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A Study on Synthesis and Characterization Analysis of Metal Ions Doped High Temperature Oxide Y-123

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Abstract:
In this paper, we have presented our studies regarding the variation in superconducting properties when Cu metal in YBCO has been doped by metal ion M (=Zr) .The sample is prepared by solid state-reaction method. Characterisation of the sample is done by measuring d.c. electrical resistivity and X-Ray diffraction studies of the sample. The excess conductivity above T_c *in HTSC is more important than for low temperature superconductors. In order to find the excess resistivity or excess conductivity of the sample, Aslamazov and Larkin derived the relation* $\Delta\sigma = A\varepsilon^{\lambda}$*, Where* $\Delta\sigma$ *is the excess conductivity, A is a temperature independent constant,* ε *is the reduced temperature and* λ *is the critical exponent. The resistance of the sample is determined by d.c. four probe method.*

Key words: *d.c. four probe method, excess conductivity, critical exponent*

1. Introduction

The special features of superconductors compared to conventional conductors are the dissipation less current carrying capacity in the presence of strong magnetic field and the Josephson phenomenon observed in weakly coupled junctions. These two features of superconducting materials have been exploited into technological devices where the efficiency is several orders higher as compared to conventional materials. But the main difficulties with classical superconductors are that they exhibit superconductivity only at extremely low temperatures, where cooling to such lower temperature is much expensive and have lot of practical limitations. Following the discovery of extra ordinary high temperature oxide superconductors by Bednorz and Muller unprecedented research and development efforts have been made worldwide to evolve new materials with higher transition temperature (T_C) , critical current density (j_c), and better superconducting properties as well as to explore the possibilities of their applications in technology.

Thermodynamic fluctuations studies are expected to play crucial role in mechanism of superconducting materials and about their nature. There are several causes for studying thermodynamic fluctuations in high temperature oxide superconductors. Thermodynamic fluctuations may affect most of the static and dynamic properties of superconductors around T_c. However, as the normal electrical conductivity above T_c is small, the relative excess conductivity due to fluctuations will be very important for these materials, so in HTSC it may be possible to probe fluctuations by studying an easily accessible magnitude of the electrical resistivity ρ (T) above T_c. From a theoretical point of view, the influence of fluctuations on ρ (T) is now very well established for conventional low temperature superconductors on the ground of Bardeen Cooper Schiffer (BCS) theory.

Perhaps the most notable complicating factor in the high T_c superconductors is the existence of a whole new parameter which can be tuned: carrier concentration. In HTSC materials the parent compound are insulators, and it is not until charge carriers are added that these materials become superconducting. Typically charge carriers in the form of holes are added by removal of oxygen from stoichiometric positions (e.g. $YBa_2Cu_3O_{7-\delta}$).

In this paper, we studied the effect of doping on superconducting properties of YBCO a high temperature oxide system.

2. Theoretical Basis

Finite temperature causes thermodynamic superconducting fluctuations and creates cooper pair even above the transition temperature. As lamazov and Larkin derived the relation for the excess conductivity as:-

$$\Delta\sigma = A\varepsilon^{\lambda}$$

Where A is a temperature independent constant. ε is the reduced temperature[$\varepsilon = (T-T_c)/T_c$] and λ is the critical exponent. DC electrical resistivity of the sample was measured by using the relationship

$$\rho = R^*(A)/l \text{ ohmcm}$$

The excess conductivity of the sample was determined from the resistivity data points by applying the relation:

$$\Delta\sigma = \sigma_{measured} - \sigma_{background} \qquad (1)$$

$$= 1/\rho_{measured} - 1/\rho_{background}$$

Background resistivity was measured by a linear fit of the temperature vs. resistivity data points and extrapolating it to a low temperature. Fitting is done for the equation

ρ (T) =a+Bt

The resistance of the sample was measured by using the d.c. four probe methods. Critical temperature (temperature at which the resistivity is zero) is determined by the plot between temperature and temperature derivative of the resistivity. In this plot critical temperature may be estimated, as the value of temperature at which the temperature derivative of resistivity ($d\rho/dT$) is maximum, and the transition width ΔT_c is the full width at half maxima.

Slope of log log graph between reduced temperature and excess conductivity gives the value of the critical exponent (λ). In log log plot lines parallel to experimental data are the theoretical slopes corresponding to the critical exponent (λ), hence the theoretical values agree with the experimental values. Now the relationship between D and λ is $D=2(2+\lambda)$, from which the dimensionality of the doped sample is calculated. Now coherence length ξ (0) is calculated in case of 3D system and characteristic length (d) in 2D system by using the relationship

$A=e^2/32\hbar\xi(0)\,\sigma(rt)$, for $\lambda=0.5$ and 3D
$A=e^2/16\hbar d\sigma(rt)$, for $\lambda=1$ and 2D

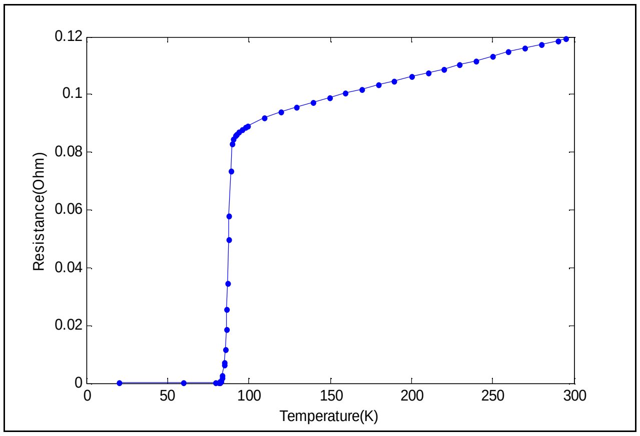
3. Material Synthesis

The sample is prepared by the solid state reaction method. Stoichiometric amounts of Y_2O_3, $BaCO_3$, CuO, and metal oxide are thoroughly mixed. The mixture was ground by using agate mortar for 3-4 hours. Now the mixture is placed in die, compressed into pellets by using the hydraulic press. These circular pellets are kept into alumina boat; boats are cleaned by using acetone.These alumina boats are placed in a muffle furnace. The samples are placed in a furnace at a temperature of 910-934°c for 24 hours followed by furnace cooling. The mixture was reground and again pressed into pellets and sintered at a temperature of 940 °c for 24 hrs.The procedure was repeated at least three times in order to get the homogeneous sample. The final cooling was done slowly with intermediate annealing at 650 °c 600 °c, 550 °c, 500 °c, 450 °c and 400 °c for 12 hrs each to ensure the formation of the orthorhombic phase.

4. Results and Discussion

The variation of resistivity as a function of temperature, etc. for the $YBa_2Cu_{3-x}M_xO_{7-\delta}$ (Where x=0.1 and M= Zr) superconducting sample are shown below.

5. Plots between Various Physical Quantities



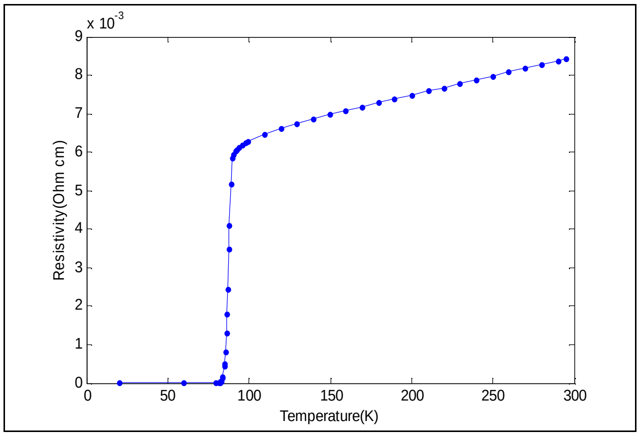
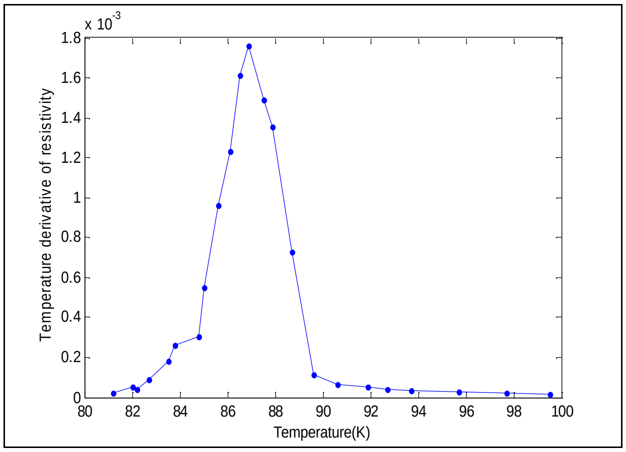


Figure 1: Temperature dependent resistance for sample SZr
Figure 2: Temperature dependent resistivity for sample SZr



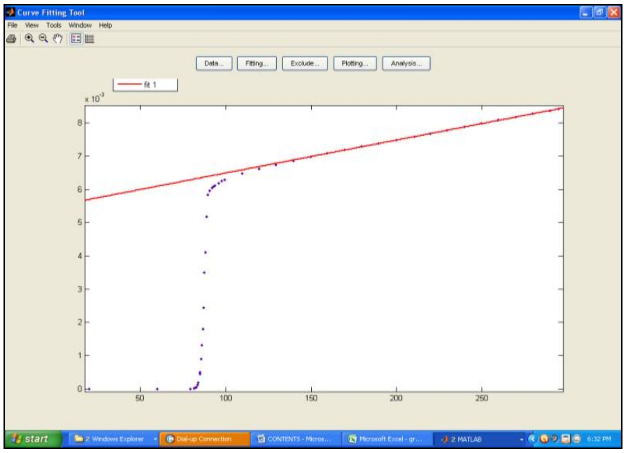


Figure 3: Plot of temperature derivative of resistivity for sample SZr
Figure 4: Plot of fit of data of resistivity vs. temperature graph to equation ρ (T) =a+bT for sample SZr

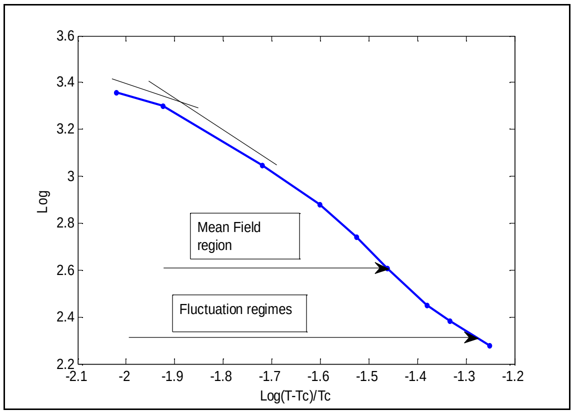


Figure 5: Logarithmic plot of normalized excess conductivity as a function of the reduced temperature of sample SZr

From the temperature derivative of resistivity versus temperature Fig 3, for the SZr doped sample, mean field critical temperature (T_c) for sample SZr (YBCO doped with Zr) is found to be 84 K, which is corresponding to the point of inflection obtained in the plot of temperature derivative of resistivity versus temperature, and from resistivity versus temperature Fig 2 the onset temperature is 89K and offset temperature is 82K .The plot of resistivity versus temperature exhibits two regions .The one is corresponding to the normal state that shows a metallic behavior,the other is the region characterized by the contribution of induced fluctuation cooper pairs to the conductivity (the AL term) above Tc. Now the log-log graph is plotted between excess conductivity and reduced temperature, slope of parallel lines in Fig 5 gives the critical exponent (λ). From the linear fitting of the resistivity versus temperature Fig 4 sample is found to be metallic in nature at room temperature and shows superconducting behavior at low temperature range, hence Aslamazov and Larkin theory is applicable to explain the linear behavior of the sample.

Logarithmic Fig 5 of normalized excess conductivity as a function of the reduced temperature of sample SZr shows the line parallel to the experimental curve. Slope of the line gives critical exponent (λ). In the log log plot of excess conductivity vs. reduced temperature different λ values or the exponents, for different fluctuation regions above and below the crossover temperature are observed. From the log log graph it is found that the doped samples are 3d at lower temperature and 2d at higher temperature .The regime that is close to Tc in the mean field region has 3D type of fluctuations and at the particular temperature there is crossover from 2D to 3D region of fluctuations. Critical exponent (λ) is found to be -0.58538 corresponding to 3D and λ= -.25695 corresponding to 2D fluctuation. A good agreement between the theoretical and experimental values is obtained for the critical exponent. Coherence length [ξ (0)] for Zr doped sample is in good agreement with the theoretical values and is of interatomic distance range. Transition width (ΔT) is calculated from the temperature derivative of resistivity versus temperature FIG.3, and is found to be 7K hence transition width increases as compared to the pure system.

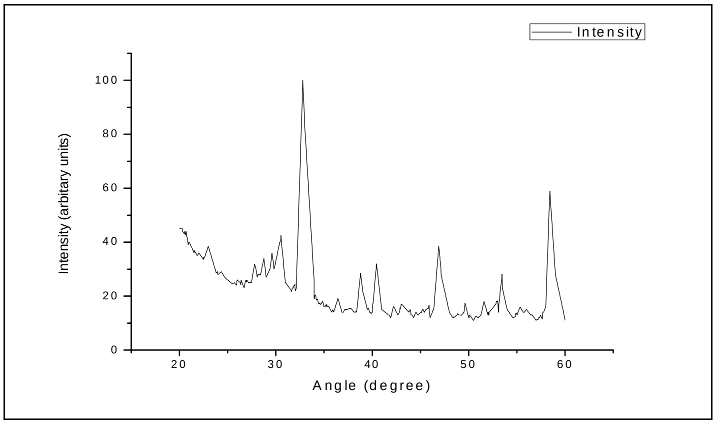


Figure 6: XRD pattern of SZr sample

From Xrd pattern of the doped sample (fig.6) it is observed that all the doped samples are orthorhombic as expected for a superconducting sample. In XRD pattern of Zr doped sample extra peaks are obtained at certain angles. Original peak Intensity (peaks corresponding to pure sample intensity) changes, slight shifting of peaks (may be due to the impurity phases) is also observed.

6. Conclusion

In the present study the doping of YBCO by Zr decreases the critical temperature (T_c) of the sample. In case of Zr doped YBCO, T_c decreases, but it does not alter the structural symmetry of YBCO but orthorhombicity parameter decreases.

These studies shows that Cu-O assembly is primary responsible for the superconductivity, When Cu atoms are substituted by other atoms, the transition temperature usually decreases. Attempts to raise the T_c as well as to improve the superconducting properties of $YB_2Cu_3O_{7-\delta}$ have revealed that superconductivity is severely suppressed by the substitution of copper by other element such as Zr.

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