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## Specific Heat of the High-$T_c$ Superconductor $(Bi_{1.66}Pb_{0.34})Ca_2Sr_2Cu_3O_{10}$

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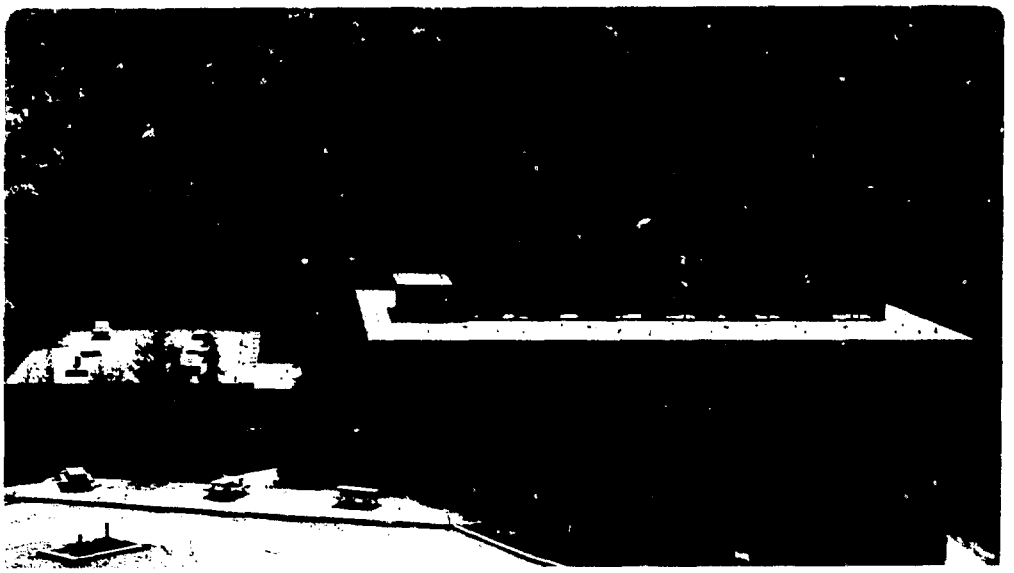

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# SPECIFIC HEAT OF THE HIGH-$T_c$ SUPERCONDUCTOR $(Bi_{1.66}Pb_{0.34})Ca_2Sr_2Cu_3O_{10}$

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The specific heat (C) was measured for H=0 and 7T in the ranges 0.4 to 20K and 65 to 125K. The coefficient of the low-temperature linear term in C was 0±0.5 mJ/K²·mole. On initial cooling, no anomaly in C was observed at $T_c$, but there were dramatic temperature hysteresis effects.

Samples in the Bi-Ca-Sr-Cu-O system[1] usually consist of mixtures of compounds with $T_c$'s in the range 80 to 115K. Nearly pure single phase material can be synthesized with $T_c$~107K by partial substitution of Pb for Bi.[2] In this paper we report measurements of C on a $(Bi_{1.66}Pb_{0.34})Ca_2Sr_2Cu_3O_{10_3}$ sample which had previously been used for elastic constant measurements.

Field-cooled susceptibility ($\chi_v$) measurements were made on a cylinder (d/h=0.45) cut from the calorimetric sample with the measuring field applied at 130K. $\chi_v$, corrected for demagnetizing effects, is shown in Fig. 1. Points labeled 1 were taken on the initial cool-down; points labeled 2 were taken after re-warming to 130K; and points labeled 3 were taken after again re-warming to 130K and exposure to 5T at that temperature. Hysteresis effects have also been observed in elastic-constant measurements.[3]

$\chi_v$ was measured from 110 to 300K in 2T. The data are plotted in Fig. 2 where the straight line is the least-squares fit to the indicated Curie-Weiss law. Assuming S=1/2 and g=2, a paramagnetic impurity fraction $[n_i(\chi)]$=0.020 was calculated from $\sigma$.

C/T vs $T^2$ in the low-temperature region is plotted in Fig. 3. At H=0 the upturn in C/T is associated mainly with the onset of magnetic impurity ordering, which in 7T produces a Schottky-like anomaly. By evaluating the entropy associated with the 7T anomaly, and assuming S=1/2, the impurity fraction $n_i(C)$=0.018, in good agreement with $n_i(\chi)$. In 7T, hyperfine interactions, primarily that of H with the nuclear magnetic moments of Bi and Cu, but including a Bi quadrupole term, account for the low-temperature upturn in C/T. The measured $C_{hf}(7T)T^2$=1.5 mJ/K²·mole is in good agreement with measurements

by Caspary et al.[4] At H=0 the data in the range $3 \le T \le 12$K were fit by: $C(H=0)=260/T^2+0.5T+2.49T^3+0.0277T^5-0.000101T^7$ with an rms deviation of 0.333%. $\gamma(0)=0\pm0.5$ mJ/K$^2$·mole to within the accuracy of the data, similar to values found previously for Pb-free Bi-Ca-Sr-Cu-O superconductors.[5] $\Theta_0=246$K. No hysteresis was observed in the T<20K data.

Measurements of C, in H=0, following initial cool-down exhibited the anomaly shown in Fig. 4, where the horizontal bar is $\Delta T_c$ from the 10-90% transition in $\chi_v$. Subsequent measurements in both H=0 and 7T, made without heating the sample above 130K, had run-to-run variations as large as 20%. After warming to room temperature and re-cooling, the first measurement reproduced the original one, while subsequent determinations were again erratic. This hysteresis is no doubt connected with those in the Meissner-effect and elastic-constant[3] data. The vertical line in Fig. 4 represents an ideal entropy conserving transition at $T_c=104$K, from which $\Delta C(T_c)/T_c=37$ mJ/K$^2$·mole. Assuming the BCS weak coupling limit, $\gamma=26$ mJ/K$^2$·mole.

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3. H. M. Ledbetter et al., Phys. Rev. B39 (1989) 9689.

4. R. Caspary et al., Origin of the Nuclear Specific Heats in High-$T_c$ Superconductors, this volume.

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FIGURE CAPTIONS

1. Meissner fraction vs T showing hysteresis.

2. Fit of $\chi$ data above $T_c$ to a Curie-Weiss law.

3. C/T vs $T^2$ in the low-temperature region.

4. C/T near $T_c$ following initial cool-down.

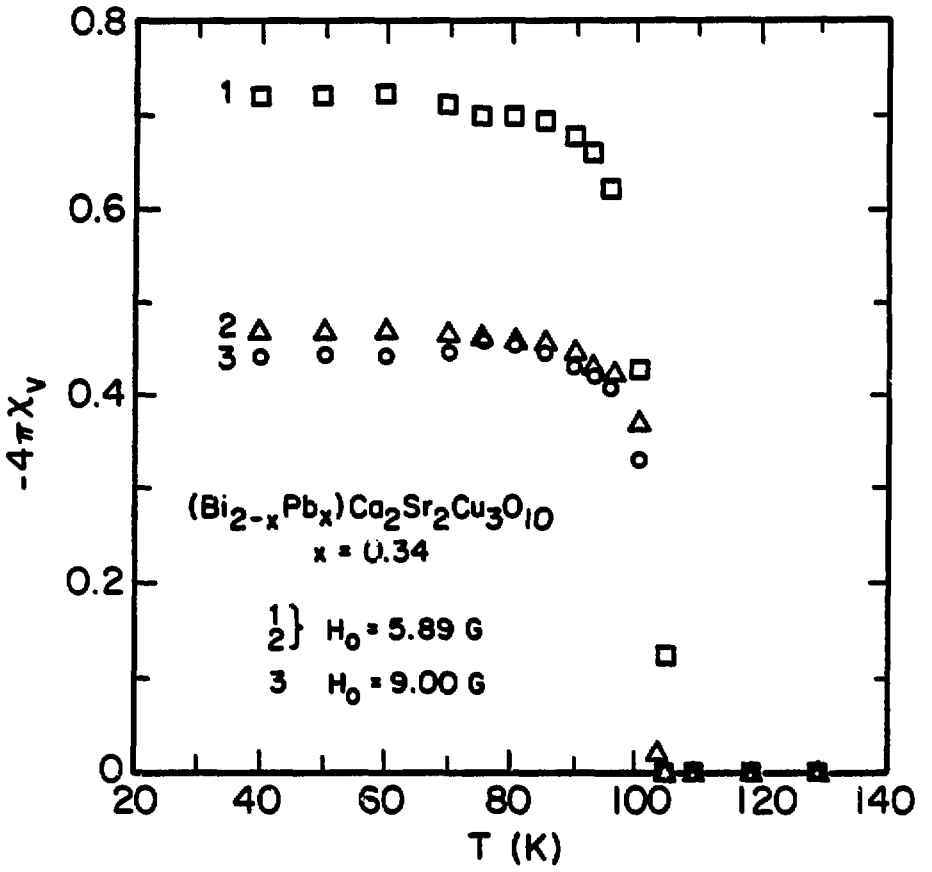


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Fig. 1

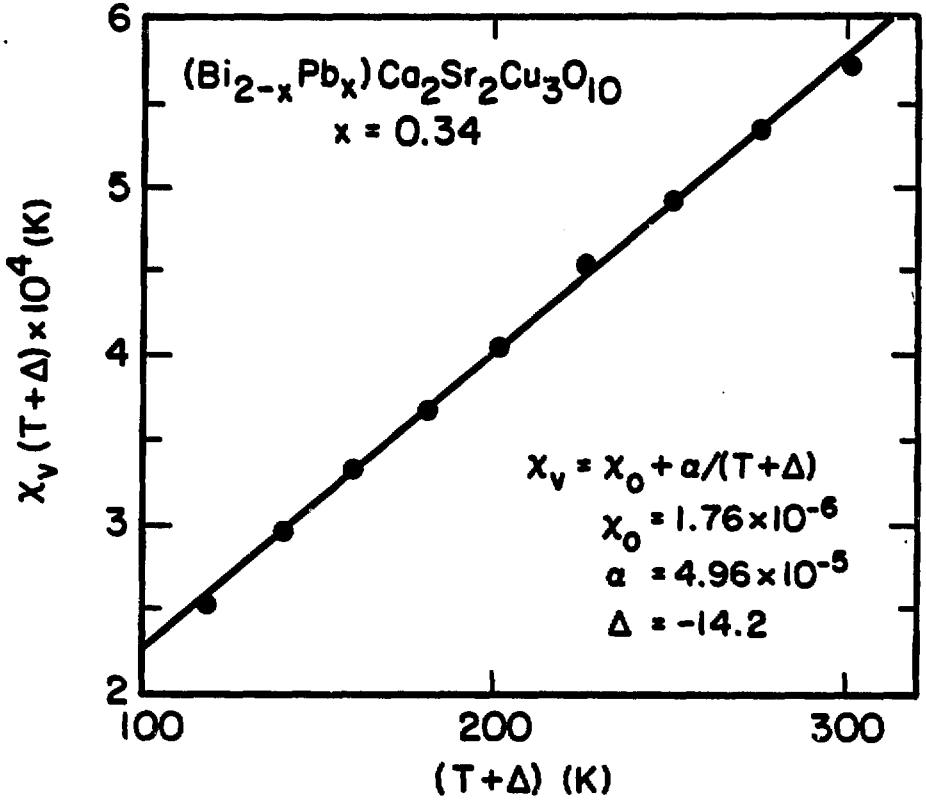


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Fig. 2

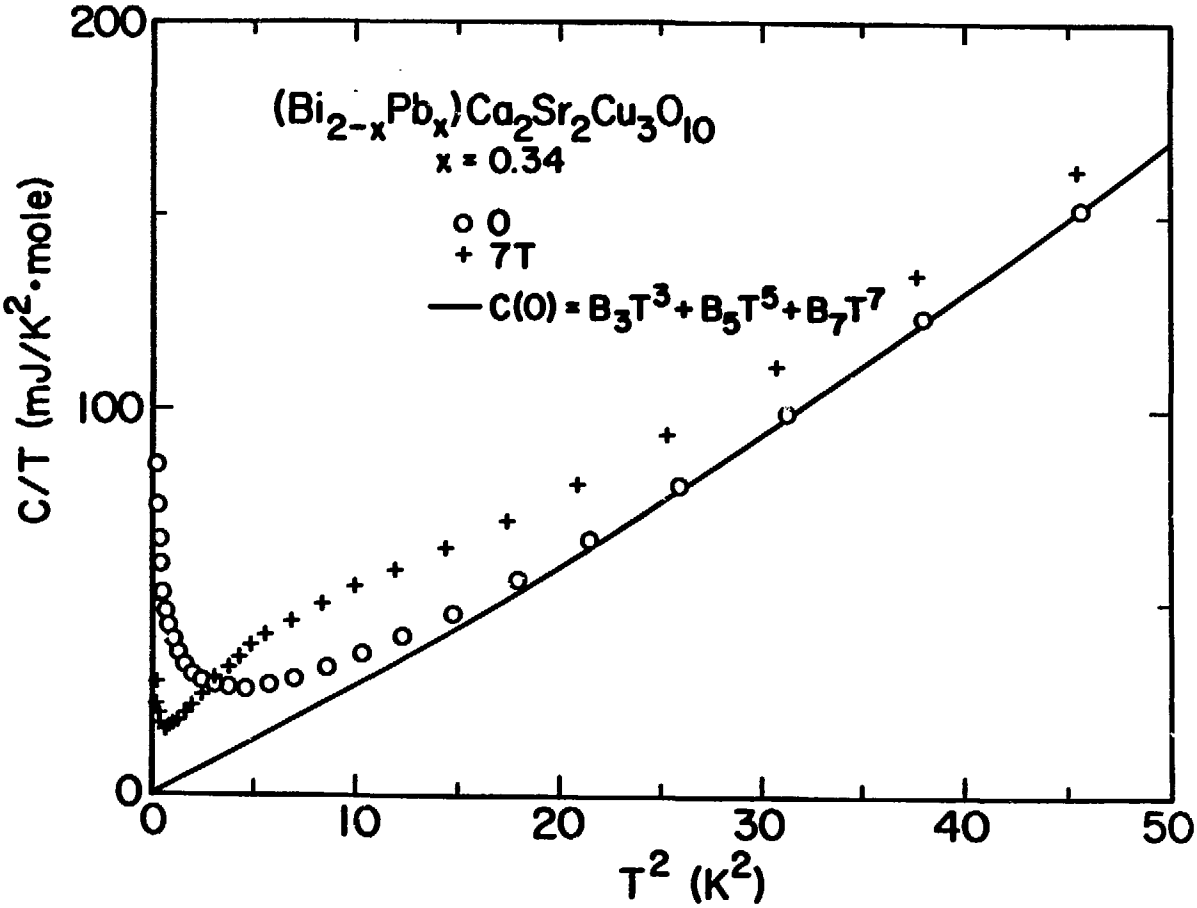


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Fig. 3

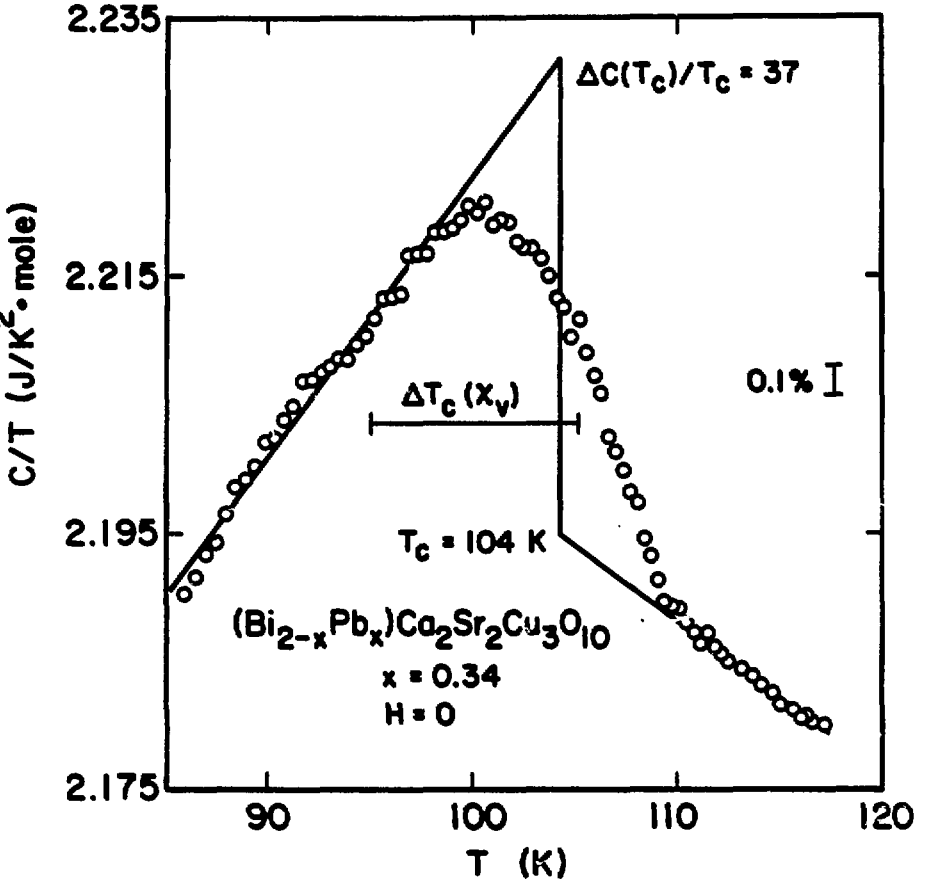


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Fig. 4