Title
Sample-to-Sample Variation of the Volume Fraction of Superconducting Material in YBa{sub 2}Cu{sub 3}O{sub (7-{delta})}

Authors
Fisher, R.A.
Gordon, J.E.
Phillips, N.E.

Publication Date
1991-12-01

LBL-31628
Extended Abstract

Lawrence Berkeley Laboratory

UNIVERSITY OF CALIFORNIA

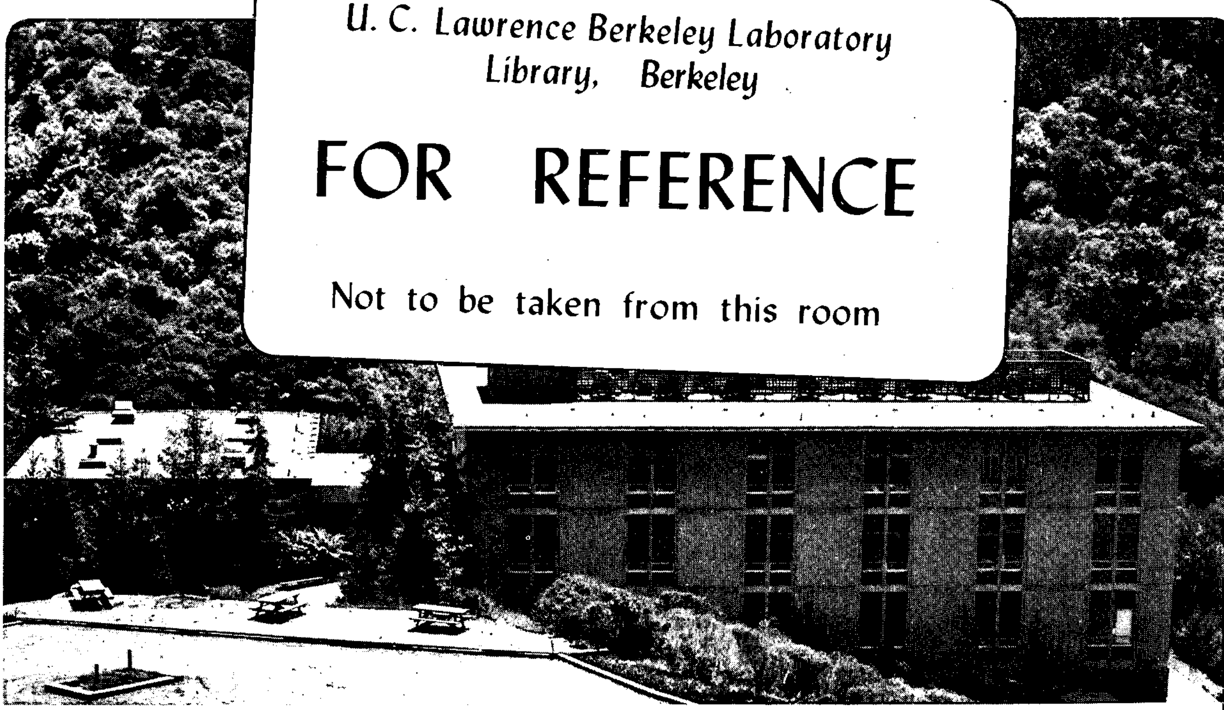
Materials & Chemical Sciences Division

Presented at the Fall Meeting of the Materials Research Society, Boston, MA, December 2–6, 1991, and to be published in the Proceedings

Sample-To-Sample Variation of the Volume Fractions of Superconducting Material in $YBa_2Cu_3O_{7-\delta}$

R.A. Fisher, J.E. Gordon, and N.E. Phillips

December 1991



Prepared for the U.S. Department of Energy under Contract Number DE-AC03-76SF00098

SAMPLE-TO-SAMPLE VARIATION OF THE VOLUME FRACTION OF SUPERCONDUCTING MATERIAL IN $YBa_2Cu_3O_{7-\delta}$

R.A. Fisher[a)], J.E. Gordon[a,b)] and N.E. Phillips[a)]

[a)]Materials Science Division,
Lawrence Berkeley Laboratory,
University of California
Berkeley, CA 94720

[b)]Physics Department,
Amherst College
Amherst, MA 01002

Presented at the MRS Meeting in Boston, MA
December 2-7, 1991

This work was supported by the Director, Office of Energy Research,
Office of Basic Energy Sciences,
Materials Sciences Division of the U.S. Department of Energy
under contract DE-AC00003-76SF00098.

SAMPLE-TO-SAMPLE VARIATION OF THE VOLUME FRACTION OF SUPERCONDUCTING MATERIAL IN $YBa_2Cu_3O_{7-\delta}$

R.A. Fisher, J.E. Gordon* and N.E. Phillips

Materials Science Division,
Lawrence Berkeley Laboratory,
Berkeley, CA 94720

*Permanent address: Physics Dept.,
Amherst College, Amherst, MA 01002

This work was supported by the Director, Office of Energy Research,
Office of Basic Energy Sciences,
Materials Sciences Division of the U.S. Department of Energy
under contract DE-AC00003-76SF00098.

SUMMARY

Specific heat (C) measurements on high-T_C superconductors show dramatic sample-to-sample variations. Three quantities derived from C for YBCO that show such a sample dependence are mutually proportional and suggest that the sample dependence reflects a corresponding variation in the volume fraction of superconductivity (f_s). They are (1) $d\gamma^*/dH$, the field dependence of the coefficient of the "linear term," which is associated with the creation of vortices in the superconducting regions (see Fig.1); (2) $\Delta C(T_c)$ the mean-field discontinuity in C at T_c (see Fig. 2); (3) ΔS, an entropy change in the superconducting regions produced by the application of a magnetic field (see Fig. 3). These quantities have been used to determine relative values of f_s (see Fig. 4). Their correlation with a concentration of Cu^{2+} magnetic moments (n_2) (see Fig. 1) suggests that the transition to the superconducting state is suppressed either by these moments themselves or by some other defect that is correlated with these moments. The limit $n_2=0$ is taken to correspond to $f_s=1$, thus establishing absolute values of f_s (see Fig. 5). The conclusion is that substantial fractions of these materials, even of samples believed to be "good" superconducting material, can be non superconducting.

Fig. 1. Analysis of the low-temperature C for a typical YBCO sample into its four components: (1) C_ℓ = lattice specific heat. (2) $C_e(H) \equiv \gamma^*(H)T$, the field-dependent linear contribution, one term of which is $H d\gamma^*/dH$. (3) $C_m(H)$, associated with Cu^{2+} moments. For H=0 it appears here as the well-known "upturn" in C/T; for H=7T it is a Schottky anomaly that determines the concentration of Cu^{2+} moments (n_2). The points for $C_m(7T)$ represent experimental data from which the other contributions have been subtracted. (4) $C_h(H)$, the hyperfine component.

Fig. 2. The determination of $\Delta C(T_c)$ for a sample that shows no obvious fluctuation effects. The simple entropy-conserving construction, represented by the dashed lines, gives essentially the same value of $\Delta C(T_c)$ as a fit with a gaussian distribution of T_c, represented by the solid curve. The dash-dot curve, a harmonic-lattice extrapolation from high temperatures, represents the background used for the gaussian fit.

Fig. 3. ΔS, a measure of the effect of a 7-T magnetic field on the entropy associated with the anomaly at T_c. Thermodynamically, ΔS is approximately related to $d\gamma^*/dH$ by $\Delta\gamma^* = H d\gamma^*/dH \approx \Delta S/T_x$, but experimentally it is an independent measure of f_s.

Fig. 4. The correlations among $d\gamma^*/dH$, $\Delta C(T_c)$, and ΔS, scaled to fall on the same line for a number of polycrystalline YBCO samples. For each sample the three quantities are plotted at the relative value of f_s that best represents all three.

Fig. 5. The correlation of the relative values of f_s with n_2, which suggests that n_2 measures the concentration of a defect that suppresses the transition to the superconducting state. The association $n_2=0$ with $f_s=1$ puts the values of f_s on an absolute scale.

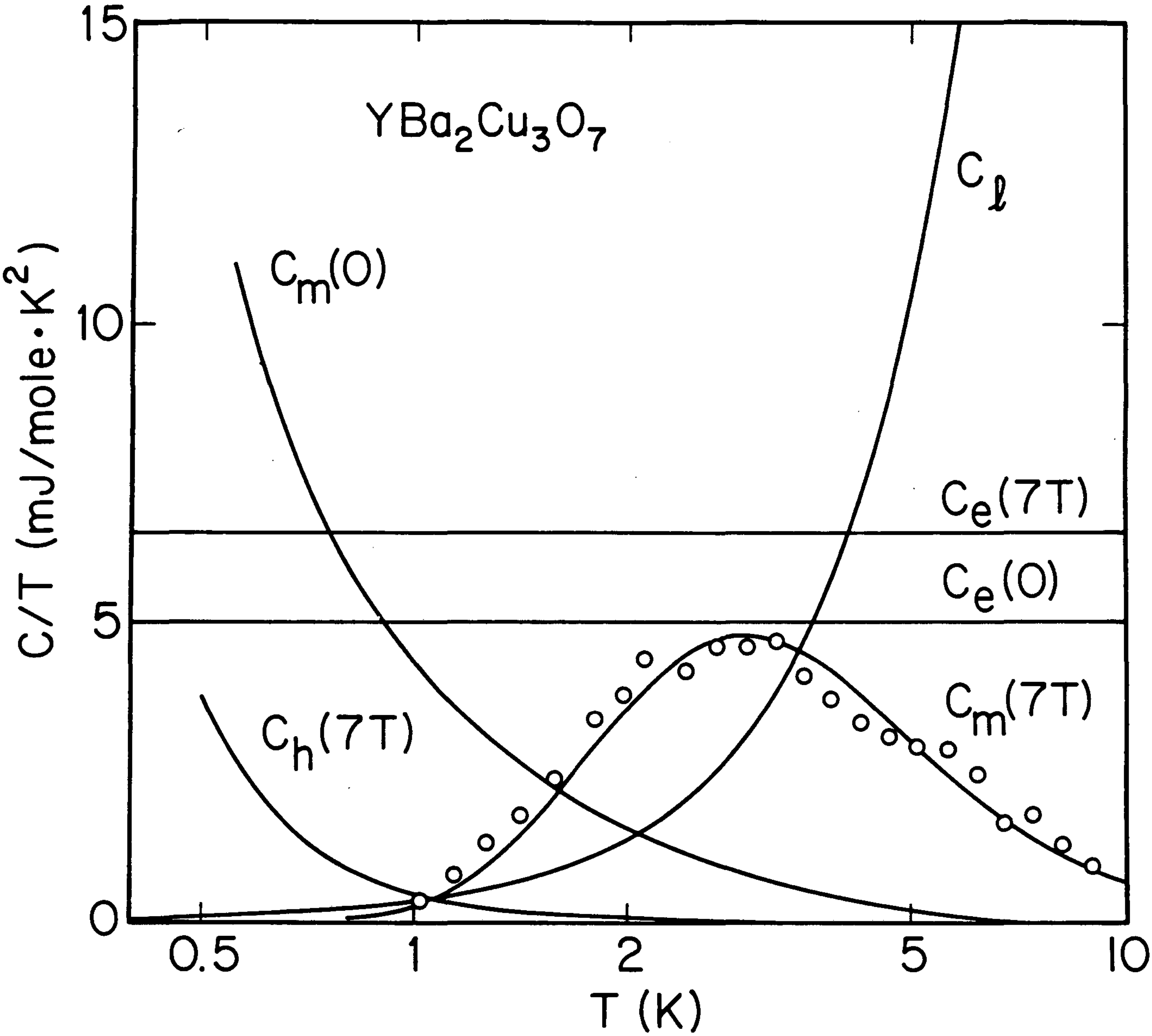
POSSIBLE EFFECT OF OXYGEN STOICHIOMETRY

Oxygen deficiency, $\delta > 0$, reduces $\Delta C(T_c)$ and the density of electron states, and, presumably, $d\gamma^*/dH$ and ΔS. However, it is unlikely that variations in oxygen stoichiometry play a significant role in the effects represented in Fig. 3 because:

(1) The Pauli susceptibility for these samples is essentially constant, ruling out the variation in electron density of states that would be required to explain the results.

(2) For these samples the 0-K Debye temperature and $\gamma^*(0)$ vary strongly with f_s, but other work [Y. Nakazawa and M. Ishihara, Physica C458, 381 (1989)] shows that they are nearly independent of δ in the relevant range of δ.

(3) Similar correlations have been observed for $(La_{1.85}Sr_{0.15})CuO_4$ for which there is no reason to expect variations in oxygen stoichiometry.



XBL 904-1224

FIG. 1

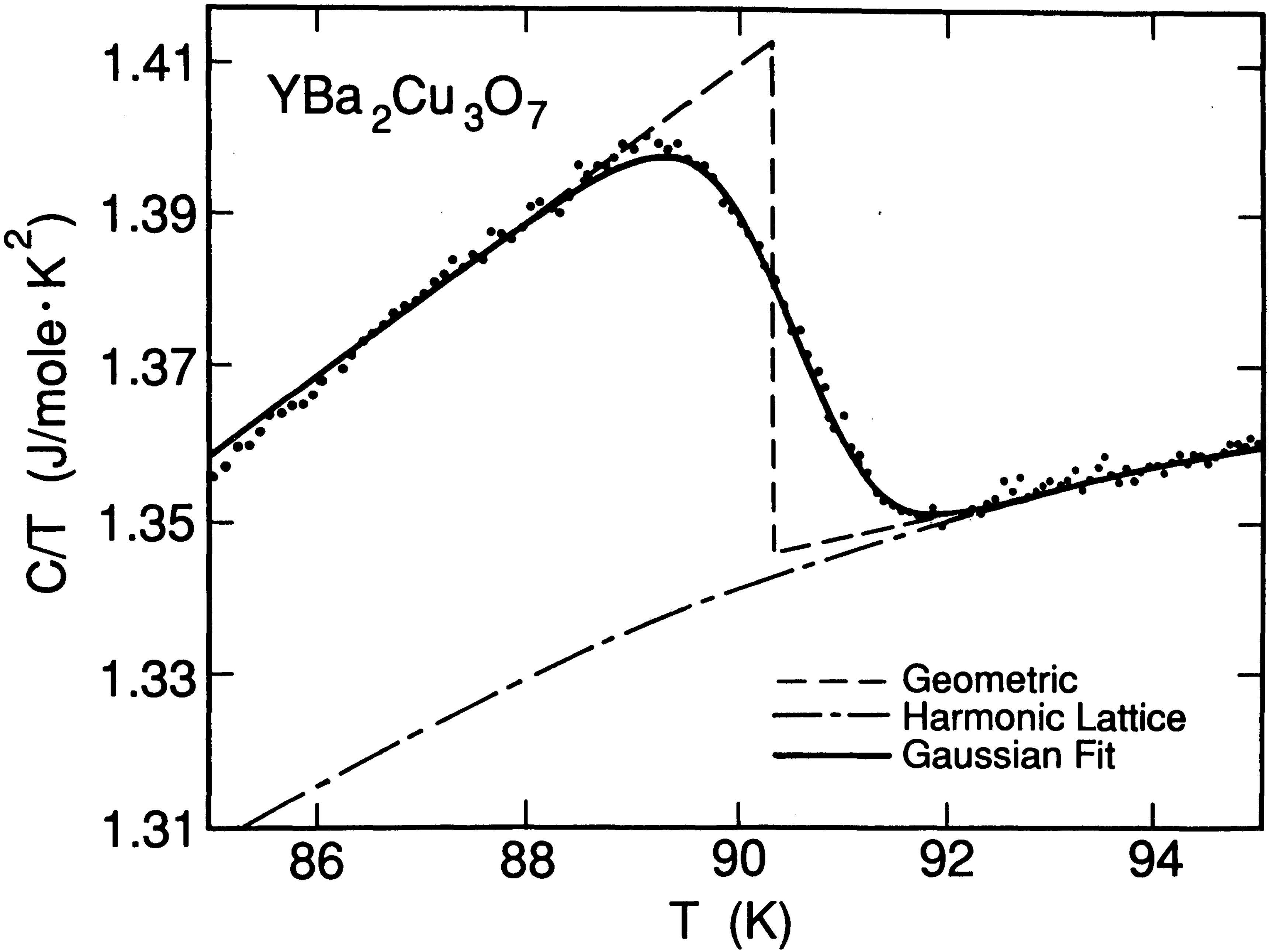
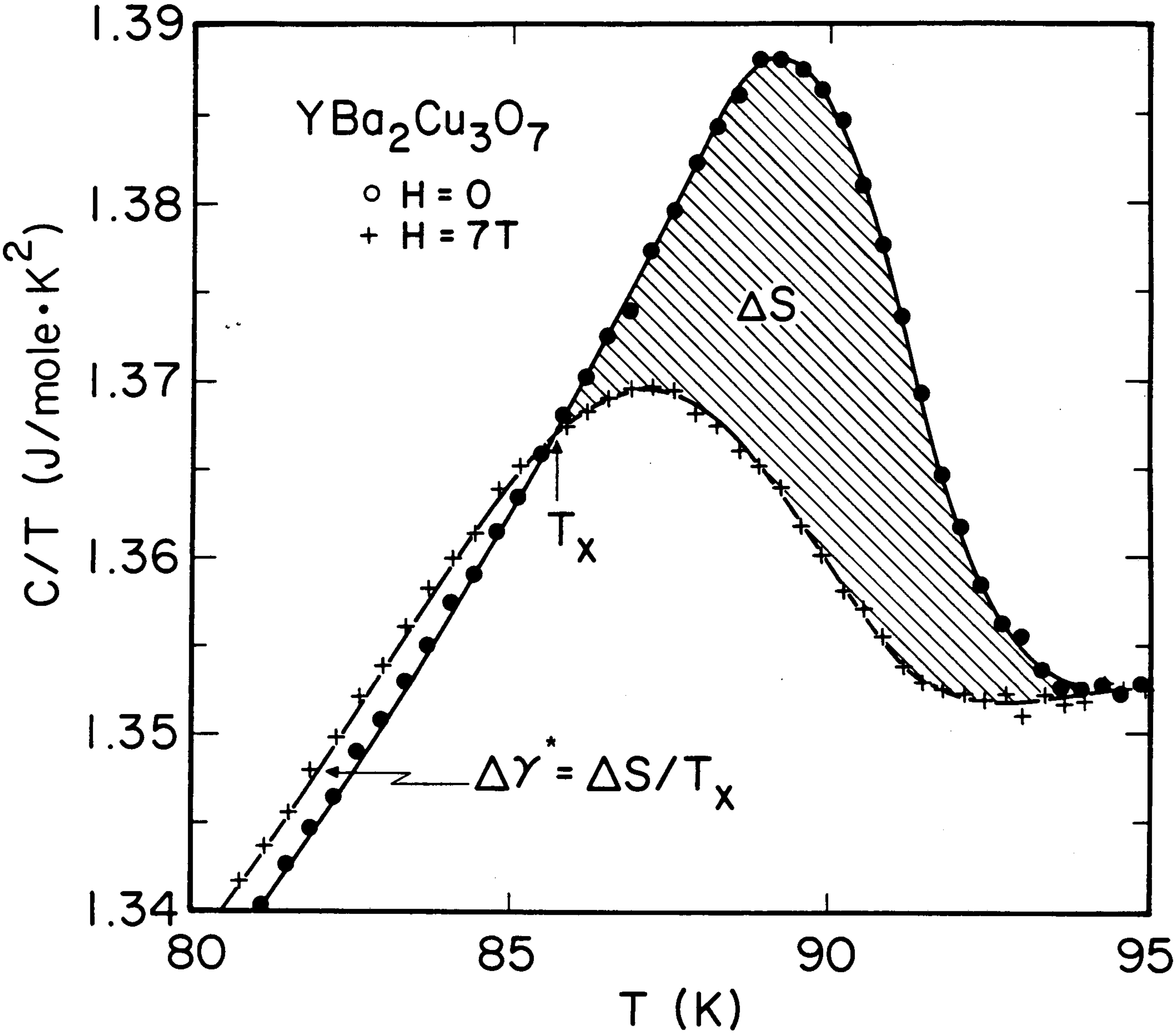


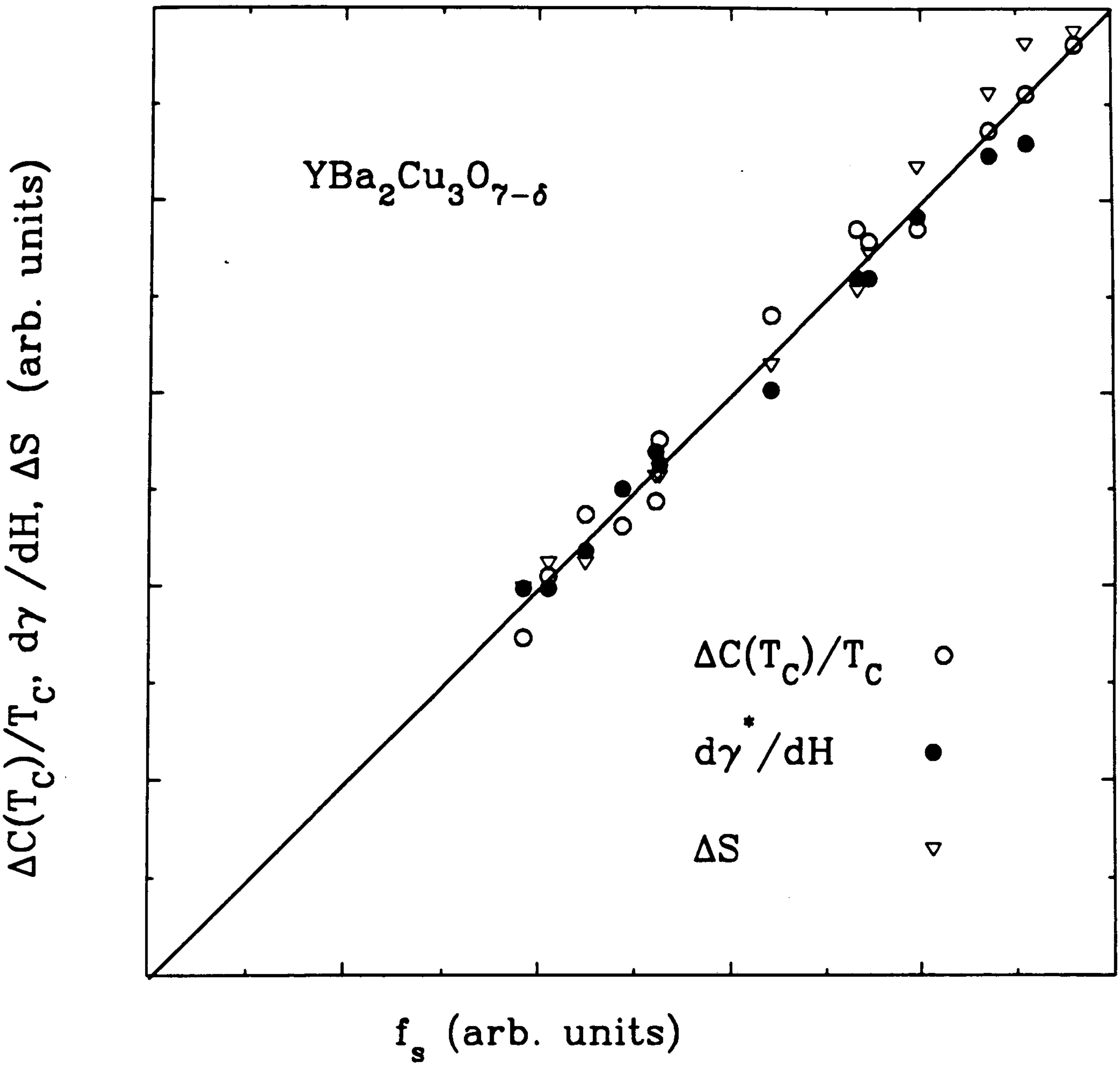
FIG. 2

XBL 901-63



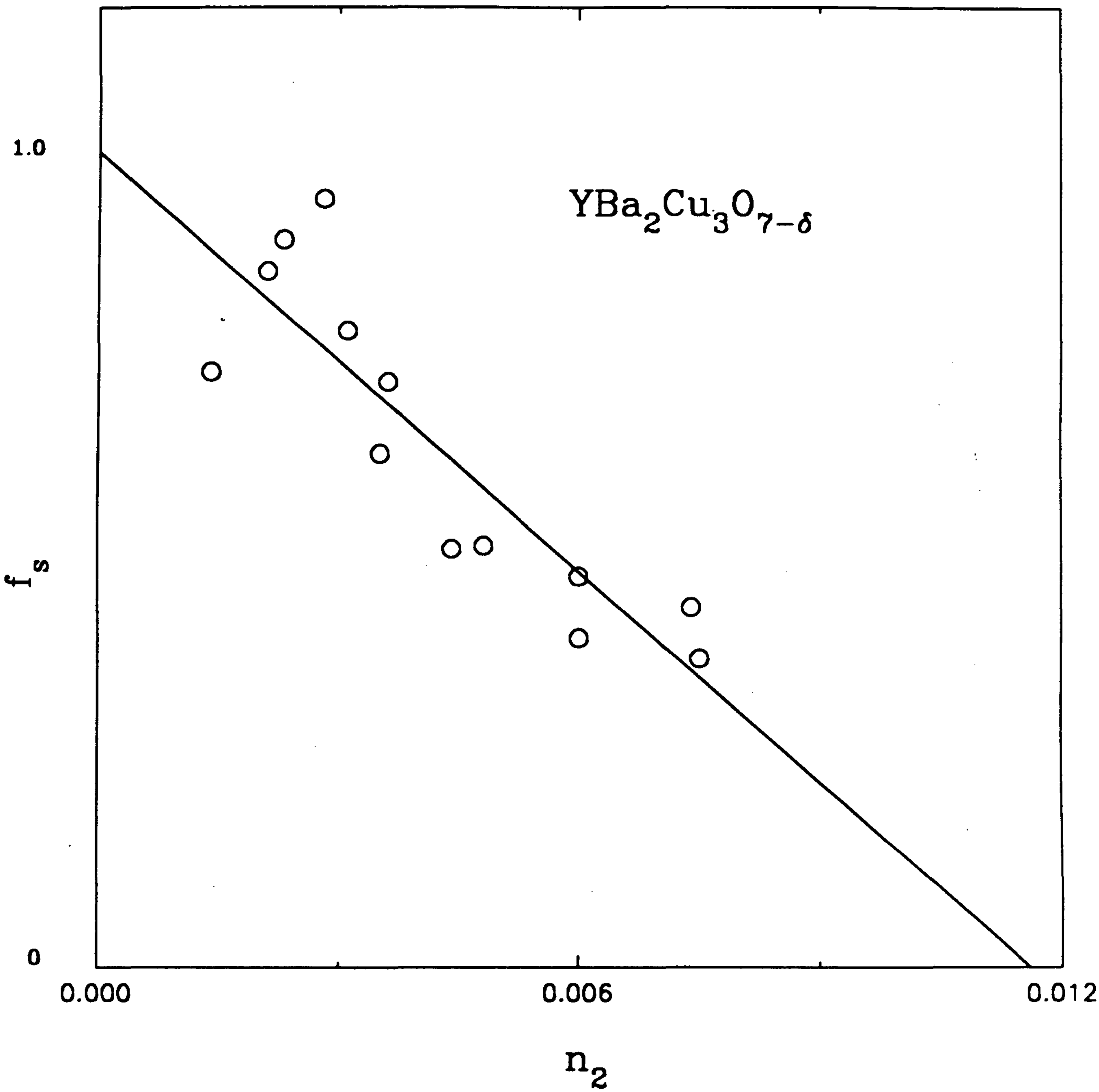
XBL 8911-4189

FIG. 3



XBL 9111-2461

FIG. 4



XBL 9111-2462

FIG. 5

LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
INFORMATION RESOURCES DEPARTMENT
BERKELEY, CALIFORNIA 94720