INFRARED STUDY OF YBCO IN HIGH MAGNETIC FIELDS

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Introduction

Far-infrared spectroscopy has been widely applied to investigate the vortex dynamics in high T_c superconductors. Karrai *et al.* [1] measured the transmittance of $YBa_2Cu_3O_{7-\delta}$ thin films, finding an increase in transmittance below ~125 cm-1 with increasing field. In contrast, Liu *et al.* [2] measured $YBa_2Cu_3O_{7-\delta}$ films at various temperatures in magnetic fields up to 30 T. Their data clearly indicates that at low temperatures (below 50 K) there is no significant field dependence to either reflectance or transmittance.

Experimental

We studied superconducting and nonsuperconducting films on several substrates. The substrates used for the superconducting $YBa_2Cu_3O_{7-\delta}$ films were MgO and sapphire, with a CeO buffer layer. The films are about 400 Å in thickness, with T_c around 85-90 K. A non-superconducting $YBa_2Cu_3O_{6+x}$ film on silicon was also studied. The experiment used a Bruker 113v spectrometer and light pipe in conjunction with an 18-Tesla superconducting magnet.

Results and Discussion

The transmittance spectra of the films taken at 4.2 K at different magnetic fields are shown in Fig. 1. We observed practically no influence of the magnetic field on the far-infrared transmittance spectra of any of the films. The noise around 140 and 230 cm-1 is due to poor beam-splitter efficiency at these frequencies. The nonsuperconducting sample (Fig. 1, panel c) also showed no field-dependent absorption. (The oscillations in this sample are due to multiple internal reflections in the Si substrate.) We model the vortex state as a parallel mixture of vortex cores (normal state) surrounded by superconductor. The fractional area of the cores is $H/H_{c2}(T)$ with H_{c2} the upper critical field. The dielectric function of this model is:

$$\varepsilon(\omega) = -\frac{\omega_{ps}^2}{\omega(\omega + i0^+)}\left[1 - \frac{H}{H_{c2}}\right] - \frac{\omega_{ps}^2}{\omega(\omega + i/\tau_s)}\left[\frac{H}{H_{c2}}\right] + \varepsilon_{ir} \qquad (1)$$

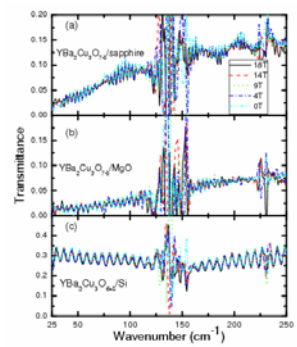

Fig. 1. Field dependent transmittance of YBCO films.

Where ω_{ps} is the superfluid plasma frequency, $1/\tau s$ is the damping constant inside the vortex, and ε_{ir} is the non-superconductor part of the dielectric function. The change in $\sigma(\omega)$ due to a conversion of superfluid to normal fluid is given by $\Delta\sigma(\omega) = \omega_{ps}^2(H/H_{c2})[S(\omega) - i/\omega]/4\pi$. Specifically, $\Delta\sigma(\omega)$ is maximum at zero frequency and decreases rapidly with frequency for $\omega > 1/\tau_s$. In our experiment, the measurements are limited to $\omega > 25$ cm^{-1} and the quasiparticle scattering rate $1/\tau_s$ of our films is very small. Moreover, the change in $\Delta\sigma(\omega)$ is expected to be not big for fields up to our maximum field of 18 T when H_{c2} is about 240 T. Thus, it is possible that any change in the spectra should be relatively small in our far-infrared frequency and magnetic field range.

Conclusions

The transmittances of $YBa_2Cu_3O_{7-\delta}$ films were measured at 4.2 K in high magnetic field up to 18 T. The transmittance spectra did not show significant changes with the magnetic field.

Acknowledgements

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References

1. Karri, K., *et al.*, Physical Review Letters, **69**, 152-155 (1992).
2. Liu, H.L., *et al.*, Solid State Communications, **109**, 7-12 (1999).