Superconducting and normal state properties of $Nd_{1.85}Ce_{0.15}CuO_{4-y}$

J.W. Chen and Wen-Chien Chou

Department of Physics
National Taiwan University
Taipei, Taiwan, R.O.C.

Ac electrical resistance $R(T)$ measurements have been performed on the electron-doped superconductor $Nd_{1.85}Ce_{0.15}CuO_{4-\delta}$ samples which have been prepared under various conditions. It was found that both the normal state resistance behavior and the superconducting transition temperature vary significantly with the sample preparation conditions. Superconductor which exhibits metallic behavior in the normal state resistance and a superconducting transition starting from 24 K was observed in the samples which have been prepared under helium atmosphere. Dc magnetization measurement reveals that the diamagnetic signal shows up at $T = 23$ K.

I. INTRODUCTION

The recently found electron-doped superconductors $Ln_{2-x}Ce_xCuO_{4-y}$ ($Ln = Pr, Nd, Sm$ and Eu)^{1,2} $Ln_{2-x}Th_xCuO_{4-y}$ ($Ln = Pr$ and Nd)³ with the superconducting transition temperature up to 24 K have attracted a lot of research interest in these systems. Until now, it has been found that the properties in these systems are very sensitive to the sample preparation conditions and all the electron-doped superconductors found are semiconducting in the normal state. Using ac electrical resistance measurement on the $Nd_{1.85}Ce_{0.15}CuO_{4-y}$ samples prepared under various procedures we have found that $Nd_{1.85}Ce_{0.15}CuO_{4-y}$ superconductor can exhibit metallic behavior in the normal state.

II. EXPERIMENTAL DETAILS

The samples used in this study were prepared by solid state reaction from high purity Nd_2O_3 (99.9 %), CeO_2 (99.99 %) and CuO (99.9 %). Two groups of samples have been made. In group I, stoichiometric mixtures of the starting materials were ground together and sintered in air at 900°C for 1 day and furnace cooled to room temperature. The resulting powders were pressed into pellets and fired in various gases at atmosphere (Ar, He, N_2, O_2 and air) at 900°C for 1 day and furnace cooled to room temperature (For N_2 atmosphere, a quenched sample was made also). These

pellets were cut into bars for ac electrical resistance measurements. In group II, the mixture powders were ground together and sintered in air at 900°C for ~ 20 hours and removed from the furnace and quenched in air to room temperature, reground again and fired in air at 900°C for ~ 20 hours and quenched to room temperature. The resulting powders were then pressed into pellets and fired in air at 1100°C for ~ 18 hours, and quenched to room temperature. The pellet were then sintered in He or N_2 atmosphere at 1000°C for ~ 18 hours and furnace cooled to room temperature in He or N_2 flow. Ac electrical resistance $R(T)$ measurements on bar-shaped samples were performed with the conventional four-wire technique using a Linear Research Model LR 400 ac resistance bridge operating at a frequency of 16 Hz with platinum and germanium thermometers as the temperature sensors. Dc magnetization measurements on the metallic sample were performed using the Quantum Design MPMS with a field of 20 Gauss.

III. RESULTS AND DISCUSSION

The normalized ac electrical resistance $R(T)/R(280\text{ K})$ as a function of temperature T data for the group I samples are shown in Fig. 1. The samples annealed in N_2 and Ar atmosphere exhibit semiconducting behavior and $R(T)/R(280\text{ K})$ starts to drop at 24 K, indicates that there are superconducting grains in the

FIGURE 1

$R(T)/R(280K)$ vs T curves for $Nd_{1.85}Ce_{0.15}CuO_{4-y}$.

samples. The sample annealed in N_2 and furnace cooled has the best result, but the transition is still uncompleted down to 4.2 K. The samples annealed in He , air, and O_2 atmospheres show similar $R(T)/R(280 K)$ behavior and $R(T)/R(280 K)$ increases rapidly as the temperature decreases from room temperature.

Shown in Fig. 2 are $R(T)/R(280 K)$ vs T curves for group II samples and dc magnetization curves as a function of temperature for the sample annealed under He atmosphere. The sample annealed in N_2 at $1000^\circ C$ still exhibit semiconducting behavior in the normal state, with $R(T)/R(280 K)$ increases with decreasing T and starts to drop at 23 K. The transition is still uncompleted down to 4.2 K. So it seems that the properties of the sample is not very sensitive to the annealing temperature when it is annealed in the N_2 atmosphere. For the He -annealed (at $1000^\circ C$) sample, the normal state resistance decreases monotonic with decreasing temperature and $R(T)/R(280 K)$ reaches a value of ~ 0.7 at 24 K. The abrupt drop in $R(T)$ at 24 K reveals the occurrence of superconductivity in this sample. The midpoint transition temperature T_c (50

FIGURE 2

(a) $R(T)/R(280K)$ vs T for He -annealed and N_2 -annealed samples of $Nd_{1.85}Ce_{0.15}CuO_{4-y}$

(b) M vs T for the He -annealed $Nd_{1.85}Ce_{0.15}CuO_{4-y}$

%) is 19 K and the transition width $\Delta T_c(T_c(90\%) - T_c(10\%))$ is about 9 K. This is quite different from what have been reported that $Nd_{1.85}Ce_{0.15}CuO_{4-y}$ shows semiconducting behavior in the normal state. Shown in Fig. 2 (b) are the dc magnetization curves for this He -annealed sample with zero field cooling (diamagnetic screening) and with a 20 Gauss field cooling (Meissner effect). The temperature at which both diamagnetic screening and Meissner effect start to appear is 23 K, in consistent with the result of $R(T)$ measurement.

REFERENCES

1. Y. Tokura, H. Takagi and S. Uchida, Nature 337 (1989) 345.
2. J.T. Markert, E.A. Early, T. Bjornholm, S. Ghamaty, B.W. Lee, J.J. Neumeier, R.D. Price, C.L. Seaman, and M.B. Maple, Physica C 158 (1989) 178.
3. J. T. Markert and M. B. Maple, Solid State Commun. 70 (1989) 145.