Physica C 235-240 (1994) 1155-1156
North-Holland

PHYSICA C

ELECTRON PAIRING BY RAMAN SCATTERING IN THE HIGH Tc SUPERCONDUCTORS

Reuben Shuker and Yacov Biton

Physics Department
Ben-Gurion University of the Negev
Beer-Sheva 84105, ISRAEL

The electronic Raman spectrum spans the region up to a few thousand cm^{-1}. The intensity of the peak of this quadratic continuum as well as the integrated intensity exhibit sharp increase at the critical temperature, exhibiting the formation of the Cooper pairs and the resulting correlation. The Raman intensity continues to increase with decreasing temperature which indicates the continuos increase in the number of Cooper pairs.

1. Introduction

Using the fact that Raman scattering is a correlation function of the single particle density of states we have experimentally probed the correlation of the Cooper pair electrons. We have observed abrupt change in the intensity of Raman scattering of the electronic excitations at Tc which, as we show below is a signature of the correlation. The capability of using Raman scattering technique in exploring the effects of correlation and correlation length was exhibited in the study of disordered and amorphous materials[1]. In that case, the finite or rather the short correlation length gives rise to the breakdown of the **k** = 0 selection rule in Raman scattering and to the display of the phonon density of states of these materials. Indeed, most recently, disorder and weak localization is invoked to account for the broadening of the phonon Raman lines in the high temperature superconductors (HTSC) [2]. However, the Fano broadening of the phonon lines is seems to be a better explanation[3].

2. Electronic Raman

One of the most interesting and general phenomena in physics is that of coherence and the correlation accompanying it. Cooperative emission becomes proportional to N^2 rather than to the number of emitters, N, as in the case of N noncorrelating emitters [4-5]. In particular, for Raman intensity in high temperature superconductors below Tc when Cooper pairs form, this is exhibited by the abrupt increase in the electronic Raman scattering intensity at the superconducting transition temperature. We believe this increase to be the result of the forming of the Cooper pair correlation at the transition of the material into a superconductor. We have observed this effect by studying the Raman intensity of the low frequency electronic excitations vs. temperature across the transition temperature.

3. Experiment

We study the electronic Raman scattering as a function of temperature. Both bulk and thin film samples of $YBa_2Cu_3O_{7-x}$ are studied. The thin films were prepared by laser ablation on sapphire with c orientation. The Tc of these samples is 89.3K and the film thickness 0.3 micron. The resistivity of the film is displayed in Fig. 1. Argon ion laser line at 488 nm is

SSDI 0921-4534(94)01141-9

used for excitation. The intensity is on the order of 30mW.

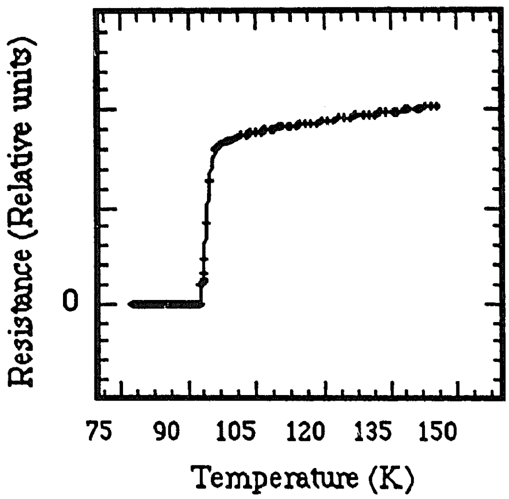

Figure 1. The resistivity dependence on temperature of thin film $YBa_2Cu_3O_{7-x}$.

The samples are cooled in a displex refrigerator capable of cooling to 20K. The electronic single particle excitations manifest themselves in the continuum low frequency Raman spectrum that peaks at several thousands wave numbers of Raman shifts. The spectrum of these excitation is parabolic in frequency [6-8].

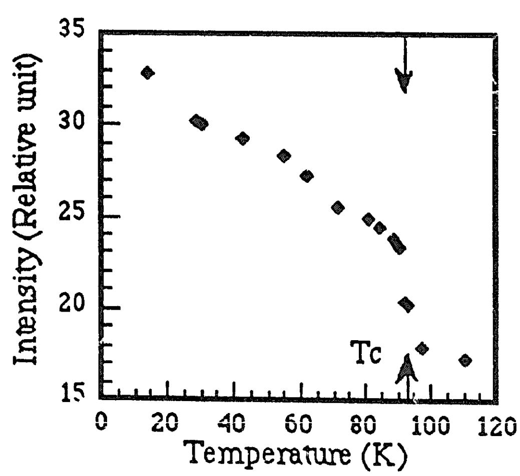

Figure 2. Raman scattering intensity of the electronic excitation of thin film $YBa_2Cu_3O_{7-x}$ superconductors in a-b scattering plane.

A striking feature is revealed: as temperature decreases there is an abrupt increase in the intensity of the electronic Raman scattering. In particular, an abrupt increase is seen at the phase transition temperature, Tc. This is displayed in Fig. 2 for a thin film of $YBa_2Cu_3O_{7-x}$. This change in the Raman intensity vs temperature is obtained for all the HTSC samples studied.

4. Summary

Superconducting phase transition in the HTSC manifest in the electronic Raman spectrum intensity. This intensity exhibits sudden increase at the transition temperature. which coincides exactly with the abrupt increase in the conductivity at the transition temperature. This is the manifestation of electron correlation of the Cooper pairs in the HTSC.

REFERENCES

1. R. Shuker and R. W. Gammon, Phys.Rev. Lett. 25, 222 (1970).
2. O.V. Misochko and E.Ya. Sherman, Physica C 222, 219 (1994).
3. C. Thomsen and M. Cardona, Physica C 206, 137 (1993)
4. M.Ya. Amusia and A.V. Korol', Phys. Lett. A 186, 230 (1994).
5. R. Coisson, Eur. J. Phys.15 29-32 (1994).
6. S. L. Cooper,M. V. Klein,B. G.Pazol, J. P. Rice and D. M. Ginsberg, Phys. Rev. B 37, 5920 (1988).
7. S.S. Jha and M.R. Press, Physica C 185-189,13031 (1991)
.8. V. N. Kostur and G. M. Eliasberg, JETP Lett. 53, 373 (1991).