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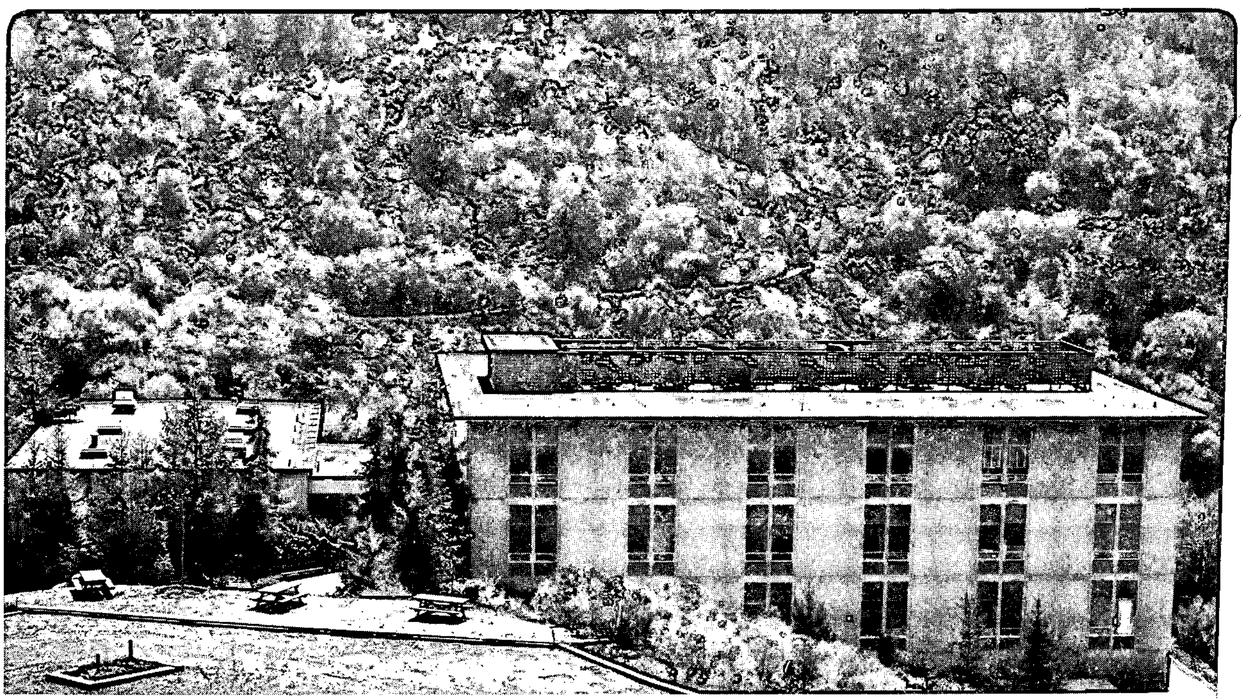

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DISCLAIMER

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QUENCHING AND ANNEALING EFFECTS ON THE SPECIFIC HEAT OF $YBa_2Cu_3O_{7-\delta}$

by

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Quenching and Annealing Effects on the Specific Heat of $YBa_2Cu_3O_{7-\delta}$

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The effect of heat treatments and quenching with no change in oxygen content was studied for a polycrystalline sample of YBCO. Quenching the sample changes the properties drastically, as seen in the specific heat and the resistivity. This study shows that non-superconducting regions, some of which are not associated with Cu^{2+} moments, can be created in YBCO by heat treatment alone.

The volume fraction of superconductivity (f_s) in $YBa_2Cu_3O_{7-\delta}$, as determined by the discontinuity in the specific heat (C) at T_c, shows large sample-to-sample variations and a negative correlation with a low concentration (n_2) of Cu^{2+} magnetic moments. [n_2 (moles Cu^{2+}/mole YBCO) is determined by the amplitude of a Schottky anomaly in C in an applied magnetic field, C_m(7T) (see Fig. 1).] The correlation of f_s with n_2 shows that the Cu^{2+} moments must be located mainly on the YBCO lattice and suggests that they are associated with defects that suppress super-conductivity. As part of an effort to relate n_2 to differences in sample preparation, a ceramic sample of YBCO has been subjected to a series of heat treatments—two successive quenches into liquid nitrogen after heating to 200°C; a rapid cooling through the tetragonal/orthorhombic (T/O) transition (actually from 950°C to 350°C); and finally, "reconstitution" by annealing at 950°C and slow cooling to 350°C—with intermediate measurements of f_s, n_2, and resistivity (ρ). Since the superconducting properties are also sensitive to the value of δ, the oxygen stoichiometry was monitored by high temperature susceptibility measurements which showed that no significant changes occured.

Table I gives the value of f_s determined by $\Delta C(T_c)$, and for comparison, n_2 and the fraction of superconductivity derived directly from n_2, $f_s(n_2)$. Both f_s and $f_s(n_2)$ are based on a correlation of $\Delta C(T_c)$ with n_2 derived from data on a large number of independent samples.[1,2] Both n_2 and $\Delta C(T_c)$ are determined with a precision of about 3% (Figs. 2, 3).

The first quench reduced f_s from 0.85 to 0.78; increased n_2, but by a larger relative amount; and changed ρ, dramatically increasing its magnitude and altering the T-proportional behavior (see Fig. 4). (Changes in ρ of this kind have been attributed to changes in δ, but evidently, they can be produced by the quench itself, when a quench is used to freeze in the value of δ.) The second quench, and the rapid cooling through the T/O transition produced further reductions in f_s but no significant increases in n_2. The second quench caused a small further increase in ρ; reheating to 950°C, even with rapid cooling through the T/O transition, restored ρ to its original value. Apparently the defects that changed ρ, that were produced in the first quench, were completely repaired by heating to 950°C. Finally, after reconstitution at 950°C and slow cooling to 350°C, f_s increased and n_2 decreased, but the volume fraction of superconductivity remained lower than in the original sample.

The discrepancies between f_s and $f_s(n_2)$ are not large compared with the experimental precision, but they do suggest that the correlation between f_s and n_2 is an oversimplification. They must arise from non-superconducting regions produced by defects that are not associated with Cu^{2+} moments, and which could be either metallic or insulating in character. There is some indication that these regions were produced by the intermediate heat treatments and were eliminated by the reconstitution.

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REFERENCES

1. N. E. Phillips *et al.*, The Specific Heat of High-T_c Superconductors in: Prog. Low-Temp. Phys. **13**, North-Holland, Amsterdam, 1992.
2. N. E. Phillips *et al.*, Chinese J. Phys. **30**, 799 (1992).

FIGURE CAPTIONS

1. C_m(7T) is determined by subtracting the linear (C_e), lattice (C_l), and hyperfine (C_h) components.

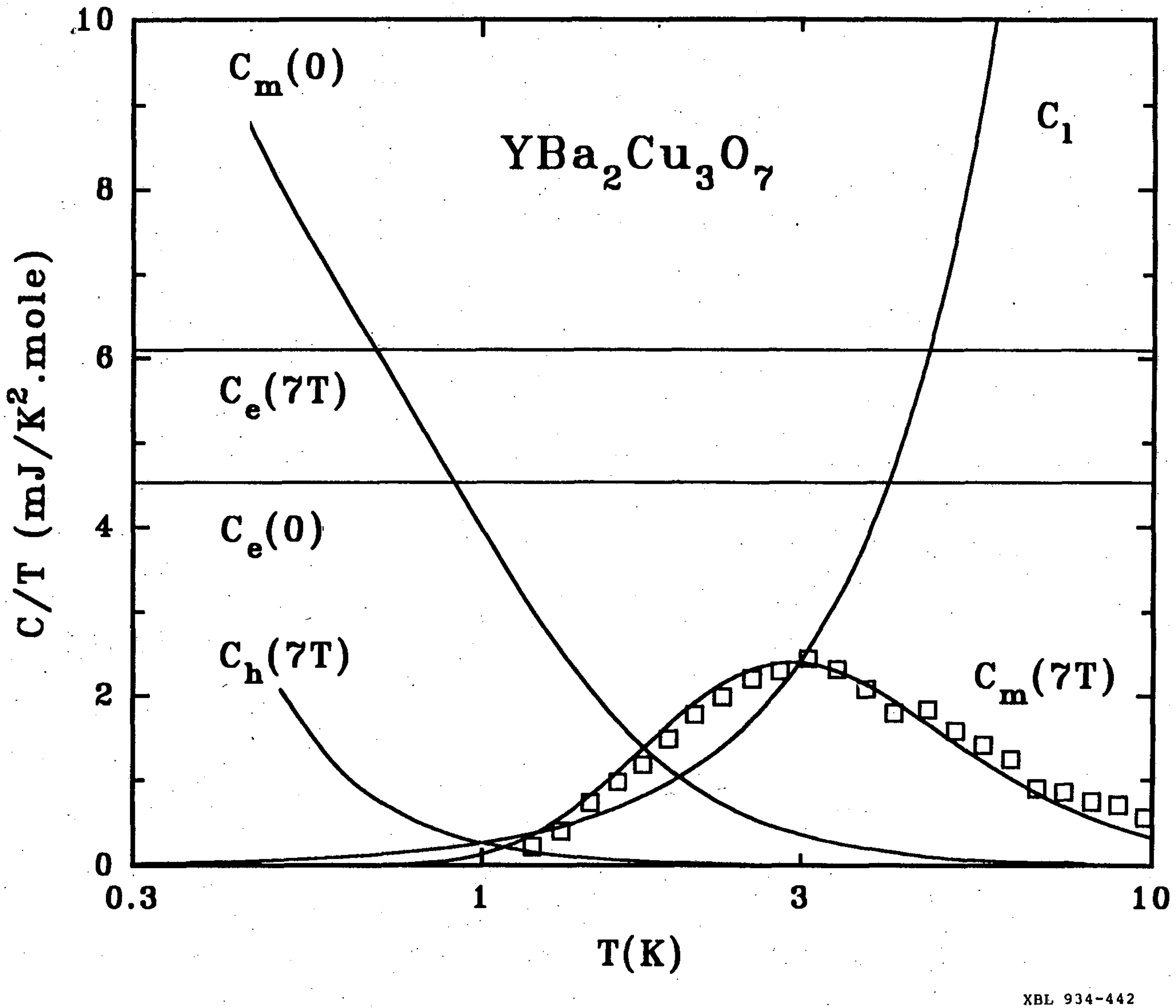
2. C_m(7T) before (lower) and after first quench.

3. Specific heat anomaly at T_c determined using an entropy conserving construction. Other methods for determining $\Delta C(T_c)$ yield similar results.

4. Resistivity vs. temperature for YBCO.

Table I. Volume fraction of superconductivity determined from $\Delta C(T_c)$, $f_s = \Delta C(T_c)/78T_c$; n_2; $f_s(n_2) = 1 - n_2/0.012$.

Condition	f_s	n_2	$f_s(n_2)$
Original	0.85	0.0023	0.81
After first quench	0.78	0.0036	0.70
After Second Quench	0.73	0.0037	0.68
After rapid cool, 950-350°C	0.62	0.0038	0.68
After reconstitution	0.73	0.0032	0.73



10
8
6
4
2
0
C/T (mJ/K².mole)
$C_m(0)$
YBa₂Cu₃O₇
C_l
$C_e(7T)$
$C_e(0)$
$C_h(7T)$
$C_m(7T)$
0.3
1
3
10
T(K)
XBL 934-442

FIGURE 1

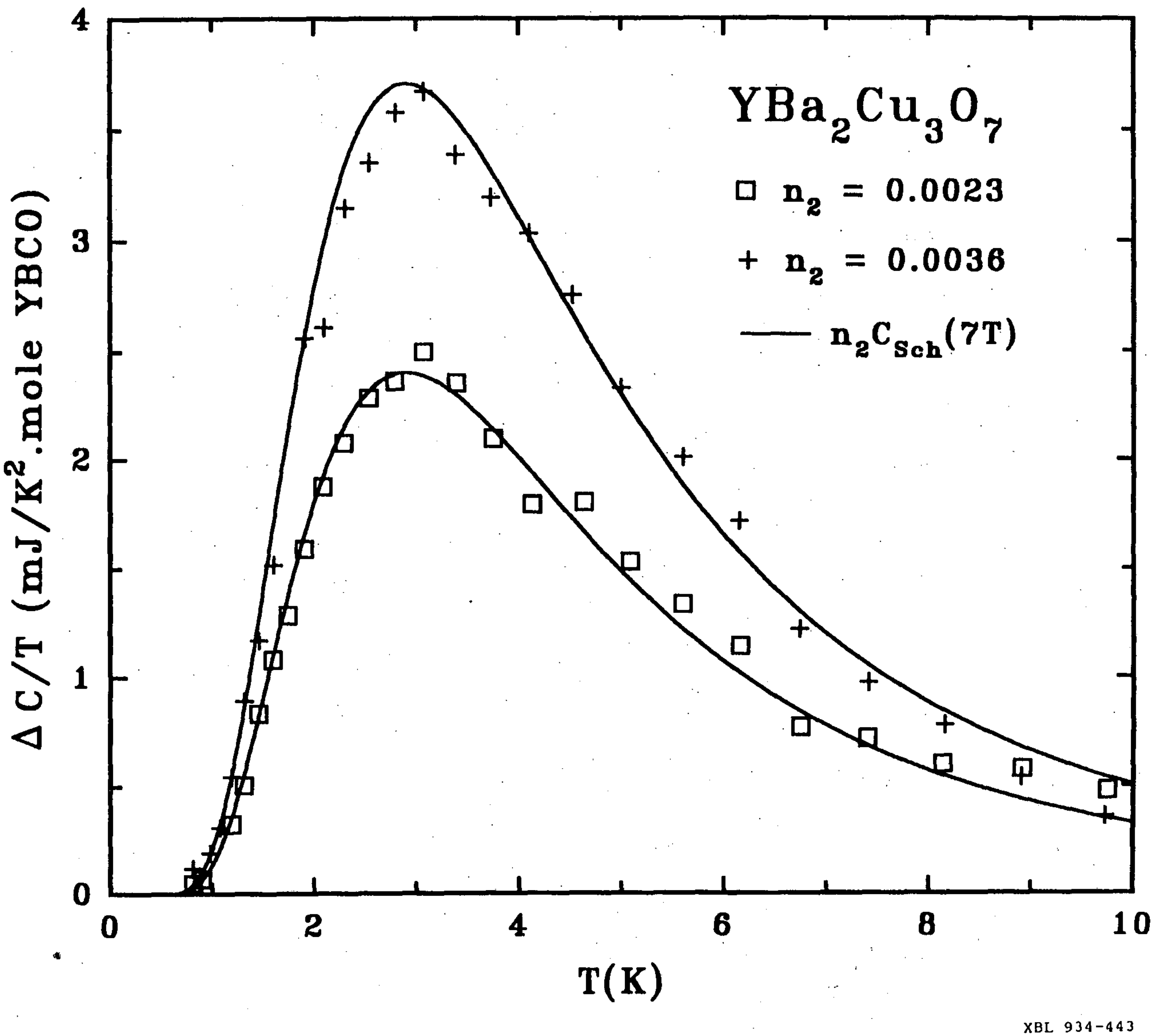
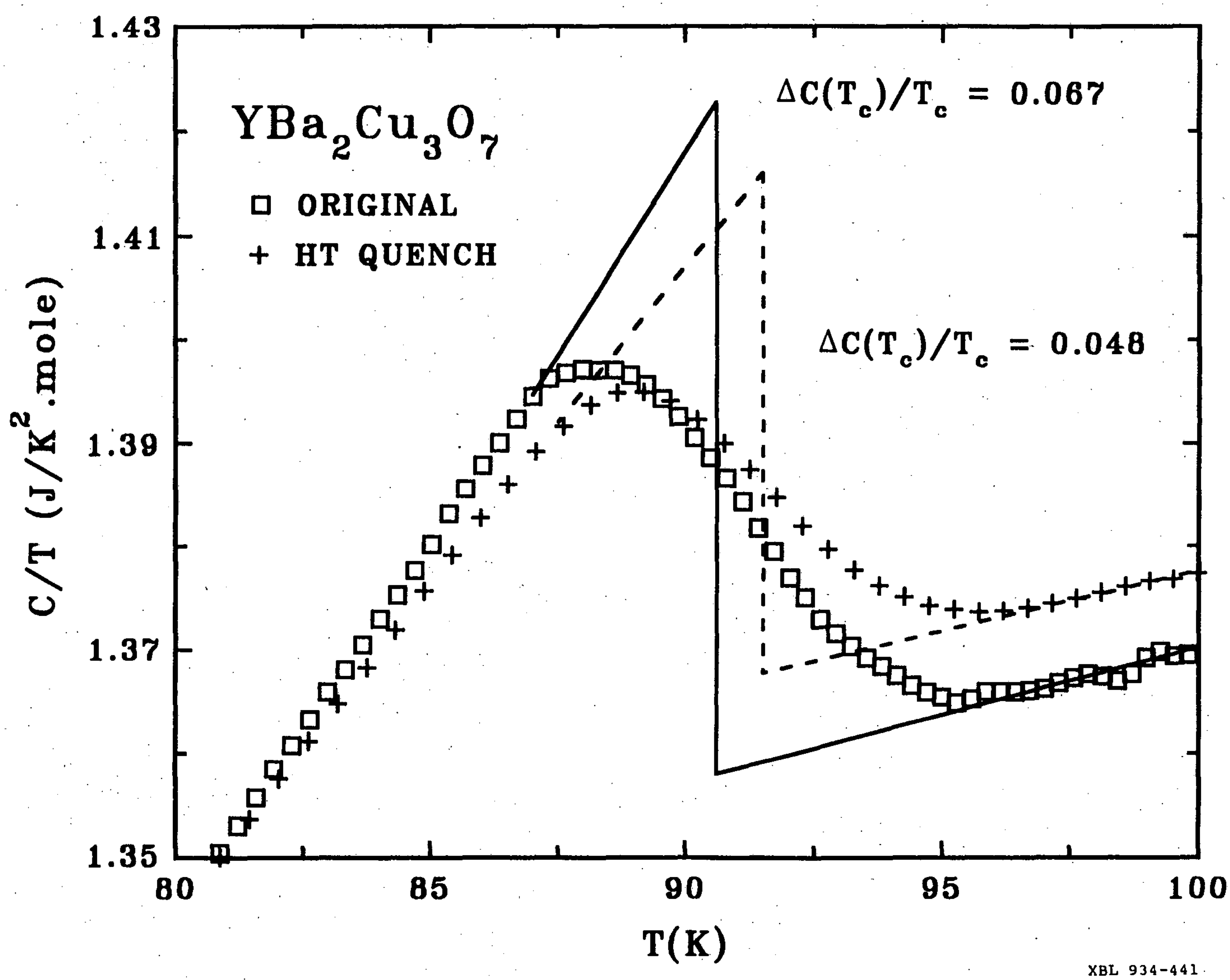

YBa2Cu3O7
n2 = 0.0023
n2 = 0.0036
n2CSch(7T)
ΔC/T (mJ/K2.mole YBCO)
T(K)
0
1
2
3
4
0
2
4
6
8
10
XBL 934-443

FIGURE 2



1.43
1.41
1.39
1.37
1.35
80
85
90
95
100
C/T (J/K².mole)
T(K)
YBa2Cu3O7
ORIGINAL
HT QUENCH
ΔC(Tc)/Tc = 0.067
ΔC(Tc)/Tc = 0.048
XBL 934-441

FIGURE 3

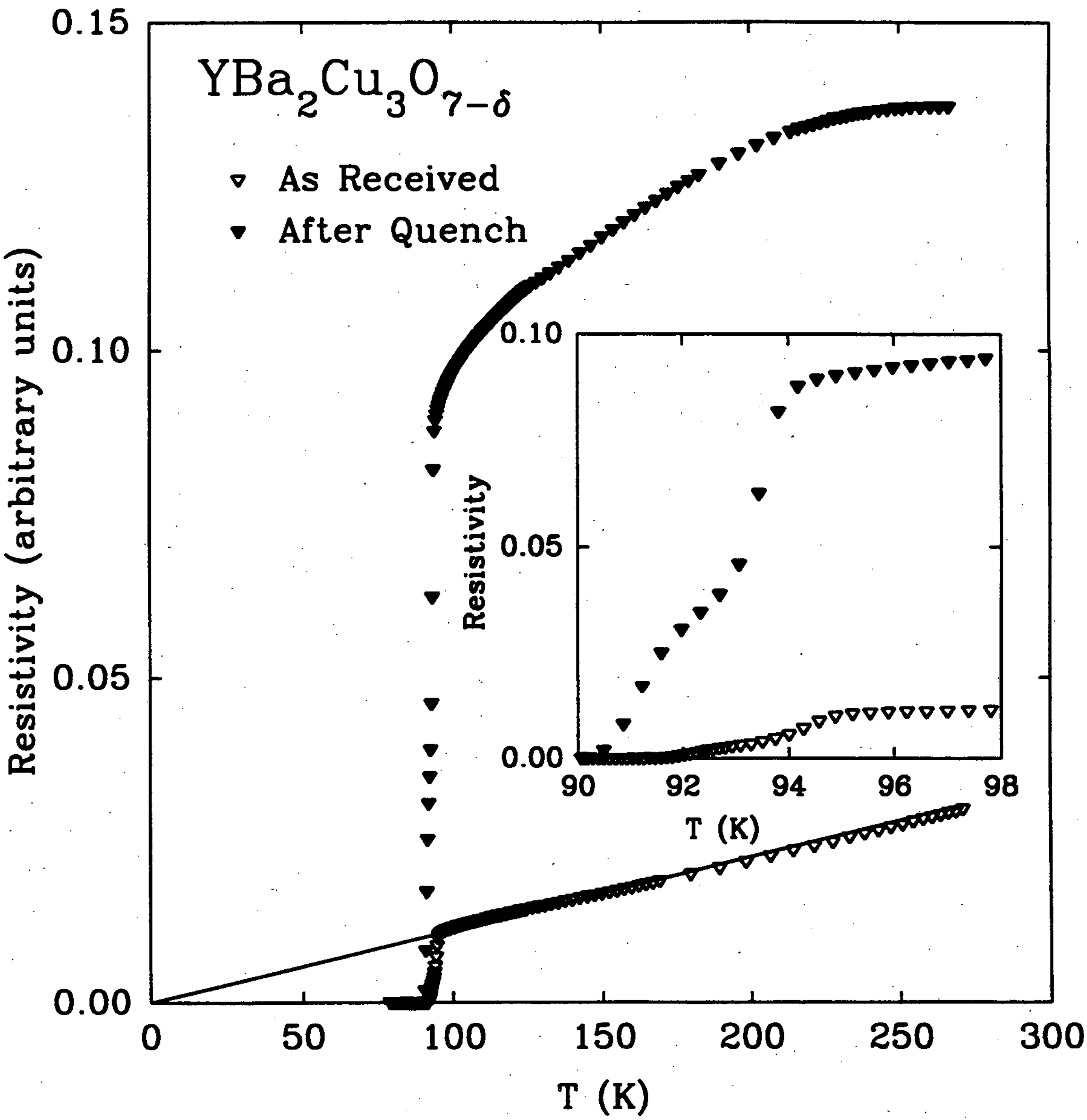


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FIGURE 4

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