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STRENGTH OF INFRARED PHONONS IN R $Ba_2Cu_3O_{7-x}$ CERAMIC SUPERCONDUCTORS

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The infrared reflectance spectra for mixed rare earths and lanthanides ceramic superconductors were measured in the normal state at ambient temperature. The dielectric response function obtained by Kramer-Kronig analysis of the reflectance data is analyzed using a four component dielectric response model. The Drude parameter results show that the oscillator strength of the phonon modes reduced as Yittrium is partially replaced by Europium and Gadolinium. The infrared d.c. conductivity calculated from the oscillator model fit and from K-K analysis, disagree with the four probe d.c. conductivity. The critical temperature of R $Ba_2Cu_3O_{7-x}$ superconductors reduces systematically on partial substitution of Yittrium by lanthanides.

1. INTRODUCTION

The infrared optical properties as well as transport properties of ceramic material are complex, it is because of their rough and granular surface, and also because of being isotropic in nature. Due to these complexities a normal state data cannot fit with a simple Drude model alone. Tanner et al [1] have used the following relation to overcome the complexities of the matetial.

$$\epsilon(\omega) = \frac{\omega_{pD}^2}{\omega^2 + i\omega/\tau} + \frac{\omega_{pe}^2}{\omega_e^2 - \omega^2 - i\omega\gamma_e} + \sum_{j=1,N} \frac{S_j \omega_j^2}{\omega_j^2 - \omega^2 - i\omega\gamma_j} + \epsilon_\infty \quad \ldots \quad \ldots. \quad \ldots.(1)$$

In the above dielectric response function equation there are four contributions. Firstly the Drude part which is characterised by a plasma frequency ω_{pD} and a relaxation rate $1/\tau$. Secondly the mid infrared, having a strength ω_{Pe}, a center frequency ω_e and a width γ_e. Thirdly the contribution from the infrared active phonons represented by N ocillators, and finally the high frequency part which includes the high frequency dielectric constant (ε_∞).

2. EXPERIMENTAL

We have prepared R $Ba_2Cu_3O_{7-x}$ (where R = Y_1, $Y_{0.5}Eu_{0.5}$ and $Y_{0.5}Gd_{0.5}$), - ceramic superconductors from research grade Y_2O_3, Gd_2O_3, Eu_2O_3, $BaCO_3$ and CuO, powder materials. The four probe technique was used to measure the temperature dependent resistivity and ultimate T_c of these materials, the results obtained are listed in Table II.

Reflectivity at near normal incidence for all the samples was recorded at ambient temperature in the range of 100-4500 cm^{-1} using IFS Brucker interferometer at University of Florida and the range of 4000 to 25000 cm^{-1} was measured with Cary 2300 spectrometer at Bahrain University.

3. RESULTS AND DISCUSSION

The frequency dependent conductivity and dielectric response function were determined by Kramer-Kronig (K-K) analysis of the reflectance data and by the least square fit to the oscillator model. The approximate center frequencies of the phonon modes can be obtained directly from the maxima of the reflectance spectra Fig.1 or by the maxima observed in the real part of the frequency dependent conductivity Fig.2.

To extract precise values of the center frequency and oscillator strengths of the phonon modes, we used equation(1) to obtain the complex dielectric response function, which was then used to obtain the optical conductivity $\sigma_1(\omega)$ as ;

$$\sigma_1(\omega) = \frac{\omega}{4\pi} \mathrm{Im}[\epsilon(\omega)] \quad \ldots \quad \ldots \quad \ldots(2)$$

a non linear least square fit program was also used to fit the data of equation (2). The values of various parameters, such as Drude plasma frequency ω_{pD}, oscillator strength S, center frequency ω_e, relaxation rate $1/\tau$., and other parameters used in the fitting routine are listed in Table.I and Table.II.

The purpose of fitting the data is manyfold. Firstly to extract the precise values of the infrared phonons in the reflectance and conductivity spectra. This is because the real values are shifted slightly by line shape effects associated with the dielectric response. Secondly to study the effect of partial substitution of Y by heavy lanthanides such as Eu and Gd on the mode strength and the damping of the phonon modes. The center frequencies for the infrared active phonon listed in Table 1 are in agreement with the earlier reports on similar materials [2-3]. The mode assignments for most of the phonon modes are referenced earlier [3].

Table-I-
Parameter used to fit phonon peaks in the frequency dependent conductivity of the ceramic superconductors with Lorentzian lineshape

$YBa_2Cu_3O_7$ cm^{-1}				$Y_{.5}Eu_{.5}Ba_2Cu_3O_7$ cm^{-1}				$Y_{.5}Gd_{.5}Ba_2Cu_3O_7$ cm^{-1}			
ω_p	ω_e	γ	S	ω_p	ω_e	γ	S	ω_p	ω_e	γ	S
375	150	12	6.25	245	153	12	2.56	225	153	15	2.19
100	189	7	0.28	40	180	10	0.05	50	181	9	0.07
200	279	11	0.31	185	285	22	0.42	160	280	22	0.32
180	308	15	0.34	160	310	20	0.26	150	310	40	0.23
				210	415	24	0.25	100	415	15	0.05
50	566	8	0.008	180	567	20	0.01	100	567	18	0.03
60	618	15	0.01	60	618	17	0.01	60	618	15	0.001

From Fig.1 and 2 and the results listed in Table.1, we see that the R translational mode i.e. Y mode appearing at 189 cm^{-1} is shifted to 180 cm^{-1} on partial substitution of Y by Eu and to 181 cm^{-1} on partial substitution by Gd, in R $Ba_2Cu_3O_{7-x}$ compound. This shift is in accordance with the average reduced mass of the mixture. From Fig.1 and 2 we also observe extra mode appearing in both YEu and YGd compound at 415 cm^{-1}. A similar mode is observed in Eu $Ba_2Cu_3O_7$ and Gd $Ba_2Cu_3O_7$ compound at slightly higher frequency [4]. Following the assignment of [4], the peak at

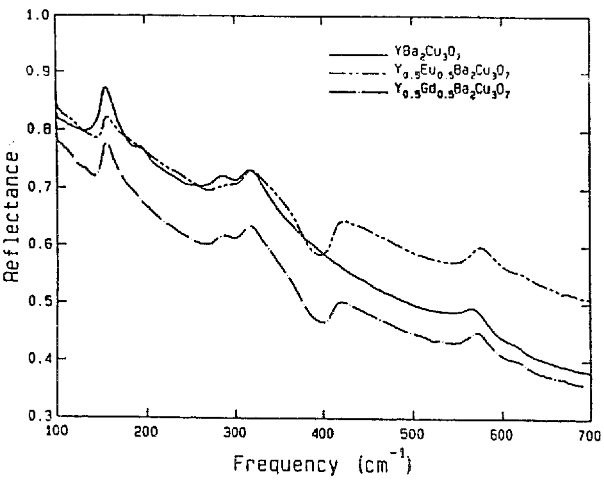

FIGURE 1. Infrared reflectance spectra

Table-II-
Drude Parameters and d.c. conductivity results

Parameters	$YBa_2Cu_3O_7$	$Y_{.5}Eu_{.5}Ba_2Cu_3O_7$	$Y_{.5}Gd_{.5}Ba_2Cu_3O_7$	Units
Drude ω_{oD}	3675	3000	2500	cm^{-1}
$1/\tau$	500	428	694	cm^{-1}
σ_{IR}	450	370	150	$(\Omega cm)^{-1}$
σ_{dc}	3330	1666.6	12 50	$(\Omega cm)^{-1}$
T_c	92.6	78	75.51	K

415 cm^{-1} could be attributed to Cu(1)-O(1) in plane bond. The oscillator strengths of most of the phonons in Y compound are higher than those of YEu and YGd compounds as

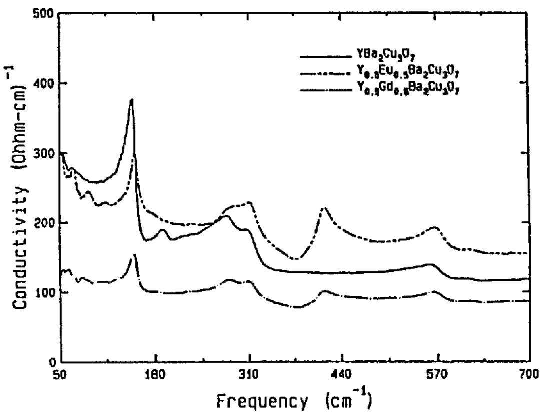

FIGURE 2. Infrared conductivity spectra

listed in Table.I. The value of infrared σ_{dc} as obtained by the K-K analysis and least square model fit, disagree with the d.c. conductivity measured by the four probe technique. The results are listed in Table. II. We think that this disagreement between the two results is due to the fact that the infrared reflectance measurements provide the surface properties of the material, whereas the d.c. measurements record the bulk resistivity and conductivity of the materials. Also, the infrared conductivity is highly effected by the granular surface of the presented ceramic materials The results in Table.I also show that the damping of all the phonon modes in the mixture of YEu and YGd is higher as compared to that of pure Y compound, this indicates, that the phonon activity in the mix materials is reduced. This observation is further supported by the systematic decrease in T_c of these material. The presence of the extra mode at 415 cm^{-1} in the mix material also indicates that the structure of the mixture is inclined towards the disturbed phase rather than the pure orthorhombic[4].

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