Far Infrared Optical Absorption Study and Characterization of $Y_1Ba_2Cu_3O_{7-\delta}/Pr_{0.5}Y_{0.5}Ba_2Cu_3O_{7-\delta}$ Superlattices

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We report infrared reflection measurements on $Y_1Ba_2Cu_3O_{7-\delta}/Pr_{0.5}Y_{0.5}Ba_2Cu_3O_{7-\delta}$ (60Å/60Å, 16 layers and 60Å/24Å, 16 layers on $SrTiO_3$ (100) substrate) high T_C superconducting superlattice films. We measured absorption spectrum of these films from 30 - 700 cm^{-1} (3.7 - 66.9 meV) and 80 - 300 K. These films showed resistive superconducting transitions with an on set at 80 K. Some of the phonons are smear out because of strong electron-phonon mediation. The appearance of vibration modes are around 547, 361, 279, 172, 150, 125 cm^{-1} at 80 K. Some contribution and interaction between layers were observed from measured spectra. The different configuration of interlayer thickness of these superlattices have 1 - 2 cm^{-1} peaks shift in spectra. The dielectric and electron-phonon behaviors due to interaction of superlattice layers will go further studies.

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1. INTRODUCTION

Scientists pay a lot love of attention to the high T_C superlattices after the first superlattice YBCO/DBCO had been successfully made by Triscone et al.[1] More recently, several groups have reported the superconducting properties of alloys of $Y_1Ba_2Cu_3O_{7-\delta}/Pr_{0.5}Y_{0.5}Ba_2Cu_3O_{7-\delta}$ layered structure superconductors.[2-6] This material has been extensively studied.[7] The coupling and layer number of copper oxide layer in high temperature superconductor has play an important roles for the superconductivity.[8] In this paper we study the dielectric mechanism of these superconducting layers of multilayer high T_C superlattice films.[9-14]

It is interesting to know the infrared (IR) behaviors of these films and its dielectric behavior of different layer configuration. In this article, we report the detailed temperature dependent infrared absorption study of YBCO/PYBCO superlattice over the temperatures between 80 and 300 K. The phonon behavior of these materials were studied and discussed.

2. EXPERIMENT

$Y_1Ba_2Cu_3O_{7-\delta}/Pr_{0.5}Y_{0.5}Ba_2Cu_3O_{7-\delta}$ (YBCO/PYBCO, 60Å/60Å 16 layers and 60Å/24Å 16 layers on (100) $SrTiO_3$ substrate) high T_C superconducting superlattice films were prepared by radio frequency magnetron sputtering (RF sputtering).[15] The configuration of RF sputtering system is shown in Fig. 1. A commercial type 5×5×0.5 mm³, 99.95% pure single crystal $SrTiO_3$ with mirror like surface in (100) face were used as substrate. These film showed resistive superconducting transitions with an on set at 80 K by resistivity vs temperature measurements. These samples also examined by powder X-ray

Fig. 1. The configuration diagram of RF sputtering system for these samples

diffraction, SQUID · Hall measurement. All of these examinations and measurements ensured that these superlattice films have good quality.

Infrared absorption measurements of reflectivity at near normal incident were made on Bruker IFS-120HR with a resolution of 2 cm^{-1} ranging from $30\text{--}700\text{ cm}^{-1}$. Mercury-Arc lamp was used for far-infrared source. High throughput mylar beamsplitter was used in our experiments. The radiation was detected by a Liquid-helium-cooled silicon bolometer (Noise equivalent power = $1.3 \times 10^{-13}\text{ W/Hz}^{0.5}$) with suitable filters. The specimens were mounted on the liquid-nitrogen 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

The infrared reflection measurements on YBCO/PYBCO ($60\text{\AA}/60\text{\AA}$, 16 layers) is shown in Fig.

Fig. 2. Infrared reflection measurements of YBCO/PBCO ($60\text{\AA}/60\text{\AA}$, 16 layers) superlattice

2. The appearance of vibration modes are around 547 , 361 , 279 , 172 , 150 , 125 cm^{-1} at 80 K . Some contribution and interaction between layers were observed from measured spectra. The infrared

reflection measurements on YBCO/PYBCO ($60\text{\AA}/24\text{\AA}$, 16 layers) superlattice films is shown in Fig. 3. Some of the phonons are smear out because of strong electron-phonon mediation. The different configuration of interlayer thickness of these superlattices have $1\text{--}2\text{ cm}^{-1}$ peaks shift in spectra.

Fig. 3. Infrared reflection measurements of YBCO/PBCO ($60\text{\AA}/24\text{\AA}$, 16 layers) superlattice

In normal state, we fit this spectrum with assuming Drude-like free carriers as well as lorentzian phonon oscillators of films dielectric function. In superconducting state, the contribution of conductivity was added to dielectric function. The electron-phonon behaviors due to interaction of superlattice layers, carrier concentration, mobility, effective mass as well as their dielectric behavior of these crystals will go further study.

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