Analysis of infrared - visible - near - ultra violet reflectivity of conducting and superconducting oxides

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Abstract

We analyse infrared-visible-near-ultraviolet spectra of oxide materials in the semiconducting or metallic phase. We show that the response of laser-ablated $YBa_2Cu_3O_7$ film can be fitted by a modified Drude term without mid-infrared absorptions. Mid-infrared and visible absorptions are discussed for textured YBaCuO, $BaBiO_3$ and $Pr_2NiO_{4+\delta}$ as well as indication of their polaronic origin.

1. INTRODUCTION

Since the discovery of high-T_c superconductivity by Bednorz and Mullcr [1], an enormous interest in conducting and superconducting oxides has appearcd. Despite the monumental number of works in this field, many points remain still unclear either in the normal state behaviour or in the superconducting one. To better understand the phenomena observed in these materials, we have performed room temperature polarised measurements in various conducting oxide materials for comparison.

2. EXPERIMENTAL

Reflectivity measurements have been performed with a new IFS 307 Bruker spectrometer composed of two complementary interferometers covering the spectral range of 20 to 25000 cm^{-1}. Samples used have been obtained by laser ablation (YBaCuO), crystallisation of molten $BaBiO_3$, floating zone (Pr_2NiO_4) and texturation methods (textured YBaCuO).

3. MODIFIED DRUDE MODELLING

A Drude model cannot account for the conducting behaviour of oxides [2]. Generally, additional mid-infrared bands and/or frequency dependent damping are necessary [3]. Here we propose a very simple extension of a Drude behaviour which introduces different dampings (γ) at plasma (ω_p) and zero frequency yielding at dielectric susceptibility (χ_{pl}).

$$\chi_{pl} = -\varepsilon_{\infty} \frac{\Omega_p^2 + i(\gamma_p - \gamma_0)\omega}{\omega(\omega - i\gamma_0)} \qquad (1)$$

Note that on setting $\gamma_p = \gamma_o$ one arrives at the well known Drude behaviour. We show in Fig. 1 reflection measurements of a laser ablated YBaCuO *ab*-oriented film besides fits obtained from a simple Drude term and a modified one (Eq. 1) Changes of reflectivity introduced by phonons oscillators or mid-infrared bands are negligible because they are screened by the plasmon, so that we can state that the conducting behaviour is expressed by a free charge carrier based model only.

4. MID INFRARED EXCITATIONS

Up to now, we have observed mid-infrared and visible bands in all oxides with a charge carrier concentration lower than 10^{21} cm^{-3}, a threshold above which they are screened by the plasmon. Here we present two examples: $BaBiO_3$ (Fig. 2) has an absorption near 2 eV. This absorption is generally interpreted as a charge disproportionation between Bi sites. Being in a effective +4 site, Bi atoms would sit at these sites in states +3 and +5 creating an energy gap which can originate the absorption [5]. An alternative is to think in terms of a dynamic interchange of the valence of the Bi atom.

Pr_2NiO_{4+x} shown in Fig. 3. presents only phonons when x = 0. Both Drude-likc profile and mid-infrared bands appear when the compound becomes conducting with oxygen excess ($\delta \neq 0$). The plasma frequency increases upon heating and starts screening both phonons and mid-infrared band. No change is observed for the polarisation parallel to the *c* axis, with only phonons in all cases. Electronic properties are thus clearly found bi-dimensional with, for the conducting *ab*-planes simultaneous appearance of two excitations. One is a Drude like component. The other (at 5000 cm^{-1}) might be a polaronic signature.

Finally, a similar effect can be observed in textured YBaCuO sample with an oxygen concentration of about 6.5. Its reflectivity spectra are shown in Fig. 4. In this case we do observe a mid-infrared band in the conducting *ab*-plane but such an absorption is not so evident along the almost insulator *c*-axis [6]. Once again we observe that this extra absorption (near 4000 cm^{-1}) in the *ab*-plane is associated with the presence of free charge carriers introduced by oxygen stoichiometry, This means that possibly this absorption is also polaronic in YBaCuO.

5 CONCLUSION

We have shown that the infrared-visible-near UV conductivity of oxides with highest charge carrier concentration can be explained in terms of a modified Drude model alone with no need for additional mid-infrared bands. Nevertheless, these mid-infrared bands do exist in the conducting plane of 2D systems, for moderated electronic concentrations, and they may have a polaronic origin.

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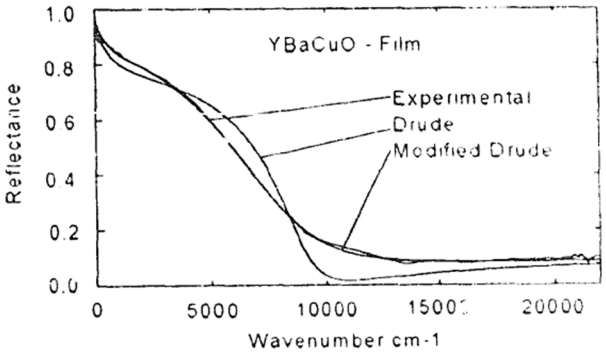

Fig. 1: Room temperature YBaCuO reflectivity and fits by Drude and modified Drude models

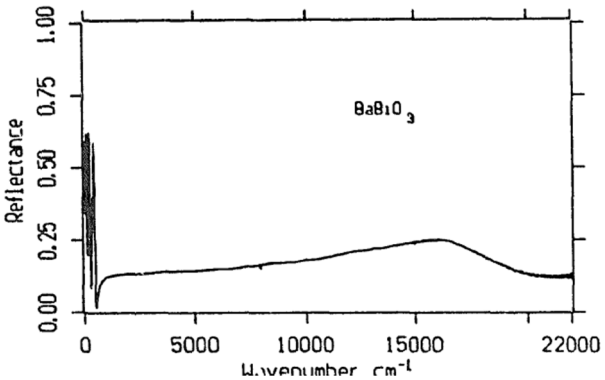

Fig. 2: Visible absorption in $BaBiO_3$

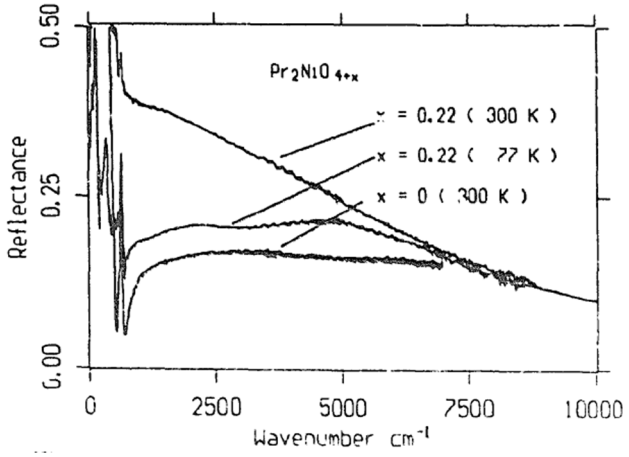

Fig. 3: reflectivity of conducting and insulator Pr_2NiO_4 in the *ab*-plane only

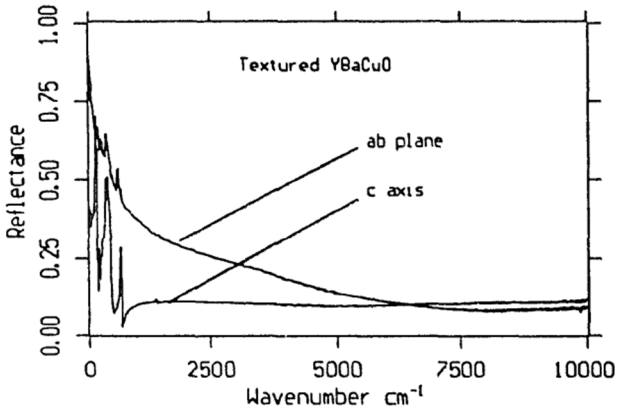

Fig. 4: Reflection in textured oriented YBaCuO