Complex conductivity of YBa2Cu3O7 single crystals at radiowave frequencies

Andrei Pimenov, Alois Loidl

Angaben zur Veröffentlichung / Publication details:

Pimenov, Andrei, and Alois Loidl. 1994. "Complex conductivity of YBa2Cu3O7 single crystals at radiowave frequencies." *Physica C: Superconductivity* 235-240 (Part 3): 1831–32. https://doi.org/10.1016/0921-4534(94)92137-7.

Complex conductivity of $YBa_2Cu_3O_7$ single crystals at radiowave frequencies.

A.Pimenov and A.Loidl

Institut für Festkörperphysik, TH Darmstadt, 64289 Darmstadt, Germany

The complex (surface) impedance of superconducting $YBa_2Cu_3O_{7-d}$ single crystals have been measured as function of temperature in the vicinity of superconducting phase transition. A technique using a resonance circuit at frequencies 200 MHz and 1 GHz was utilized. The penetration depth $\lambda(T)$ and the complex conductivity $\sigma^*(T)$ can be evaluated from these measurements. The temperature dependence of the penetration depth is well described by the Gorter-Casimir two-fluid model, yielding the surface reactance X(0) at 0K. The complex conductivity is compared with the predictions of the BCS theory. While the imaginary part can well be described using a dirty parameter $\xi_0/\ell \sim 0.1$, the real part of the conductivity does not follow the BCS predictions (even with the addition of the distribution of transition temperatures T_c's).

The single crystals of $YBa_2Cu_3O_{7-\delta}$ 1x1x0.02 mm^3 in size were synthesized by the method of spontaneous crystallization from nonstoichiometric melt [1]. The samples were then annealed in Ar gas to obtain a different values of δ in the range 0÷0.5. A helicon resonator was used for measurements of surface impedance. The sample was placed at the point of the maximal AC magnetic field with the field perpendicular to the sample plane. The field strength is estimated to be $H \leq 1$ Oe. Resonance frequency and bandwidth of the helix were measured as function of temperature with and without sample. The sample caused changes in these values are proportional to the surface reactance and resistance respectively thus allowing to measure values R/R_N ; X/R_N.

We observe quite sharp and uniform phase transition only for samples with T_c in the vicinity of 90K (δ<0.3). The samples with T_c < 90K (δ>0.3) show smoothed phase transition or even a series of phase transitions.

The surface resistance data are given at Fig.1. One can clearly see the δ - dependence of the data (insert): the sharpest resistance step is observed at $\delta \sim 0$, then the surface resistance approximately linear increase as a function of δ.

Surface reactance data are presented at Fig.2. In this case we see no direct dependence between X and δ, but we want to point out, that the linear dependence within the two-fluid model can be observed only for small δ (namely samples with $\delta \leq 0.2$), allowing to calculate in the two-fluid approximation the value of X(0).

Our next step is to compare these data with the BCS theory. The result of such a

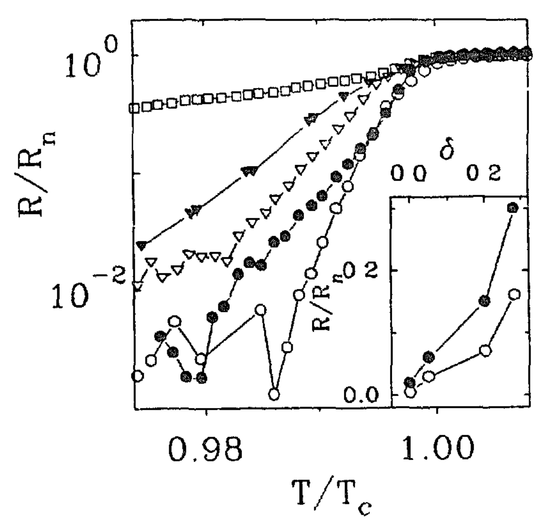

Figure 1. Surface resistance of $YBa_2Cu_3O_{7-\delta}$ at 1.1GHz as function of temperature Symbols correspond to the following values of δ. ○ - 0.0; ● - 0.05; ▿ - 0.2; ▾,□ - 0 28 (two different samples).
Insert shows the corresponding dependence of surface resistance upon δ at temperatures T/T_c=: ○ - 0.987; ● - 0 990.

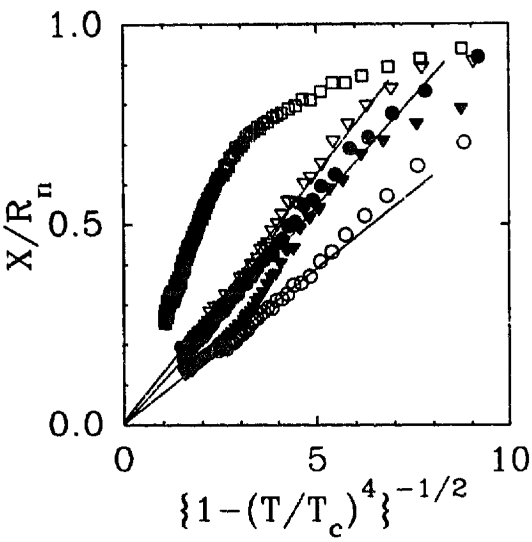

Figure 2. Surface reactance of $YBa_2Cu_3O_{7-\delta}$ at 1.1GHz in the two-fluid model representation. Symbols notation is the same as at Fig.1. Strait lines indicate the expected behavior according to the model without nonzero frequency corrections.

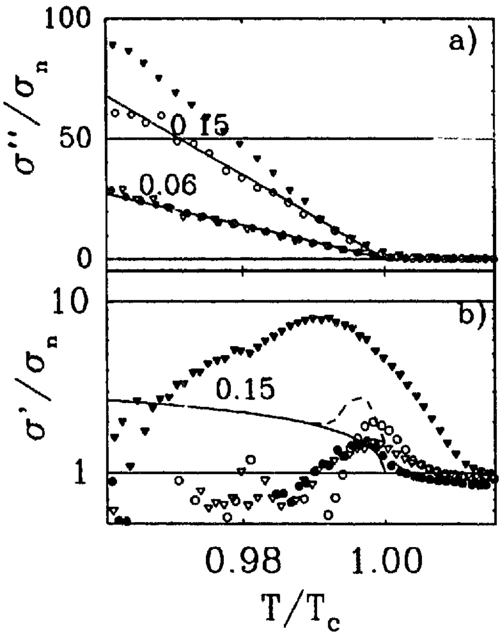

Figure 3a,b. The complex conductivity of $YBa_2Cu_3O_{7-\delta}$ as function of temperature: bottom - real, top - imaginary part. Symbols notation is the same as at Fig.1. The full lines show BCS theoretical predictions with the parameters values: ω=1.1GHz, T_c=92K and dirty parameters $\pi\xi_0/2\ell$ are indicated near lines. The broken line represents the effect of the addition of the 0.25K distribution of T_c's.

comparison is shown at Fig.3. The imaginary part of conductivity could be good described by theoretical curve. One see, that in this temperature range $T \sim T_c$ the theoretical and experimental curves are linear, because according to BCS:

$$\sigma'' \sim \pi\Delta/kT_c \cdot \tanh(\pi\Delta/2kT) \sim \Delta^2 \sim 1-T/T_c.$$

The situation with the real part of conductivity is more complicated. σ' shows a peak in the vicinity of T_c, which could not be described with the BCS-theory: the theoretical curve is always higher, then the experimental one, except the region very near T_c. In this narrow temperature region it is, in principle, possible to describe the conductivity data with the theory if we use the distribution of transition temperatures T_c. In the example of Fig.3b we have used the Gaussian T_c distribution with the width ΔT=0.25K.

In conclusions, we observe an approximate linear dependence of the surface resistance from oxygen content δ in the samples. The smallest R values are that corresponding to δ=0. A possible explanation of this effect is the growing nonuniformity of crystals with growing δ. For small values of δ the surface reactance X is to be described with the two-fluid model and a values of X(0) are determined. Complex conductivity is evaluated and compared with the predictions of BCS theory. While the imaginary part can well be described using a dirty parameter $\xi_0/\ell \sim 0.1$, the real part of the conductivity shows a sharp peak near T_c, which does not follow the BCS predictions even with the addition of the distribution of transition temperatures T_c's.

REFERENCES

1 A.B.Bykov, L.N.Demianets, I.P.Zibrov, G.V.Kalinnikov, O.K.Melnikov, S.M.Stichov, J.Cryst.Growth 91, 302, 1988.