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Ac-Susceptibility of Granular Superconductors

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ABSTRAK

Bahagian-bahagian nyata dan gambaran kerentanan $Y Ba_2 Cu_3 O_x$ tersinter dan superkonduktor-superkonduktor $(Bi_{1.6} Pb_{0.2} Sb_{0.2}) Sr_2 Ca_2 Cu_3 O_x$ diukur sebelum dan selepas dihaluskan. Kerentanan suhu-bersandar mungkin boleh diasingkan kepada dua kontribusi iaitu sensitif dan yang satu lagi secara relatif tidak sensitif kepada magnitud kawasan pengukuran. Sebahagian superkonduktor yang asal, tertekan apabila sampel dihimpit secara kasar. Ia tertekan sepenuhnya selepas benar-benar halus. Sesetengah model kelihatan teratur bersama hasil yang dibincangkan.

ABSTRACT

The real and imaginary parts of ac-susceptibility of sintered $Y Ba_2 Cu_3 O_x$ and $(Bi_{1.6} Pb_{0.2} Sb_{0.2}) Sr_2 Ca_2 Cu_3 O_x$ superconductors were measured before and after powdering. The temperature-dependent susceptibility may be separated into two contributions, one sensitive and the other relatively insensitive to the magnitude of the measuring field. The former is partially suppressed by coarsely crushing the sample. It is completely suppressed after finely powdering. Some of the models apparently consistent with the results are discussed.

Keywords: granular effect, superconductivity, ac-susceptibility

INTRODUCTION

The discovery of high-T_c ceramic superconductors has stimulated a remarkable range of scientific and technological research activity. Although intense work has been pursued for the past several years it is still debatable whether these experimental facts are consistent with conventional theories for bulk metallic superconductors.

Crucial to understanding these materials are the two aspects: whether superconductivity is a bulk phenomenon, and the role of dimensionality. From a materials perspective, the importance of particle size and sintering parameters must be emphasized. The influences of these parameters on the magnetic shielding and Meissner effects are thus of immediate interest. In this paper we study the decrease in diamagnetic susceptibility of sintered $Y Ba_2 Cu_3 O_7$ and Bi-2223 with the composition $(Bi_{1.6} Pb_{0.2} Sb_{0.2}) Sr_2 Ca_2 Cu_3 Ox$ (BSCCO) as they are crushed and finely powdered into presumably isolated grains.

There have been indications in high-T_c superconductors of coexistence of two contributions to the magnetic susceptibility even in single-phase materials

(Gallagher *et al.* 1987; Rao *et al.* 1987; Goldfarb *et al.* 1987; Mazaki *et al.* 1987a,b; Chen *et al.* 1988). Examination of the magnetic-field dependence of ac-susceptibility is a particularly useful method for separating the two contributions (Goldforb *et al.* Mazaki *et al.* 1987a,b; Chen *et al.* 1988). It has been shown that a moderate field of about 50 A/m is sufficient to suppress one of the contributions near T_c (Goldfarb *et al.* 1987; Chen *et al.* 1988).

MATERIALS AND METHODS

The samples $Y Ba_2 Cu_3 O_7$ (YBCO) and Bi-2223 with the composition $(Bi_{1.6} Pb_{0.2} Sb_{0.2}) Sr_2 Ca_2 Cu_3 O_x$ (BSCCO) were prepared by solid state reaction and characterized as per the procedures reported in the literature (Popov *et al.* 1992; Scheurell 1992).

To allow for an approximate comparison of sintered and powdered samples of different packing densities, mass susceptibility, rather than volume susceptibility, was measured in all cases. The real (χ') and imaginary (χ'') parts of ac-susceptibility of a YBCO and a BSCCO sample in three stages–sintered, coarsely crushed and finely powdered were examined. A laser particle size analyser was used to measure the size of the powder, and the average particle size in the crushed stage in 100 μm and the average particle size of fine powdered particles was 10 μm. The average size of the sintered samples, as measured from SEM micrographs, was 10 μm. In comparison, the estimate penetration depth for YBCO compounds was $\lambda_{ab} = 0.15_{\mu m}$ and $\lambda_c = 0.6$ 'm and for BSCCO compound was $\lambda_{ab} = 0.2_{\mu m}$ and $\lambda_C = 1_{\mu m}$ (Cyrot and Pavuna 1992). The powders were loosely packed into a cylindrical plastic holder of roughly the same dimensions as those of the original sintered samples. Ac fields of 50A/m rms at 333.3 Hz were used.

RESULTS AND CONCLUSION

The results of real and imaginary parts of ac-susceptibility of sintered, coarsely crushed, and finely powdered YBCO superconductors as a function of temperature are shown in *Fig.1*. In the well-sintered sample, instead of a single sharp drop at T_c, two contributions to a diamagnetic signal were observed occurring around 92K and 82K respectively. Coarse grinding partially suppressed the low temperature drop while fine grinding totally suppressed it. Unlike the sintered samples, the susceptibility curves for the finely ground samples are independent of the magnitude of the measuring field. *Fig.* 2 shows the results of BSCCO superconductor samples. Basically, the same effect was seen on these samples also. The sintered samples showed two drops, occurring at 107K and 97K respectively. Such behaviour is typically seen in Bi-2212 superconductors and has also been reported in substituted phases of Bi-2212 (Sarkar and Maartense 1990; Prabhu *et al.* 1993, 1994). This granular behaviour was enhanced in the presence of additives such as $Ca_{0.85} Sr_{0.15} Cu_{O2}$ and $Ba Bi O_3$ (Prabhu and Varadaraju 1994). However, in the powdered samples (both coarse and fine) in the present study, a single drop was

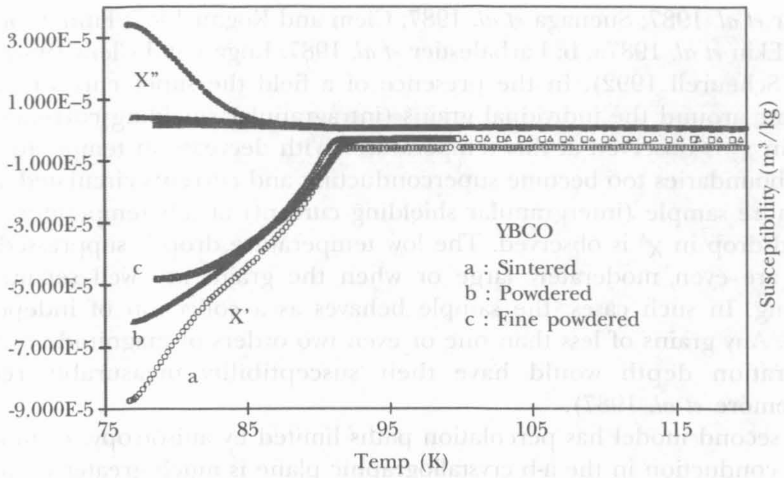

Fig. 1 Ac-susceptibility of YBCO samples as a function of temperature

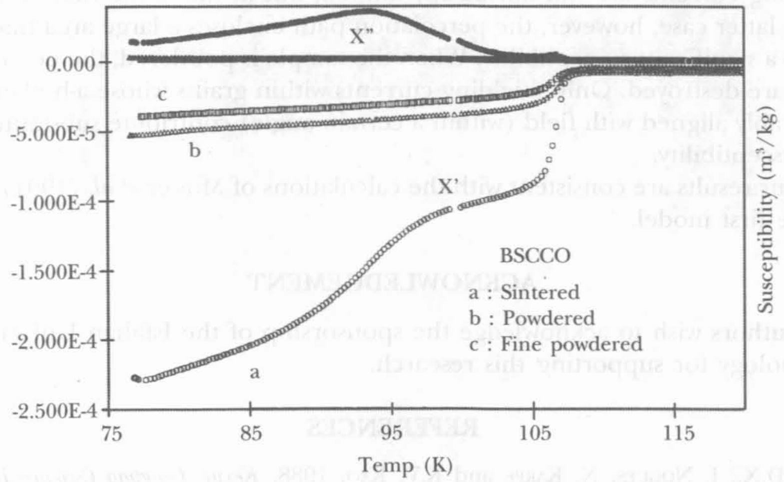

Fig. 2 Ac-susceptibility of BSCCO samples as a function of temperature

observed at 107K and the low temperature drop was not seen. χ''-plot showed a sharp peak at around 93K in the sintered sample. Since χ'-T plots clearly showed two drops, one normally expects two peaks in the χ''-T plot. The high temperature peak is not observed due to the small signal strength. In the coarsely ground sample, the low temperature peak became smaller and almost disappeared in finely powdered samples.

Several models have been proposed to explain this behaviour. The first model has that superconducting grains in the sintered sample coupled by intergranular Josephson weak links (Mazaki *et al.* 1987b; Renker *et al.* 1987;

Kupfer *et al.* 1987; Suenaga *et al.* 1987; Clem and Kogan 1987; Finnemore *et al.* 1987; Ekin *et al.* 1987a, b; Larbalestier *et al.* 1987; Kogan and Clem 1987; Popov 1992; Scheurell 1992). In the presence of a field the super currents initially circulate around the individual grains (intragranular shielding current) and a drop in χ' is observed at this temperature. With decrease in temperature, the grain boundaries too become superconducting and currents circulated around the entire sample (intergranular shielding current) at this temperature and a second drop in χ' is observed. The low temperature drop is suppressed when fields are even moderately large or when the grains are well separated by grinding. In such cases, the sample behaves as a collection of independent grains. Any grains of less than one or even two orders of magnitude times the penetration depth would have their susceptibility measurably reduced (Finnemore *et al.* 1987).

A second model has percolation paths limited by anisotropy. In moderate fields, conduction in the a-b crystallographic plane is much greater than along the c axis. Owing to a distribution in grain orientations in the sintered sample, bulk shielding currents will include some c-axis conduction. At low fields, the shielding currents are not anisotropy limited, but in moderate field, they are. In the latter case, however, the percolation path encloses a large area that gives rise to a significant susceptibility. When the sample is powdered, the percolation paths are destroyed. Only shielding currents within grains whose a-b planes are favourably aligned with field (within a certain angle) contribute substantially to the susceptibility.

Our results are consistent with the calculations of Muller *et al.* (1991) based on the first model.

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REFERENCES

CHEN, D.X., J. NOGUES, N. KARPE and K.V. RAO, 1988. *Kexue Tongpao (Science Bulletin) Academia Sinica* **33**.

CLEM, J.R. and V.G. KOGAN. 1987. *Jpn. J. Appl. Phys.* **26(3)**: 1161.

CYROT, M. and D. PAVUNA. 1992. *Introduction to Superconductivity and High-T_c Materials.* Singapore: World Scientific.

EKIN, J.W., A.I. BRAGINSKI, A.J. PANSON, M.A. JANOCKO, D.W. CAPONE. 1987a. *J. Appl. Phys.* **62**: 4821.

EKIN, J.W., A.J. PANSON, A.I. BRAGINSKI, M.A. JANOCKO, M. HONG, J. KWO, S.H. LIOU and D.W. CAPPONE. 1987b. In *High Temperature Superconductors,* ed. D.U. Gubser and M. Schluter, Vol. EA-11, p. 223-226. Pittsburgh: Materials Research Society.

FINNEMORE, D.K., R.N. SHELTON, J.R. CLEM, R.W. MCCALLUM, H.C. KU, R.E. MCCARLEY, S.C. CHEN, P. KLAVINS and V.KOGAN. 1987. *Phys. Rev.* **B35**: 5319.

GALLAGHER, W.J., R.L. SANDSTROM, T.R. DINGER, T.M. SHAW and D.A. CHANCE. 1987. *Solid State Commun.* **62**: 323.

GOLDFARB, R.B., A.F. CLARK, A.J. BRAGINKSI and A.J. PANSON: 1987. *Cryogenics* **27**: 475.

KOGAN, V.G. and J.R. CLEM. 1987. *Jpn. Appl. Phys* **26(3)**: 1159.

KUPFER, H., I. APFELSTEDT, W. SCHAUER, R. FLUKIGER, R. METER-HIRMER and H. WUHL. 1987. *Z. Phys.* **B69**: 159.

KWAK, J.F., E.L. VENTURINI, D.S. GINLEY and W. FU. 1987. In *Novei Superconductivity*, ed. S.A. Wolf and V.Z. Kresin, p. 983-991. New York: Plenum.

LARBALESTIER, D.C., M. DAEUMLING, X. CAI, J. SEUNTJEANS, J. MCKINNEL, D. HAMPSHIRE, P. LEE, C. MEINGAST, T. WILLIS, H. MULLER, R.D. RAY, R.G. DILLENBURG, E.E. HELLSTROM and R. JOYNT. 1987. *J. Appl. Phys.* **62**: 3308.

MAZAKI, H., M. TAKANO, R, KANNO and Y. TAKEDA. 1987a. *Jpn. J. Appl. Phys.* **26**: L780.

MAZAKI, H., M. TAKANO, Y. IKEDA, Y. BANDO, R. KANNO, Y. TAKEDA and O. YAMAMBO. 1987b. *Jpn. J. Appl. Phys.* **26**: L1749.

MULLER, K.H., S.J. COLLOCOTT, R. DRIVER and N. SAVVIDES. 1991. *Supercond. Sci. Technol.* **4**: S325.

POPOV, A.G., V. P. DOVGOPOL, F.M. OLEVSKY, V.S. MELNIKOV and V.M. PAN. 1992. *Supercond. Sci. Technol.* **5**: 654.

PRABHU, P. SUMANA and U.V. VARADARAJU. 1994. *Bull. Mater. Sci.* (India) **17**: 615.

PRABHU, P. SUMANA, M.S. RAMACHANDRA RAO and G.V. SUBBA RAO. 1993. *Physica* **C211**: 279.

PRABHU, P. SUMANA, M.S. RAMACHANDRA RAO, U.V. VARADARAJU and G.V. SUBBA RAO. 1994. *Phys. Rev.* **B50**: 6929.

RAO, K.V.. D.X CHEN, J. NOGUES, C. POLITIS, C. GALLO and J.A. GERBER. 1987. In *High Temperature Superconductors* ed. D.U. Gubser and M. Schluter, Vol. EA-11, p. 133-135. Pittsburgh: Materials Research Society.

RENKER, B., I. APFELSTEDT, H. KUPFER, C. POLITIS, H. RIETSCHEL, W. SCHOLZ, H. WUHL, U. GOTTWICK, H. KNEISSEL, U. RAUSCHSHWALBE, H. SPILLE and F. STEGLICH. 1987. *Z. Phys.* **B67**: 1.

SARKAR, A.K. and I. MAARTENSE. 1990. *Physica* **C168**: 591.

SCHEURELL, S., F. SCHOLZ, T. OLESCH and E. KEMNITZ. 1992. *Supercond. Sci. Technol.* **5**: 303.

SUENAGA, M., A. GHASHI, T. ASANO, R.L. SABATINI and A.R. MOODENBAUGH. 1987. In *High Temperature Superconductors*, ed. D.U. Gubser and M. Schluter, Vol. EA-11, p. 247-249. Pittsburgh: Materials Research Society.