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RESEARCH ARTICLE

INFLUENCE OF Pr_2Co_7 MAGNETIC NANOMETER PARTICLES ADDITION ON $\text{YBa}_2\text{Cu}_3\text{O}_y$ SUPERCONDUCTOR MAGNETO-CONDUCTIVITY'S IN FLUCTUATION REGIME.

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Abstract

We perform magneto-conductivity fluctuation study on polycrystalline samples of $\text{YBa}_2\text{Cu}_3\text{O}_y$ (YBCO) superconductor added with $x\%$ ($x=0.0, 0.1$ and 0.3) in weight of magnetic nanometer particles (20 nm) of Pr_2Co_7 . Standard solid state reaction method is used to elaborate samples. X-ray diffraction patterns refinement by Rietveld method show the orthorhombic to tetragonal phase transition from 0.3% wt of Pr_2Co_7 addition. Magneto-resistance measurements are performed in magnetic field ranging from 0 to 40 mT, orthogonal to current. The magneto-conductivity fluctuation is analyzed assuming excess conductivity in magnetic field follows power law. The results show two steps of transition. The pairing transition above T_p (maximum of temperature derivative of resistivity) and the coherence transition below T_p . Transition width goes large for each samples when magnetic field increases and is more higher in samples containing Pr_2Co_7 . Above T_p , the fluctuation regime in presence of magnetic field is not changed in comparison to the results obtained out of magnetic field. Magneto-conductivity fluctuation analysis near zero resistance temperature, T_{CO} , shows two critical regimes with samples containing 0.0% and 0.1% in weight of Pr_2Co_7 but only one critical regime in sample containing 0.3% wt of Pr_2Co_7 .

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Introduction:-

Due to their small coherence length and anisotropy, high temperature superconductors induce large fluctuation phenomena around the transition region in their physical properties such as electrical conductivity, magnetic susceptibility, specific heat ... (Y. A. Opat et al., 2011; N. M. Vladimirova et al., 1998). Their granular character leads to high density of grains boundaries which behave as Josephson junctions that are sensitive to external magnetic fields makes this phenomenon pronounced (R. M. Costa et al., 2007).

Particularly, their resistive transition shows a characteristic two-stage behavior. When decreasing temperature, one first observes a pairing transition, at the bulk critical transition temperature T_c , arising in homogenous regions called grains which are not necessarily coincident to crystallographic grains; and the coherence transition at T_{CO} where the

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fluctuating phases of the Ginzburg-Landau (G-L) order parameter of individual grains couple into a long range ordered state, leading to the zero resistance state (R. M. Costa et al., 2007, M. Sahoo and D. Behera, 2013).

The fluctuation study in transition region may be useful tool to obtain information about the effective dimensionality and the Ginzburg-Landau coherence length of high temperature superconductors (R. M. Costa et al., 2001). This study can be down out of magnetic field such as in magnetic fields (R. M. Costa et al., 2001; F. M. Barros et al., 2004; F. M. Barros et al., 2006).

In high magnetic fields, the superconducting transition should be described by lowest-Landau-level~LLL! approximation of the GL theory (R. M. Costa et al., 2001).

In this paper, we report the effect of Pr_2Co_7 addition on magneto-conductivity fluctuation of $\text{YBa}_2\text{Cu}_3\text{O}_y$ superconductor in low magnetic field, by using the excess conductivity formula obtained from the approximation of Ginzburg-Landau theory (F. M. Barros et al., 2004; F. M. Barros et al., 2006).

Material and method:-

Polycrystalline samples of magnetic nanometer particles of Pr_2Co_7 (20 nm average) addition on YBCO ($\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$) superconductor were synthesized throughout the standard solid-state reaction route in two steps. In the first step, single phase of YBCO was synthesized by mixing an appropriate quantity of high purity Y_2O_3 (99.9%), Ba_2CO_3 (99.9%) and CuO (99.9%) in an agate mortar. The mixture is pelletized at 750 MPa and placed in alumina crucible before calcination at 950 °C for 12 h in air. In the second step, after furnace cooling, the pellets are finely ground in mortar agate and x% in weight (wt) of Pr_2Co_7 magnetic nanometer particles amount are added (x=0.0, 0.1, 0.3). Then, the reactants are reground and pressed again at 750 MPa, placed in alumina crucible before sintered in air, at 950 °C during 12 h.

The resistivity temperature dependence were carried out in a CCS 450 cryostat system, using standard four-probe technique, on samples cut as rectangular with nearly similar dimensions and using silver paint for electrical contact with resistivity less than 0.5 Ω . Magnetic fields were applied perpendicular to current ranging from 0 to 40 mT.

In order to extract the derivative of resistivity and other parameters, the resistivity measurements are spaced closely.

X-ray diffraction characterization:-

The crystalline structures of these samples were characterized by powder XRD using a Philips 1710 diffractometer with $\text{CuK}\alpha$ radiation ($\lambda = 1.5406 \text{ \AA}$) at room temperature. Detailed structural parameters were obtained by Rietveld refinements using FULLPROF program. We discuss about the x-ray powder diffraction patterns and the crystallographic parameters characteristics of all the sintered samples elsewhere (D. Mani Kongnane et al., 2015). For example, Fig. 1 shows a Rietveld structural refinement of 0.3% in weight of Pr_2Co_7 addition on YBCO sample. In general manner, crystallographic parameters vary with increasing Pr_2Co_7 level, decreasing the orthorhombicity of sample which becomes tetragonal from 0.3% wt of Pr_2Co_7 addition.

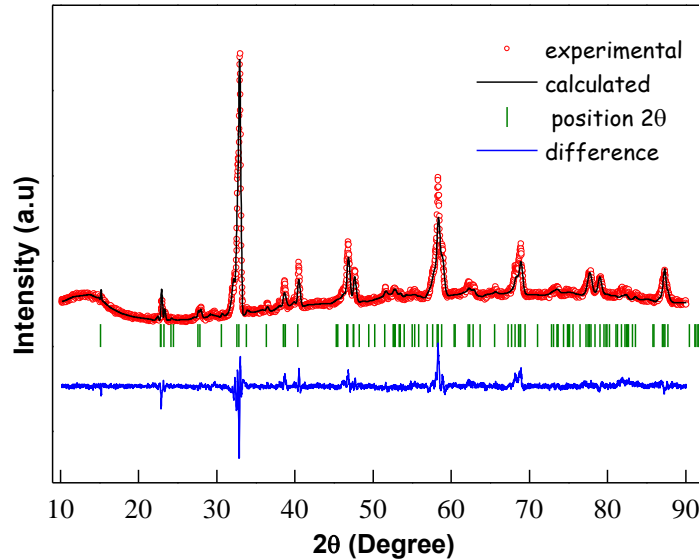


Fig.1:- Illustration of Rietveld refinements by x-ray diffraction patterns for 0.3% wt Pr_2Co_7 sample

Method of analysis:-

We assume that magneto-conductivity $\Delta\sigma$ diverges as a power law given by :

$$\Delta\sigma = A(T - T_C(H))^{-s} \quad (1)$$

where $\Delta\sigma = \sigma - \sigma_R$, A is the critical amplitude, s the critical exponent. The conductivity $\sigma(H, T)$ is obtained by resistivity measurements under magnetic field and the regular conductivity is obtained by extrapolation from the high temperature behavior (R. M. Costa et al., 2001).

To determine simultaneously T_C and λ , the numerical logarithmic derivative of $\Delta\sigma$ is done from experimental data :

$$\chi_\sigma = -\frac{d}{dT} \ln(\Delta\sigma(H, T)) \quad (2)$$

And with the combination of Eqs. (1) and (2), we obtain :

$$\frac{1}{\chi_\sigma} = \frac{1}{\lambda}(T - T_C(H)) \quad (3)$$

After the determination of T_C and λ , the amplitude A can be deduced from Eq. (1) by substituting in it the values of T_C and λ within the region of temperature the scaling is observed.

Results and discussion:-

In Fig. 2 we show the electrical resistivity under magnetic field of samples containing (a) 0.0%, (b) 0.1%, (c) 0.3% of Pr_2Co_7 and (d) their irreversible lines.

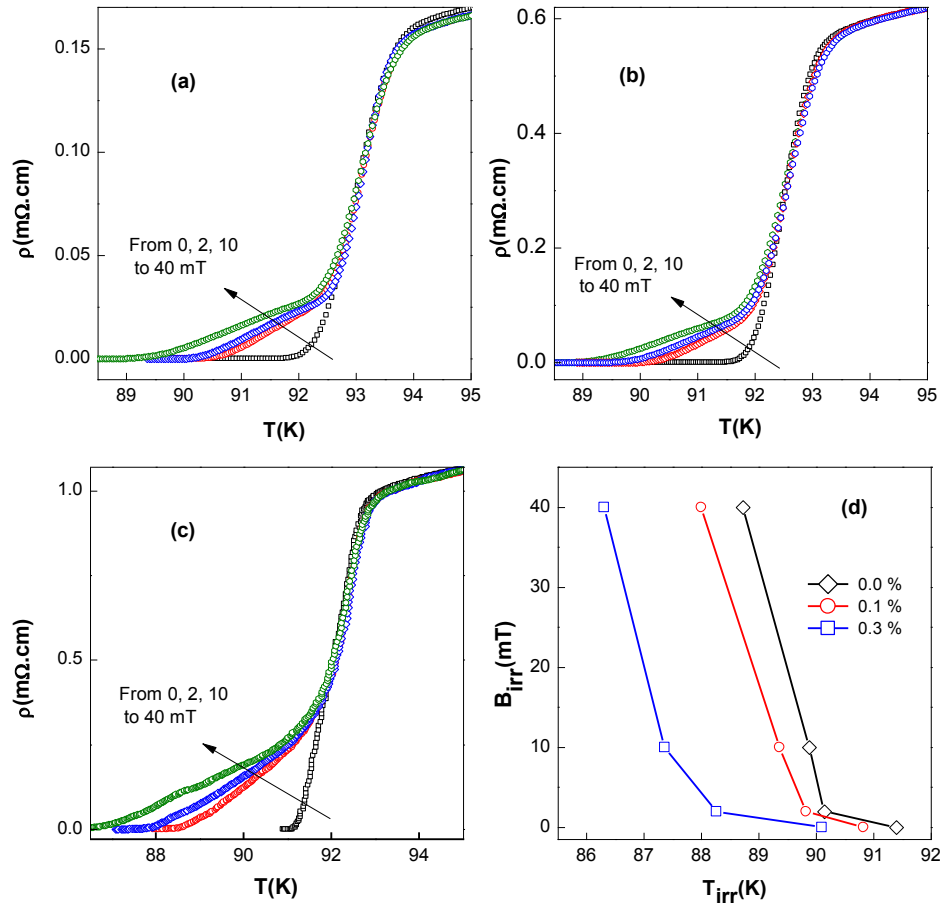


Fig. 2 :- Magneto-resistance curves versus temperature of (a) 0.0%; (b) 0.1%; (c) 0.3% of Pr_2Co_7 addition and (d) their irreversible lines

The magneto-resistance curves are not almost affected by applied field in the region above the maximum of the temperature derivative $d\rho/dT$, whose is denoted by T_p in Fig. 3. This temperature is approximately the same with pairing transition temperature T_c . This result is consistent with those of J. Roja-Roja (J. Roa-Rojas et al., 2000). Below T_p and near zero resistance temperature, the magneto-resistance curves are strongly dependent of samples granularity and applied magnetic fields. When applied magnetic field increases, the zero resistance temperature decreases, enlarging the transition region width due to vortex motion thermally activated. In our case, this phenomenon is not minimized because applied magnetic field is perpendicular to current (R. M. Costa et al., 2007). We called the transition temperature under magnetic field irreversible temperature and the corresponding magnetic field the irreversible field. In Fig. 2. (d), the irreversible lines obtained with this method show the pinning properties degradation induced by Pr_2Co_7 addition.

The fluctuation regime above T_p under magnetic field does not change significantly and is not presented here. Below T_p , we assume the magneto-conductivity follows power law. In Fig. 3, we represent the temperature derivative of resistivity $d\rho/dT$ and the curves of χ_σ^{-1} versus temperature according to Eq.(3). The critical exponents observed out of magnetic fields, near zero resistance region are for 0.0% $s \sim 2.7$, for 0.1% $s \sim 3.7$ and for 0.3% $s \sim 3.33$ (D. Mani Kongnine et al., 2016).

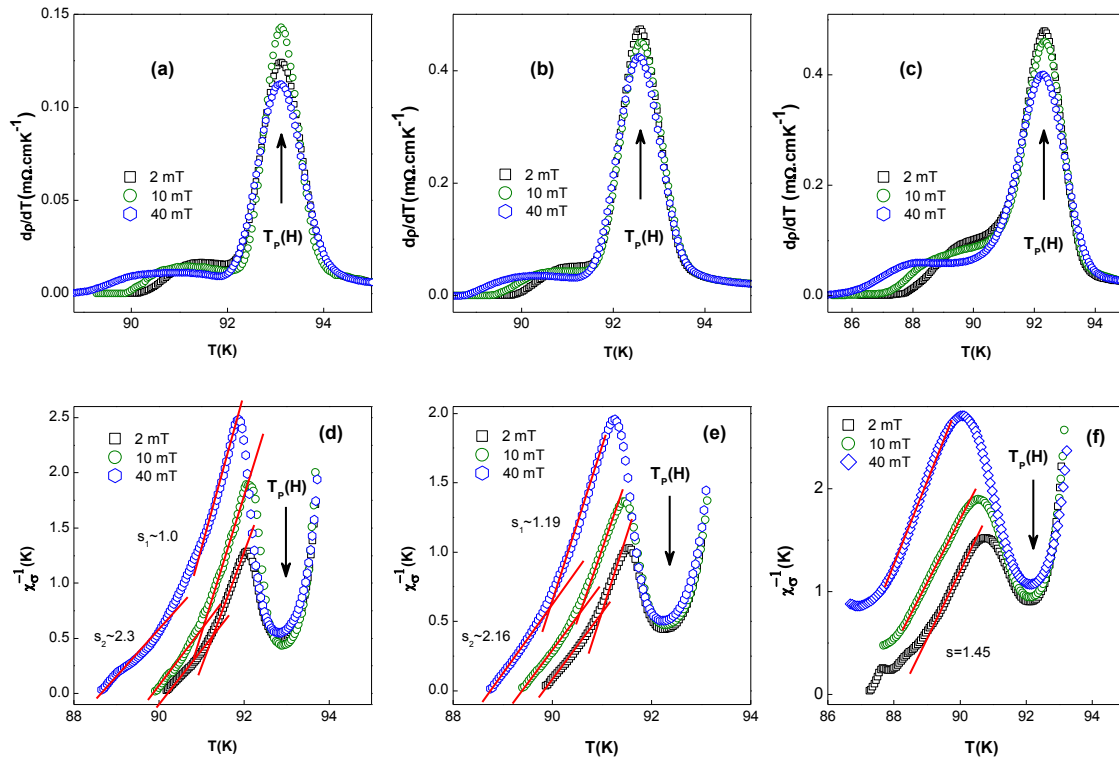


Fig. 3:- Temperature derivative curves of (a) 0.0% (b) 0.1%, (c) 0.3% of Pr_2Co_7 and (d), (e) (f) their χ^{-1} versus temperature respectively

We note for each sample that $T_p(H)$ does not change with applied magnetic field and the critical exponent s is sample dependent only. Indeed, we observe, for each percentage of Pr_2Co_7 content : $x=0.0\%$, two critical exponents $s_1 \sim 1.0$ and $s_2 \sim 2.3$; for $x=0.1\%$, $s_1 \sim 1.19$ and $s_2 \sim 2.16$ and for $x=0.3\%$ only one critical exponent $s \sim 1.45$ suggesting that the two critical exponents observed in other samples collapse to one critical exponent. Aside from, 0.1% wt Pr_2Co_7 whose critical exponent s_1 is consistent with 2D Aslamazov and Larkin theory (P. Marra et al., 2012), others critical exponents are not consistent to any specific critical regime.

These results are different to that of R. M. Costa and J. Roja-Roja (R. M. Costa et al., 2007; J. Roa-Rojas et al., 2000), probably due to experiment conditions and samples characteristics'. We apply magnetic field perpendicular to current and the dissipation phenomena, associated to disorder introduced by Pr_2Co_7 in microscopic/mesoscopic level may play a predominant role disturbing magneto-conductivity fluctuation phenomena.

Conclusion:-

We have studied the effect of Pr_2Co_7 addition on the magneto-conductivity in fluctuation regime of $\text{YBa}_2\text{Cu}_3\text{O}_y$ superconductor. The obtained critical exponents do not permit to identify clearly any specific regime of fluctuation except for sample containing 0.1% wt Pr_2Co_7 . However, we identify two critical regimes in samples containing 0.0% and 0.1% in weight of Pr_2Co_7 and only one critical regime in sample containing 0.3% of Pr_2Co_7 . Dissipation phenomena, related to the thermal activated flux flow may be responsible of these results.

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