

MEASUREMENTS OF ELECTROMAGNETIC SHIELDING EFFECT USING HTSC MATERIALS

V. VIDYALAL, K. RAJASREE and C. P. G. VALLABHAN

*Opto-Electronics Lab., International School of Photonics,
Cochin University of Science and Technology, Cochin 682 022, India*

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A simple experimental set-up is described to measure the electromagnetic shielding property of high T_c superconducting samples. Measurements were performed using HTSC materials in the form of laser ablated thin films, powders and sintered pellets. Samples used were Gd-123 in pure and doped form as well as a few Bi-based superconducting ceramics. For comparison, similar measurements were carried out on metals like aluminium, copper and μ metal. Very effective shielding was observed for HTSC materials compared to the conventional materials mentioned above. However it also depended on the sample types and poor shielding was observed for powdered HTSC material in comparison to thin films prepared by laser ablation.

1. Introduction

One of the promising applications anticipated of HTSC materials is in the fabrication of magnetic shields. Quantitative measurements of shielding effect are thus of great importance in characterising HTSC materials for this specific purpose. In addition to this, a slightly modified version of this method can be used to determine mechanical flaws such as cracks in these materials which cannot be easily detected by resistivity or from Meissner effect studies.

Investigations of the shielding effects of $\text{YBa}_2\text{Cu}_3\text{O}_{7-x}$ have shown that superconducting ceramic shields are more effective (at low frequencies) than aluminium or high permeability ferrous materials like μ metal.^{1,2} Studies on thin films have shown that oriented monocrystalline films of thickness $\approx 1 \mu\text{m}$ can shield power densities of upto 10^6 W/cm^2 from DC to ultraviolet.⁹ 100% flux shielding was observed in $\text{YBa}_2\text{Cu}_3\text{O}_{7-x}$ at 4.2 K by Larbalestier *et al.*⁴ One added advantage of high T_c materials over conventional materials like aluminium is the effectiveness of the former at low frequencies and the reduction in thickness (several mm of thickness is needed for Al at low frequencies) needed for total shielding.

Shielding measurements carried out on HTSC materials in the form of laser ablated thin films, powders and sintered pellets are described in the following figure.

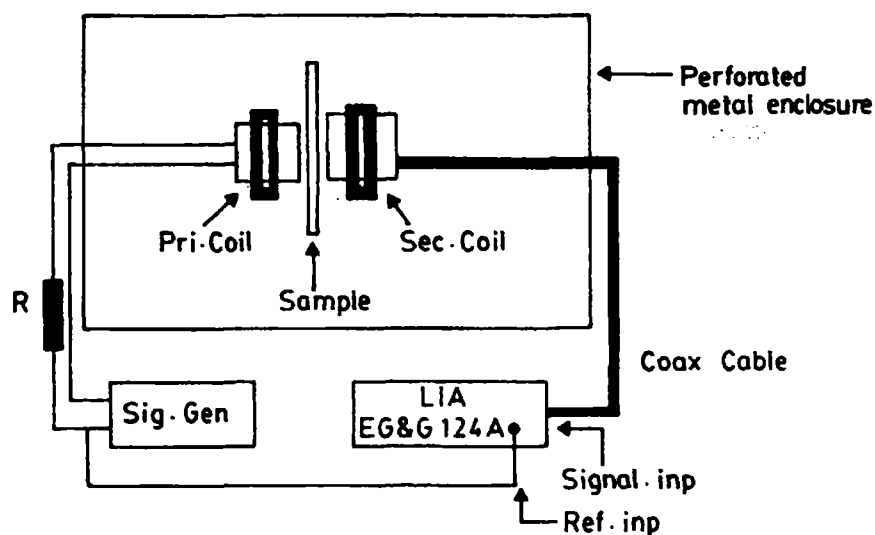


Fig. 1. Schematic diagram of the experimental setup.

2. Experimental

The schematic diagram of the setup is given in Fig. 1. Basically it is a pair of coils with the shielding material placed in the space between them. The primary coil consisted of 25 turns and the secondary coil had 35 turns of 0.3 mm insulated copper wire and the diameter of the coils were less than the sample width. This would minimise the flux leakage to the secondary winding. The coils were wound on teflon formers. The primary winding was excited using an alternating current within 5–50 mA which was kept constant. A lock in amplifier (EG&G model 124A) was used to detect the voltage induced in the secondary. The sample material was introduced in the space between the coils. Powdered samples were sandwiched between two thin glass slides which were inserted in the space. Measurements were carried out at 77 K by immersion in liquid nitrogen. Lock in technique helps to obtain noise free data.

High T_c materials were synthesised according to the procedures cited in the literature.⁵ The specific HTSC materials used here for shielding studies were thin films of laser ablated, bulk and powder samples of $\text{GdBa}_2\text{Cu}_3\text{O}_{7-\delta}$, $\text{GdBa}_2\text{Cu}_3\text{O}_{7-\delta} + \text{K}$, BiCaSrCuO (2223) + Pb and BiCaSrCuO (2223) + Na. For comparison similar measurements were carried out on metals like aluminium, copper and μ metal. The shielding properties were then evaluated at different frequencies both at room and at liquid nitrogen temperatures.

3. Results and Discussion

The shielding factor (S_F) was determined by performing the measurements both at room temperature as well as at liquid nitrogen temperatures. The shielding factor is

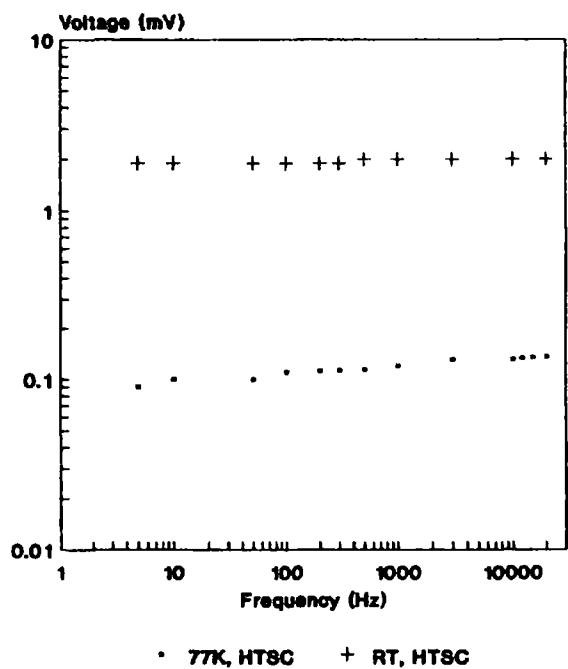


Fig. 2. Plot of the output voltage of the pickup coil versus frequency for a HTSC (Gd-123) sample.

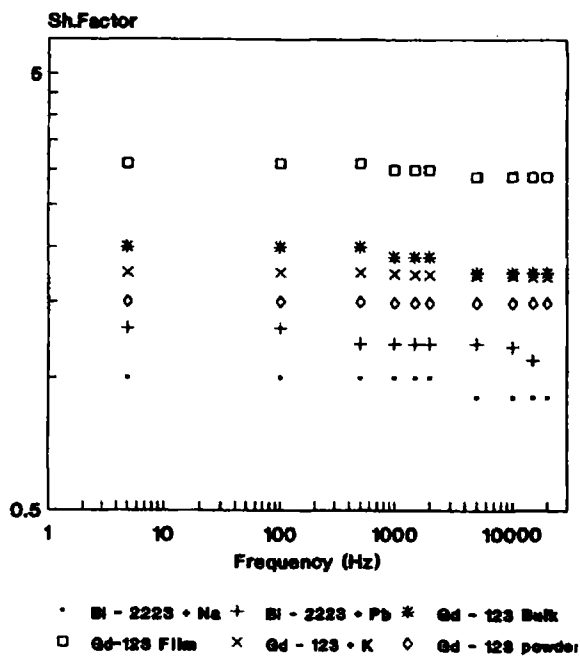


Fig. 3. Plot of the shielding factor versus frequency for HTSC materials.

the ratio of the induced voltage at room temperature to the same at liquid nitrogen temperature.

$$S_F = \frac{U_{RT}}{U_{LN2}} \quad (1)$$

From Fig. 2, it is clear that at a given frequency, as the sample is cooled to liquid nitrogen temperature, the output voltage of the secondary coil decreases to a value mainly determined by the type of sample used. Figure 3 gives the S_F values for few of the HTSC materials. Poor S_F was obtained for powders and doped HTSC materials mentioned above. This is probably due to the poor interconnectivity between the grains and flux lines being concentrated between the grains. Therefore good bonding between the particles is essential for effective shielding. Such effective shielding is observed in melt textured samples which have better S_F values. Therefore it can be concluded that powders and to some extent ceramics synthesised by conventional preparation methods are ineffective for total shielding purposes. This has been observed by other workers also who measured the critical shielding current density for YBCuO superconducting ceramic plates.⁶ Their results show that the value is proportional to the thickness of the sample as expected from the Beans critical model.⁷ Therefore for superconducting ceramics, the main parameters that control the shielding is the critical current density and thickness of the sample.

The values obtained for copper, HTSC thin film material (laser ablated Gd-123), μ metal and aluminium are shown in Fig. 4. There was no appreciable change in the

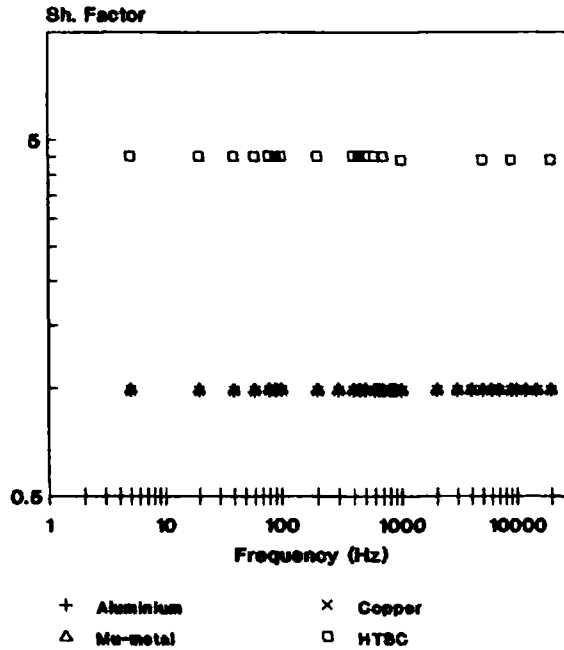


Fig. 4. Plot of the shielding factor versus frequency for copper, aluminium, μ metal and a HTSC thin film material (laser ablated Gd-123).

value of S_F , at different frequencies both at room temperature and at liquid nitrogen for the metals compared to the superconducting ceramic. The exceptional shielding properties of these new materials at low frequencies and low power densities make them superior to conventional materials used for low frequency shielding.

References

1. J. C. MacFarlane, R. Driver, R. B. Roberts, and E. C. Horrigan, *Cryogenics* **28**, 303 (1988).
2. J. C. MacFarlane, R. Driver, R. B. Roberts, E. C. Horrigan, and C. Andrikidis, *Physica C* **153**, 1423 (1988).
3. K. K. Likharev, *Supercond. Sci. Technol.* **3**, 325 (1990).
4. D. C. Larbalestier, M. Daeumling, X. Cai, J. Seuntjens, E. E. Hellstorm, and R. Joynt, *J. Appl. Phys.* **62**, 3308 (1987).
5. See for e.g. V. Vidyalyal, K. Rajasree, and C. P. G. Vallabhan, *Int. J. Mod. Phys. B* **7**, 3273 (1993) and references cited therein.
6. A. Yahara and H. Matsuba, *IEEE Trans. Magn. MAG* **25**, 2498 (1988).
7. C. P. Bean, *Rev. Mod. Phys.* **36**, 31 (1964).