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Optical Response of CuO_2-plane and CuO-chain in YBaCuO

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Abstract

We have measured the polarized reflectivity of $YBa_2Cu_{3.5}O_{7.5}$ with $\vec{E}$ parallel to the **a** - and **b** axes. With a model of shunted conduction channels, we could evaluate the optical conductivity of the CuO_2-plane and the CuO-chain, respectively.

Introduction

The well studied $YBa_2Cu_3O_7$ (123) superconductor has the disadvantage to be twinned. Thus, the socalled "ab-plane" response is rather an average of the CuO_2-plane and the CuO-chain (along the b-axis) properties. Untwinned $YBa_2Cu_{3.5}O_{7.5}$ provides the opportunity to measure the polarized reflectivity along the **a**-direction i. e. the genuine reflectivity of the 2D CuO_2-plane.

Results

Fig.1 shows the reflectivity of a $T_c = 70$ K sample at 300 and 4.2 K. The light was polarized along the **a** - and **b** axes. A large anisotropy exists in the IR spectral range, coming from the additional response of the chains. The anisotropy exists down to zero frequency i. e. the chains contribute to σ_{DC} [1]. Below T_c, an additional plasma edge has developed around 20 meV.

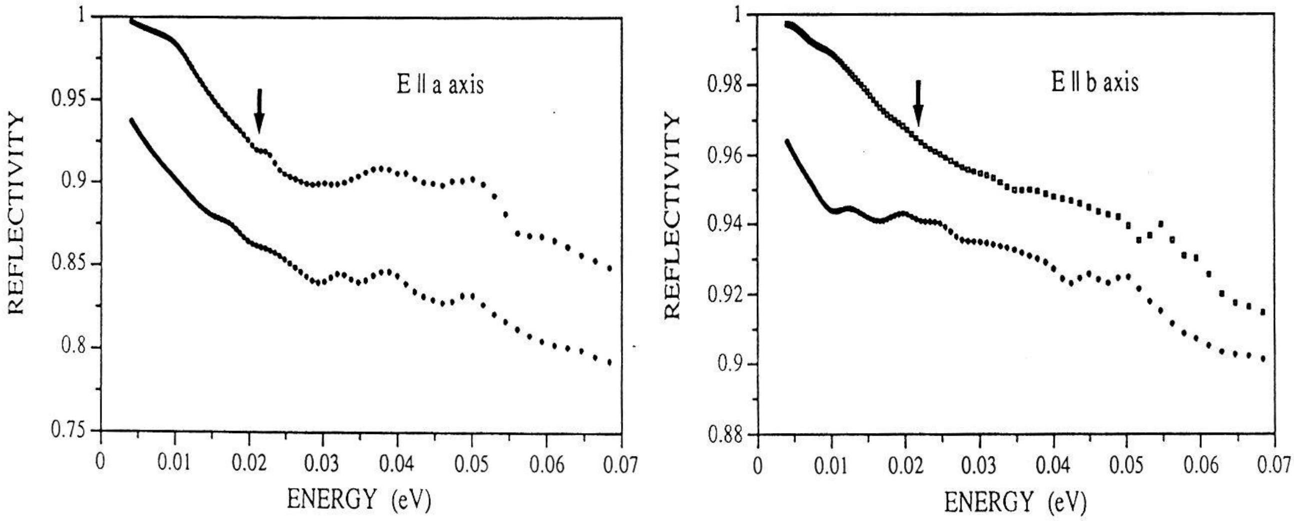

Figure 1: Near normal reflectivity of $YBa_2Cu_{3.5}O_{7.5}$ at 300 K (lower curves) and 4 K (upper curves) for $\vec{E}$ || **a** (left panel) and $\vec{E}$ || **b** (right panel) axes, respectively.

On the reflectivities (4 meV - 12 eV), we performed the Kramers-Kronig transformation. The real part of the optical conductivity σ_1 is depicted in fig.2. If we postulate a model of shunted conduction channels for the **b** direction ($\sigma_1^b = \sigma_{1,chain}^b + \sigma_{1,plane}^b$), we can extract the conductivity of the chain alone, assuming $\sigma_{1,plane}^b = \sigma_1^a$ (fig.2).

Discussion

The response of the CuO_2 plane $\sigma_1^a(\omega)$ has been analyzed [2], in order to take into account unusal (non-Drude) excitations, with a frequency dependent scattering rate $\Gamma(\omega)$

$$\sigma(\omega) = \frac{ne^2}{m^*} \cdot \frac{1}{\Gamma^*(\omega) - i\omega}$$

with $m^*(\omega)$ a renormalized mass and $\Gamma^*(\omega)$ a renormalized scattering rate (fig.3). An astonishing linearity comes out for the scattering rate $\Gamma^*(\omega)$ which has been thought of as an evidence of a nearly localized Fermi liquid [3].
The steep increase of the reflectivity below T_c around 20 meV (fig.1) can be simulated by a two-fluid model [2], where the superconducting fraction is described by the London model. The poles of the real dielectric constant in the SC state $\epsilon_1^{sup} = \epsilon_1^{normal} - \omega_{ps}^2/\omega^2$ determines right the additional plasma edge with ω_{ps}^2 the plasma frequency of the condensed Bosons (e.g. bipolarons).

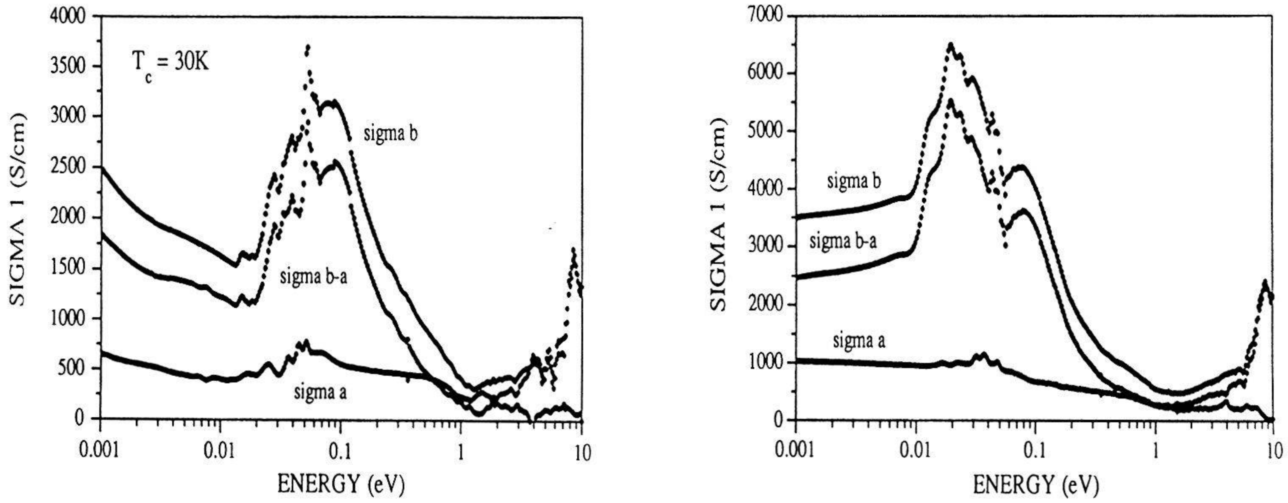

Figure 2: Optical conductivity $\sigma_1^a(\omega)$ and $\sigma_1^b(\omega)$ for the **a** - and **b** direction, respectively, for a T_c =30 K (left) and T_c =70 K (right) sample. Also shown is the response of the chain alone.

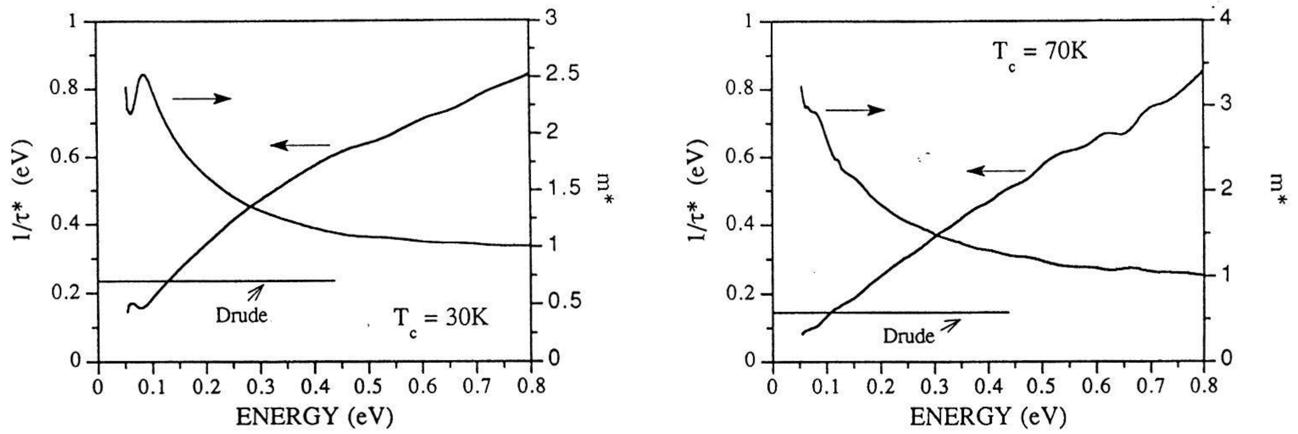

Figure 3: Frequency dependent scattering rate $\Gamma^*(\omega)$ and renormalized mass m^* of the **a**- direction for a T_c =30 K (left) and T_c =70 K (right) sample. Also shown is $1/\tau_{Drude}$ as fitted in Ref. [2].

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