PRESSURE EFFECT ON THE RESISTIVITY, RESISTIVITY ANISOTROPY AND SUPERCONDUCTING TRANSITION TEMPERATURE IN $Bi_2Sr_2CaCu_2O_8$ AND $YBa_2Cu_3O_7$ SINGLE CRYSTALS

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Abstract

Effects of high pressure on resistivity (ρ) and superconducting transition temperature (T_c) were investigated. Interaction between CuO_2 planes is considered to have an important role on the pressure dependence of T_c. Smaller interplane distance (c) implies a stronger interaction and smaller values of $|d\rho/dP|$, dT_c/dP and $\rho c/\rho ab$.

Pressure dependence of the transition temperature and normal state resistivity are two important parameters for the understanding of high temperature superconductors. When $d\rho/dP$ is known, one can calculate $d\lambda_{tr}/dP$, where λ_{tr} is the transport electron-phonon interaction parameter. The pressure dependence of $d\lambda/dP$ where λ is the standard electron-phonon interaction parameter in the BCS theory is expected to be the same as that of $d\lambda_{tr}/dP$[(1)]. Therefore, if the dependence of λ_{tr} on pressure is known one can derive the pressure dependence of T_c.

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The results of dT_c/dP are shown in the Fig. 1 and 2. From the values of $T_c(P)-T_c(0)$ $\rho ab(P)/\rho ab(0)$ and $\rho_c(P)/\rho_c(0)$ we derived the following T_c/dP results: $dT_c/dP \approx 0.16$ K/kbar $d[\rho ab(P)/\rho ab(0)]/dP = -0.75\%$/kbar and $d[\rho_c(P)/\rho_c(0)]/dP \approx -4.0\%$/kbar for $Bi_2Sr_2CaCu_2O_8$ (2212) monocrystals[2], and $dT_c/dP \approx 0.055$ K/kbar, $d[\rho ab(P)/\rho ab(0)]/dP = -1.0\%$/kbar and $d[\rho_c(P)/\rho_c(0)]/dP \approx -1.35\%$/kbar for $YBa_2Cu_3O_7$ (123) monocrystals.

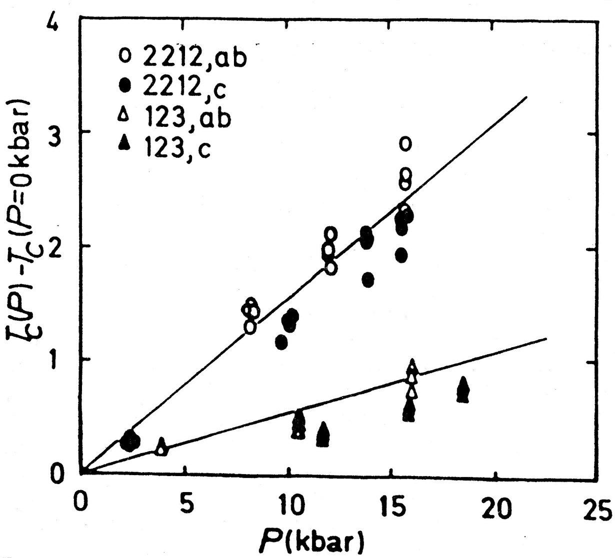

Fig. 1: Pressure dependence of the transition temperature (Tc) deduced from resistivity measurements both in the ab and c crystallographic direction for single crystals of Bi2Sr2CaCu2O8 (2212) and YBa2Cu3O7 (123).

It is difficult to understand the factor of 3 difference in dT_c/dP between 2212 and 123 in the standard BCS theory having similar ρ_{ab} and T_c (~ 150 μΩcm and and ~ 200 μΩcm; T_c = 84K and 91K for 2212 and 123 respectively.) However, they differ considerably in the distance between CuO_2 planes (c-parameters: c(2212) ≈ 12Å, c(123) ≈ 6Å), and in resistivity anisotropy ratio (ρ_c/ρ_{ab} (2212) ≈ 10^4 and ρ_c/ρ_{ab}(123) ≈ 15). Considering the importance of the c parameter, we have tried to understand our results in a special BCS two band model, following the works of Tesanovic[3] and Ihm and Yu[4]. In this model T_c is determined by in-plane and interplane coupling constants. Qualitatively if one lattice is more compressible in the c direction in one case than in the other, the pressure dependence of T_c will be stronger. The c axis compressibility is monitored by $\rho_c(P)$: in 2212 ρ_c changes more with pressure than in 123, hence dT_c/dP is stronger.

The discrepancies of hithero published results[5] can be explained by the c axis sample quality; especially the oxygen content, is important.

To check the model we extended the measurement on a $YBa_2Cu_3O_7$ sample with a lower value of T_c. This lowering was achieved by a reduction of the oxygen content in the sample. This reduction enlarges the c-parameter.

The reduction of T_c to 51 K caused a larger pressure dependence of ρ_c, $d[\rho_c(P)/\rho_c(0)]/dP$ ≈ -2.1% $kbar^{-1}$. This testifies that the lattice is "softer" in the c direction for the T_c = 51 K sample.

Pressure dependence of T_c for T_c = 51 K is also larger, dT_c/dP ≈ 0.37 K/kbar. We can note that the pressure effects of the 123 sample with the reduced value of T_c are closer to the effects in the 2212 sample than in the 123 sample with T_c = 90K. The T_c = 51K 123 sample has also a semiconductor behavior of the ρ_c resistivity, ρ_c ~ exp(-const/T), which is characteristic of the 2212 sample, too.

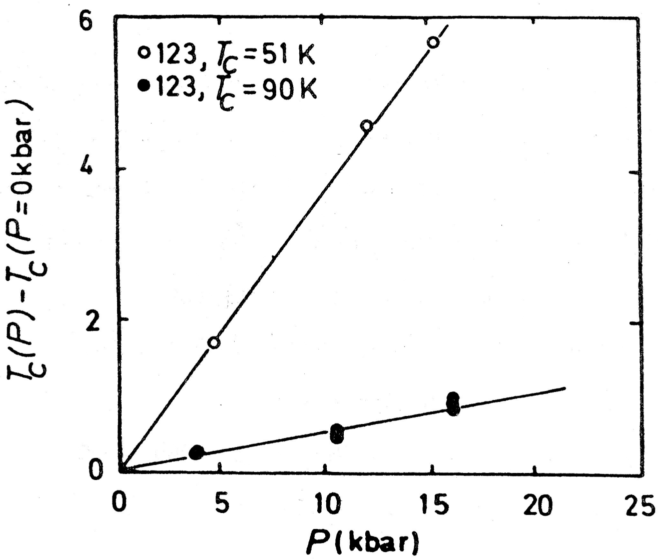

Fig 2: Pressure dependence of the transition temperature for YBa2Cu3O7 single crystal for two different transition temperatures, 51K and 90K deduced from resistivity measurements in the c crystallographic direction.

Conclusion: The effect of pressure on the transition temperature and resistivity depends on c lattice parameter. Larger values of c imply larger values of dT_c/dP and $|d\rho_c/dP|$. dT_c/dP can be explained in a model which takes into account the interplane couplings.

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