

Effect of Cu-O Planes and Oxygen Content on Optical Properties of BISCO Crystals

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Abstract. We have studied the infrared and optical reflectivity of high quality BISCO crystals at room temperature: three 2201 samples ($n=1$) varying from semiconducting to perfect linear $\rho(T)$ behaviour as a function of oxygen content, and a 2212 superconductor ($n=2$, $T_c=91$ K). We analyze the data in a two-component model (Drude conductivity + midinfrared absorption). We find that the Drude part in the 2201 metallic samples changes in width but its intensity remains constant as oxygen is added; the transition to 2212, on the other hand, increases the plasma frequency considerably. The oscillator strength of the MIR band depends only on the number of Cu-O layers, being twice as large for $n=2$ than for $n=1$. We conclude that oxygen content in the 2201 samples changes the mean free path but not the carrier concentration, while the new Cu-O plane in 2212 acts as a source of carriers for both the Drude and MIR absorption.

1. Introduction

Although a considerable amount of information has been accumulated by now [1], an unambiguous explanation of the optical properties of high T_c materials is still missing. Recently, emphasis has been shifted to systematic investigations to clarify the role of individual "building blocks" of these systems, by polarization [2] or doping [3, 4] studies.

In this paper we compare optical properties of 2201 BISCO crystals with varying oxygen concentration in the Bi-O planes and a 2212 superconducting crystal. This allows us to probe the contribution of the Bi-O planes and that of a second Cu-O plane to the frequency dependent conductivity.

2. Experimental

Our samples were large area ($> 5 \times 5 \text{ mm}^2$) single crystals of the 2201 compound whose conducting properties were changed by annealing in different at-

mospheres from semiconducting to metallic to a metal with very low resistivity (called "supermetal" in the following). Details about preparation, annealing and transport properties are given in Ref. [5]. The 2212 sample was grown from BiO flux [6]. The transition temperature, determined by magnetic susceptibility, was 91 K for this sample.

Reflectivity measurements were performed by a Bruker 113v FTIR spectrometer and a home-made grating spectrometer based on a Perkin-Elmer monochromator. Near-normal incidence spectra were taken at room temperature with unpolarized light. The surface of the crystals is oriented normal to the c-axis, thus we obtain the average ab-plane response this way.

3. Results and discussion

Reflectance spectra of the four crystals are shown in Fig. 1. To illustrate the changes in the spectra caused by chemical modification, we show in Fig. 2. the difference in optical functions upon going from the semiconductor to the metal (Step 1), the metal to the "supermetal" (Step 2), and from the "supermetal" to the superconductor (Step 3). Steps 1 and 2 involve oxygen addition to the Bi-O planes, while Step 3 means introduction of a new CuO_2 plane. The difference curves of optical conductivity and effective number of carriers have been calculated by performing a Kramers-Kronig transformation on the reflectivity data of Fig. 1. and subtracting the respective functions from each other.

Oxygen addition to the Bi-O planes has different consequences in Steps 1 and 2: in the former, the conductivity below 1000 cm^{-1} increases strongly, but the latter only shifts the spectral weight towards lower frequencies (ΔN_{eff} is near zero above 2000 cm^{-1}). A striking increase is caused by Step 3 in both the far and mid-infrared, the shape of $\Delta\sigma$ and the two distinct steps in ΔN_{eff} suggesting a two-component process.

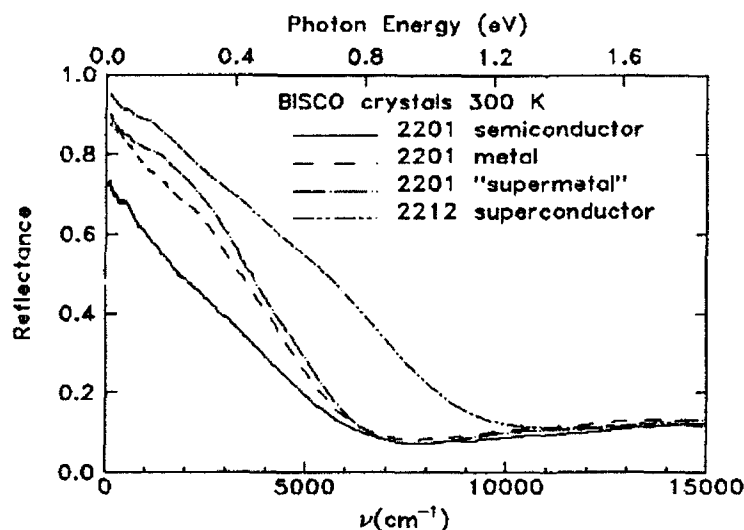


Figure 1: Reflectance spectra of the four crystals

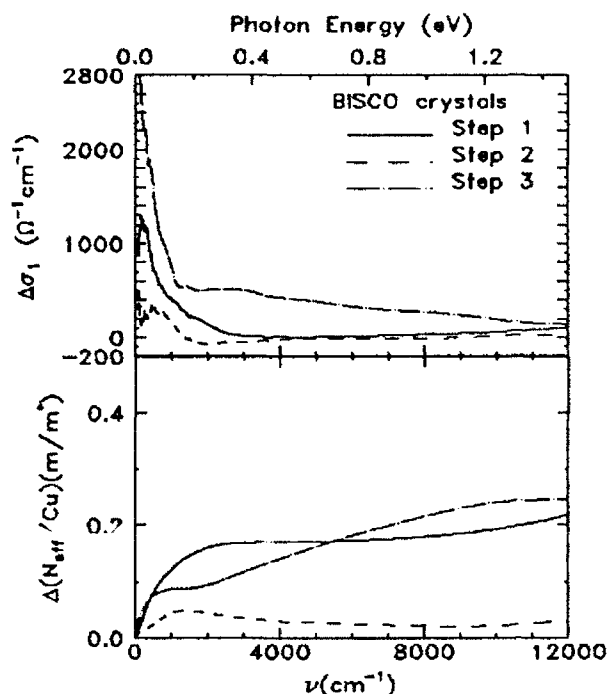


Figure 2: Changes in conductivity (upper panel) and effective number of carriers (lower panel) on chemical modification (see text)

On the basis of the observed changes, we regard Step 1 as addition of free carriers to the CuO_2 planes through increased charge transfer, Step 2 as an ordering process increasing the mean free path but not the concentration of the carriers, and Step 3 as addition of both free and bound carriers. Fits of the reflectivity curves to Drude-Lorentz dielectric functions confirm the above assignments [?].

The strong mid-infrared contribution to $\Delta\sigma$ which appears during Step 3 is of special importance. In $\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$, the midinfrared absorption above 2000 cm^{-1} has been attributed entirely to the CuO chains; in our materials, by analogy, it should correspond to the BiO planes. However, the fact that the intensity in the midinfrared doubles by adding a new CuO plane suggests the absorption up to 1 eV to be an intrinsic property of the conducting planes. It remains to be seen whether the enhancement is simply a consequence of increased transfer of holes from the charge reservoirs or if coupling between adjacent planes is important.

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