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Microwave Conductivity of Laser Ablated YBaCuO Superconducting Films and Its Relation to Microstrip Transmission Line Performance

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The discovery of high temperature superconductor oxides has raised the possibility of a new class of millimeter and microwave devices operating at temperatures considerably higher than liquid helium temperatures. Therefore, materials properties such as conductivity, current density, and sheet resistance as a function of temperature and frequency, possible anisotropies, moisture absorption, thermal expansion, and others, have to be well characterized and understood. In order to evaluate the suitability of such devices, and in an attempt to understand the nature of superconductivity in these new high Tc superconductors, the millimeter wave response of these new oxides has been investigated.

In this paper, we have studied the millimeter wave response of laser ablated $YBa_2Cu_3O_{7-x}/LaAlO_3$ thin films as a function of temperature and frequency. In particular, we have concentrated our efforts in the evaluation of their microwave conductivity, since knowledge of this parameter provides a basis for the derivation of other relevant properties of these superconducting oxides, and for using them in the fabrication of actual passive circuits. The microwave conductivity for these films has been measured at frequencies from 26.5 to 40.0 GHz, in the temperature range from 20 to 300 K. The values of the conductivity are obtained from the millimeter wave power transmitted through the films, using a two fluid model. The behavior of the real and imaginary parts of the complex conductivity, σ_1 and σ_2 respectively, at temperatures below T_c, is consistent with the predictions of carrier pairing mechanisms, as is shown in figures 1 and 2.

Values of the order of 1.8×10^7 and 4.9×10^3 S/M, for the imaginary and real parts of the microwave conductivity respectively, have been obtained at temperatures around 20 K. Values for the surface resistance, magnetic penetration depth, superconducting carrier density, and an effective energy gap (assuming BCS theory applicability), derived using σ_1 and σ_2, are reported.

A microstrip ring resonator was produced on 10 mil lanthanum aluminate by patterning a laser ablated film in a liquid bromine/ethanol etch, and evaporating 1 micron of gold for a ground plane (Fig.3). The resonator operated at a frequency of 35 GHz. The quality factor "Q" of resonators made entirely of evaporated gold on lanthanum aluminate (both strip and ground plane). Around 20 K, the "Q" of the hybrid was approximately twice that of the gold circuit, while closer to the transition temperature T_c of the HTS film, the improvement in Q was less. The improvement in "Q" implies a reduction in the surface resistance and losses in the HTS as compared to gold.

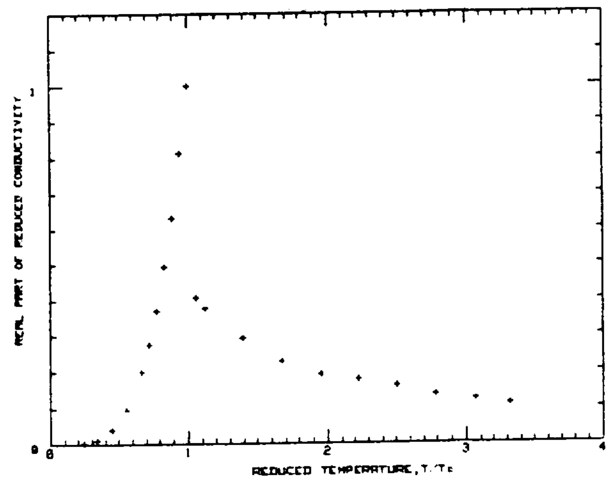

Figure 1: Real part of the microwave conductivity for a Laser Ablated $YBa_2Cu_3O_{7-x}/LaAlO_3$ thin film (.7 microns, T_c=89.7K) at 38.0 GHz.

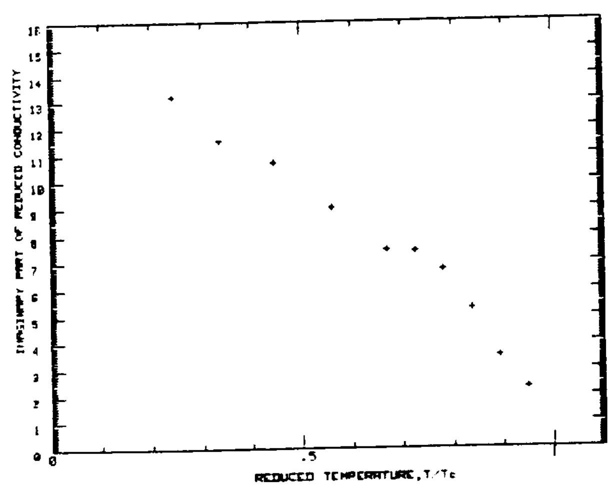

Figure 2: Imaginary part of the microwave conductivity for a Laser Ablated $YBa_2Cu_3O_{7-x}/LaAlO_3$ thin Film (.7 microns, T_c=89.7K) at 38.0 GHz.

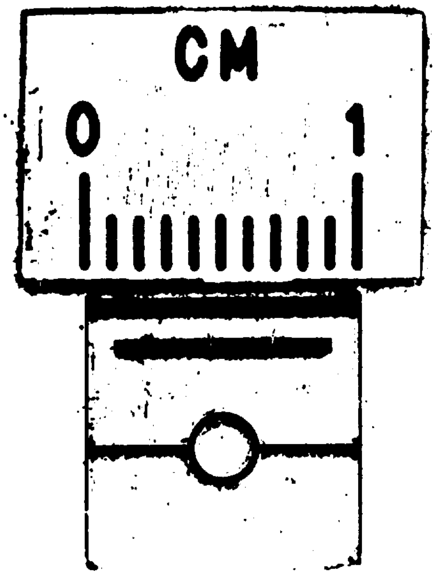

Figure 3: 35 GHz Ring Resonator circuit on $LaAlO_3$ substrate

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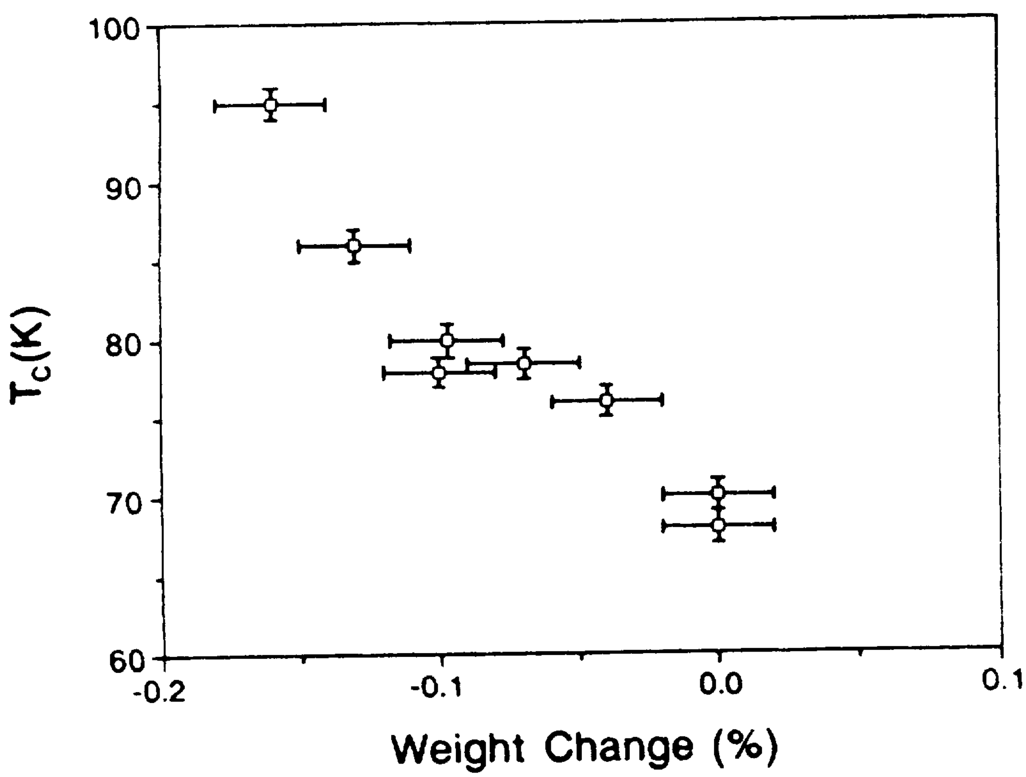

Fig.1 Superconductor transitions T_c verses weight change for 2211 phase