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INFRARED TEMPERATURE DEPENDENT STUDIES OF $Bi_2Sr_2CaCu_2O_8$ GLASS CERAMIC SUPERCONDUCTORS

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We report on the investigation of infrared reflectance spectroscopy on $Bi_2Sr_2CaCu_2O_8$ glass ceramics superconductor in the temperature range 20 K to 300 K and between the frequency of 100 to 20000 cm^{-1}. The frequency dependent conductivity was calculated by Kramer-Kronig transformation of the reflectance spectra. Analysis by Drude and lattice vibration models reveals the Drude plasma frequency and the reflectance edge, closer to those of a single crystal. All the predicted phonon modes are observed in the measured spectra. We did not find any appreciable change in the frequency and oscillator strength of the phonons in the present temperature range.

1. INTRODUCTION

While large number of studies have been performed using Raman spectroscopy of BISCO superconductors infrared measurements are scarce [1]. Studies of $MBa_2Cu_3O_7$ ceramic compounds [2] have shown that a strongly pronounced structure due to infrared active phonons are superimposed to a broad band reflectivity caused by electronic conductivity. The temperature dependent study of these compounds shows either the softening of vibrational features or a sudden increase in the line width is observed while going from the superconducting to the normal state.

2. EXPERIMENTAL PROCEDURE

Staichiometric amounts of Bi_2O_3; $SrCO_3$; $CaCO_3$; and CuO were mixed and calcined at 800°C for 10 h in air. The calcined powders were melted in an alumina crucible at 1250°C for about 25 minutes in an electric furnace. The melt was poured onto a stainless steel plate and pressed quickly to a thickness of about 2 mm.

The melt-quenched samples were heated to 1293K at a heating rate of 8 K min^{-1} and annealed for 230 h in air.

Measurements of T_c were performed using the conventional four-probe technique.

Electrical contacts were made to the sample with conducting silver paste, each sample was cooled to about 20 K and then slowly warmed upto room temperature .

Reflectivtiy at near normal incidence was recorded at various temperatures in the range of 100-20,000 cm^{-1} using two different interferometers .

3. RESULTS AND DISCUSSION

Fig. 1 shows the temperature dependent resistance and a.c. susceptibility of $Bi_2Sr_2CaCu_2O_8$ glass ceramic superconductor. The resistance of the sample starts decreasing as the temperature reduces to 100 K and it falls to zero at 80 K. The a.c. susceptibility measurements performed on the powder sample, shows diamagnetic behaviour below 80 K and the susceptibility remains constant below 80 down to 20 K.

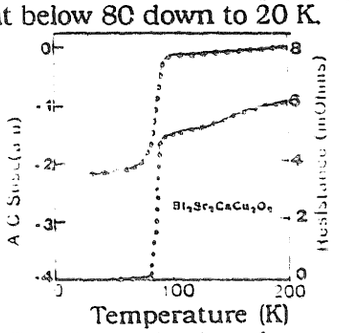

Fig. 1 : Resistance (• o) and susceptibility vs temperature.

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Fig. 2 and Fig. 3 show the reflectance and conductivity spectra at three (300, 100 and 20 K) temperatures for the IR range.

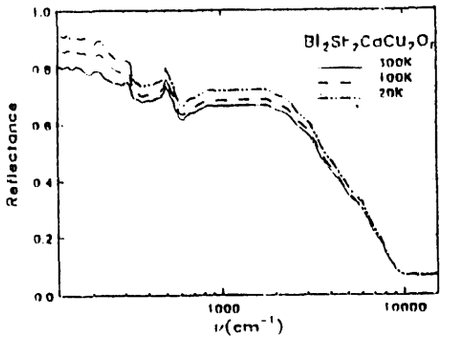

Fig.2 : Infrared Reflectance Spectra at different temperatures.

The normal state data of a superconductor cannot fit with a simple Drude model alone, instead a dielectric function which is sum of a lattice vibration and Drude term must be used i.e.

$$\varepsilon(\omega) = \varepsilon_\infty + \Sigma_{j=1}^{N} \frac{Sj\ \omega_j^2}{\omega_j^2 - \omega^2 - i\omega\,\Gamma j} - \frac{\omega_P^2}{\omega^2 + i\omega/\tau}$$

where the first two terms represent lattice behaviour including sum of oscillators for midinfrared and phonon absorptions with ωj ω_P;and Γj; being the resonant frequency, oscillator strength and width of the jth Lorenz oscillator respectively. The last term is Drude oscillator described by plasma frequency : ω_P and relaxation time τ of the free carriers, ε_∞ is the high frequency limit of ε(ω), it is found from a fit to R(ω). Attempts to analyse the spectra by Drude Lorentz fits to the reflectance using independent oscillators gave frequency and line widths for all modes which are constant below the superconducting state, on the other hand both frequencies and line widths increasing with temperature above T_c. The center frequencies for various peaks at the ambient temperature are: 146, 165, 207, 308 and 505 cm^{-1}. The frequencies of these modes agrees well with the published data [1-3].

Fig. 3 represents conductivity of the sample at three temperatures, phonon modes are more clear in the conductivity spectra, than that of reflectivity spectra.

The reflectance spectra of Fig. 2 can be separated into two regions. Region 1 from 100-600 cm^{-1} includes most of infrared active phonons involving CuO_2 and Bi-O-Cu vibrations and bending modes respectively. Where as region two extending to high frequencies shows a steady drop in reflectivity; and it has plasmone like drop in reflectivity around 1 eV which presumably corresponds to the plasma excitation of the free carrier.

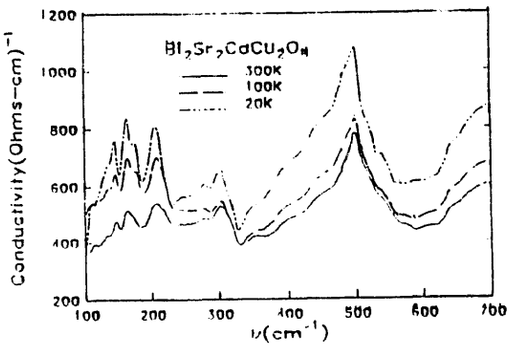

Fig.3 : Infrared conductivity spectra

In summary, we have investigated electrical and optical properties of glass ceramic superconductor $Bi_2Sr_2CaCu_2O_8$. The phonon modes observed in our spectra agrees well with the published work for the single crystals. We observed increase in reflectance below 1000 cm^{-1} when sample is cooled from 300 K to 20 K. This increase is due to an increase in the free carrier scattering time τ, consistent with temperature dependence of the resistivity. We did not observe any major change in the phonon structure, below the critical temperature.

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