Bull. Mater. Sci., Vol. 14, No. 3, June 1991, pp. 789–792. © Printed in India.

Effect of modulation amplitude on low-field microwave absorption in hafnium-doped Y–Ba–Cu–O

Md SHAHABUDDIN, A G VEDESHWAR, H D BIST[†], PREM CHAND, S K AGARWAL* and A V NARLIKAR*
Department of Physics, Indian Institute of Technology, Kanpur 208 016, India
*National Physical Laboratory, New Delhi 110 012, India.

Abstract. Low-field differential microwave absorption has been studied for hafnium-doped Y–Ba–Cu–O at the first harmonic of modulation field. The effect of modulation amplitude on peak height, peak position and the area under hysteresis curve has been discussed.

Keywords. Microwave absorption; Hf doping; modulation amplitude.

1. Introduction

The recently discovered high T_c superconducting (HTSC) materials provide puzzles, both on microscopic and macroscopic levels. At the microscopic level it is the mechanism for pairing that is being debated. At the more phenomenological level it is the apparent glass-like properties of the materials (Mullar *et al* 1987) or the giant flux creep (Yeshurun and Malozemoff 1988) that is drawing experimental and theoretical attention. The non-resonant low field microwave absorption (LFMAS) in HTSC is interesting. The imaginary parts of the resultant field-dependent susceptibility gives rise to large absorption in low magnetic fields. Most of the properties of the LFMAS have been explained in terms of the intergrain Josephson currents between weakly coupled clusters of superconducting grains (Blazey *et al* 1987; Khachaturyan *et al* 1987).

The EPR spectrometer yields the first derivative of the actual absorption line when small modulation amplitude is used. The modulation effect on LFMAS in $YBa_2Cu_3O_{6.93}$ has been studied (Rakvin *et al* 1989) and the shape of the LFMAS detected at first and second harmonic had been explained using the earlier developed relation between surface impedance and magnetic field (Portis *et al* 1988) and introducing of weak modulation field into surface impedance.

We report the effect of modulation amplitude on the peak height (h_p), peak position (H_m) and the area under the hysteresis curve (ΔA) of LFMAS.

2. Experimental

Hafnium doped Y–Ba–Cu–O samples were prepared in the same way as in the case of Zr-substituted samples using solid-state mixing technique reported elsewhere (Jayaram *et al* 1988). Materials were characterised by XRD (Sieman D-500 X-ray diffractometer) and SEM (JEOL JSM 3SCF scanning microscope). Resistance was

---

[†]For Correspondance

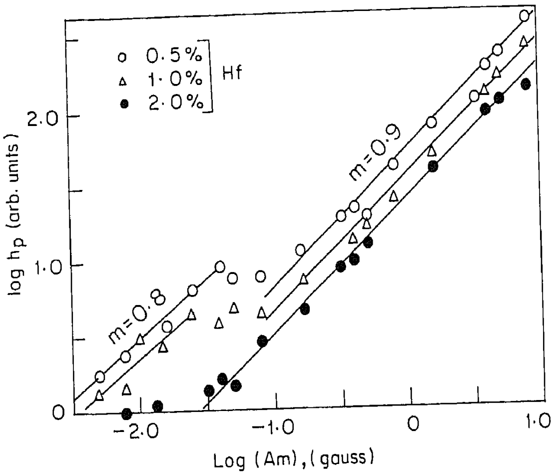

Figure 1. Log-log plot of h_p vs A_m for Hf-doped Y–Ba–Cu–O samples. Slopes are specified at each plot.

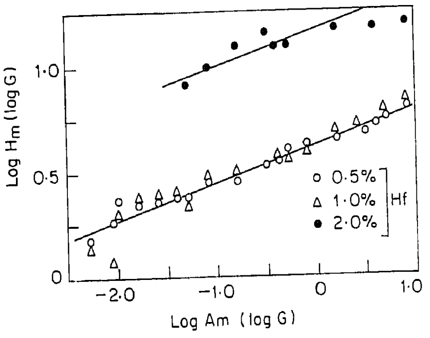

Figure 2. Log-log plot of H_m vs A_m for different Hf-doped samples.

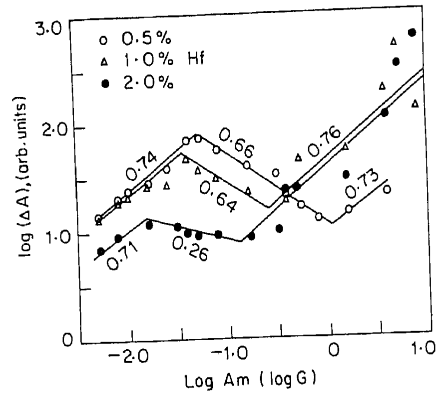

Figure 3. Log-log plot of the area under hysteresis loop ΔA vs A_m for different Hf-doped Y–Ba–Cu–O samples. Slopes are specified at each plot in all regions.

measured by the conventional four-probe technique and the temperature measured by a standard 100 ohm platinum resistance thermometer. For studies of the modulation field amplitude effect on low field microwave absorption signal (LFMAS) an 100 kHz phase sensitive detection has been used and first derivative of absorption signal was recorded at X-band microwave frequencies (~ 9 GHz). Samples in equal amount (~ 20 mg) were taken in spherical shape from the pellets and protected from humidity by sealing them in quartz tubes. LFMAS were recorded at liquid nitrogen temperature by dipping directly the thin sealed quartz tube containing the sample in liquid nitrogen. A varian E-109 X band spectrometer was used to record the LFMAS. A pair of Helmholtz coil and current source was used to cancel the residual magnetic field of the electromagnet and to provide the scan through zero field.

3. Results

The three samples studied have 0·5%, 1% and 2% Hf doping. The zero resistance transition temperature T_c was 90, 89 and 88 K for 0·5%, 1% and 2% Hf-doped samples respectively.

The LFMAS for each of the samples was recorded keeping microwave power, temperature and modulation frequency constant in the following steps (i) The sample was zero field cooled to LNT and the signal in the forward direction was recorded, followed by a reverse sweep recording back to zero field, (ii) the first step was repeated changing the modulation field amplitude.

LFMAS is sensitive to modulation amplitude. Parameters like h_p, H_m and ΔA of LFMAS are sensitive to modulation amplitude. The h_p for all three samples as a function of modulation amplitude (A_m) is shown in figure 1. It is clear that h_p increases approximately linearly in the whole range of A_m except the deviation around 30 mG. All samples show this deviation but at lower A_m as doping percentage is increased. Peak position H_m, as a function of A_m is shown in figure 2. H_m shifts towards higher field with increasing A_m. The behaviour of the amount of trapped flux (area enclosed by the hysteresis loop ΔA) with A_m is quite interesting. The variation of ΔA for all samples as a function of ΔA is shown in figure 3. Initially ΔA increases with increasing A_m except in a certain range in which ΔA decreases with increasing A_m. A_m at which ΔA starts to decrease shifts towards lower value as doping percentage of Hf is increased. The range of A_m in which ΔA decreases with increasing A_m also decreases with increasing percentage of Hf doping. The first discontinuity in h_p vs A_m and ΔA vs A_m curves shows interesting correlation.

4. Discussions

The modulation amplitude dependence of LFMAS indicates two regions of linear dependence separated by a nonlinear region. The anomalous nonlinear behaviour can be attributed to two different contributions to LFMAS. One of the contributions seems to saturate at low modulation amplitude ~ 30 mG. It has been suggested by Rakvin *et al* (1989) that the low modulation region results due to a dispersion contribution and the two different contributions to LFMAS comes from two different types of fluxons. Alternatively it has been proposed that the LFMAS is due to two components, one of which is due to the modulation of the magnetic flux through the sample and the other due to the components which depend on the boundary current (Pozek *et al* 1989). However, no definite explanation is available in literature for the anomalous nonlinear dependence on modulation amplitude of LFMAS and there is need for further theoretical efforts.

Acknowledgements

Financial support from the Department of Science and Technology, New Delhi under the National Programme on superconductivity and the Council of Scientific and Industrial Research, New Delhi is gratefully acknowledged. We are also thankful to Mr D K Kanaujia for technical help.

References

Blazey K W, Muller K A, Bednorz J G, Berlinger W, Ammoretti G, Buluggiu E, Vera A and Matacotta F C 1987 *Phys. Rev.* **B36** 724

Jayaram B, Agarwal S K, Nagpal K C, Gupta A and Narlikar A V 1988 *Mater. Res. Bull.* **23** 701

Khachaturyan K, Weber E R, Tejedar P, Stacy A M and Portis A M 1987 *Phys. Rev.* **B36** 8309

Müller K A, Takashige M and Bednorz J G 1987 *Phys. Rev. Lett.* **58** 1143

Portis A M, Blazey K W, Mûller K A and Bednorz J G 1988 *Europhys. Lett.* **5** 467

Pozek M, Dulcic A and Rakvin B 1989 *Solid State Commun.* **70** 889

Rakvin B, Pozek M, Paljevic M and Brnicevic N 1989 *Solid State Commun.* **70** 729

Yashurun Y and Malozemoff A P 1988 *Phys. Rev. Lett.* **60** 2202