MAGNETIC STUDIES OF Pr1Ba2Cu3O7-δ AND La1Ba2Cu3O7-δ

S. Chittipeddi, Y. Song, J. Gaines, W. Farneth, E. Mccarron, A. Epstein

To cite this version:
S. Chittipeddi, Y. Song, J. Gaines, W. Farneth, E. Mccarron, et al.. MAGNETIC STUDIES OF Pr1Ba2Cu3O7-δ AND La1Ba2Cu3O7-δ. Journal de Physique Colloques, 1988, 49 (C8), pp.C8-2141-C8-2142. 10.1051/jphyscol:19888958 . jpa-00229239

HAL Id: jpa-00229239
https://hal.archives-ouvertes.fr/jpa-00229239
Submitted on 1 Jan 1988
MAGNETIC STUDIES OF Pr1Ba2Cu3O7-δ AND La1Ba2Cu3O7-δ

S. Chittipeddi (3) *, Y. Song (1), J. R. Gaines (1), W. E. Farneth (2), E. M. McCarron III (3) and A. J. Epstein (3)

(1) Department of Physics, University of Hawaii, Manoa, Hawaii, U.S.A.
(2) E.I. du Pont de Nemours and Company, Central Research and Development, Wilmington, DE 11898, U.S.A.
(3) Department of Physics, The Ohio State University, Columbus, OH 43210, U.S.A.

Abstract. - We report magnetic susceptibility $\chi^{\text{spin}}(T)$, and magnetic scattering (neutron) studies for the superconducting complex La$_1$Ba$_2$Cu$_3$O$_7$ and the insulating complex Pr$_1$Ba$_2$Cu$_3$O$_7-\delta$. The magnetic susceptibility and scattering measurements on the compound Pr$_1$Ba$_2$Cu$_3$O$_7-\delta$ show no sign of magnetic ordering. For the La$_1$Ba$_2$Cu$_3$O$_7-\delta$ samples we observe only a small change in the Pauli susceptibility and a decrease in the Curie-constant as $T_c$ of the samples is increased.

In compounds of the generic form RBa$_2$Cu$_3$O$_7-\delta$ of which trivalent R ion is used from among yttrium and the rare earths [1, 2], it has been found that $T_c$ for superconductivity is not substantially altered by the presence of the rare earth. The exceptions to this rule are the Pr, Tb and Ce compounds, where the semiconducting behavior of these compounds [3] has been attributed to the valency of the rare earth ions. The incorporation of Pr into the Y-Ba-Cu-O complex leads to drastic decrease in the transition temperature [4] whereas Ce phase segregates into BaCeO$_3$ [5]. This behavior is of particular interest, with respect to the magnetic ordering which occurs in the CuO planes [6, 7]; the reason being that if Pr (in the compound Pr$_1$Ba$_2$Cu$_3$O$_7-\delta$) were in a +4 valence, then a simple valence counting argument would show if $\delta = 0$, then the most of the Cu ions would be in a +2 valence state. The direct observation of (antiferromagnetic) ordering using susceptibility techniques however is difficult due to the magnetic contribution of the Pr ion. The magnetic ordering of the Cu spins in the CuO planes can be studied using elastic neutron scattering techniques. The La$_1$Ba$_2$Cu$_3$O$_7-\delta$ system has been the subject of extensive study by our group; $T_c$ of this system of compounds has not been as high as that reported for the corresponding Y$_1$Ba$_2$Cu$_3$O$_7-\delta$ case [7]. The role of disorder of La/Ba has already been established to be a major reason for the low $T_c$'s in this system [8, 9], but until now no correlation has been made, of the interplay between magnetism and disorder.

In this paper we report the results of magnetic susceptibility and elastic neutron diffraction measurements for Pr$_1$Ba$_2$Cu$_3$O$_7-\delta$ for samples of La$_1$Ba$_2$Cu$_3$O$_7-\delta$ with zero-resistance temperatures of 44 K ($\delta = 0.6$), 55 K ($\delta = 0.4$), and 72 K ($\delta = 0.25$) (see Fig. 1). The La$_1$Ba$_2$Cu$_3$O$_7-\delta$ sample with $T_c$ below 50 K was found to be tetragonal (within experimental error) whereas sample with $T_c$ above 50 K showed orthorhombicity [9]. The magnetic susceptibility measurements were carried out using a Faraday balance [10], and an applied field of 2.25 kG. The measured spin susceptibility was fit to a function of the form $\chi^{\text{spin}} = \chi^0 + \chi^{\text{Pauli}} + \chi^{\text{Curie-Weiss}}(T)$, where $\chi^0$ refers to the sum of the temperature independent core diamagnetism and the Van Vleck paramagnetic terms. The core diamagnetism was obtained by adding the core diamagnetism due to the individual components in this system [11], and the Van Vleck term is assumed to be negligible since La$_3^+$ has a closed shell structure. The Pauli term can hence be obtained by using the infinite temperature intercept in a plot of $\chi^{\text{spin}}$ vs. $1/T$. The density of states at the Fermi energy is obtained from the Pauli susceptibility by using the relation $\chi^{\text{Pauli}} = \mu_B^2 D(\epsilon_F)$ (assuming no Coulomb repulsion). These magnetic measurements together with some of our earlier work [14] establish that as the disorder in the La/Ba case decreases, $T_c$ increases and the degree of localization decreases.

Fig. 1. - Spin Susceptibility $\chi^{\text{spin}}$ vs. temperature, $T$ for La$_1$Ba$_2$Cu$_3$O$_7-\delta$ at a field of 2.25 kG.

* AT & T Bell Labs, Division 5216, 555 Union Blvd., Allentown, PA 18103, U.S.A.
The susceptibility measurements on the Pr$_1$Ba$_2$Cu$_3$O$_{7-\delta}$ samples were carried out at a field of 10.54 kG. When $\chi^\text{spin}$ is fit to an expression of the form $\chi^\text{spin} = \chi^0 + C/(T - \theta)$, we obtain $\alpha \chi^0 = 2.19 \times 10^{-3}$ emu/mol, $C = 1.37$, and $\theta = -5$ K [12]. This rather large value of $\chi^0$ is due to the Van Vleck contribution arising from strong crystal field splittings [12] and can be contrasted with the much smaller Pauli-like susceptibility reported for Y$_1$Ba$_2$Cu$_3$O$_{7-\delta}$ [13].

The elastic neutron diffraction experiments were performed on the triple axis spectrometer at the H4 Satellite beam line at the High Flux Beam Reactor at the Brookhaven National Labs (HFBR). The La$_2$Ba$_2$Cu$_3$O$_{7-\delta}$ system did not show any 3-D magnetic ordering for the superconducting samples, but it is not possible to unambiguously rule out the presence of all 3-D magnetic ordering in the tetragonal $T_c = 44$ K sample due to the presence of impurity peaks (nuclear) of BaCu$_2$O$_2$ which contaminate our data. In Pr$_1$Ba$_2$Cu$_3$O$_{7-\delta}$, the $\delta = 0$ case which had an orthorhombic $a-b$ splitting of 0.02 Å did not show any magnetic ordering even at temperatures as low as 10 K. The absence of magnetic ordering in this system may arise due to changes in the electronic structure caused by Pr which result in destroying the superconductivity. This system did not reveal the presence of either the $(1/2, 1/2, 1/2)$ or $(1/2, 1/2, 1/2)$ type ordering which occurs in the corresponding oxygen deficient Y$_1$Ba$_2$Cu$_3$O$_{7-\delta}$ system [6, 7]. The samples which were characterized in this study had a large fraction of the non magnetic impurity Ba-Pr-O, whose nuclear peak contaminates the $(1/2, 1/2, 2)$ peak, but even with that, it is hard to fully understand the origins of the absence of magnetism in the Cu-O planes in this compound; though the overlap of the Cu 3d and Pr 4f orbitals might be responsible for the absence of superconductivity in this system.

In summary, we have studied the magnetic properties of the La$_2$Ba$_2$Cu$_3$O$_{7-\delta}$ system, and the Pr$_1$Ba$_2$Cu$_3$O$_{7-\delta}$ system. The susceptibility measurements show that as disorder for the La$_2$Ba$_2$Cu$_3$O$_{7-\delta}$ system decreases, the localization decreases and the Pauli susceptibility changes slightly. No evidence for 3-D magnetic ordering in the Cu-O planes has been found for the orthorhombic La$_2$Ba$_2$Cu$_3$O$_{7-\delta}$ samples. The absence of magnetic ordering in the Cu-O planes for the oxygen enriched Pr$_1$Ba$_2$Cu$_3$O$_{7-\delta}$ samples shows that though the Cu valence can be similar to that of Y$_1$Ba$_2$Cu$_3$O$_{7-\delta}$ the presence of the rare earth ion superconductivity is suppressed.

Acknowledgements

This work was supported in part by the Department of Energy Division of Materials Science Grant No. DE-FG02-86ER45271. A000.