Microwave Josephson absorption of high-temperature superconductors

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Abstract

Magnetic field dependence of the Direct (DMA) and the Magnetically Modulated (MMMA) Microwave Absorption of a number of Y-, Bi- and Tl-based high-temperature superconductors were measured at 4.2 K and 77 K by X-band microwave spectrometer. Correlation between value of the Low Field Maximum (LFM) of the absorption and the inter-grain critical currents of Josephson junctions was found. Results were analyzed and compared to theoretical models of microwave absorption available in the literature yielding good agreement.

Key words: microwave magnetoabsorption; Josephson junctions; critical currents

1. Introduction

The MMMA in superconducting state of high-temperature superconductors (HTS) was observed in very low applied magnetic field with the so-called LFM in magnetic field of a few mT due to existence of natural inter-grain Josephson junctions in those systems [1–10]. The microwave absorption was measured mostly by the standard microwave spectrometers yielding the record of the first derivative of the absorption as a function of magnetic field [1–3,5]. Only a few results of measurements of DMA without applying of the modulation field were presented up to now [5–7] because intensity of the effect is very small. However, the comparison of the DMA results with theoretical relations is more rational because the MMMA signal contains also contribution coming from the modulation field.

A few theoretical models were proposed to explain the phenomenon. They assume that Josephson junctions form the rf- or dc-SQUID or Resistively Shunted Josephson Junctions (RSJJ) system which absorbs the microwave power [7,9,10]. Our motivation was to measure both MMMA and DMA as a function of magnetic field and temperature because DMA may be directly compared to the available theoretical models.

2. Experimental results and their analysis

The samples of YBa$_2$Cu$_3$O$_{7-\delta}$ were prepared by the standard procedure and the chemical sol-gel method [11]. The samples of Bi$_{1.85}$Pb$_{0.15}$Sr$_{1.9}$Ca$_{2.05}$Cu$_{3}$O$_{\sim 10}$ (Bi(2223)), Tl$_{0.6}$Pb$_{0.5}$Sr$_{1.8}$Ba$_{0.2}$CaCu$_3$O$_{\sim 10}$ (Tl(1223)), and series of Tl(1223) with Bi, F and U, were synthesized by various methods (standard mixed oxide, co-precipitation and gel methods) [12].

Superconducting transition temperature $T_c$ as well as the intergrain critical current densities $J_c$ were determined from $ac$-susceptibility measurements in our previous paper [13]. The MMMA and DMA were measured by X-band (9.5 GHz) spectrometer at temperatures 4.2 K, 66 K and 77 K and in magnetic field from zero to 1 T (see Fig. 1). The special microwave bridge was build up to measure the very low DMA signal [8].
3. Conclusions

The intergrain microstructure and critical currents determine the microwave absorption of HTS. The plot of $B_{LFM}$ vs $J_c$ at 77 K shows linear dependence (cf. Fig. 2). The RSJJ model describes the microwave absorption of HTS in sufficiently good way.

References