Suppression of Superconductivity Due to Cd-substitution in $(Y_{0.8}Pr_{0.2})$ $Ba_2Cu_3O_{7-\delta}$ Superconductor

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Abstract:

In the present communication a systemic study on the studies on structural and superconducting properties of $(Y_{1-x-y}Pr_xCd_y)$ $Ba_2Cu_3O_{7-\delta}$ system with fixed Pr and different Cd-concentrations is reported. It has been seen that the valency of dopant plays an important role in monitoring the copper valence (the mobile charge concentration, p) as the superconducting behaviour depends on it. Amongst various substitutional studies, the partial substitution of Pr (3+ → 4+) and co-substitution of Ca (2+) at Y-site in $YBa_2Cu_3O_{7-\delta}$ has attracted much attention as the hole filling or localization of holes in Cu_2O planes due to Pr-substitution is found to be compensated by mechanism of hole doping due to optimum Ca-substitution along. Considering this, a systematic study on the role played by Cd-substitution at Y-site in place of Ca in $(Y_{1-x}Pr_x)$ $Ba_2Cu_3O_{7-\delta}$ modifying the structural and superconducting properties has been carried out. That reveals the suppression of super conductivity with Cd doping.

Keywords: *Structural and superconducting properties, Cd-concentrations*

1. Introduction

Several studies on the possible site-selective cationic substitutions in $(YBa_2Cu_3O_{7-\delta})$ (YBCO) have been reported to understand the origin of superconductivity and composition – structure –property correlations in the system [1-4]. It has been seen that the valency of the dopant plays an important role in monitoring the effective copper valence (the mobile carrier concentration, p) or the oxygen content in YBCO superconductor, as superconducting behaviour depends on it [5,6]. Amongst various substitution studies, partial substitution of praseodymium (Pr) for Y in YBCO compound has been found to be interesting, since the effect of fluctuating valency of Pr (3+ → 4+) on the suppression of T_c has been explained on the basis of two mechanisms.

1. Pr-induced hole filling or localization of mobile holes in the conducting Cu_2O planes [7] and
2. magnetic pair breaking through the hybridization of trivalent Pr 4f and O-2p states of Cu_2o planes [8].

The main evidence for these two mechanisms has been presented by Neumeir et al [9] in a study of the superconducting behaviour of $(Y_{1-x-y}Pr_xCa_y)$ $Ba_2Cu_3O_{7-\delta}$ (YPrCaBCO) system.

Further reported work on similar system [10-12] and the observed reduction of T_c with increasing x in $(Y_{1-x}Pr_x)$ $Ba_2Cu_3O_{7-\delta}$ (YPrBCO) supports the view that magnetic pair breaking by local moments and hole localization / filling contribute substantially to the suppression of superconductivity by Pr and clearly demonstrates that this suppression can be compensated by appropriate hole doping with Ca along [13].

Keeping in mind the similarity between the valency of Cd (2+) with Ca(2+) and their ionic radii {Cd (0.9 A°), Ca (0.99A°) }, a systematic effort to understand the role played by Cd substitution at Y-site in

place of Ca in $(Y_{1-x}Pr_x)$ $Ba_2Cu_3O_{7-\delta}$, in modifying the structural and superconducting properties, has been undertaken.

$(Y_{1-x-y}Pr_x$ $Cd_y)Ba_2Cu_3O_{7-\delta}$ with (x =o and y =0, x=0.2 and y = 0.0 to 0.3) were synthesised and characterized. The selection of x = 0.2 was made after referring to the reported work by Bhalodia et al [14] suggesting that the mechanism of compensation of T_c suppression by hole doping with Ca is not observed for x < 0.2 and Y < 0.1. In the present work Ca is replaced with Cd to study the possibility of hole doping mechanism in $(Y_{0.8}Pr_{0.2})$ $Ba_2Cu_3O_{7-\delta}$ system.

2. Experimental

All the samples with different concentration of x and y in the system $(Y_{1-x-y}Pr_x$ $Cd_y)$ $Ba_2Cu_3O_{7-\delta}$ were prepared using standard solid state reaction method. The stoichiometric quantities of required constituent oxides of Yttrium, Copper, Praseodymium, Cadmium and Barium Carbonate all AR grade chemicals were thoroughly dry mixed in an agate mortar. After following the standard solid state reaction method, sample pellets were prepared at a pressure of 2 tones/cm.

The XRD studies were carried out using JEOL -800 DX X-ray diffractometer using Cuk_α radiation. X-ray diffraction patterns were obtained in the 2θ range of 20°-70° with a step size of 0.02 and step time 1°/sec. The XRD data was analysed using the computer programmed based on the method of least squares fitting. The unit cell parameters, volume and orthorhombicity were calculated. In order to know the stoichiometric composition of the individual constituents in the final products, Scanning Electron Microscope (SEM) attached with an EDAX (Energy Dispersive Analysis by X-ray) is used. The Oxygen content determination was carried out using iodometric double titration method. For the resistivity D.C. four probe method was employed within a temperature range 15 K – 300 K using APD closed cycle refrigerator system. The transition phase was also verified by magnetic susceptibility measurements.

3. Results and Discussions

All samples were characterises using XRD, SEM, resistivity and susceptibility studies. X-ray analysis revealed that all the Pr-Cd doped samples remain orthorhombic. The oxygen content (iodometry) shows that the oxygen content decreases from 6.89 to 6.70 with increasing Cd-concentration (Y = 0.1 to 0.3 respectively) in $(Y_{0.8-y}$ $Pr_{0.2}$ $Cd_y)$ $Ba_2Cu_3O_{7-\delta}$, thereby reducing the effective mobile charge concentration (p) . Fig. 1 depicts the variation of T_c (R = 0) for different Cd-concentrations in $(Y_{0.8-y}$ $Pr_{0.2}$ $Cd_y)$ $Ba_2Cu_3O_{7-\delta}$ and compares this variation with that of reported for Ca-doping in $(Y_{1-x}$ Pr_x $Ca_y)$ $Ba_2Cu_3O_{7-\delta}$. Figure shows that T_c increases for Ca-doping upto an optimum concentration while Cd-doping does not help to increase the T_c and suppresses superconductivity similar to Pr-substitution in Y $Ba_2Cu_3O_{7-\delta}$. The possible reason for non observance of hole doping due to Cd- concentration in $(Y_{1-x-y}$ Pr_x $Cd_y)$ $Ba_2Cu_3O_{7-\delta}$ may be attributed to the difference in electronic configurations of Cd^{2+} and Ca^{2+} and also to the observed oxygen effect.
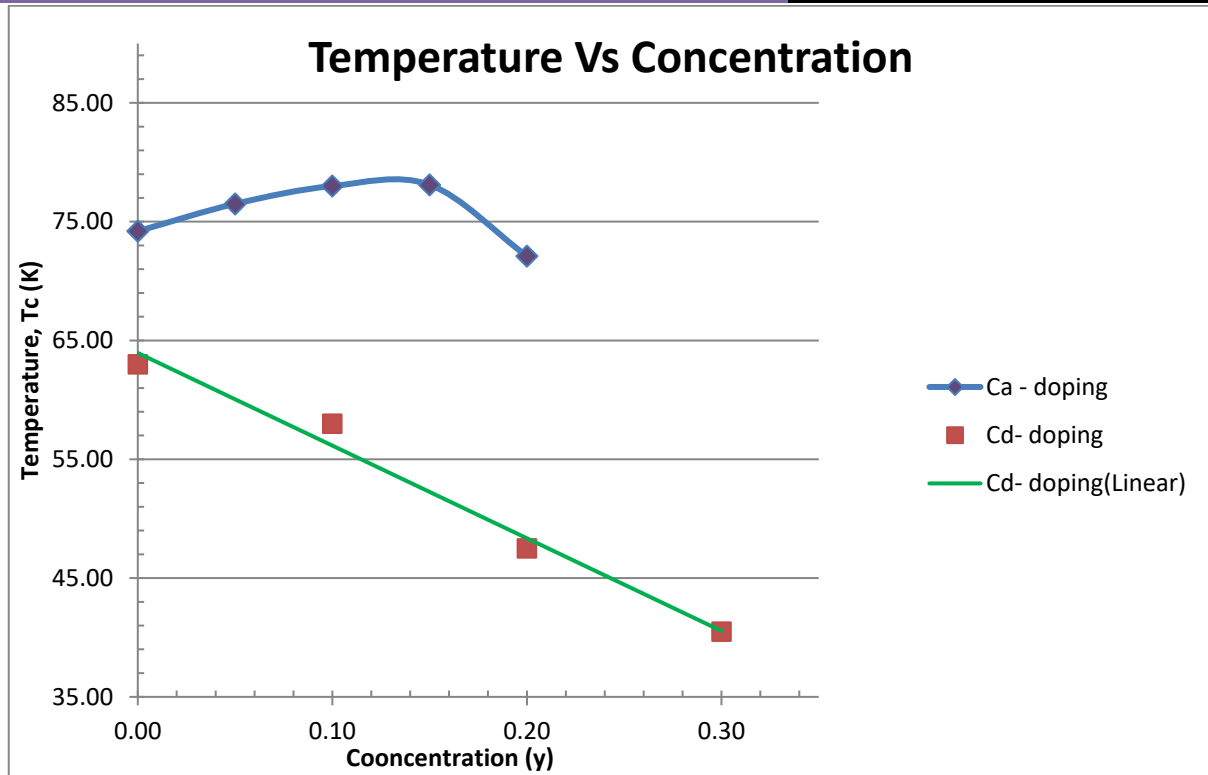
Fig.1: Comparison of variation in T_C for Ca and Cd dopped YBaCuO systems

4. Conclusion

It is observed that the substitution of Cd at constant Pr for Y in $(Y_{1-x-y} Pr_x Cd_y) Ba_2Cu_3O_{7-\delta}$ shows reduction in T_c with increasing Cd-concentration very similar to $(Y_{1-x} Pr_x) Ba_2Cu_3O_{7-\delta}$ but unlike $(Y_{1-x-y} Pr_x Ca_y) Ba_2Cu_3O_{7-\delta}$ (with Pr constant and Ca increasing) suggesting that magnetic pair breaking alone due to Pr ions is responsible for the suppression of T_c and Cd doping does not contribute in hole doping mechanism and the possible counterbalance of the hole filling as observed in $(Y_{1-x-y} Pr_x Ca_y) Ba_2Cu_3O_{7-\delta}$ systems.

This comparison reveals that the Ca posses +2 valency i.e. $4S^2$ and a vacant d-level $(3d^0)$ while Cd has filled d-levels $(3d^{10})$. Hence the mechanism of hole doping due to Ca substitution at Y site in $(Y_{1-x} Pr_x) Ba_2Cu_3O_{7-\delta}$ is prominent while the Cd^{2+} does not contribute to hole doping due to filled d-levels.

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