On the measurement of microwave absorption of bulk YBaCuO superconductors in X-band (8–12 GHz)

J K SINGH, H S KOTHARI, O P DAGA, B R SINGH and
W S KHOKLE

Semiconductor Devices Area, Central Electronics Engineering Research Institute, Pilani
333 031, India

Abstract. Microwave absorption at the surface of high T_c YBaCuO superconducting sample has been determined in X-band by measuring VSWR. Power reflectivity $> 98\%$ has been observed in the frequency range of 8.2–10.5 GHz indicating very low absorption at the surface. At some of the frequencies, however, negligible microwave loss has been observed.

Keywords. Microwave absorption; VSWR.

1. Introduction

The advent of high T_c superconducting materials has tremendous potential for its use in superconducting electronics, perhaps due to the fact that the temperature range of operation of these new materials overlaps that of cooled semiconductor devices and systems. In order to determine the suitability of these high T_c materials, particularly for microwave applications, such as in making of high Q cavities and resonators etc knowledge of their microwave properties is essential. Already some work has been done by Gittleman *et al* (1989), Newman *et al* (1989) and Tatenio *et al* (1987), who have mostly studied about the RF superconductivity/surface resistance of the materials and its variation with temperature at a fixed single frequency. We have for the first time studied the variation of microwave absorption with frequency (complete X-band) due to bulk YBaCuO superconducting material using reflection technique. The present paper reports our results.

2. Experimental

The high T_c superconductor samples used for microwave measurement were prepared using high purity powders of oxides of YBaCuO in the ratio 1:2:3 respectively. After thorough mixing the powder was calcinated at 950°C for 24 h. After granulation, pellets of desired dimension (0.9" $\times$ 0.4") were formed and sintered at 950°C for about 10 h in oxygen ambient followed by slow cooling (2°C/min). Critical temperature of 91 K was observed in these samples (Singh *et al* 1988).

The standard test set-up consisting of a HP 8350B sweep oscillator, hp 8510 network analyser, hp 8512A reflection/TX test set-up and hp 7470 plotter was used for measuring VSWR. A block diagram of the set-up is shown in figure 1. First, the bench was calibrated and VSWR of a fixed metal short was measured. The fabricated superconducting sample was then placed immediately before the fixed metal short and the same measurement repeated at room temperature and liquid nitrogen temperatures. It may be mentioned here that to clearly distinguish the effect of

Figure 1. Schematic block diagram for the measurement of VSWR.

frequency on VSWR the entire X-band was divided into three sub-bands i.e. from 8 to 9.5, 9.5 to 11 and 11 to 12.5 GHz ranges and the VSWR scales were also chosen differently for room and liquid nitrogen temperatures.

3. Results and discussion

The variation of VSWR with frequency for high- T_c YBaCuO superconducting sample at room and LN temperatures are shown in figures 2a–d, where the dotted line represents the results when the sample was at room temperature and the continuous line shows the measured values of VSWR when the sample was immersed in liquid nitrogen. As mentioned above, VSWR scales have been chosen according to convenience, as shown in the figures.

It may be seen from the figures that at room temperature, VSWR in general varies from 10 to 25 although some peaks are also observed at certain frequencies. This value of 10–25 is smaller than those in the case of fixed metal short where VSWR observed was between 40 and 50 in the whole of X-band (figure 2a). Lower values are obviously due to lower conductance of the surface of the superconductor sample in normal state (room temperature). Rough surface and its porosity is also responsible for small values. The above mentioned peaks observed at some of the frequencies may be attributed to the non-uniform surface resistance of the material.

Significant increase in VSWR values has been observed between the frequency range of 8 and 10.5 GHz when the sample attains its critical transition temperature. VSWR greater than 5000 is however observed at some frequencies mainly in 9.5 to 11 GHz range as shown in figure 2. Similar result has also been observed at 8.3 GHz. Table 1 shows the typical frequencies at which the VSWR of the sample at T_c is very very high and may be considered to be tending towards its infinite value. VSWR of the sample at room temperature and values of power reflectivity and absorption coefficient at room and liquid nitrogen temperature at the above mentioned frequencies are also listed in the table for comparison.

Our results clearly establish that the magnitude of the reflected power is in general much higher (94–98%) when the sample is in superconducting state than its value at room temperature or even from the fixed metal short alone. But at frequencies shown

Figure 2. Variation of VSWR with frequency for fixed metal short alone (a) and superconducting sample at room and liquid nitrogen temperature (b), (c) and (d). (a) 8–12.5 GHz. (b) 8–9.5 GHz. (c) 9.5–11 GHz. (d) 11–12.5 GHz.

in table 1, the observed power reflectivity is more or less complete and therefore the microwave power loss at the surface of the sample at T_c is almost negligible. The reason for the very high VSWR (> 5000) at some discrete frequencies in the 8.2 to 10.5 GHz range is still under investigation. Extremely low microwave absorption due to superconducting sample at T_c is in accordance with the physical behaviour of oxide superconductors, where dissociation of Cooper pairs due to increase of temperature, adds to the microwave loss and vice versa. Extremely high microwave losses observed beyond 10.5 GHz (figure 2) indicate that the material may not be suitable for this frequency range.

Table 1. Measured VSWR and power reflectivity/absorption ratio at room and liquid nitrogen temperature for different frequencies in X-band.

Frequency (GHz)	VSWR		Power reflectivity $R = (1 - r)/(1 + r)$		Absorption ratio
	Room Temp.	LN temp. (T_c)	Room Temp.	LN temp. (T_c)	$A = 1 - R$ at T_c
8.3	20	5000	0.8185	0.9996	0.004
9.65	14	5000	0.7512	0.9996	0.004
9.72	15	5000	0.7658	0.9996	0.004
10.02	57	5000	0.9323	0.9996	0.004
10.10	25	5000	0.8520	0.9996	0.004
10.35	20	5000	0.8186	0.9996	0.004
10.62	50	5000	0.9231	0.9996	0.004

4. Conclusion

Microwave absorption at the surface of YBaCuO superconducting sample at its critical transition temperature T_c is in general very low in 8.2 to 10.5 GHz range with almost negligible loss at some intermediate frequencies. The magnitude of microwave loss is lower than that reported by Tateno *et al* (1987).

Acknowledgement

We are thankful to Dr R K Jha and Dr B Jha of the Institute of Technology, Banaras Hindu University, Varanasi for facilities and help in microwave measurements.

References

- Gittleman J I *et al* 1989 *J. Appl. Phys.* **65** 688
 Newman H S *et al* 1989 *Appl. Phys. Lett.* **54** 389
 Singh B R *et al* 1988 *Phys. Status Solidi (a)* **106** K53
 Tateno J *et al* 1987 *Jpn. J. Appl. Phys.* **36** L1654