

PRESSURE EFFECT ON THE RESISTIVITY, RESISTIVITY ANISOTROPY
AND SUPERCONDUCTING TRANSITION TEMPERATURE
IN $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_8$ AND $\text{YBa}_2\text{Cu}_3\text{O}_7$ SINGLE CRYSTALS

V. Ilakovac¹, L. Forró¹, C. Ayache², J.Y. Henry², and B. Keszei³

1. Institute of Physics of the University, Bijenicka c.46, P.O. Box 304, 41000 Zagreb, Yugoslavia
2. D.R.F., C.E.N.G. BP 85X, 38041 Grenoble Cedex, France
3. Central Research Institute for Physics, H-1525 Budapest, Hungary

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 $|\text{d}\rho/\text{d}P|$, $\text{d}T_c/\text{d}P$ and ρ_c/ρ_{ab} .

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

(received October 25, 1989)

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 $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_8$ (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 $\text{YBa}_2\text{Cu}_3\text{O}_7$ (123) monocrystals.

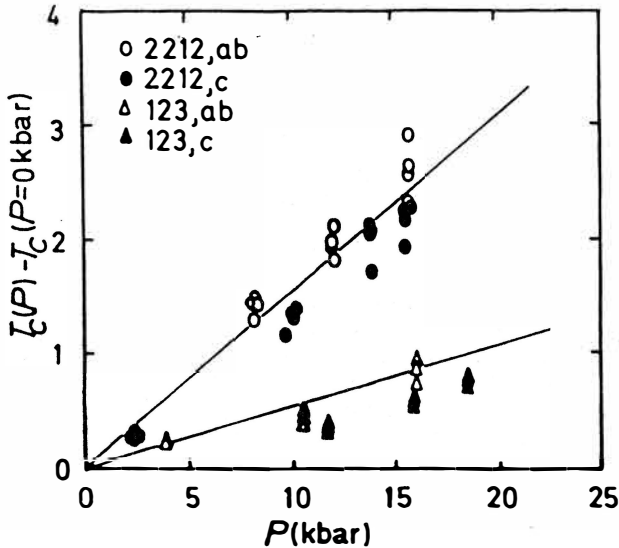


Fig. 1: Pressure dependence of the transition temperature (T_c) deduced from resistivity measurements both in the ab and c crystallographic direction for single crystals of $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_8$ (2212) and $\text{YBa}_2\text{Cu}_3\text{O}_7$ (123).

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 ($\sim 150 \mu\Omega\text{cm}$ and $\sim 200 \mu\Omega\text{cm}$; $T_c = 84\text{K}$ and 91K for 2212 and 123 respectively.) However, they differ considerably in the distance between CuO_2 planes (c -parameters: $c(2212) \approx 12\text{\AA}$, $c(123) \approx 6\text{\AA}$), and in

resistivity anisotropy ratio (ρ_c/ρ_{ab} (2212) $\approx 10^4$ 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 , $d[\rho_c(P)/\rho_c(0)]/dP \approx -2.1\% \text{ kbar}^{-1}$. This testifies that the lattice is "softer" in the c direction for the $T_c = 51 \text{ K}$ sample.

Pressure dependence of T_c for $T_c = 51 \text{ K}$ is also larger, $dT_c/dP \approx 0.37 \text{ K/kbar}$. 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 $T_c = 90\text{K}$. The $T_c = 51\text{K}$ 123 sample has also a semiconductor behavior of the ρ_c resistivity, $\rho_c \sim \exp(-\text{const}/T)$, which is characteristic of the 2212 sample, too.

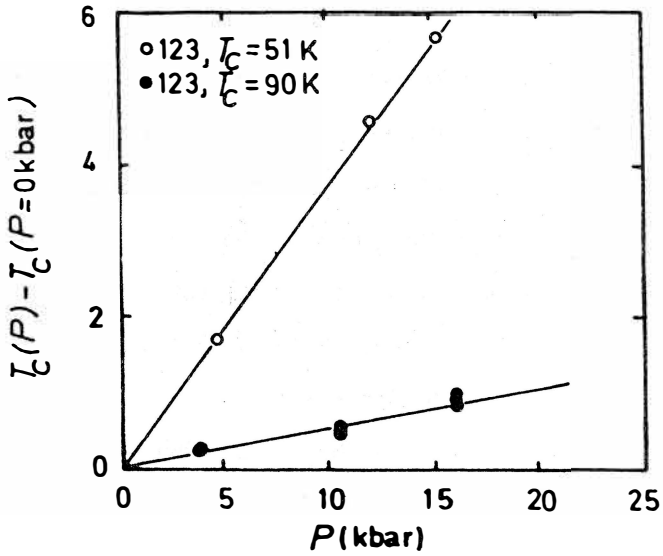


Fig 2: Pressure dependence of the transition temperature for $\text{YBa}_2\text{Cu}_3\text{O}_7$ single crystal for two different transition temperatures, 51K and 90K deduced from resistivity measurements in the c crystallographic direction.

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.

Acknowledgements: We would like to thank the Budapest group for the loan of the pressure chamber, J.R. Cooper for many discussions, and the Foundation for the Scientific Cooperation of the European Community and Yugoslavia and O.T.K.A. for financial support.

- (1) B. Sundquist, *Solid State Commun.*, 66 (1988) 623
- (2) L. Forró, V. Ilakovac, B. Keszei, submitted to *Phys. Rev.*
- (3) Z. Tešanovic, *Phys. Rev. B* 36 (1987) 2364
- (4) J. Ihm and Byung Deok Yu, *Phys. Rev. B* 39 (1989) 4760
- (5) R. Griessen, *Phys. Rev. B* 36 (1987) 5284