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Specific heat anomaly in the 90 K superconductor $HoBa_2Cu_3O_{7-y}$

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Abstract. We report here the results of our heat capacity C_p measurements on a monophasic material $HoBa_2Cu_3O_{7-y}$. $\Delta C_p/T_c$, the jump in C_p at the superconducting transition temperature ($=91$ K) of the material is measured to be 31 mJ/mol-K^2.

Keywords. $HoBa_2Cu_3O_{7-y}$; anomaly in heat capacity; high temperature superconductivity.

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1. Introduction

One of the most important questions regarding the recently discovered high T_c superconductors (Malik and Vijayaraghavan 1987), namely, of the $YBa_2Cu_3O_{7-y}$-type and $La_{2-x}M_xCuO_{4-\delta}$-type, is 'what is the mechanism of superconductivity' in these materials. Is a new mechanism of pairing at work which leads to such extraordinary high values of T_c ($=90$ K in $YBa_2Cu_2O_{7-y}$ type materials)? Or is it that the usual phonon-mediated attractive coupling between the two partners of a Cooper pair is operating in these materials also? Various experiments have been performed on these materials to seek answers to such basic questions. Measurements of heat capacity C_p and the jump ΔC_p in C_p at the superconducting transition temperature of the material yield very useful information about the superconductivity behaviour. Not only does this measurement allow one to make a definite statement about the bulk nature of superconductivity but also leads to a better insight about its mechanism. C_p and ΔC_p have been measured for $YBa_2Cu_3O_{7-y}$ (Nevitt *et al* 1987) and $La_{1.8}Sr_{0.2}CuO_{4-\delta}$ (Dunlap *et al* 1987) and important conclusions have been drawn about the density of states at the Fermi level. Low temperature heat capacity measurements have been reported by Nambudripad and Dhar (1987) in $YBa_2Cu_3O_{7-y}$. In this brief report, we present preliminary results of our heat capacity measurements of a single phase material $HoBa_2Cu_3O_{7-y}$.

2. Experimental

Samples of $HoBa_2Cu_3O_{7-y}$ were prepared by sintering a mixture of Ho_2O_3, $BaCO_3$ and CuO taken in the required proportion (to yield a composition $HoBa_2Cu_3O_{7-y}$). The mixture was ground very thoroughly for about an hour and calcined at 900°C for 12 h. The calcined mass so obtained was powdered, pelletized and sintered at

900°C. This process was repeated until a single phase sample (as revealed by powder X-ray diffraction) was obtained.

The sample in the specific heat measurement weighted 117·16 mg. The measurement was performed by the usual heat pulse method. All the quantities in this method including ΔT, the change in temperature, are measured digitally. The sample holder consists of a sapphire substrate supported by 16 gold wires, 40 mm thick, which also serve as the input lead. A nichrome film deposited on the substrate serves as the heater. The thermometer is a bare thin film platinum resistor deposited on Al_2O_3. The total weight of the sample holder and the thermometer is 93 mg. The resistance of the thermometer at 0°C is 100 Ω. The resistance of the thermometer is measured by an ac bridge coupled with lock-in-techniques. The sample was attached to the substrate with a very thin layer of Apiezon-N grease. The heat capacity of the sample holder was measured separately and contributed roughly 30% of the total at 77 K. The accuracy of this measurement is ~0·2%. The details of the apparatus will be given elsewhere.

3. Results and discussion

From the observed powder diffraction pattern of the material, it is concluded that the sample is essentially monophasic. The lattice constants, as obtained from the diffraction pattern, are in good agreement with those reported in literature.

Figure 1 shows the temperature dependence of the ac-susceptibility of the material. It is clear that the material exhibits strong diamagnetic response and the transition temperature T_c as inferred from this response is $T_c = 91$ K.

A piece of this material weighing 117·16 mg was loaded in the calorimeter. The results of our heat capacity measurement in the temperature interval $96\,\mathrm{K} \geqslant T \geqslant 77\,\mathrm{K}$ are shown in figures 2 and 3. Figure 2 exhibits the heat capacity of the sample from which the jump ΔC_p in C_p in the neighbourhood of 90 K can be discerned. The thermal spread in the anomaly ΔC_p is due possibly to the inhomogeneities in the material. Figure 3 displays the temperature dependence of C_p/T; ΔC_p can be seen rather clearly in this plot. The value of $\Delta C_p/T_c$ in $HoBa_2Cu_3O_{7-y}$ as inferred from figure 3 is 31 mJ/mol K^2 which should be compared with that in $YBa_2Cu_3O_{7-y}$ reported by Nevitt *et al* (1987)

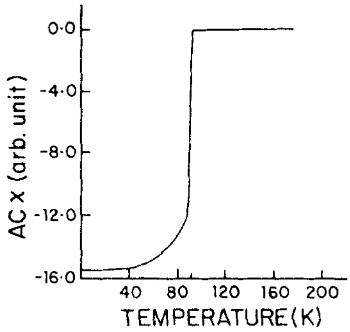

Figure 1. AC susceptibility of a single phase sample of $HoBa_2Cu_3O_{7-y}$. The strong diamagnetic response of the sample (in the neighbourhood of $T = 91$ K) gives the superconducting transition temperature $T_c = 91$ K.

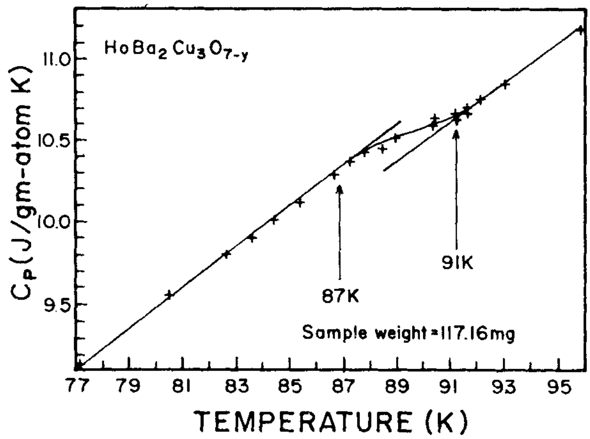

Figure 2. Heat capacity C_p of the sample of $HoBa_2Cu_3O_{7-y}$. The line drawn through the experimental points is a guide to the eye.

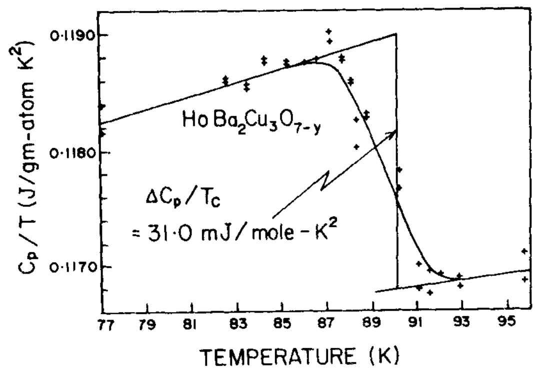

Figure 3. C_p/T of $HoBa_2Cu_3O_{7-y}$. The jump in heat capacity $\Delta C_p/T_c$ can be seen very conveniently.

(= 55 mJ/mol K^2), Inderhees *et al* (1987) (= 45 mJ/mol K^2), Junod *et al* (1987) (= 39 mJ/mol K^2) and Kitazawa *et al* (1987) (= 22 mJ/mol K^2). Reeves *et al* (1987) report $\Delta C_p/T_c = 39$ mJ/mol K^2 in $GdBa_2Cu_3O_{7-y}$. Though the values of $\Delta C_p/T_c$ in $YBa_2Cu_3O_{7-y}$ as reported by various workers differ considerably, it is clear, however, that all of them do see the jump in C_p in the neighbourhood of T_c. In view of this scatter in the values of $\Delta C_p/T_c$ and uncertainty in determining the value of γ (the coefficient of the electronic heat capacity) it is difficult to calculate the number $\Delta C_p/\gamma T_c$ with a reasonable degree of certainty. This forbids a reliable comparison with a theoretical prediction. BCS theory predicts this number to be equal to 1·43 for a weak coupling superconductor. If one could overcome these difficulties, it should be possible to make a definite statement about the validity of one model or the other with regard to the superconducting behaviour in these oxide materials.

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References

Dunlap B D, Nevitt N V, Slaski, Klippert T E, Sungaila Z, McKale A G, Capone D W, Poeppel R B and Flandermeyer B K 1987 *Phys. Rev.* **B35** 7210

Inderhees S E, Salomon M B, Friedmann T A and Ginsberg D M 1987 *Phys. Rev.* **B36** 2401

Junod A, Bezinge A, Cattani D, Cros J, Decroux M, Fischer O, Genoud P, Hoffmann L, Jorda J L, Muller J and Walker E 1987 *Jpn. J. Appl. Phys. Suppl.* **26** 1119

Kitazawa K, Atake T, Ishi H, Sato H, Takagi H, Shinchi Uchida, Saito Y, Fueki K and Tanaka S 1987 *Jpn. J. Appl. Phys.* **26** L748

Malik S K and Vijayaraghavan R 1987 *Reviews of solid state science* (Singapore: World Scientific Publishing Co.) (submitted)

Nambudripad N and Dhar S K 1987 *Pramana – J. Phys.* **29** L433

Nevitt M V, Crabtree G W and Klippert T E 1987 *Phys. Rev.* **B36** 2398

Reeves M E, Citrin D S, Pazol B G, Friedmann T A and Ginsberg D M 1987 *Phys. Rev.* **B36** 6915