temperature readings. The frequency dependence of ΔT for different ac fields is reported in Fig. 2.

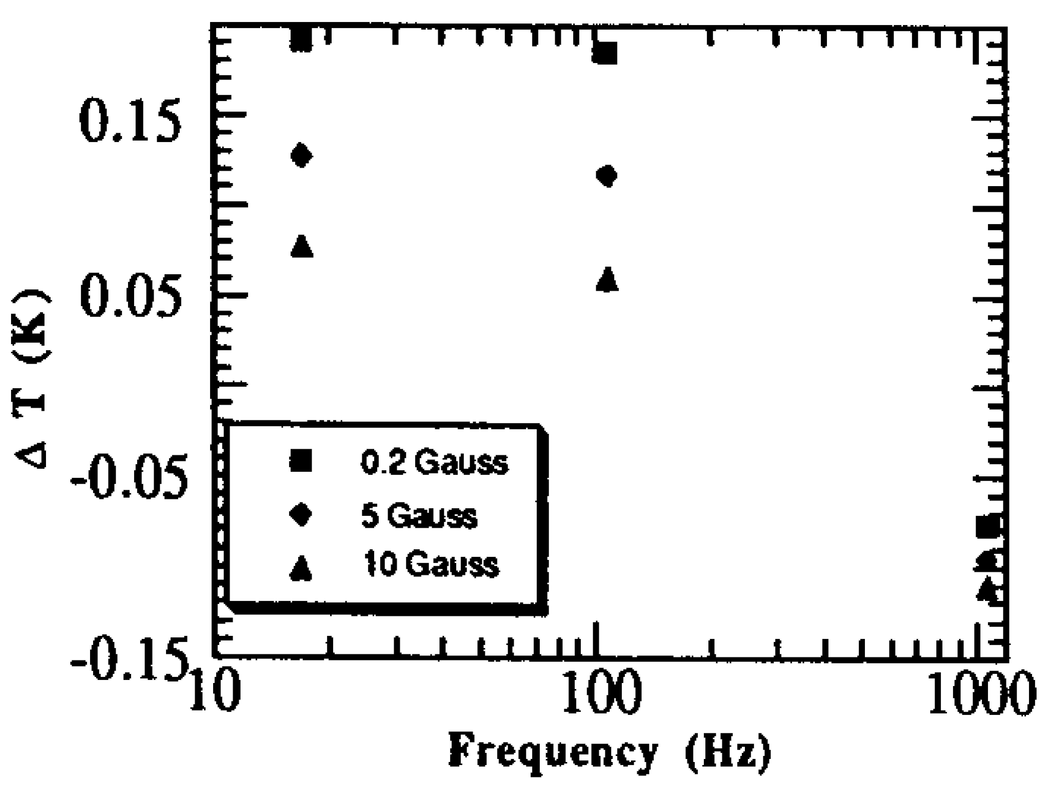

FIG.2 – Frequency dependence of ΔT for different ac fields.

In general ΔT decreases as the frequency increases, due to the different frequency dependence of χ' and χ''. In particular the onset of χ' is found to be independent of the frequency, while the onset of χ'' shifts at higher temperature as the frequency increases.

From the analysis of a narrow temperature range (few Kelvin) below T_{on}, the temperature dependence of the susceptibility appears affected by the amplitude of the applied field, pointing out the presence of non linear effects. Moreover the presence of a non linear behaviour is confirmed also by the detection of the first seven harmonics of the susceptibility. The temperature dependences of the 2nd and 3rd harmonics in the range 88–95 K are showed in Figure 3.

From all these findings we can argue that the low field magnetic behaviour near Tc cannot be due only to the presence of an ohmic Flux Flow regime.

Moreover a complex frequency dependence of both the χ' (T) and χ'' (T) curves is found for few K below T_{on}, so that a pure critical state model is not suitable in this temperature range.

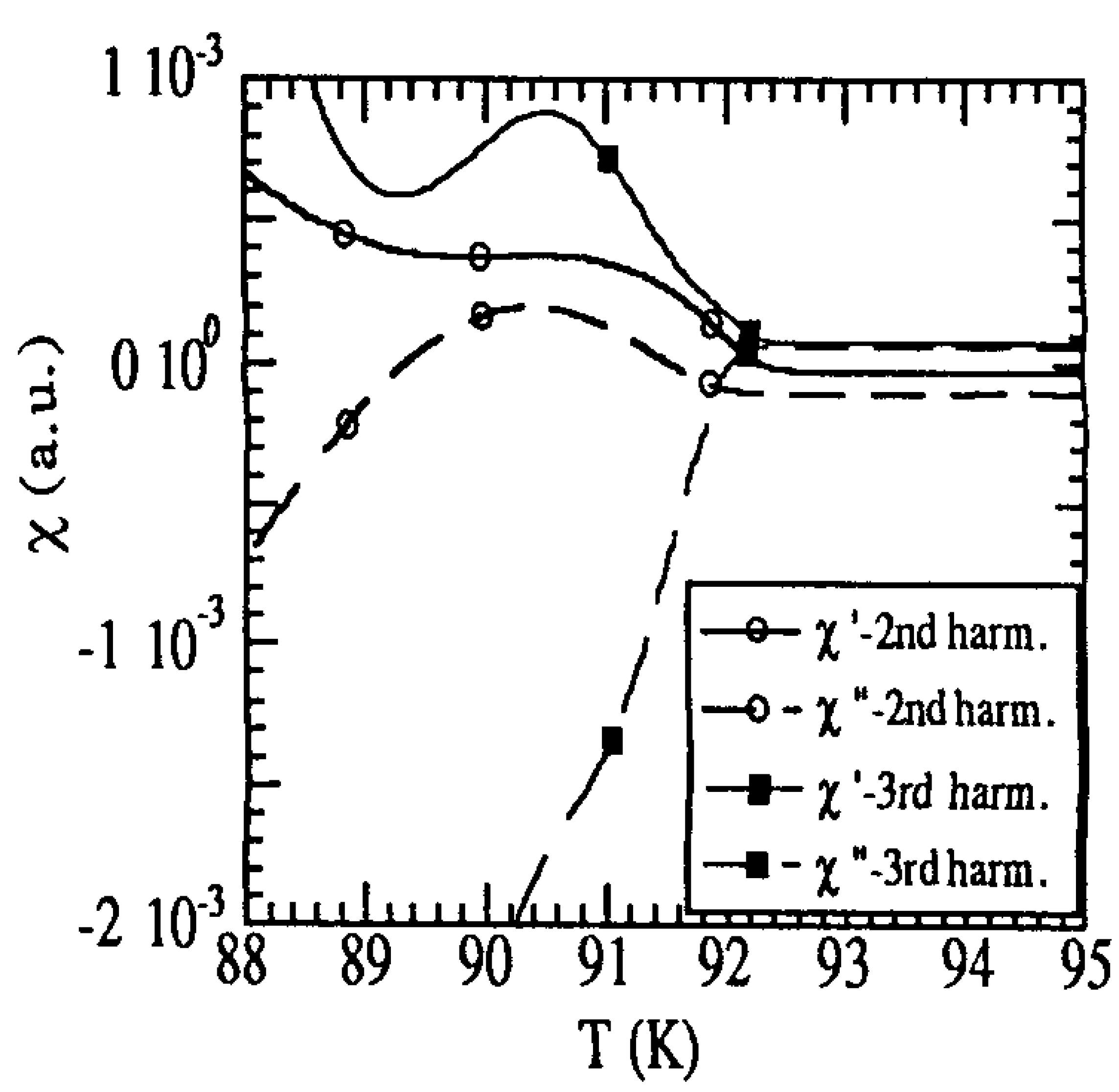

FIG. 3 – Measured 2nd and 3rd harmonic of χ

In conclusion the study of the temperature dependence of the ac susceptibility in a neighbourhood of the transition region shows a quite complex dependence on the frequency and the amplitude of the ac magnetic field. The observed behaviour cannot be explained by an ohmic Flux Flow or Critical State model, so that intermediate regimes or different non linear phenomena are to be considered. Further experimental and phenomenological analysis is in progress for a deeper understanding of such phenomena.

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the c–axis [5]. We can affirm that the oxidation modalities depend also from the film orientation on the substrate.

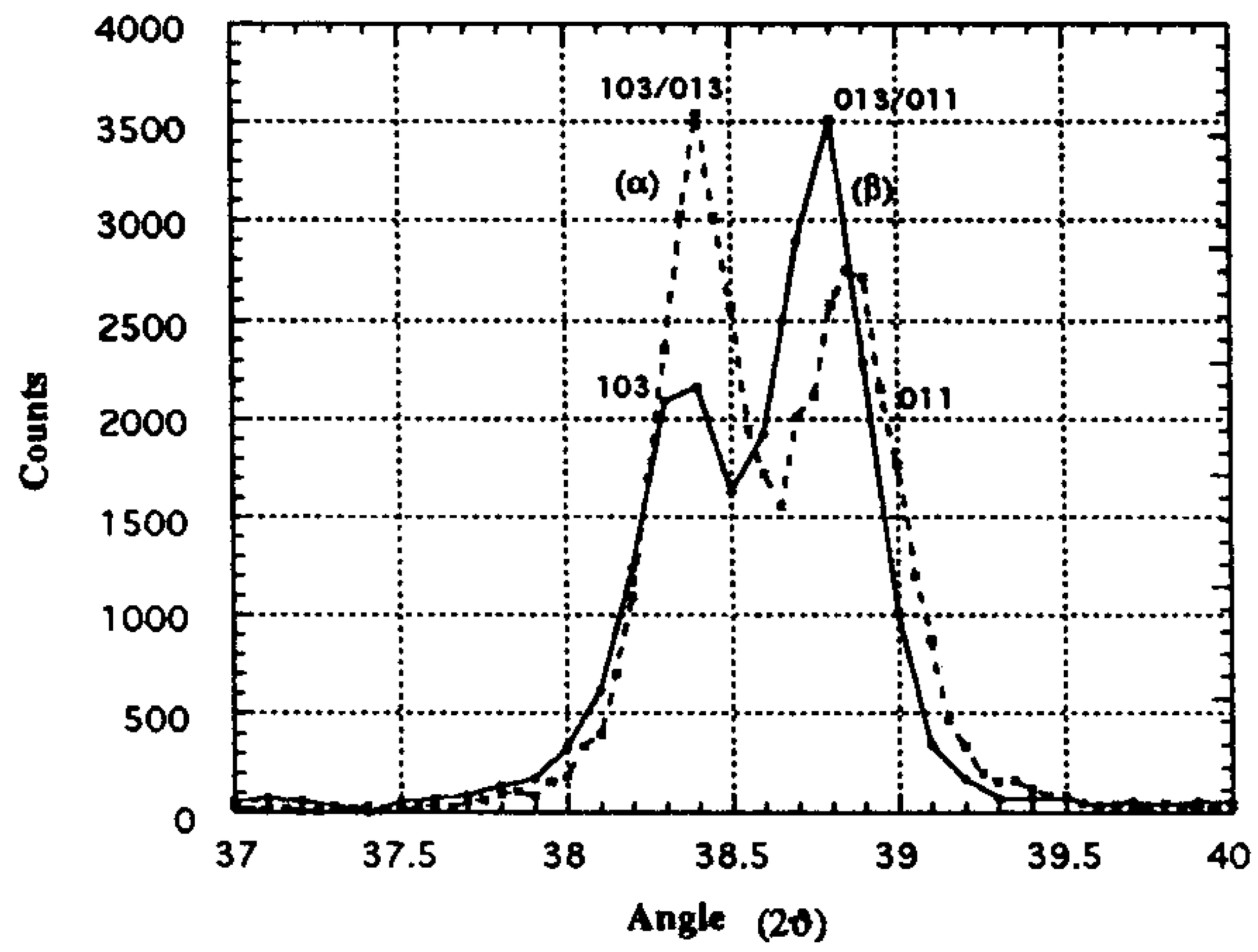

FIG. 3 – X–ray diffraction pattern before (α) and after (β) the electrochemical treatments of the sample F041.

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