Infrared Properties of Single Crystal SrTiO_3 , A Substrate for High Temperature Superconducting Films

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Infrared optical characterization of single crystal SrTiO_3 , an important substrate for high- T_c superconducting films, had been studied by transmission and reflection measurements. We measured absorption spectrum of this crystal, from 50 - 5000 cm^{-1} and 80 - 300 K. This crystal has highly reflectivity behavior in far-infrared (FIR) range. The vibration modes of this crystal are clearly shown temperature dependent behavior. The main absorption dips of FIR reflection measurements are shown in 170, 483 cm^{-1} at 80 K. These dips have 3 cm^{-1} shift at temperature from 300 K down to 80 K. In addition to this main dips, there is another dip appeared at 441 cm^{-1} when the temperature down below 100 K. This feature did not show in previous reports. The vibration modes of this crystal substrate, as well as dielectric behaviors that are important characters for analyzing superconducting films will go further studies. (This works supported by National Science Consul: NSC 84-0208-003-041)

1. INTRODUCTION

Strontium titanate (SrTiO_3) has the features of relatively high dielectric constant, ease of preparation and structural stability.[1] In the last few years, SrTiO_3 has gained additional importance as the most widely used substrate for superconducting perovskite films.[2] It has a lattice constant matched with the oxide ceramic high T_c superconductor $\text{YBa}_2\text{Cu}_3\text{O}_{7-x}$.[3], and it has become an important substrate for HTSC films. In order to model optical process of superconducting films on this substrate, We are interested to know the infrared(IR) behaviors of the substrate and its dielectric function with very high accuracy.

Although the infrared properties of strontium titanate have been investigated over and over in the last three decades. Where the sample quality has also improved in recent years, inspired the high demand, rendering many of the earlier results obsolete. However, there are no comprehensive experimental investigations on SrTiO_3 has been performed in the frequency and temperature range significant for high T_c research. In this paper, we present the detailed temperature dependent infrared optical absorption study of SrTiO_3 single crystals over a temperature range between 80 and 300 K. The phonon behavior of these materials were studied and discussed.

2. EXPERIMENT

Commercial type 5x5x5 mm^3 , 99.95% pure single crystal SrTiO_3 with mirror like surface had been grown in (100) face. Infrared absorption measurements of reflectivity at near normal incident were made on Bruker IFS-120HR(Fig. 1) with a resolution of 2 cm^{-1} ranging from 50 - 5000 cm^{-1} .

Fig. 1 Bruker 120-HR Infrared Spectrometer

Mercury-Arc lamp and hologon lamp were used for far-infrared and mid-infrared light sources. High throughput mylar and calcium fluoride beamsplitter were used in our experiments. Liquid helium cooled bolometer and liquid nitrogen cooled MCT and InSb detectors are used in different IR spectrum regions. The

specimens were mounted on the finger tip type continuous flow APD cryogenics with x-y-z sample stage. A mirror like gold was mounted next by the sample on the cold finger tip of cryogenics. The absolute reflectivity value of samples were done by comparison with the gold mirror. The measurements of samples and gold mirror were made at temperature between 80 to 300 K. The temperature of finger tip inside cryogenics were controlled by Lake-shore 331 temperature controller with a temperature stability of 0.5 K and better.

3. RESULTS AND DISCUSSIONS

Single crystal SrTiO_3 bulk has a dielectric constant as high as $400\epsilon_0$ and 50 times higher at LN_2 temperature.[4] It is an incipient ferroelectric very promising for use to micro size thin superconducting film, owing to its high dielectricity and non-hysteretic polarizability even at low temperatures. The far-infrared data from 80 to 300 K is shown in Fig. 2. The main absorption dip is shown in 170 cm^{-1} at 80 K.

Fig. 2. Infrared reflection measurements of SrTiO_3 from 50 - 450 cm^{-1} at 80 - 300 K

At low temperature, additional features superposed on the absorption curves are observed. The temperature below 100 K has another feature appear in 440 cm^{-1} which did not show in earlier reports. The origin of these features will be discussed in future study. The mid-infrared data also shown in Fig. 3.

As experiment on superconducting samples of films with c axis in the plane or superlattice, etc. are becoming more common.[5] SrTiO_3 has been attractive as an important substrate. Early studies contributed

essentially to the understanding of soft modes in perovskites.[6] Many important features of crystals are caused by lowest frequency phonon modes,

Fig. 3. Infrared reflection measurements of SrTiO_3 from 850 - 4800 cm^{-1} at 80 - 300 K

so-called soft modes, which are strongly dependent on temperature. They are responsible for high values of dielectric permittivity ϵ at low temperature as well.[7] The lattice vibration dynamic properties of these phonon modes, carrier concentration, mobility, effective mass as well as their dielectric behavior of these crystals will go further study.

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