On the electron superconductors $\text{Nd}_{2-x}\text{Ce}_x\text{CuO}_{4-y}$

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Abstract. The compounds $\text{Nd}_{2-x}\text{Ce}_x\text{CuO}_{4-y}$ for $x = 0$ to 0.18 have been synthesized and characterized. Superconductivity is observed for $x = 0.14$ to 0.16. The normal state resistivity and d.c. magnetic susceptibility of these compounds have been measured in the range 4.2 to 300 K. Both the superconducting and non-superconducting compounds exhibit a Curie-Weiss behaviour at high temperatures, giving an effective moment for the Nd ion close to the free-ion value.

Keywords. Electron superconductors; superconductors; magnetic properties.

1. Introduction

The newly discovered electron superconductors based on the $\text{Nd}_{2-x}\text{Ce}_x\text{CuO}_{4-y}$ compounds by Tokura *et al* (1989) are significant from the point of view of understanding the basic mechanism of superconductivity in the copper oxide superconductors, and how the nature of “doping” affects the superconducting properties. A comparison of both the normal state and superconducting properties of the electron superconductors with those of the hole superconductors is essential to see if new mechanisms have to be invoked to understand the behaviour of these new superconductors. With this in mind, a systematic study of the superconducting and normal state properties such as resistivity, susceptibility (both a.c. and d.c.) has been undertaken on a wide range of Ce concentrations in $\text{Nd}_{2-x}\text{Ce}_x\text{CuO}_{4-y}$ and is reported in this paper.

2. Experiments

The compounds $\text{Nd}_{2-x}\text{Ce}_x\text{CuO}_{4-y}$ for $x = 0$ to 0.18 were prepared by solid-state reaction starting from high purity Nd_2O_3 , CeO_2 and CuO . The mixture was first heated at 900 C for 24 h and then at 1100 C for 12 h. The resulting powder was ground thoroughly and pelletized. The pellets were sintered at 1150 C for 12 h, followed by a quench to room temperature in air. The pellets were then annealed at 1000 C in a flow of argon to achieve the oxygen deficiency required for superconductivity. The X-ray powder patterns taken on these samples showed them to be single phase and the lattice parameters obtained agree with those published, showing a decrease in the c parameter with increasing cerium content.

Resistivity was measured on the argon-annealed samples from 300 K to 4.2 K to study the normal-state resistance as well as to obtain the superconducting transition temperatures.

Magnetic susceptibility was measured on all the compounds to study the superconducting transitions as well as their normal state magnetic properties. Both a.c. and d.c. magnetic susceptibilities were measured first to obtain the superconducting transitions. The d.c. magnetic susceptibility in the normal state was measured using a Faraday Balance in a field of 2 kOe, from 4.2 K to 300 K.

3. Results and discussion

Figure 1 shows the resistivity plots for all the cerium-substituted compounds. The resistivity behaviour of these compounds is quite unlike that of the $\text{YBa}_2\text{Cu}_3\text{O}_7$ compounds. The parent compound $\text{Nd}_2\text{CuO}_{4-y}$ is a semiconductor but with substitution of Ce, a transition from a semiconductor to metallic phase takes place. The resistivity of all the compounds studied is almost temperature-independent at high temperatures, but all the compounds show a rise in the resistivity beginning around

Figure 1. Resistivity vs temperature plots for the compounds $\text{Nd}_{2-x}\text{Ce}_x\text{CuO}_{4-y}$. Superconductivity is observed for $x = 0.14, 0.15$ and 0.16 .

Figure 2. Magnetic susceptibility (d.c.) of $\text{Nd}_{1.85}\text{Ce}_{0.15}\text{CuO}_{4-y}$, showing the superconducting transition at 20 K in a field of 20 G.

50 K, followed by a drop at lower temperatures, even in the case of the non-superconducting compounds. Superconductivity is observed only for x between 0.14 and 0.16 (see figure 1). Figure 2 shows the d.c. magnetic susceptibility of $\text{Nd}_{1.85}\text{Ce}_{0.15}\text{CuO}_{4-y}$, measured over the superconducting transition in an external field of 20 G.

The plots of inverse susceptibility versus temperature are shown in figure 3. The susceptibility variation with temperature follows a Curie-Weiss behaviour at high temperatures in all the compositions studied, but there is a deviation from linearity in the inverse susceptibility vs T plots below ~ 50 K. This is similar to what has been reported by Seaman *et al* (1989) in the non-superconducting phase $\text{Nd}_2\text{CuO}_{4-y}$. It is now established that there is magnetic ordering of the Nd ions at ~ 1.8 K in the parent compound and that this order persists in the superconducting phases as well (Skanthakumar *et al* 1989). The downturn in the inverse susceptibility plots is therefore indicative of this ordering, and of the presence of crystal field effects. The effective moment obtained for the Nd ion after a fit to the high temperature linear portion of the

Figure 3. Magnetic susceptibility (d.c.) plots for the whole series $\text{Nd}_{2-x}\text{Ce}_x\text{CuO}_{4-y}$, $x = 0$ to 0.18. The solid line is a fit to Curie-Weiss law in the temperature range 100 to 300 K.

plots is close to the free ion moment value, $3.6 \mu_B$, for all values of x . The intercept θ obtained from the fit is also given. The high temperature antiferromagnetic ordering of the Cu which occurs at ~ 240 K is, however, not shown in the susceptibility of the non-superconducting Ce-doped compounds.

4. Conclusions

The resistivity measurements on the argon-annealed $\text{Nd}_{2-x}\text{Ce}_x\text{CuO}_{4-y}$ compounds show that their normal state resistivity is not linear with temperature as is in the case of the $\text{YBa}_2\text{Cu}_3\text{O}_7$ superconductors. The susceptibility measurements indicate the dominance of the magnetic contribution arising due to the Nd ions in both the superconducting and non-superconducting compounds of the series.

References

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