MICROWAVE DIELECTRIC RESONANCE EFFECT IN THE $YBa_2Cu_3O_7$ SINGLE CRYSTAL

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ABSTRACT

First observations of the microwave dielectric resonance in a single crystal of the YBa2Cu3O7 are presented. With the YBa2Cu3O7 single crystal inserted into the microwave (f ~ 9 GHz) resonator we observe the appearance of the new intense and broad transmission band. The transmittivity value of this band exhibits remarkable temperature hysteresis. The data show that the observed birefringence is the intrinsic property of the HTSC material resulting from the spatial dispersion and nonlinearity of HTSC electric properties due to the metal-insulator-type instability.

1. INTRODUCTION

In the papers [1] the observations of the new dielectric-type microwave resonance in high T_c superconductor ceramic samples have been reported. The $YBa_2Cu_3O_7$ ceramic sample sample, being inserted into the microwave resonator cavity, demonstrates the dielectric-like properties under variation of spatial characteristics of the microwave resonator field. An electromagnetic wave begins to penetrate and to propagate inside the sample with a relatively low attenuation. It has been argued that the observed effects are a consequence of nonlinearity and spatial dispersion of the HTSC electric properties, caused by the intrinsic instability of the metal-insulator type of these materials rather than by the ceramic structure of samples. In this paper we present first experimental findings of the microwave dielectric resonance in a single crystal of the $YBa2Cu_3O_7$. Excitation of the dielectric resonance in a single crystal and the observed hysteresis in its temperature behavior provide an evidence for the intrinsic nature of the spatial dispersion and nonlinearity effects in HTSC materials.

2. RESULTS

2.1. Experimental

Measurements were performed in the Nb microstrip resonator [1] schematically shown in Fig.1. All investigated samples (HTSC, Nb, Cu) had the same rectangular shape and dimensions (1.5×1.4×0.5mm) and were measured at the same set of positions in a resonator. The sample

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position was characterized by the angle α measured in plane of the resonant strip off the polar axis, directed along the transverse axis of the strip (Fig.1 a). The $YBa_2Cu_3O_7$ single crystal was grown in an alumina crucible [2] and was characterized by T_c=90 K and $\Delta T_c \approx 3$ K. The T_c of the Nb sample was 9.2 K.

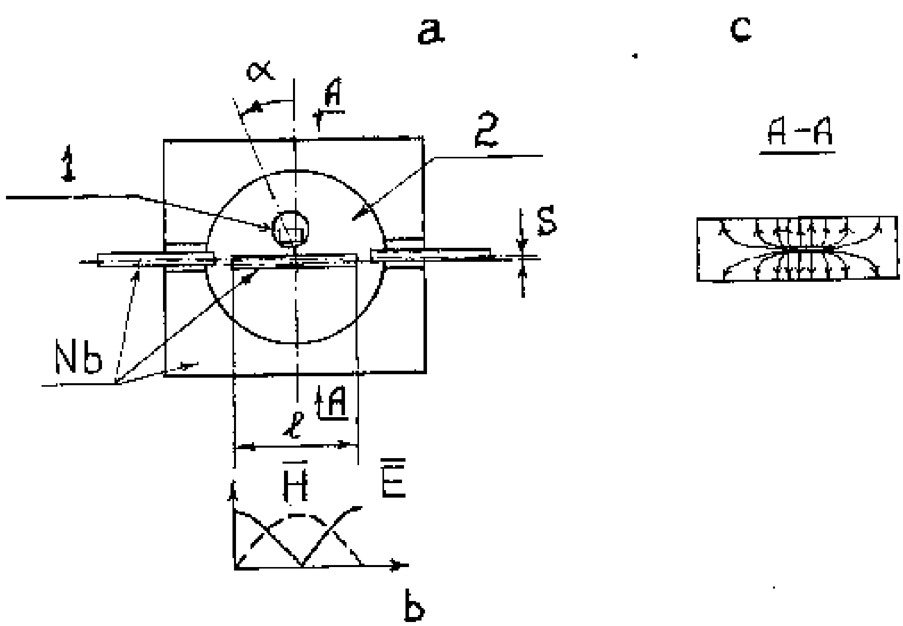

Figure 1. Scheme of the measuring microstrip niobium resonator. (a) Top view: 1 - sample, 2 - teflon disk; (b) Spatial distribution of electromagnetic field amplitudes along the resonator; (c) Configuration of the field line in the cross-section.

2.2. Dielectric resonance

The transmittivity spectra of resonator with the Cu, Nb or single crystal $YBa_2Cu_3O_7$ samples are shown in Fig.2 and 3 for two positions of the sample. At the position corresponding to the angle of 63° (Fig.2) with the HTSC sample inserted into the resonator instead of the identical Cu or Nb sample it demonstrates the significantly enhanced resonator transmittivity. A new intense broad transmission band with the modulated amplitude is seen at frequencies below 8.9 GHz, which is especially pronounced at higher temperatures (c,d). As seen from **Figs.2 b, d** and **3 b** the modulation of the spectra does not depend on temperature or spatial position of sample and should be assigned to the parasitic resonances of the outer waveguide interconnections. The new broad band was observed at the strictly defined spatial positions of the HTSC sample in a resonator.

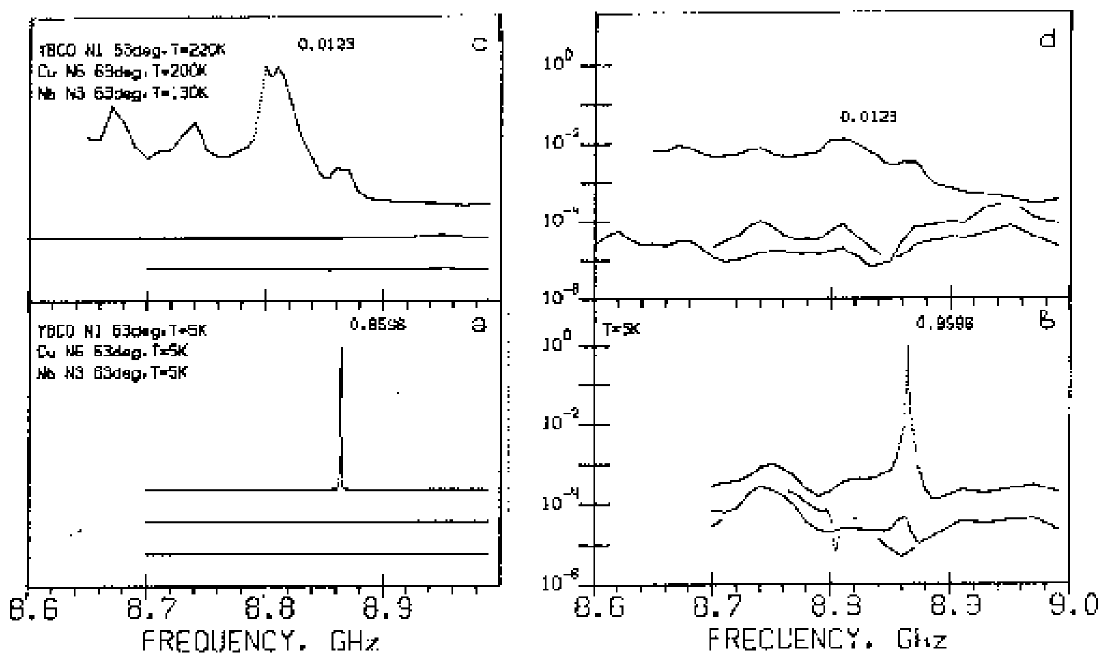

Figure 2. Microwave power transmittivity spectra for the resonator with Cu, Nb or single crystal $YBa_2Cu_3O_7$ samples at temperatures of 5-220 K for the position of samples in a resonator cavity ($\alpha = 63°$) corresponding to the presence of the dielectric resonance excitation. Spectra in the **a (c)** and **b (d)** plots are the same but plotted on linear **(a,c)** and logarithmic **(b,d)** *y*-axis scale. For the sake of convenience spectra in linear plots **(a,c)** are constantly shifted along the vertical axis. Numbers over the curves correspond to a transmittivity at the maximum.

For other spatial configurations, transmittivity of the resonator was of the same order of magnitude for all investigated samples of Cu, Nb and HTSC (Fig.3) in the whole temperature range of 5-300 K. These experimental findings are similar in general features to the observed excitation of the dielectric resonance in ceramic HTSC samples [1] and can be explained as an appearance of the dielectric resonance in the $YBa_2Cu_3O_7$ single crystal. The rounded stepwise form and the absence of a pronounced peak (Fig.2 d) indicate the very low quality-factor value (the order of 10) of the dielectric resonance and the dominant role of relaxation processes in this phenomena. So it can be concluded that the frequency of current carrier scattering is very low (~10^{10} Hz) under conditions of the dielectric resonance excitation, in accordance with previous estimations [3], and that the relaxation processes may be significant for a collapse in the scattering rate at microwaves [4].

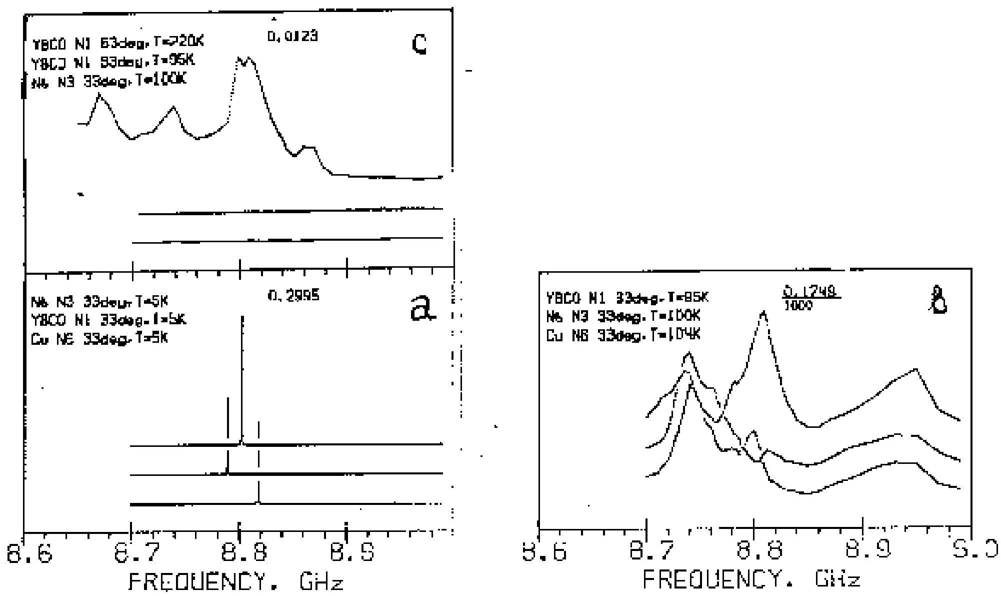

Figure 3. Microwave power transmittivity spectra for the resonator with Cu, Nb or single crystal $YBa_2Cu_3O_7$ samples at temperatures of 5-104 K for the position of samples in a resonator cavity (α = 33°) corresponding to the absence of the dielectric resonance excitation. Spectra are plotted on linear *y*-axis scale. An enlarged y-axis view of low transmittivity spectra at temperatures of 95-104 K is presented in **(b)**. In **(c)** the dielectric resonance spectrum is shown for comparison

2.3. Temperature hysteresis

Excitation conditions of the new resonance exhibit remarkable temperature hysteresis. In course of the first cooling between 300 K and 208 K, intensity of the broad dielectric resonance demonstrates about 10 oscillations with the two-order-of-magnitude amplitude. Upon subsequent heating from temperatures well below T_c, the dielectric resonance transmittivity reveals the highest level without any temperature oscillations. This highest level spectrum, shown in Fig.2c, d, occurs to be metastable until the change of the spatial position of the HTSC sample in a resonator.

3. DISCUSSION AND CONCLUSIONS

There is no way to explain the found new resonance and its nonlinear properties in frames of the metal impedance model. The boundary conditions are not changed and can not give rise to a new spectral feature for different investigated metallic samples. It is more reasonable to assume [1,3] the possibility for electromagnetic waves to penetrate into the volume of HTSC and the occurrence of the new type of resonances. The data show that the observed birefringence is the intrinsic property of the HTSC material resulting from the spatial dispersion and nonlinearity of HTSC electric properties due to the metal-insulator-type instability.

REFERENCES

1. E.M. Golyamina, V.A. Dravin, B.G. Zhurkin, A.L. Karuzskii, A.N. Lykov, and V.N. Murzin, Kratk.Soobsh.Fizike FIAN, Nos.1-2 (1993) 14 [Bulletin of the Lebedev Phys.Inst., No.1 (1993) 10); *ibid.*, Nos.5-6 (1993) 17 [No.5 (1993) 13]; Physica C 235-240 (1994) 2072.
2. G. G. Kacharava, Yu.F. El'tsev, V.R. Karasik, E.Yu. Dovidenko and G.A. Tsintsadze, Supercond. Sci. Technol. 4 (1991) 707.
3. A.L. Karuzskii, V.I. Kovalenko, A.E. Krapivka, Preprint FIAN №215, Moscow 1988.
4. D.A. Bonn, P. Dosanjh, R. Liang, and W.N. Hardy, Phys.Rev.Lett. 68 (1992) 2390.