Superconductivity in the $RE_{1-x}Cd_xBa_2Cu_3O_{7-\delta}$ ($RE = Y, Nd, Sm, Gd, Dy, Ho, Yb$) systems

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Ac electrical resistance $R(T)$ and powder X-ray diffraction measurements have been performed on the pseudo-quaternary systems $RE_{1-x}Cd_xBa_2Cu_3O_{7-\delta}$ with $RE = Y, Nd, Sm, Gd, Dy, Ho$ and Yb for $0 \leq x \leq 1.0$. Powder X-ray diffraction patterns reveals that although impurity phase shows up in the samples as Cd concentration x increases, but the majority phase of the samples are of the 123 perovskite oxygen deficiency type structure. Substitution of the RE elements with Cd produces the effect of changing the normal state resistance from metallic behavior to semiconducting behavior as x increases for all system. However, the effects of Cd concentration x on the superconducting transition temperature T_c are different for different RE elements and can be roughly assorted into two different types. In one case, increasing Cd concentration x produces no appreciable effect on T_c for $x \leq 0.5$ for RE elements such as Y, Gd and Ho . While for $RE = Dy, Nd$, T_c decreases monotonically as x increases.

I. INTRODUCTION

There have been many experimental studies of the chemical substitution effect on the 90 K superconductor $YBa_2Cu_3O_{7-\delta}$ by replacing Y, Ba or Cu with other elements. Most of the study leads to the results of changing the samples from orthorhombic to tetragonal structure as well as destroying the superconductivity as the doping concentration increases. Recently, we studied the pseudoquaternary system $Y_{1-x}Cd_xBa_2Cu_3O_{7-\delta}$ for $0 \leq x \leq 1.0$ and found that although the sample becomes tetragonal for $x \geq 0.4$, T_c remains essentially unchanged up to $x \approx 0.6^2$. In this report, we report our experimental data on the $RE_{1-x}Cd_xBa_2Cu_3O_{7-\delta}$ system with $RE = Y, Nd, Sm, Gd, Dy, Ho$ and Yb .

II. EXPERIMENTAL DETAILS

The samples used in this study are prepared by solid state reaction method. Appropriate amount of RE_2O_3 (99.99%), $BaCO_3$ (99.9%), CuO (99.9%) and CdO (99.95%) powders were mixed together, pulverized and heated in the oven at 900°C for one day in air. The samples were then pulverized again and then pressed into pellets. These pellets were then sintered in O_2 atmosphere between 880°C and 930°C, depend-

ing on RE and x , for one day and slowly cooled down to room temperature in flowing O_2 . Ac electrical resistance $R(T)$ measurements on bar-shaped samples are 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. The X-ray diffraction data were obtained using a Phillips XRD PW 1729 powder diffractometer utilizing $Cu K\alpha$ radiation.

III. RESULTS AND DISCUSSION

X-ray powder diffraction pattern for the $RE_{1-x}Cd_xBa_2Cu_3O_{7-\delta}$ systems reveals that the amount of the impurity phases in the samples grows as Cd concentration x increases. However, the majority phase of the samples are of the perovskite oxygen deficiency type structure for $x \leq 0.6$. Moreover, the crystal structure changes from orthorhombic to tetragonal structure as x increases. For example, tetragonal structure is obtained at $x \geq 0.4$ and $x \geq 0.5$ for $RE = Y^2$ and Gd , respectively.

Normalized electrical resistance $R(T)/(300 K)$ data for the $Ho_{1-x}Cd_xBa_2Cu_3O_{7-\delta}$ system with $0 \leq x \leq 1.0$ are plotted in Fig. 1. For $x=0$, $R(T)/R(300 K)$ de-

FIGURE 1

$R(T)/R(300\text{ K})$ vs T curves for $Ho_{1-x}Cd_xBa_2Cu_3O_{7-\delta}$.

creases linearly with decreasing T in the normal state and becomes superconducting at $T \approx 91\text{ K}$ with a superconducting transition width $\Delta T_c \sim 1.5\text{ K}$. As x increases, $R(T)/R(300\text{ K})$ decreasing rate above T_c starts to decrease. For $x \geq 0.6$, $R(T)/(300\text{ K})$ changes from metallic behavior to semiconducting behavior. T_c and ΔT_c remain essentially unchanged up to $x \sim 0.4$. For $x = 0.6$, the transition curve shifts to lower temperature and the transition width gets broadened. Superconductivity was destroyed at $x \sim 0.8$. For $RE = Y$ and Gd , similar behavior in $R(T)$ vs x curves was obtained.

The superconducting transition temperature T_c as a function of Cd concentration x for $Dy_{1-x}Cd_xBa_2Cu_3O_{7-\delta}$ and $Ho_{1-x}Cd_xBa_2Cu_3O_{7-\delta}$ are plotted in Fig. 2 with solid circles represent T_c 's and vertical bars represent ΔT_c 's. For $RE = Dy$ (and similarly Nd, Sm, Yb), T_c starts to drop for $x \geq 0.2$ and superconductivity is destroyed at $x \approx 0.8$. While for $RE = Ho$ (and similarly Y and Gd), T_c remains essentially unchanged up to $x \approx 0.6$. The reason for two distinct types of behavior observed upon substituting Cd for RE in the

FIGURE 2

T_c and ΔT_c as a function of Cd concentration x for $Dy_{1-x}Cd_xBa_2Cu_3O_{7-\delta}$ and $Ho_{1-x}Cd_xBa_2Cu_3O_{7-\delta}$

$REBa_2Cu_3O_{7-\delta}$ systems may due to the sample preparation problem. Investigations for characterizing the relation between annealing conditions and the sample properties are in progress. Preliminary dc magnetization measurements reveal that the diamagnetic signals at $T \approx 90\text{ K}$ decrease monotonically with increasing x . This indicates that the amount of superconducting grains decreases as RE is replaced by Cd . Which leads to a gradual change of the normal state resistance from metallic to semiconducting behavior as x increases and rapid dropping in T_c above certain value of x when the amount of superconducting grains in the samples is not enough for coupling a superconducting path between the grains through the samples.

REFERENCES

1. M.K. Wu, J.R. Ashburn, C.T. Torng, P.H. Hor, R.L. Meng, L. Gao, Z.J. Huang, Y.Q. Wang, and C.W. Chu, Phys. Rev. Lett. 58 (1987) 908.
2. J.W. Chen and C.F. Chen, Solid State Commun. 69 (1989) 1079.