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STUDY OF SUPERCONDUCTIVE BEHAVIOUR ON YBa_2Cu_3O / POLYANILINE COMPOSITE

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ABSTRACT

This paper addresses the properties of a composite consists of a high T_C superconducting ceramic and a conducting polymer. A composite of Yttrium Barium Copper Oxide and Polyaniline of equal composition has been prepared and characterized. The composites of YBCO/PANI were subjected to structural, optical, magnetic and superconducting studies. The composite was observed as superparamagnetic at normal conducting state and diamagnetic at superconducting state. The composite posses the critical transition temperature of 70 K, i.e. below which the YBCO/PANI composite exhibits superconductivity.

Key words: Polymer composites, Magnetic Properties, Electrical properties, X-ray diffraction

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1. INTRODUCTION

The discovery of high superconductivity has sparked the world-wide effort to develop materials for the diversity of practical applications. Electromagnetic shielding using high T_C superconductor is one such large scale industrial application with peculiar requirements [1-4]. The field of electronics holds great promise for practical applications of superconductors [5-7]. However, high T_c superconductors have some drawbacks like brittleness, difficulty in shaping and chemical instability which have impeded the development of their applications. Also their mechanical properties cannot compete with those of conventional metallic superconductors [8]. This difficulty has been overcome to some extent by the use of high temperature superconductor/polymer composites with proper choice of polymeric materials to achieve the desired physical properties. Superconducting ceramic/polymer composites have superior mechanical properties, better machinability and processing flexibility in comparison with ceramic alone[9-12]. Development of high T_C superconducting plastics will be very much useful in the field of Medicine like Magnetic Resonance Imaging (MRI). Moreover it is also used in Nuclear Magnetic Resonance (NMR) machines, mass spectrometers, and the beam-steering magnets used in particle accelerators.

2. EXPERIMENTAL

2.1 MATERIALS AND METHODS

2.1.1 Preparation of Yttrium Barium Copper Oxide (YBCO)

Yttrium Barium Copper Oxide (YBCO) was prepared by mixing 11.29 g of Yttrium oxide (Y_2O_3), 39.47 g of Barium Carbonate ($BaCO_3$), 23.86 g of copper oxide (CuO). The mixture was heated in the muffle furnace at 925 – 950°C for about 18 hrs. As a result of this first heat treatment, the basic crystal structure of $YBa_2Cu_3O_{6.5}$ was formed and gets rid of the carbon dioxide from the barium carbonate. Porous dark gray clump is occurred. The dark gray clump was ground into the fine powder and it was kept at the temperature of 950 – 975°C for 18 hrs. After the mixture was heated allow the slow flow of oxygen into the furnace and the temperature was slowly reduced at the rate of 100°C per hour. The resultant black colored powder was finely grounded and preserved in the desiccator.

2.1.2 Synthesis of Polyaniline

Polyaniline was synthesized by solution polymerization. The method of polymerization was discussed elsewhere [1].

2.1.3 Synthesis of YBCO/PANI composite

Composite of YBCO/Polyaniline was prepared by mixing 25 g of YBCO with 25 g of polyaniline. The mixture was then heated at the temperature of 300°C for 4 hours. The mixture turned into gray colour after the heat treatment. The composite was then palletized by mixing 2 to 4 drops of Poly Vinyl Alcohol (1 g PVA in 10 ml of distilled water). The paste was then palletized using the palletizer and dried in the oven at 150°C in order to evaporate PVA.

3 RESULTS AND DISCUSSION

3.1 Structural Characteristics

Fig. 1 shows the XRD pattern of Polyaniline, YBCO and YBCO/PANI composites observed at room temperature. The XRD pattern was recorded in Shimadzu diffractometer, using the Cu K_α radiation, λ = 1.5418 Å with 40 KV and 20 mA, at 0.04° scan rate. The measurements were made at room temperature with the diffraction angle (2θ) ranging from 10 to 70 degrees. The XRD pattern suggests that the synthesized polyaniline is amorphous in nature, however the diffraction pattern of YBCO confirms the structure of bulk crystalline YBCO with the preferential orientation of (013). The diffraction pattern of YBCO/PANI composites constitute of diffraction peaks corresponds to the planes of YBCO and polyaniline which supports the formation of composites. Moreover, the pattern of composite reveals that the (004) plane of YBCO is preferentially oriented. The additional peaks in the patterns are due to the formation of secondary phases. The particle size and the strain were calculated using Williamson – Hall plot and tabulated in table 1.

3.2 Density measurement

The bulk density of the composite powder was determined using the test method specified in ASTM – 6683 (2008). The bulk density of the composite is around 3.78 g/cc. The density of the YBCO /PANI composites was determined theoretically using the following formula. $D_C = vD_S + (1-v)D_P$, where D is the density of the composite, D_S is the density of the superconductor (YBCO), D_P is the density of the Polymer (Polyaniline) and v is the volume fraction. The density of polyaniline and YBCO was determined as 1.33 g/cc and 6.28 g/cc respectively. Hence the density of the composite D_C was estimated using the above formula as 3.805 g/cc which is found closer to the estimated experimental value. This justifies the formation of better composites.

3.3 Optical characteristics

UV-Visible spectrum of the YBCO/Polyaniline composite was observed using CARY 5E UV-VIS-NIR spectrophotometer at room temperature within the wavelength ranges from 200 nm to 2500 nm in steps of 1 nm. Fig. 2 shows the UV-Visible spectrum of YBCO/PANI composites. The spectrum shows the excitonic peak at around 333 nm. In order to determine the optical band gap of the composite, a graph between optical absorption $(\alpha h\nu)^2$ and the photon energy ($h\nu$) has been plotted. The optical band gap of this YBCO/PANI composite was estimated by determining the x-intercept of the plot through extrapolation of the linear region as shown in fig. 3. The optical band gap of YBCO/PANI composites is determined to be 0.805 eV. The lower band gap value suggests the better electrical conductivity of the composites.

3.4 Superconducting Studies

The superconducting nature of YBCO/PANI composite was studied by observing the electrical resistance as a function of temperature. The composite was made into a small cylindrical pellet of 8 mm diameter and 5 mm thick. The electrical resistance using four point probe method. The composite was placed in the cryostat filled with liquid nitrogen. The composite was gradually allowed to warm and the voltage was recorded. From the DC current and voltage the resistance was calculated. The resistance as a function of temperature was plotted and depicted in Fig. 4. From the plot it is understood that the resistance above 70 K starts increasing from zero i.e. the composite exhibits superconductivity below 70 K and above which the composite transit into a normal conductor. The critical transition temperature of the YBCO/PANI composite is around 70 K.

3.5 Magnetic studies:

From the electrical measurements it is understood that the composite posses superconductivity below 70 K. In addition to the changes in electrical property, the magnetic property will also drastically changes during the transition from normal state to the superconducting state. In order to study the magnetic characteristics of the composite, it was subjected to vibrating sample magnetometry (LAKESHORE VSM, 740). The sample was tested at room temperature and at 70 K with the magnetic field of 0 – 2 tesla. Fig. 5 shows the magnetization curve (M-H curve) for YBCO/PANI composite at room temperature and the inset shows M-H curve at 70 K. It is understood that the composite posses a superparamagnetism at room temperature and diamagnetism at 70 K. A perfect Superconductor repels the magnetic field and leads to the levitation effect. The diamagnetism at 70 K proposes that the composite is a perfect superconductor. The Magnetic studies well supports the electrical studies and reveals that the YBCO/PANI composite is realized as a perfect superconductor at and below 70K. Similar diamagnetic nature of LDPE/YBCO composite was studied by Badrakumari et al [13]. Realization of a superparamagnetism in a polymer at room temperature is also a promising behaviour of the composite. Organic Superparamagnetic materials are the most suitable materials for the applications of drug delivery and drug targeting. YBCO/PANI composite can also be considered for such applications.

CONCLUSION

A superconducting polymer composite was prepared by mixing equal proportion of synthesized YBCO and Polyaniline by solid state reaction route. The composite was subjected to structural, optical, superconducting and magnetic studies. The study reveals that the composite has the energy band gap of 0.805 eV and hence expected to have better electrical conductivity. Similarly the electrical resistance measurements suggest that YBCO/PANI composite has the critical transition temperature of 70 K, i.e. below which the resistance falls to zero (transit into a superconductor from a normal conductor). YBCO/APNI composite posses superparamagnetism in the normal conducting state and diamagnetic in the superconducting state. YBCO/PANI composite is considered to be a specialized polymer exhibiting peculiar properties of room temperature superparamagnetism and high temperature superconductivity.

References:

[1] Jacob, Sanith; Santhoskumar, A. U.; Bhuvana, K. P.; Palanivelu, K.; Nayak, S. K., Investigation on the Structural and Magnetic Properties of a Polymer Composite: Polyaniline/Cr_2O_3, 51, 317 – 320 (2012).

[2] Kazuhisa Nishi, Mixed electronic states of high T_c cuprates superconductors, Phy. Procedia. 27, 80 – 83 (2012).

[3] John T. McDevitt, Chris E. Jones, Steven G. Haupt, Jianai Zhao, Rung-Kuang Lo, Conductive polymer/high-Tc superconductor bilayer structures, Synthetic metals, 85, 1319 – 1322 (1997).

[4] M.M. Abbas, L.K. Abass, U. Salman, Influences of Sintering Time on the T_C of $Bi_{2-x}Cu_xPb_{0.3}Sr_2Ca_2Cu_3O_{10+\delta}$ High Temperature Superconductors, Energy Procedia, 18, 215 – 224 (2012).

[5] A. Verdyan, I. Lapsker, J. Azoulay, Electrical properties of Y-Ba-Na-Cu-O high T_c superconductors thin films, Physica C: Superconductivity, 209, 307 – 310 (1993).

[6] Ford, P., and George Saunders, 2003. The Rise of Superconductors. Taylor & Francis.

[7] Orenstein, J., and A.J. Millis., Advances in the Physics of High-Temperature Superconductivity, Science 280, 468 – 474 (2000).

[8] Bennemann, K.H., J.B. Ketterson, and Joachim A. Kohler, 2003, Handbook of Superconductivity. Springer-Verlag.

[9] R. Abraham, S. P. Thomas, S. Kuryan, J. Isaac, K. T. Varugheses5, S. Thomas, Mechanical properties of ceramic-polymer nanocomposites, Exp. Poly. Let. 3, 177– 189 (2009).

[11]Rosalin Abraham, Soosy Kuryan, Jayakumari Isac, Ajesh K. Zacharia, Sabu Thomas, Yttrium barium copper oxide-filled polystyrene as a dielectric material, J. of App. Poly. Sci., 120, 2233–2241 (2011).

[12] Keya Bose, Kamal K. Som, Pradip K. Dey, Bijay K. Chaudhuri, A Simple Method for the Preparation of $YBa_2Cu_3O_x$ Superconducting Wires and Tapes Using Common Polymers, Jpn. J. Appl. Phys. 30, L823-L825 (1991).

[13] S Bhadrakumari, P Predeep, High-T_c superconductor/linear low density polyethylene (LLDPE) composite materials for diamagnetic applications, Supercond. Sci. Technol. 19, 808 – 812 (2006).

Figures

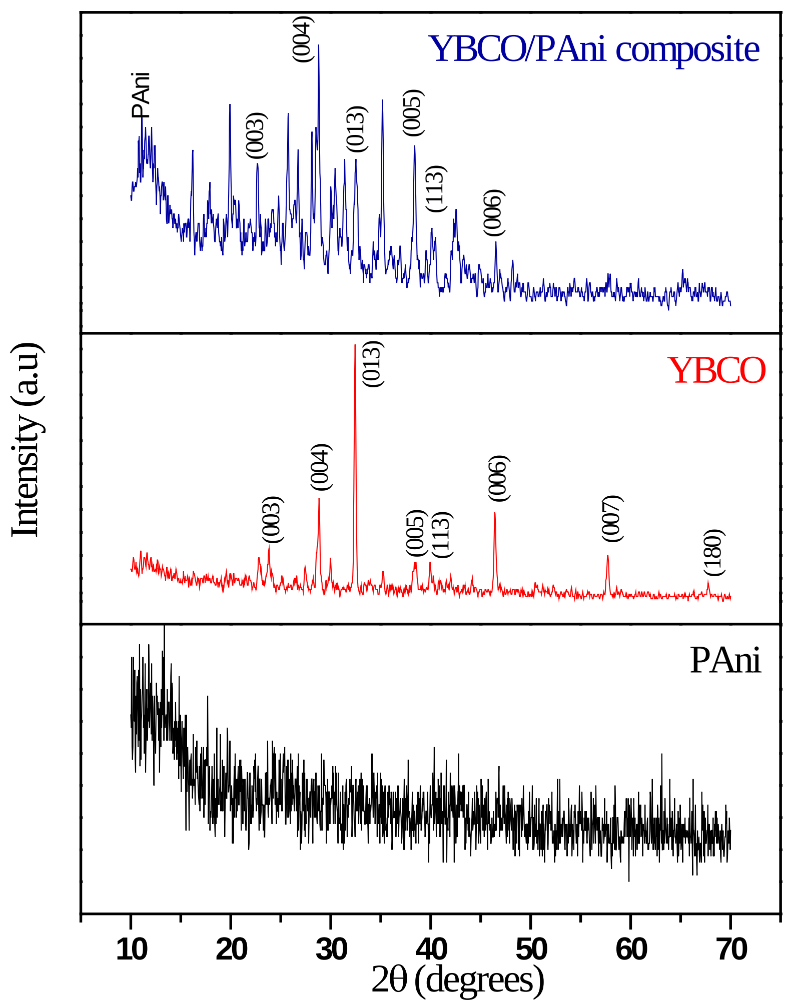
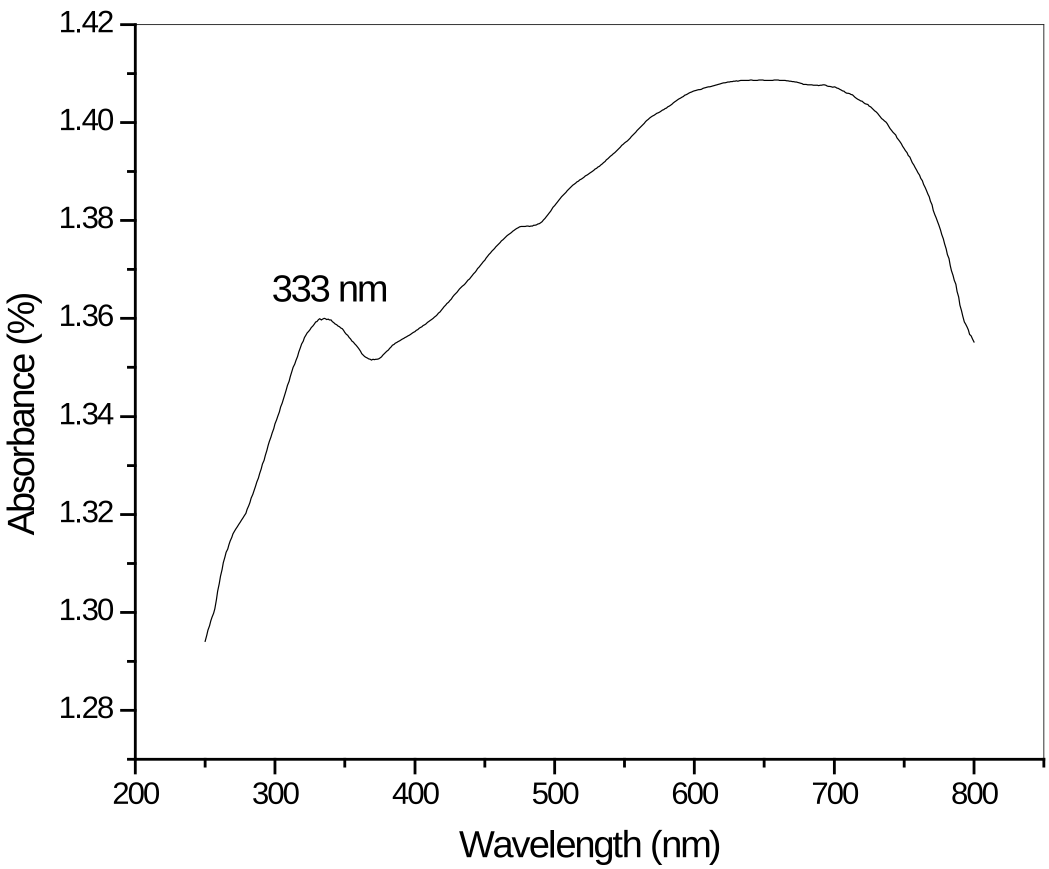


Fig. 1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1.40
1.38
1.36
1.34
1.32
1.30
1.28
Absorbance (%)
333 nm
200
300
400
500
600
700
800
Wavelength (nm)

Fig. 2

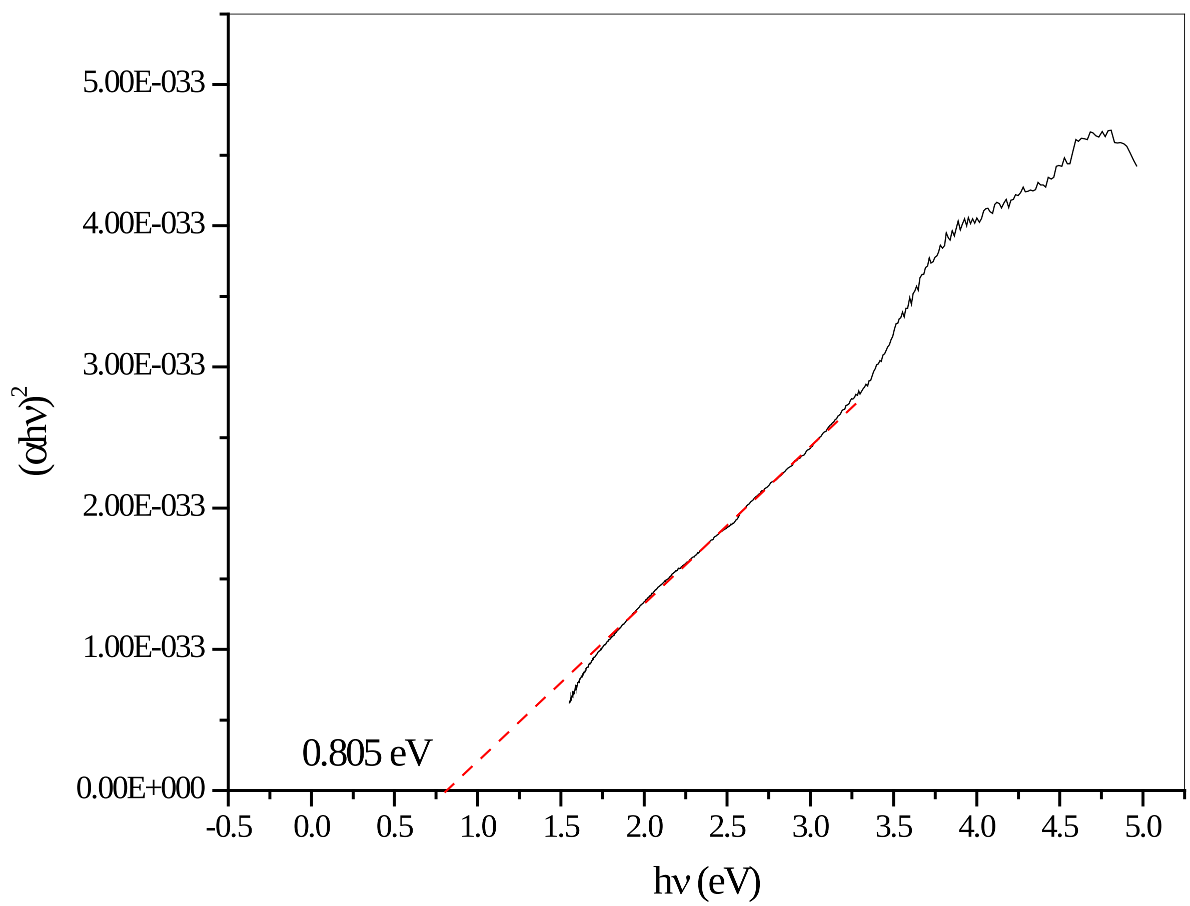
5.00E-033
4.00E-033
3.00E-033
2.00E-033
1.00E-033
0.00E+000
(αhν)2
0.805 eV
-0.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
hν (eV)

Fig. 3

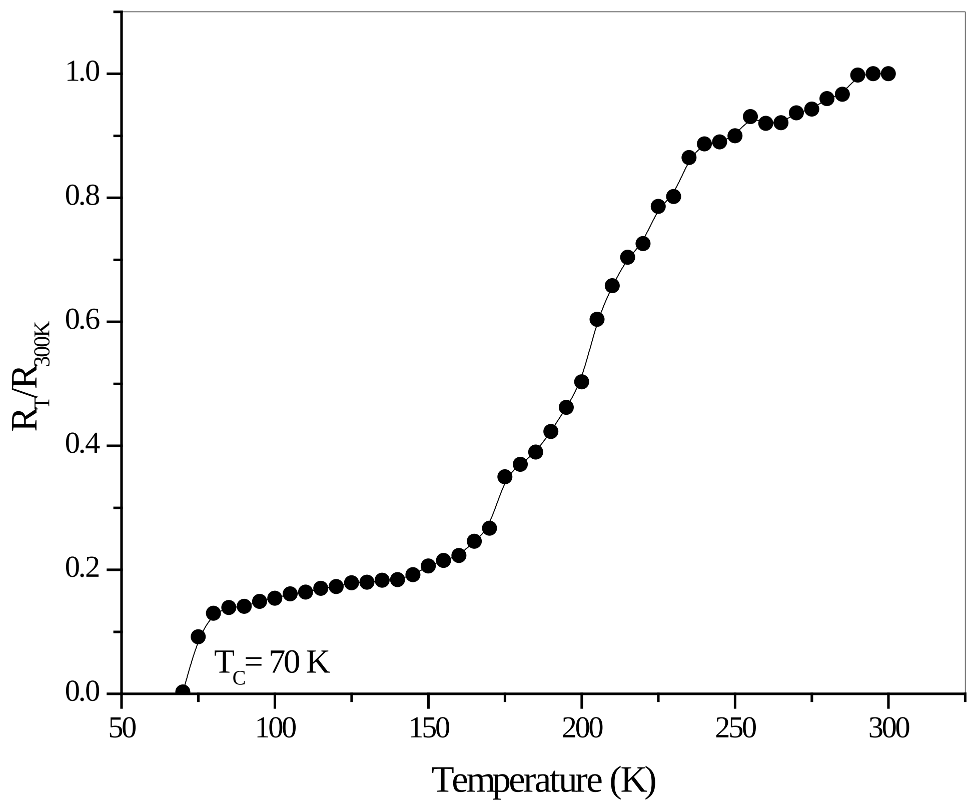
1.0
0.8
0.6
0.4
0.2
0.0
R_T/R_{300K}
T_C= 70 K
50
100
150
200
250
300
Temperature (K)

Fig. 4

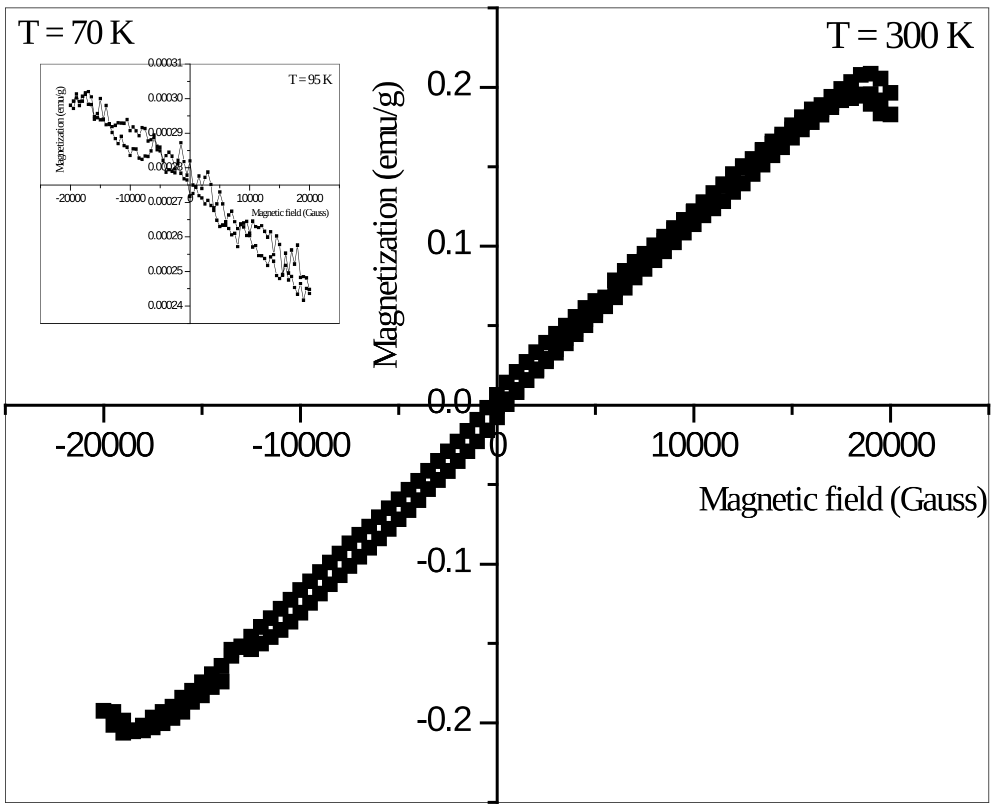
T = 70 K
T = 300 K
T = 95 K
Magnetization (emu/g)
Magnetic field (Gauss)
0.2
0.1
0.0
-0.1
-0.2
-20000
-10000
0
10000
20000

Fig. 5

Tables

Table 1

S. No.	Sample	Particle size	Strain
1.	Polyaniline	2.371 nm	-0.07830
2.	YBCO	50.04 nm	-0.00043
3.	YBCO/Polyaniline composites	34.80 nm	0.00432

*The positive value of strain suggests the tensile strain and the negative sign represents that it is compressive.

Figure captions

Fig. 1: XRD pattern of polyaniline, YBCO and YBCO/PAni composites

Fig. 2: UV absorbance of YBCO/PAni composites

Fig. 3: Tauc's plot of YBCO/Cr_2O_3 composites

Fig. 4: Temperature dependence of resistance

Fig. 5: M-H curve of YBCO/PANI composite at room temperature. Inset: @ T= 70 K.

Table captions

Table 1: Particle size and strain calculated using Williamson-Hall plot