Mohan Jacob

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Microwave Superconductivity

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NON-LINEAR SURFACE IMPEDANCE OF YBCO SUPERCONDUCTORS

MOHAN V. JACOB[*]

School of Engineering and Physical Sciences
James Cook University
Townsville, QLD 4811
AUSTRALIA

[$] *This PhD work was done at Department of Electronic Sciences, University of Delhi, India under the supervision of Prof. G. P. Srivastava*

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Preface

The American Physical Society conference of March 1987 announced the remarkable discovery of a superconductor with a transition temperature (T_c) of 90 K. Now a decade has passed since the invention of High Temperature Superconductors (HTS), and many conceivable combinations of ceramics and metals have been tested to procure room temperature superconductivity. So far the goal has not been achieved, but, higher T_c have been obtained. Now researchers are concentrating on the application side of superconductors. Many prototype devices have been successful. We can expect a major change in the next few years especially in the field of communications. The study of superconductivity is exciting and results range from new superconducting compounds through the detection of novel physical phenomena and the development of new theories to the demonstration of new devices.

A myriad of applications has been successfully demonstrated. In the domain of microwave superconductivity, HTS resonators and filters have shown their potential. But the instability of device performance with the input microwave power prevents the operation of these devices at high microwave power levels. The microwave losses are non-linear at high input power levels. The possible reasons for this non-linear loss are not clear.

Halbritter (1990, 92) modelled the non-linear phenomena by considering an HTS material as a network of grains and grain boundaries (Herd et al., 1995). Nguyen et al. (1993) proposed a grain coupled model to explain the non-linear phenomena. They explained the results by a quadratic model. However, it was applicable only at low rf power levels. Sridhar (1994) proposed a hysteresis model to explain the nonlinear loss. Wosik et al. (1997) and Hein et al. (1997) attribute the non-linear losses to heating effects. So far, none of these models are able to explain the non linear phenomena under all physical conditions such as temperature, frequency and power. A model which can elucidate the non-linear losses at all temperatures and frequencies is not available. An adequate model could shed light on this problem and this is the aim of this thesis.

In the first chapter we discuss the behaviour of superconductors at different temperatures, frequencies, microwave fields, etc. Some of the important studies carried out to investigate the physical behaviour of surface resistance were reviewed in the first chapter. From the literature review it is clear that there is no unique model that explains all physical dependence. Most of the models are either empirical or phenomenological.

The second chapter deals mostly with the effect of microwave power at low power levels. In this chapter we have modelled the non-linear surface impedance. We have obtained a power model to study the non-linear effects. A quadratic power model could explain the non-linear effects at low and intermediate (<50 Oe) power levels. This model is similar to the empirical model proposed by Oates *et al.* (1993). Beyond the intermediate power level, the losses became faster than the quadratic power and hence the model failed beyond the intermediate power level. However, the model helped to explain the onset of non-linear losses in HTS. We used the measurement results of three microstrip resonators to substantiate the model.

We have discussed in detail the different causes of the non-linear loss in high temperature superconducting microwave devices in chapter III. It has been found from the critical state model that the current density is a function of the applied rf field. In this chapter we have modelled the non-linear microwave losses by assuming the exponential model for current density. We compared the model with the experimental results of a stripline resonator and a dielectric resonator. The results are interesting because at all temperatures and frequencies this model matched the experimental data for all input power levels.

We studied the different measurement techniques (resonant) used for microwave characterisation of high temperature superconducting samples and devices and the results are drawn in chapter IV. In this chapter we discussed the cavity techniques, parallel plate methods and microstrip methods. It is understood that a dielectric resonator will give stable results. Also it is a non-destructive method for measuring HTS thin films. Hence we used the dielectric resonator for our measurement and carried out detailed analyses of the dielectric resonator. We studied the electric and magnetic field distributions inside and outside the sapphire rod.

In the fifth chapter we described the measurement system and the pulsed laser deposition (PLD) techniques used for the deposition of YBCO thin film. We carried out the measurement of two types of YBCO thin films here. The first was the pure YBCO thin film deposited by the co-evaporation technique on Lanthanum Aluminate Substrate. We measured the microwave power dependence of the samples at 10 GHz and 25 GHz frequencies at a temperature of 77 K. The second was silver doped YBCO thin films produced by the PLD technique on MgO substrates. We reported the results at a frequency of 25 GHz and a temperature of 77 K at differing microwave power levels. We also studied the XRD pattern to investigate the presence of silver. Further, we carried out the SEM analysis of the Ag doped YBCO samples to study the effect of silver doping on the microstructure.

Finally we came to the conclusions of this work in chapter VI and suggest recommendations for future studies in the field. We hope that the role by the semiconductor in this century will be played by the more powerful superconductors with less loss in the 21^{st} century. References are given at the end of the thesis.

This research was carried out at University of Delhi under the supervision of Prof. G. P. Srivastava, Department of Electronic Science. His supervision and support is acknowledged.