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ANISOTROPIC PRESSURE DEPENDENCE OF THE CRITICAL TEMPERATURE OF $REBa_2Cu_3O_{7-\delta}$

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The hydrostatic pressure dependence of the superconducting critical temperature, T_c, was measured in highly crystalline oriented $REBa_2Cu_3O_{7-\delta}$ (RE=Yb, Dy, Y, Gd) thin films grown on different substrates. The anisotropic strain field induced by the substrate and the different crystalline orientations of the films allows the three strain derivatives of the critical temperature to be estimated. A large anisotropy is found in the *ab* plane with T_c increasing on compression parallel to the CuO chains and decreasing on compression perpendicular to them. The results on *c* textured films indicate a non linear relation between T_c and the microscopic parameter which determines its pressure dependence.

The pressure, P, dependence of the critical temperature, T_c, is a direct measure of the relation between structure and superconductivity. For the highly anisotropic high T_c 123 ceramics non hydrostatic P experiments are important for obtaining information on this anisotropic relation. The difficulty imposed on these experiments by the platelet shape of single crystals can be avoided by measuring the hydrostatic pressure dependence of T_c on highly oriented thin films on a substrate. Since the strains in the plane of the film are determined by the elastic constants of the substrate an anisotropic effective stress is induced.

All the measurements reported here were made using a piston-in-cylinder pressure cell with a 25kbar maximum pressure. The transition temperature was defined at 50% of the resistive transition. Transition widths of the films were typically 1K to 1.5K. The $REBa_2Cu_3O_{7-\delta}$ (RE123) films were deposited by DC magnetron sputtering on single crystalline $SrTiO_3$ (STO), MgO and yttria stabilized zirconia (YSZ). All films showed excellent crystalline orientation in θ–2θ X-ray diffraction experiments.

We will first discuss the results on Gd123 films grown on STO. Films of *a* and *c* orientation were grown on (100) STO and of *b* orientation on 18° faceted (100) STO. For the latter the *b* axis grew parallel to the (100) STO direction, 18° out of the substrate normal. For the three cases, T_c depends linearly on P, and the pressure derivatives are $dT_c/dP|_a$=-0.02K/kbar, $dT_c/dP|_b$=0.069K/kbar and $dT_c/dP|_c$=0.10K/kbar, where the subscript refers to the orientation of the film. This indicates high anisotropy in the *ab* plane. Given the experimental linearity of T_c with P, we assume linear relationships between P, the strains, ε, and T_c for the analysis. The 18° misalignment for the *b* oriented film was neglected since; a) although it induces a shear strain in the unit cell, this is estimated to be one order of magnitude smaller than any of the compressive strains; b) it only modifies the results by 10 to 15%. Using reported values for the elastic constants of STO[1] and Y123[2] the strain derivatives estimated from our measurements are $dT_c/d\varepsilon_a$=-362K, $dT_c/d\varepsilon_b$=301K and $dT_c/d\varepsilon_c$ =239K where we define a compression as a positive strain. The *ab* plane anisotropy is rather remarkable, T_c increases on compression parallel to the CuO chains (*b* axis) and decreases on compression perpendicular to them (*a* axis). Compression along the *c* axis affects T_c by the same amount as compression along the CuO chains. From these numbers we estimate the hydrostatic pressure derivative of bulk Gd123 to be

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dT_c/dP_h=0.077K/kbar in good agreement with the reported value of 0.083K/kbar.[3] The uniaxial pressure derivatives are estimated to be dT_c/dP_a=-0.31K/kbar, dT_c/dP_b=0.038K/kbar and dT_c/dP_c=0.34K/kbar.

Figure 1 shows the measured hydrostatic pressure dependence dT_c/dP as a function of the radius of the trivalent ion, R^{3+}, for *c* oriented films grown on STO, MgO and YSZ. The ionic radius was selected as a convenient qualitative parameter since many structural and elastic constants scale with it.[4]

Several features are present in this figure. First there is very good agreement with the data of Voronovskii et al[5] on DC magnetron sputtered Y123 on STO and laser ablated Y123 on MgO. This shows little dependence on the deposition method.

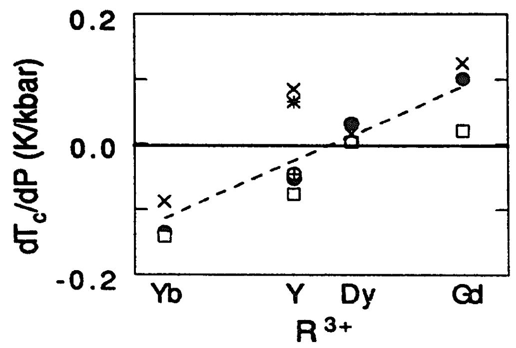

FIGURE 1
Pressure derivative, dT_c/dP, as a function of trivalent ion radius, R^{3+}, for RE123 films grown on STO, ●, MgO, ×, and YSZ, ▢, substrates. The data of Voronovskii et al[5] for Y123 films laser ablated on STO, ⊕, and DC sputtered on MgO, ✻, are included. The dashed line is a guide to the eye.

Second, a remarkable feature is the sign reversal that the derivative shows near the Dy^{3+} radius. This sign reversal evidences a non monotonic behavior of T_c with the parameter that determines its pressure dependence since; a) the strains are expected to vary monotonically with the stress; b) given the scaling of the structure with the trivalent ion radius, the substrate induced strains at P=0 are expected to scale monotonically with it. This is supported by the P dependence of T_c for a Dy123 film grown on MgO shown in Figure 2. Being close to the crossover point we expect for this case a very small slope with a non monotonic behavior, as observed.

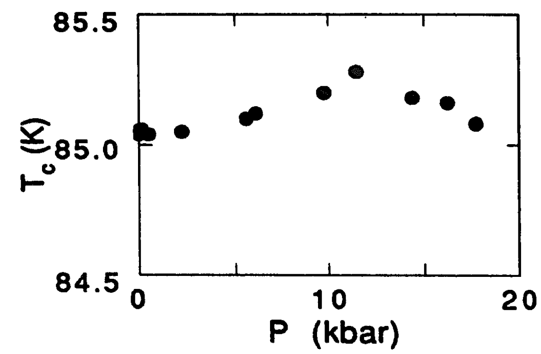

FIGURE 2
Hydrostatic pressure, P, dependence of the critical temperature, T_c, for a *c* oriented Dy123 film grown on (100) MgO.

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