Magnetic scattering and superconductivity in $Nd_{1.86}Ce_{0.14}CuO_{4-y}$

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Abstract. $Nd_{1.86}Ce_{0.14}CuO_{4-y}$ is superconducting below about 20 K and electrons are considered to be responsible for superconductivity in these materials as in the case of $Ln_{2-x}Ce_xCuO_{4-y}$ and $Ln_{2-x}Th_xCuO_{4-y}$. Structurally these materials are not very different from the p-type superconductors $La_{2-x}Sr_xCuO_{4-y}$. In both these types of superconductors, the parent compounds are antiferromagnetically-ordered insulators. The induction of holes or electrons by substitution destroys magnetic interactions and brings about superconductivity. Peng and coworkers have studied the resistivity variation of both superconducting and non-superconducting $Nd_{1.85}Ce_{0.15}CuO_{4-y}$ and have found a decrease in resistivity with temperature, obeying a $\ln T$ dependence in the superconducting samples. Such a variation was not seen by them in the nonsuperconducting samples. They ascribe the $\ln T$ variation seen in their superconducting samples to arise from magnetic scattering of electrons. To study whether such an effect exists, $Nd_{1.86}Ce_{0.14}CuO_{4-y}$ was subjected to various annealing conditions and the resistivity behaviour is presented here. Our results differ from those of Peng et al.

Keywords. Electron superconductors; magnetic scattering; $\ln T$ variation; resistivity.

1. Introduction

The discovery of superconductivity in $Nd_{1.85}Ce_{0.15}CuO_{4-y}$ has generated a lot of enthusiasm. This has shown that superconductivity in the Cu–O based super-conductors can arise both due to electrons and holes. The parent compound La_2CuO_4 for p-type superconductors and Nd_2CuO_4 for n-type superconductors have structural similarities. Both of them are antiferromagnetically-ordered insulators. Partial substitution of Sr/Ba for La in La_2CuO_4 or Ce/Th for Nd in Nd_2CuO_4 kill antiferromagnetic ordering and induces superconductivity.

Peng et al (1989) interpreted $\ln T$ dependence of resistivity found by them in their superconducting samples as arising from magnetic scattering of electrons. Such a $\ln T$ term was not found by them in the non-superconducting samples. On the other hand, resistivity studies on single crystals by Tarascon et al (1989) and Hidaka and Suzuki (1989) have shown that resistivity increases as temperature increases, both along and perpendicular to the a–b plane. It is, therefore, possible that this $\ln T$ dependence may not be intrinsic to the material but may arise from intergranular semiconducting layers. In order to find whether such a $\ln T$ dependence exists, and its dependence on annealing conditions, we have carried out systematic studies on $Nd_{1.86}Ce_{0.14}CuO_{4-y}$. These are reported in this paper.

2. Experimental details

Stoichiometric proportions of high purity (> 4N) Nd_2O_3, CeO_2 and CuO were mixed thoroughly and heated in air for 24 h at 900°C. The reacted powder was ground well, pressed into pellets and sintered at 1050°C for 16 h. Figure 1 shows the XRD of the material. All the peaks of the XRD can be indexed for the tetragonal structure of the
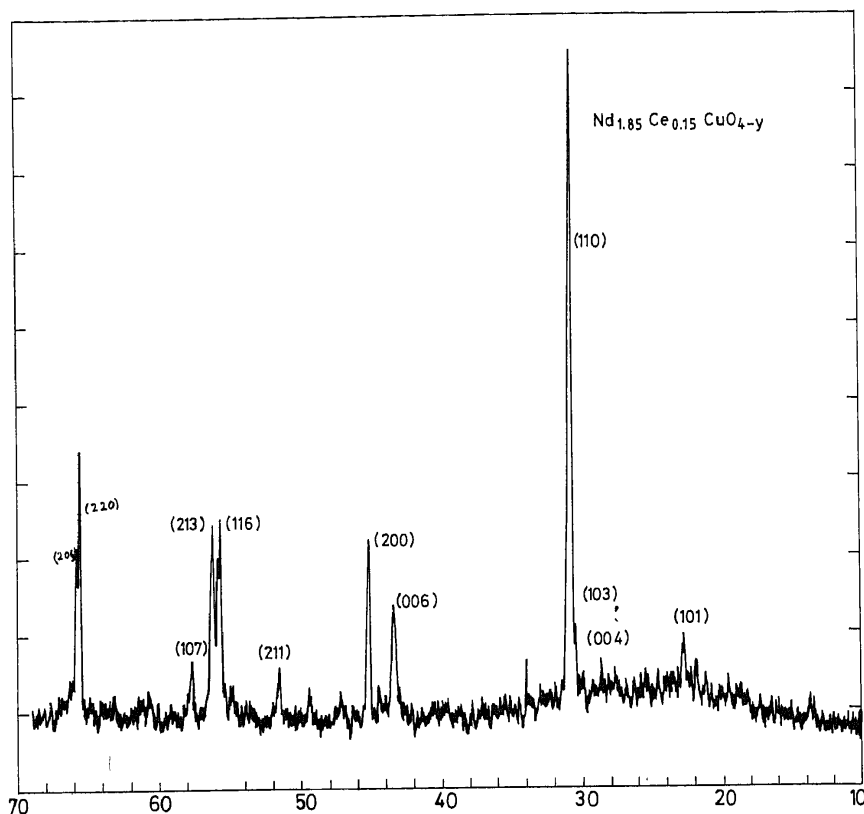
Figure 1. XRD of $Nd_{1\cdot86}Ce_{0\cdot14}CuO_{4-y}$.

single phase compound $Nd_{1\cdot86}Ce_{0\cdot14}CuO_{4-y}$. The lattice parameters are: $a = 3\cdot958$ Å and $c = 12\cdot097$ Å. The as-prepared sample was not superconducting and it was subjected to the annealing treatments described below to induce superconductivity:

(a) The pellet was heated at 900°C for 12 h in flowing He.

(b) The pellet was heated at 850°C for 2 h under continuous evacuation at a pressure of 10^{-5} torr and then slow-cooled to room temperature.

(c) The same procedure as in (b) except that the duration of heating under vacuum was for 6 h.

The resistivity of the samples (a), (b) and (c) were measured by the conventional four-probe technique from room temperature down to 4·2 K.

3. Results and discussion

Figure 2 shows the temperature variation of resistivity of samples (a), (b) and (c). Sample (a) was not superconducting down to 4·2 K. Sample (b) showed a steep drop in resistivity at 28·3 K. However, the resistivity at 4·2 K was still 50 μohm-cm. Sample (c) showed a superconducting onset at 25·8 K and a zero resistance at 15·1 K. We plotted

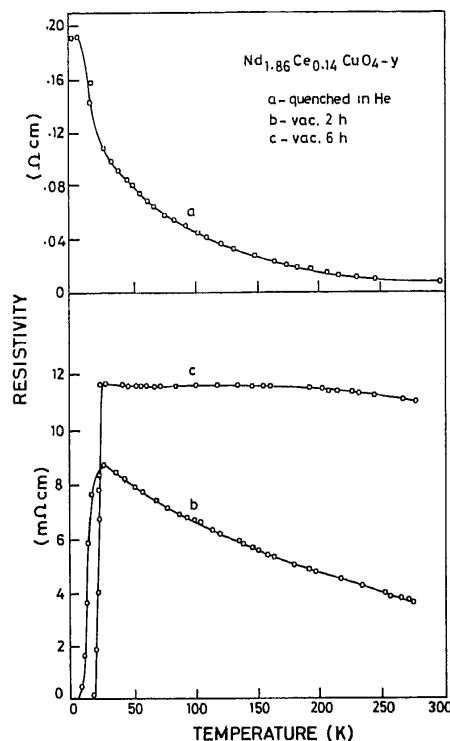**Figure 2.** Resistivity versus temperature of $Nd_{1.86}Ce_{0.14}CuO_{4-y}$.

resistivity versus $\ln T$ for all these samples. Figure 3 shows such a plot. It is seen that there is a temperature region in which the resistivity shows a logarithmic dependence. Writing,

$$\rho = \rho_0(1 - \alpha \ln T) \tag{1}$$

the values of ρ_0 and α are collected in table 1 for all these samples. In table 1, we also give the temperature range over which this relation is valid. It is seen that the coefficient α decreases from sample (a) to sample (c). For the two samples (a) and (b), α is around 0·15, but it goes to zero for sample (c). This indicates that the strength of the $\ln T$ term is more for the non-superconducting samples, a result which contrasts with the result of Peng *et al* (1989).

Since doing this work, we have carried out similar studies for Ce concentrations 0·15, 0·16 and 0·18. For the first two compositions, the annealing treatment was varied to induce superconductivity. The sample with Ce concentration 0·18 showed a metallic behaviour. The samples with Ce concentrations 0·15 and 0·16 again showed a $\ln T$ behaviour and the parameters ρ_0 and α are also collected in table 1 (Vijayashree *et al* 1990). It is again seen that in all the compositions, the strength of the $\ln T$ term decreases as superconductivity is induced in these samples.

If the $\ln T$ term arises from magnetic scattering, these results indicate that superconductivity sets in only if the magnetic scattering becomes weak. On the other hand, one cannot rule out the possibility that this $\ln T$ term arises from a semiconduct-
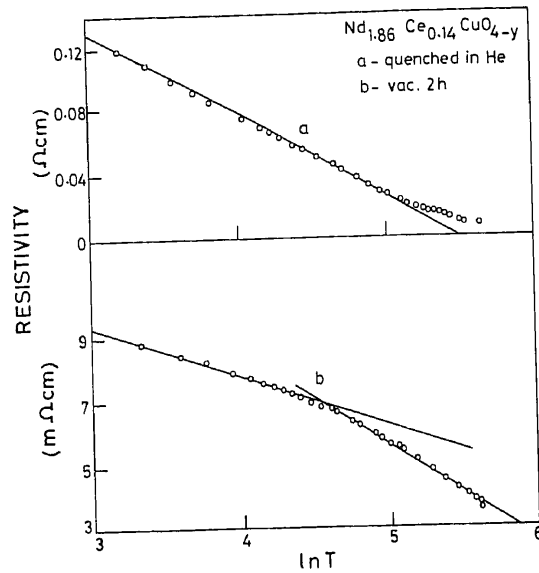
Figure 3. Logarithmic temperature dependence of resistivity of $Nd_{1.86}Ce_{0.14}CuO_{4-y}$.

Table 1. Parameters in the fit to equation (1) of the temperature dependence of the resistivity of the samples of $Nd_{2-x}Ce_xCuO_{4-y}$

Sample no.	x	Annealed in	ρ_{RT} (in milli ohm-cm)	ρ_0 (in milli ohm-cm)	α	Temperature range (in K)
a	0·14	Helium	6.95	285·7	0·182	25–150
b	0·14	Vacuum 2h	3·65	⎰ 14·77	0·120	36– 93
				⎱ 21·32	0·147	121–276
c	0·14 (sc)	Vacuum 6h	11·00	11·50	~0	30–220
a	0·15	Oxygen	114·9	15,560	0·188	50–150
b	0·15	Argon	16·7	102·7	0·149	47–273
c	0·15 (sc)	Vacuum 6h	2·47	3·78	0·069	70–140
a	0·16	—	30·1	1,154	0·184	25–150
b	0·16	Vacuum 2h	3·0	3·165	0·054	27– 95
c	0·16	Vacuum 6h	6·97	6·97	~0	27–278

ing layer at the grain boundaries. If so, the decrease in α as superconductivity is induced must be interpreted as a change in the intergranular boundary from semiconducting to metallic.

4. Conclusions

Resistivity has been studied on single-phase samples of $Nd_{1.86}Ce_{0.14}CuO_{4-y}$, subjected to various annealing treatments. There is a temperature region in which the resistivity of the non-superconducting samples decreases linearly with $\ln T$. Measurements for this concentration of Ce and for other concentrations of Ce indicate clearly that superconductivity sets in only when the coefficient of the $\ln T$ term is reduced. These results are in disagreement with the results of Peng *et al* (1989). These results may either indicate that superconductivity is seen when the intergranular semiconducting layers become metallic or when the magnetic scattering is suppressed.

Acknowledgements

References

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