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Orlando, Marcos T.A. (ea)

AC MAGNETIC SUSCEPTIBILITY BEHAVIOUR OF BiSrCaCuO HIGH Tc SUPERCONDUCTOR[1]

Marcos

M.T.A.Orlando[2], L.Gomes, S.P.Morato, E.N.S.Muccillo and R.Muccillo

Instituto de Pesquisas Energéticas e Nucleares - CNEN/SP
Caixa Postal 11049 - 05499 - São Paulo/SP - Brasil

ABSTRACT

The real and imaginary parts of the AC magnetic susceptibility of a BiSrCaCuO ceramic high Tc superconductor has been investigated. Results showed a strong difference in the AC susceptibility behaviour of the BiSrCaCuO sample when compared to the YBaCuO sample. As the BiSrCaCuO sample shows three transitions in this temperature interval, a composed band in the imaginary part of the AC susceptibility reflected this threefold structure showing the same number of bands from a dissipation curve obtained with fields in the order of 40 A/m. Studies for low fields (~10 x smaller) attempting to better resolve these contributions showed the presence of a new superconducting phase at 92K.

Introduction

The discovery of high-Tc superconducting materials has stimulated many scientists to search for those materials with tetragonal crystal structures containing CuO chains or CuO_2 planes. The first new family[1] was based on Bi_2O_2 layers which are lattice-constant matched to CuO_2 planes but not showing any superconductivity.

The bismates and thallates compounds represented by the stoichiometric formula:

$$(Bi,T\ell)_2\ (Sr,Ca,Ba)_{n+2}\ Cu_n O_{2(n+2)} \pm \delta$$

are high-Tc superconductors with the exception of the $Bi_2(Bi,Sr)_2CuO_6$ compound. The number n in the above formula can assume values such 1, 2 or 3 and gives exactly the number of CuO_2 planes encountered in the unity cell of the corresponding structure. The bismates compounds have a more complicated structure (and bigger unity cell) than the $YBa_2Cu_3O_7$, difficulting its production in a single phase material. Usually one obtains a ceramic exhibiting a mixture of superconducting phases in different proportions depending on the sample preparation.

Until now, the AC magnetic susceptibility has been used as an

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important tool to investigate the presence of different superconducting phases in ceramic high Tc superconductors. Recent measurements of the imaginary part χ'' of the AC magnetic susceptibility were related to the ceramic properties as the grain contact[2] and porosity[3].

A ceramic sample showing a good quality and high density exhibits a narrow dissipation peak while a sample of lower quality and density have a wider peak shifted toward lower temperatures. The transition in the real part of the AC magnetic susceptibility shows a temperature broadening with the increase of the magnetic field from 0.14 to 600 A/m while the dissipation (imaginary part χ'') shifts to lower temperatures[4].

As a consequence of this anomalous behavior, a good diamagnetic response can be obtained using a magnetic field with amplitude below 0.14 A/m.

As this technique is very important to investigate the properties of these ceramic high Tc material we applied it to bismate compounds. Samples in pellet form were sintered from a mixture of Bi_2O_3, $CaCO_3$, $SrCO_3$ and CuO in the molar proportion of 1-1-1-2 following the procedures below:

- Mixing and milling of appropriate masses
- Calcination at 820°C for 17 h and milling
- Calcination at 850°C for 17 h and milling
- Uniaxial pressing at 1.5 ton/cm^2
- Sintering at 880°C for 16 hrs
- Thermal annealing at 800°C/60 hrs
- Thermal annealing at 400°C/20 hrs

AC Magnetic Probe

Our experimental probe was designed to allow measurements of AC susceptibility of samples under an inductive quasi-uniform magnetic field as low as 0.034 A/m. This probe consists of a central solenoid inductor E with a cilindrical shape and two coil sensors A and B placed colinearly with E but in opposite sides. The sample in a pellet form is placed between A and E. Once in the superconducting state, the sample repels the inductive magnetic lines preventing them to reach sensor A. The differential signal (A-B) now deviates from almost zero to approximately (-B) depending on the strength of these effects. This signal is processed by an Stanford's dual phase lock-in amplifier. This probe allows for a balance of the differential (A-B) signal by fine adjusting the position of sensor B using a micrometric screw. The inductor diameter is about half the sensors diameter in order to maximize the magnetic shielding effect.

Results and Conclusions

Figure 1 shows the dependencies of χ' and χ'' with the magnetic field amplitude (0.036, 9.2 and 50 A/m) at a fixed frequency of 3 KHz.

If can be seen that firstly, both signals in χ' and χ'' parts were more concentrated around the highest temperature transitions between 80 and 110K, when using a low field of 0.036 A/m. It becames clear that this ceramic is a superconductor exhibiting three phases, two of them know and identified as $Bi_2Sr_2CaCu_2O_8$ (85K) and $Bi_2Sr_2Ca_2Cu_3O_{10}$ (110K). The third phase has a critical temperature around 92K and its presence is more pronounced than the others ones. This is a new phase and its stoichiometry has not been established. With the increase of the magnetic field, the dissipation peaks shift toward low temperatures. It seems that the two dissipation peaks correlated to the known superconducting phases (85 and 110K) behave similary to the dissipation observed in $YBa_2Cu_3O_7$ i.e. the intensity increases with the field. Reversely, the new 92K - phase decreases in that case.

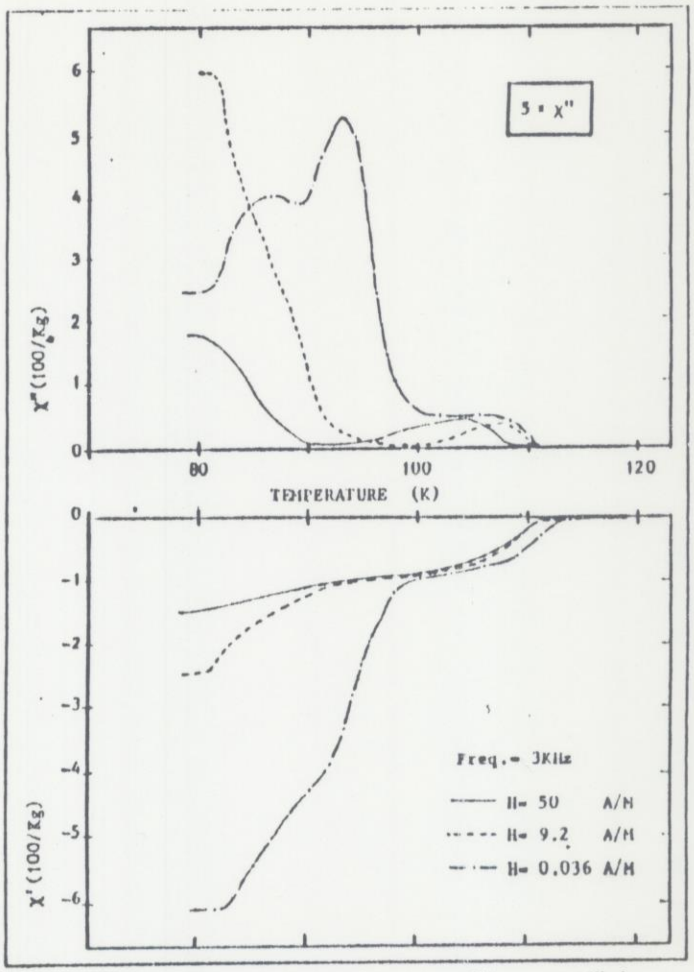

Fig. 1 χ' and χ'' parts as function of the field amplitude. Field frequency of 3 KHz.

Also the χ' part showed a pronounced Meissner effect (~60% of signal exclusion in sensor A) for low field, similar to what was observed using a $YBa_2Cu_3O_7$ sample.

In figure 2 it is shown a strong frequency dependence of the χ'' part for a fixed magnetic field of 0.20 A/m.

One sees that the dissipation corresponding to the two phases at 85 and 110K increases at low frequency while the 92K - phase increases at high frequency up to 30 KHz. This frequency dependence of the 92K-phase behaves in opposition to what is observed for the two other phases. To verify any possibility of contamination, we did X-ray diffraction studies of the sintered powder used in this bismates compounds and we did not detect any trace of a $YBa_2Cu_3O_7$ phase.

The dissipation signal of a polished ceramic where 40 microns of the surface material was eliminated, still contained the 92K - phase. Its presence was detected in the whole sample meaning to be a bulk effect.

Based on these results we conclude that each phase has a particular dissipation behaviour which depends on the intergranular Josephson tunneling currents induced by a local flux trapping variation at different non superconducting islands as non-matrix intergrain boundary phase between superconductor grains. Also the high frequency dissipation response of the 92K - phase observed, indicates the presence of a structure with a smaller anisotropy than other high Tc materials existing for superconductin currents.

We are now investigating this frequency behaviour with low field, extending the temperature range down to 10K to completely resolve the dissipation structure.

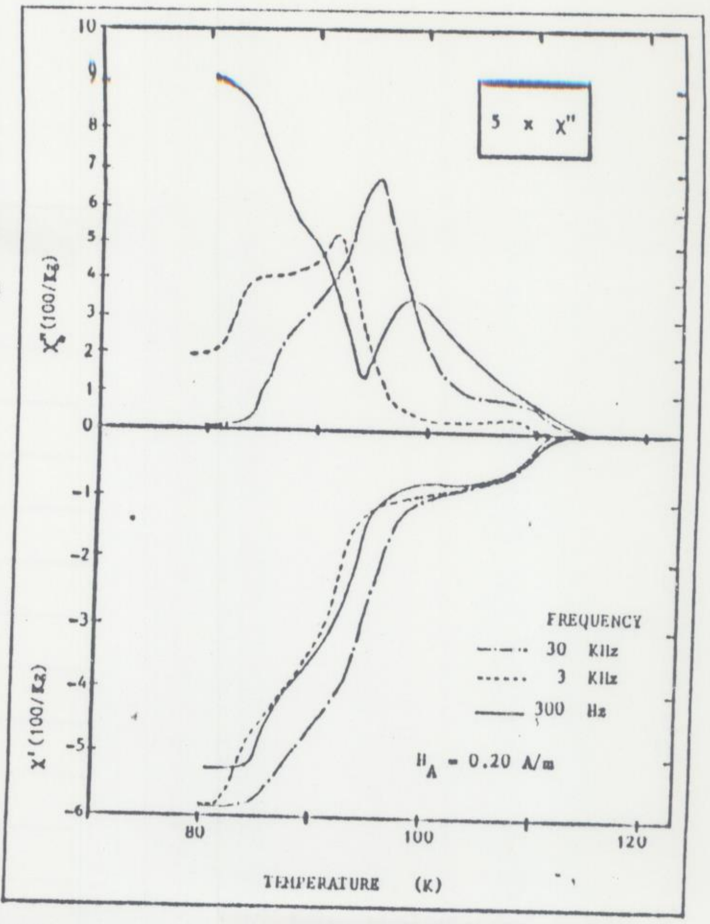

Fig. 2 χ' and χ'' parts as function of the frequency. Magnetic Field of 0.20 A/m.

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