

Comparative Study of Ce, Eu, and Gd Substituted High T_c Superconducting BISCO2223 Compounds

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ABSTRACT

We have studied the high T_c superconducting properties of rare substitution in $\text{Bi}_{1.7}\text{Pb}_{0.3}\text{Sr}_2\text{Ca}_{2-x}\text{RE}_x\text{Cu}_3\text{O}_{10+\delta}$ ($\text{RE} = \text{Ce, Eu and Gd}$) system with $x = 0.00, 0.02, 0.04, 0.08$ and 0.1 by structural, electrical and magnetic properties. The substitution of rare earth (Ce, Eu and Gd) for Ca has been found to drastically change the superconducting properties of the system. The X-ray diffraction studies of these compounds indicates decrease in the c-parameters with increased substitution of rare earth at Ca site and volume fraction of high T_c Bi_{2223} superconducting phase decreases whereas low T_c Bi_{2212} phase increases. A.C. Magnetic susceptibility of these compounds shows that the diamagnetic superconducting transition temperature (on set) varies from 109K to 48K for $x = 0.00, 0.02, 0.04, 0.08$ and 0.1 concentration. Electrical conductivity of these compounds has been studied at high temperature and room temperature. The present investigation shows that critical temperature decreases with increase in rare earth concentration. The Superconducting samples have metallic behavior at room temperature.

Key words: Superconductivity, High T_c , Rare Earth (Ce, Eu and Gd), Electrical and Magnetic properties.

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INTRODUCTION

In the Bi-based system three phases are observed with the general formula $\text{Bi}_2\text{Sr}_2\text{Ca}_{n-1}\text{Cu}_n\text{O}_y$ where $n = 1$ (2212), $n = 2$ (2212), $n = 3$ (2223), with corresponding superconducting temperature of 10K, 85K and 110K respectively. These phases were isolated by

Chu et al in 1988 [1-2], but $n = 3$ phase is very difficult to prepare in pure form as it undergoes a change to the 2212 (85K) phase. Partial substitution of Pb for Bi has been found to help the growth of the 2223 phase [3-5]. In many high T_c superconducting families of compounds, the rare-earth (Ce, Eu and Gd) plays an important role in establishing the proper structure. The substitution Ca^{2+} (divalent) by trivalent rare-earth elements in $\text{Bi}_2\text{Sr}_2\text{Ca}_1\text{Cu}_2\text{O}_{4+\delta}$ (2212) causes a drastic changes in carrier concentration and results in transition from superconductor to an insulator [6-10]. Many reasons have been suggested for decrease in the carrier concentration such as structural modulations or change in oxygen stoichiometry or change in Cu valency or both [11-13]. The magnetic interaction of the rare-earth ions with electrons/holes responsible for superconductivity is generally found to be very weak in this system so that superconductivity is not affected by presence of rare-earth ions otherwise acts as pair breaking in many systems [14-16].

The transition temperature of the system decreases with rare earth substitution, when percentage of the dopant is increased. We have substituted rare earths with very small concentration (0.00 to 0.1) in the lead-doped Bi-2223 system. The structural, electrical and magnetic properties are studied as a function of rare earth (Ce, Eu, and Gd) substitution. X-ray diffraction of these compounds were performed and variation of c -parameter has been studied. Here the electrical and Magnetic properties of rare earth substitution of $\text{Bi}_{1.7}\text{Pb}_{0.3}\text{Sr}_2\text{Ca}_{2-x}\text{RE}_x\text{Cu}_3\text{O}_{10+\delta}$ system with $x = 0.00, 0.02, 0.04, 0.08$ and 0.1 concentration is discussed. The room temperature behavior of these samples has been studied.

EXPERIMENTAL

The samples of the rare earth (Ce, Eu and Gd) substitution in $\text{Bi}_{1.7}\text{Pb}_{0.3}\text{Sr}_2\text{Ca}_{2-x}\text{RE}_x\text{Cu}_3\text{O}_{10+\delta}$ system with concentration $x = 0.00, 0.02, 0.04, 0.08$ and 0.1 were prepared by conventional solid state reaction route. Stoichiometric proportions of starting materials as Bi_2O_3 , PbO , SrCO_3 , $(\text{Ce}_2\text{O}_3/\text{Eu}_2\text{O}_3/\text{Gd}_2\text{O}_3)$ and CuO were taken. Then the powders were mixed and ground for 3 hours to each system in agate and mortar pestle and precalcined at 800°C for 24 hour. The calcined powders were ground and recalcined again at 810°C for 36 hours. The mixer was grounded again and pressed into pellets. The samples were sintered at 240 hours (10 days) for each rare earth system and annealed by furnace cooling to room temperature. Bi_{2223} phase is very sensitive for sintering temperature so care has to be taken to maintain particular temperature. The samples were analyzed by XRD to measure variation of c -parameter, volume fraction and volume cell. AC susceptibility χ and variation of critical temperature T_c of the samples were performed and interpreted in terms of structural, electric and magnetic properties of rare earth (Ce, Eu and Gd) substitution for different concentration in BiSCCO_{2223} compounds.

RESULT AND DISCUSSION

The Structural, Electrical and Magnetic properties of rare earth substitution at Ca site in $\text{Bi}_{1.7}\text{Pb}_{0.3}\text{Sr}_2\text{Ca}_{2-x}\text{RE}_x\text{Cu}_3\text{O}_{10+\delta}$ system with $x = 0.02, 0.04, 0.08$ and 0.1 high T_c superconducting compounds shows that change in c -parameter, volume fraction and volume cell shown in table 1. The lattice parameters calculated from XRD of Ce, Eu and Gd substituted in Bi_{2223} compounds indicate that these rare earths disturb the structure of the pure phase and it shows very low solubility limit of rare earth in high T_c (2223) phase. The substitution of trivalent rare earth

element for divalent Ca really causes the decrease of the carrier concentration. Concentration versus c- parameter, volume cell and volume fraction decreases with concentration shown in Table1. We conclude that different rare earth substitution at divalent Ca site neutralize hole from adjacent Cu-O plane.

The results of the resistance have shown that the rare earths substitution for Ca increases the resistivity of compounds with increase in dopant concentration. The $T_c(\text{onset})$ and $T_c(0)$ also decreases. The drop in $T_c(0)$ is more in Ce and Gd doped samples than Eu doped samples. In present investigation T_c of the Ce doped compound drastically decreased Fig.1. The hole filling is prominent in Ce substitution at Ca site as compared to Eu. At room temperature, the resistivity of all the samples increased as concentration x increases and these samples are metallic in nature.

A.C. susceptibility of rare earth substitution for Ca in BiSCCO_{2223} compounds have shown that depresses in superconducting properties as $T_c(\text{onset})$, $T_c(0)$ and superconducting volume. In susceptibility the variation of T_c is agreement with resistance data. The magnetic interaction is absent i.e. $s=0$ in Eu doping. In Gd magnetic interaction is present. Substitution of Ca in Bi_{2223} decreases the superconducting volume Fig.1.

Table1. Volume fraction, c-parameter, volume cell and room temperature resistivity of rare earth substitution in BiSCCO_{2223} system.

RE Conc. x	Volume fraction			C-parameter (\AA^0)			Volume cell (\AA^3)			Room Temp. (ρ) mohm-cm		
	Ce	Eu	Gd	Ce	Eu	Gd	Ce	Eu	Gd	Ce	Eu	Gd
0.00	65	65	67	37.010	37.223	37.000	1079.21	1089.21	1078.92	16	11	06
0.02	48	50	47	36.983	37.174	36.961	1078.42	1086.81	1076.58	25	14	13
0.04	36	40	30	36.942	37.102	36.894	1076.43	1083.89	1073.83	36	21	23
0.08	17	16	14	36.918	37.010	36.775	1075.33	1079.18	1069.18	55	29	35
0.1	00	00	00	36.894	36.920	36.698	1073.84	1076.18	1066.15	60	36	41

CONCLUSION

An analogous study was performed on rare earths (Ce, Eu and Gd) substituted $\text{Bi}_{1.7}\text{Pb}_{0.3}\text{Sr}_2\text{Ca}_{2-x}\text{RE}_x\text{Cu}_3\text{O}_{10+\delta}$ system for ($x = 0.00, 0.02, 0.04, 0.08$ and 0.1). We observed that the concentration of RE increased, the c- parameter, volume cell, volume fraction, $T_c(\text{onset})$, $T_c(0)$ and superconducting volume decreases whereas resistivity of compounds increases. The critical temperature T_c also decreases with increase in concentration of rare earths at Ca site. In susceptibility the variation of T_c is agreement with resistance data. The magnetic interaction is absent in Eu and it is present in Gd. The Gd has paramagnetic nature. Hence hole filling and magnetic pair breaking is possible. At room temperature, the resistivity of all the samples increased as concentration x increases and these samples show metallic nature. We conclude that as rare earths concentration x increases, the drastically suppression of superconductivity takes place.

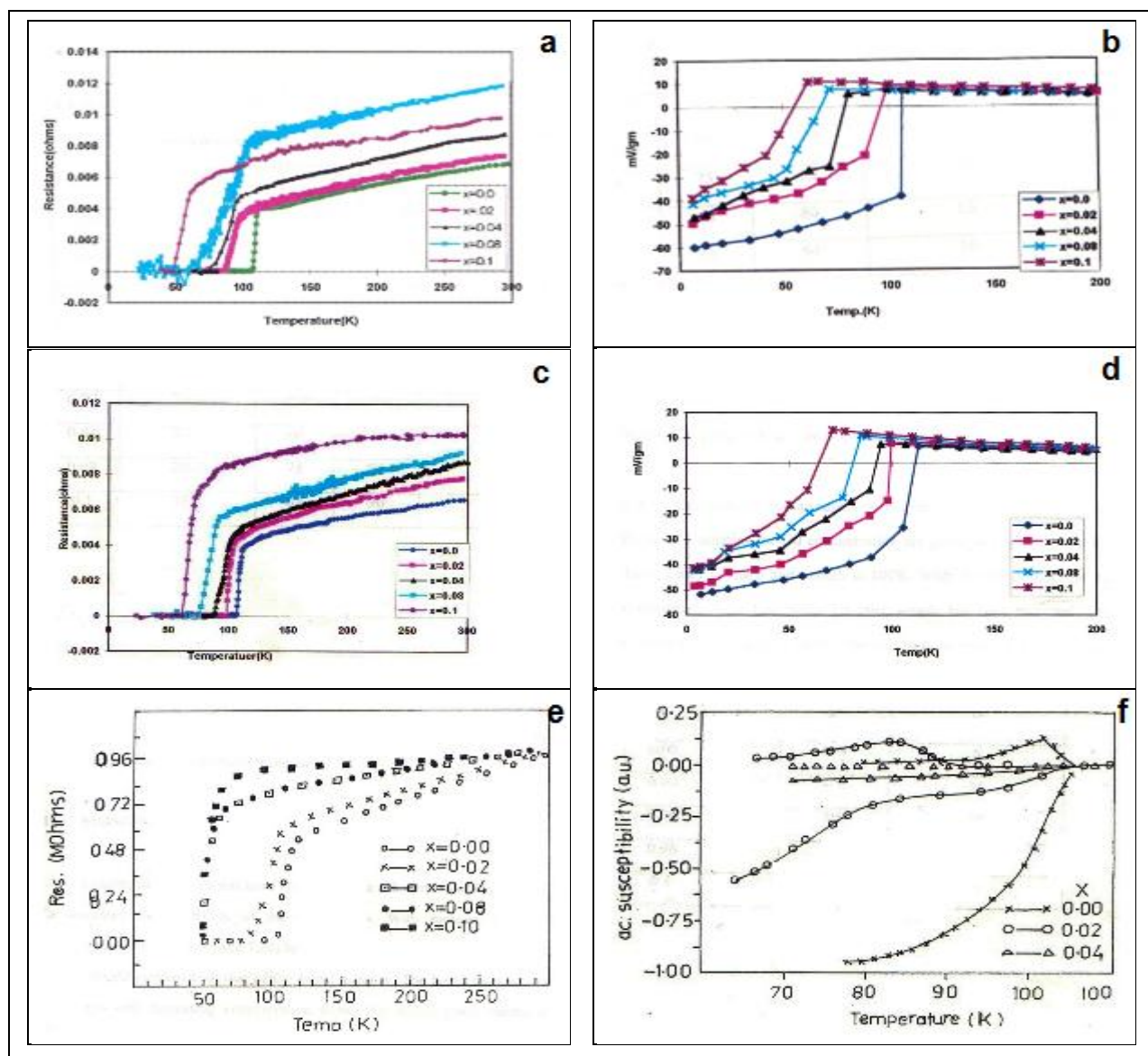
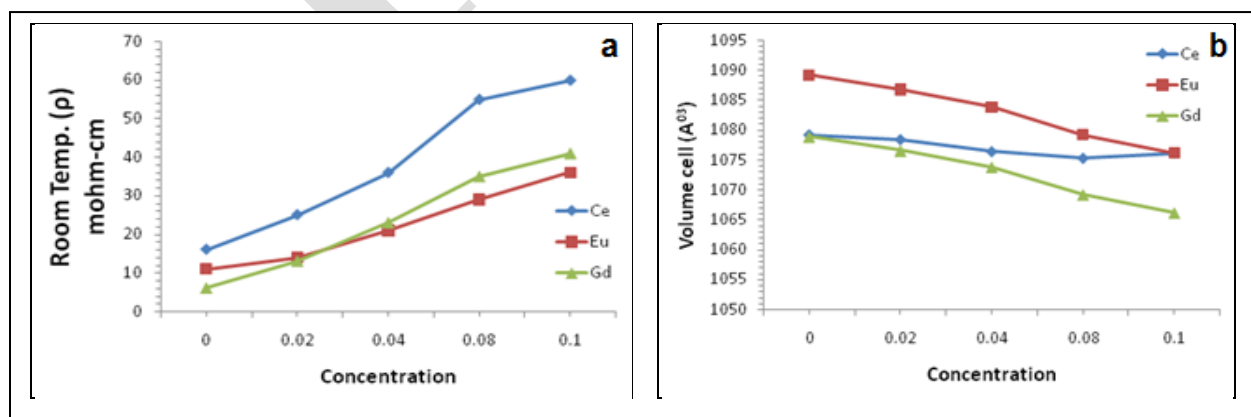


Fig-1 Resistivity(ρ) & Susceptibility(χ) of Rare earth substitution in BISCCO2223 system.



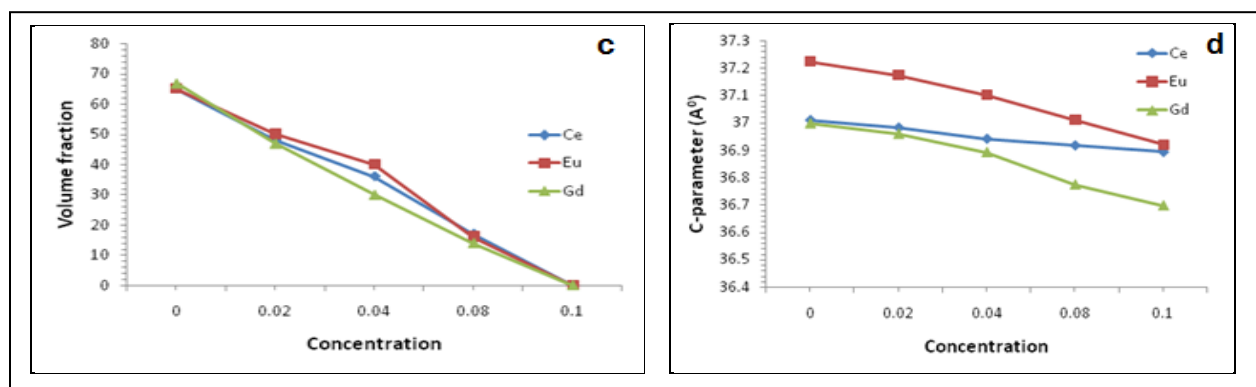


Fig-2: Plots of concentration versus a) Resistivity at room temperature b) Volume cell c) Volume fraction d) C-parameter.

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