OPEN ACCESS
OPUS AUGSBURG

Universität Augsburg
Universitätsbibliothek

High frequency resistivity in YBa2Cu3O7-δ (δ≈O) thin films

Peter Lunkenheimer, Alois Loidl, C. Tomé-Rosa, H. Adrian

Angaben zur Veröffentlichung / Publication details:

Lunkenheimer, Peter, Alois Loidl, C. Tomé-Rosa, and H. Adrian. 1991. “High frequency resistivity in YBa2Cu3O7-δ (δ≈O) thin films.” In *Supraleitung und Tieftemperaturtechnik: zum Statusseminar 25.-27. Februar 1991; Berichte zu F-&-E-Projekten aus dem Förderbereich Physikalische Technologien des Bundesministers für Forschung und Technologie*, 88–91. Düsseldorf: VDI-Verlag.

Nutzungsbedingungen / Terms of use: **licgercopyright**

Dieses Dokument wird unter folgenden Bedingungen zur Verfügung gestellt: / This document is made available under these conditions:
Deutsches Urheberrecht
Weitere Informationen finden Sie unter: / For more information see:
https://www.uni-augsburg.de/de/organisation/bibliothek/publizieren-zitieren-archivieren/publiz/

High Frequency Resistivity in $YBa_2Cu_3O_{7-\delta}$ ($\delta \approx 0$) Thin Films

P. Lunkenheimer and A. Loidl, Institut für Physik,
Johannes Gutenberg Universität, 6500 Mainz
C. Tome-Rosa and H. Adrian, Institut für Festkörperphysik,
Technische Hochschule, 6100 Darmstadt

The discovery of high-temperature superconductivity in the cuprates $La_{2-x}Sr_xCuO_4$ and $YBa_2Cu_3O_{7-\delta}$ (2:1:4 and 1:2:3 compounds, respectively) has generated great interest in the electrical transport properties in the superconducting ($x \approx 0.2$; $\delta \approx 0$) and in the semiconducting "parent" compounds ($x \approx 0$; $\delta \approx 1$). The appearance of superconductivity in these electronically highly correlated materials supported speculations that the charge carriers are polarons or bipolarons and that the superconductivity could be of bipolaronic type.[1] And indeed, experimental evidence for polaron hopping has been found in a large number of superconducting cuprates[2] and in semiconducting $Bi_4Sr_3Ca_3Cu_4O_x$[3] (which becomes superconducting when properly annealed). Hopping conduction has also been reported in La_2CuO_4[4] and in $YBa_2Cu_3O_6$.[5] In the present paper we report the frequency dependence of the conductivity in 1:2:3 compounds with $\delta \approx 0$. Measurements of $\sigma(\omega)$ are an ideal tool to identify hopping conduction. At the same time these measurements provide a direct and powerful test of the quality of films and contacts.

Thin films of $YBa_2Cu_3O_7$ were prepared by dc-sputtering on $SrTiO_3$ substrates.[6] Here we report measurements of the a.c.-conductivity for frequencies $10^6 Hz \leq \nu \leq 10^9 Hz$ and for temperatures above the superconducting phase transition temperature. The data were recorded using an HP 4191A impedance analyzer connected to a refrigerator system (CTI Cryogenics) via an air line.[7] From a variety of samples investigated we present here two representative results: sample s123 was characterized by a superconducting transition temperature of T_C=85K and a temperature dependence of the low-frequency conductivity $\rho(T)$ which pointed towards a large residual resistivity. $\rho(T)$ in sample s194 (T_C=87K) was almost "ideal", with a linear temperature dependence extrapolating to zero for T→0K. Fig. 1 shows the conductivity G vs. the logarithm of the measuring frequency f for sample s123 at different temperatures. Using network analysis the frequency dependence of the conductivity can well be described by a leaky capacitor ($R_2 \| C$) in series with an ohmic resistor (R_1) and an inductance (L). The leaky capacitor can be assigned to grain boundaries and/or complex contacts which behave like metal-to-semiconductor junctions in the normal-conducting state. The sample resistance R_1 can only be fitted including an a.c. conduction term $A*\omega^s$ which indicates hopping conductivity for s<1.

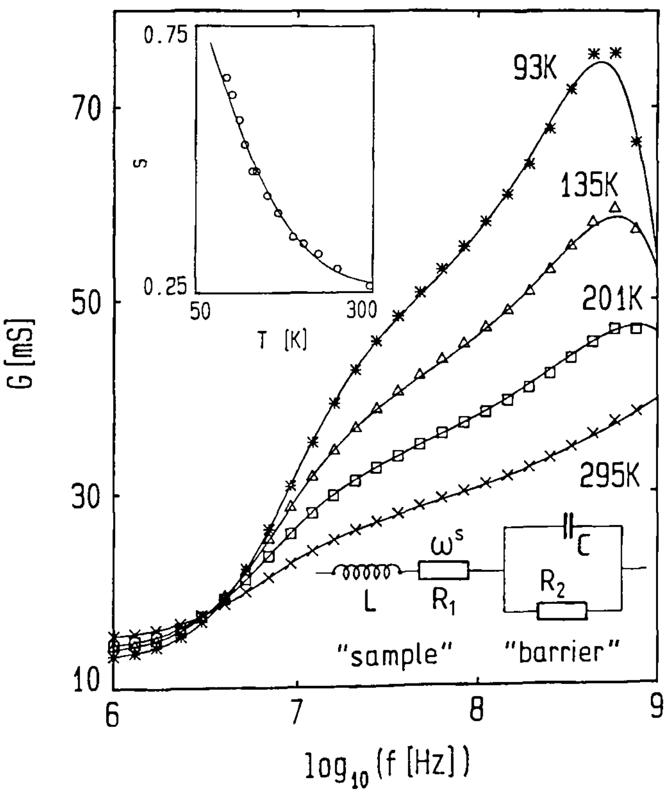

Fig.1: Conductivity G vs. the logarithm of the measuring frequency [$\log_{10}$(f)] at different temperatures. The solid lines are calculated using the equivalent circuit indicated. The inset shows the temperature dependence of the frequency exponent s. The solid line was calculated using a model of overlapping large polarons.

In Fig. 1 the first increase of $G(\omega)$ at approximately 10MHz is due to the barrier, the increase at 100MHz due to hopping conduction. The temperature dependence of the frequency exponent s is shown as inset in Fig. 1. The solid line represents results of a fit using a model of carrier transport via large overlapping polarons.[8]

As can be seen from Fig. 2, sample s194 behaves totally different. The results can be described using an ohmic resistor and an inductance in parallel with a second ohmic resistor R_2. At low frequencies the conductivity is determined by $G=1/R_1+1/R_2$. At high frequencies $G=1/R_2$,

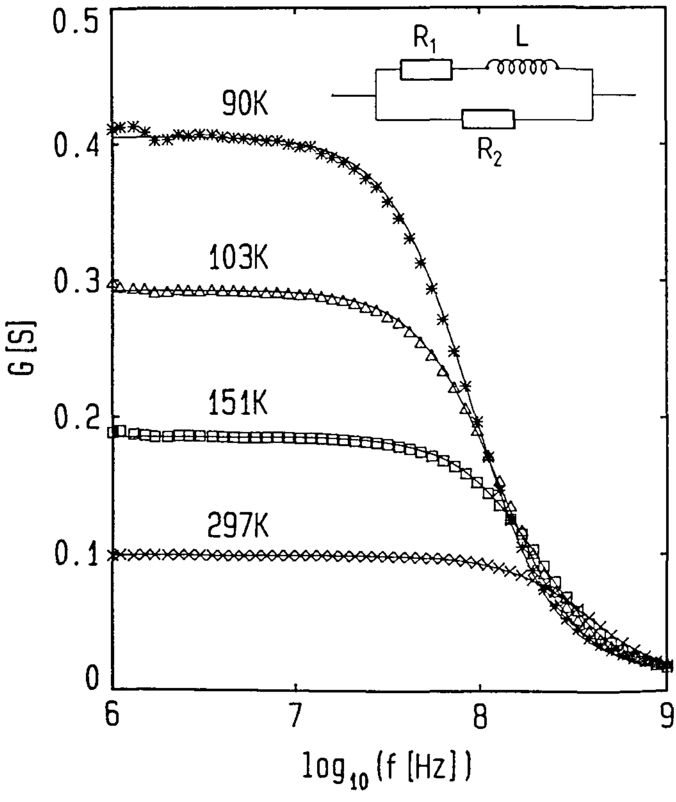

Fig. 2: G vs. $\log_{10}(f)$ at different temperatures. The solid lines are calculated using the equivalent circuit indicated.

where R_2 is almost one order of magnitude larger than R_1. This frequency dependence of G indicates pure metallic behavior, with no signs of hopping conduction and no signs of barriers. However, the fitted circuit diagram provides direct evidence that two paths lead independently through the thin film, both of which percolate.

The interpretation of these results is straightforward: Sample s123 reveals signs of polaron hopping at high frequencies. At frequencies f<1MHz the conductivity is dominated by the leakage of the barrier (R_2 in Fig.1), which originates from grain boundaries and metal-to-semiconductor contacts. Sample s194 behaves metallic for f<1GHz. For the semiconducting 1:2:3 compounds with $\delta \approx 1$, pure hopping conduction has been reported.[5] Thus, the polaron transport in s123 is the remainder of semiconducting behavior, which has totally vanished in s194. Here G(T,ω) can be described by pure metallic conductivity. From these results we conclude that polaron transport is not an important feature in high-quality samples of the doped cuprates.

References:

[1] P. Prelovsek, T. M. Rice, and F. C. Zhang, J. Phys. C: Solid State Phys. 20, L229, 1987
F. C. Zhang and T. M. Rice, Phys. Rev. B37, 3759, 1988

[2] D. Mihailovic, C. M. Foster, K. Voss, and A. J. Heeger Phys. Rev. B42, 7989, 1990

[3] K. K. Som and B. K. Chaudhuri, Phys. Rev. B41, 1581, 1990
A. Gosh and D. Chakravorty, J. Phys Cond. Matt. 2, 649, 1990

[4] C. Y. Chen, N. W. Preyer, P. J. Picone, M. A. Kastner, H. P. Jenssen, D. R. Gabbe, A. Cassanho, and R. J. Birgeneau Phys. Rev. Lett. 63, 2307, 1990

[5] G. A. Samara, W. F. Hammetter, and E. L. Venturini Phys. Rev. B41, 8974, 1990

[6] C. Tome-Rosa, A. Walkenhorst, M. Maul, G. Jakob, H. Adrian, K. Haberle, P. Przyslupski, and G. Adrian, Physica B 165&166, 1477, 1990

[7] R. Böhmer, M. Maglione, P. Lunkenheimer, and A. Loidl J. Appl. Phys. 65, 901, 1989

[8] A. R. Long, Adv. Phys. 31, 553, 1982