ISSN 2250-3153

Nano Carbon Filled Polyester Gradient Composites and their dc conductivity studies

Archana Nigrawal[1],Arun Kumar Sharma[2] and Ekta Agarwal[3]

[1].Advanced Materials and Processes Research Institute, Bhopal (CSIR) (formerly RRL Bhopal), Habibganj Naka, Bhopal -462026, INDIA
[2].MANIT Bhopal
[3].RGPV Bhopal

Abstract- Nearly 70% of HAF carbon black is used as a pigment and reinforcing filler in automobile tire. HAF carbon black also removing heat away from the tread and belt area of the tire, reducing thermal damage and increasing tire life. Particles of HAF carbon black are also used in some radar absorbent materials. This is also used in printer toner.

World production of HAF carbon black is about 8.1 million tonnes (2006). HAF carbon black is chemically and physically distinct from soot and black HAF carbon. Typically less than 60% of the total particle mass of soot or black HAF carbon is composed of HAF carbon, depending on the source and characteristics of the particles (shape, size and heterogeneity). In commercial HAF carbon blacks, organic solvents and high temperatures).

Traditional methods of producing HAF carbon black are as follows.

Ivory black is traditionally produced by charring ivory or animal bones. Vine black is traditionally produced by charring desiccated grape vines and stems.

Lamp black is traditionally produced by collecting soot, also known as lampblack, from oil lamps.

In this study, nano carbon high abrasion furnace (HAF) N330 having particle size 28-36 nm has been incorporated in unsaturated polyester resin to develop gradient composites. dc conductivity of nano carbon filled polyester graded composites has been determined in the temperature range ranging from 30 to 150 °C .It has been found that increase of nano carbon content increases the dc conductivity of composites.

Index Terms- Composite polymer, dc conductivity, HAF carbon, polyester

I. Introduction

Carbonaceous fillers used in the production of polymer composites can increase electrical conductivity and also maintain lightweight and corrosion resistance. Different types of carbon have different particle size, shape and structure. Dc electric conductivity of the polymer composites can be analyzed by the percolation theory [1-2]. Composites having high resistivity can be used in the power cables and low loss power apparatus. High conductivity can be used in shielding of electrical devices [3]. Polyesters are popular because of their low cost, ease of use, and versatility. It can be applied in laminates, castings, art objects, industrial construction, insulation, embodiments, molding compounds, coatings, and adhesives .It has high impact resistance and good weathering resistance. [4] Studies of structure formation and peculiarities of deformation of polymer compositions with fillers of carbon nature have increased their possibility to produce a new polymer composite material possessing the shape memory effect accompanied by a considerable volume increase [5]. Fillers are used with polyesters to reduce their cost and to improve some of their properties like increasing the hardness, thermal conductivity, and wear and chemical resistance; decreasing the thermal expansion; and improving the insulation properties [6-7]

The conductivity of composites can be compared to that of conducting polymer. Insulator–conductor composites can be suitable for studying percolating behavior and also for their statistical nature. Percolation concentration depends on the shape of the particles and network of the matrix .[8]It was found that carbon nanoparticles lower the glass transition temperature of the polymer and as a result of it flexibility increases and has impact resistant. The highly cross linked nano composite polymers are generally resistant to heat and weathering. [9]

There is no report on the development of HAF carbon polyester gradient composites and their dc Conductivity characteristics in the literature.

II. Materials and Methods

Nano HAF carbon powder filled polyester gradient composites have been developed by using centrifugation process, which was patented by chand and Hashmi [10]. The centrifugal force is applied in the X. direction. Gradient samples are prepared from the nano carbon filled mix having 3 wt% of nano carbon powder. Nano carbon powder was added to a mix of Polyester resin and hardener. Total mix was thoroughly stirred with the help of a glass rod. Details of set up and of the process of making gradient composites are as reported in earlier patent (Chand and Hashmi (2003)**.** The total mix was filled in the mould to make sample. The sample is rotated at 800 $\pm$ 50 RPM at a radius of 130 mm. Samples were removed from the mould after post curing at room temperature for 24 hours. These samples were coated by air drying type silver paint before the measurements.

III. DC Conductivity Measurements

The resistance of each sample was measured by using a Kiethley Electrometer model 610 C in the temperature range ranging from 30 to 150°C. Heating rate was kept constant at 1°C/min. dc conductivity $\sigma_{d.c}$ of the samples was calculated by using the following relation.

$\sigma_{d.c.} = 1 / \rho$

Where ρ is the resistivity, which is defined as

$\rho = RA / L$

Where R, A and L are the resistance of sample in ohms, cross sectional area (cm^2) and thickness (cm) of the sample respectively.

IV. Results and Discussions

Fig.1 shows the variation of dc conductivity vs temperature for nano carbon filled polyester sample1. There is a sudden increase in dc conductivity after 88°C.In this case there is an increase in dc conductivity up to 150°C .At 150 °C the dc conductivity of HAF carbon filled polyester sample was $1.87\text{x}10^{-10}$

Fig. 2 shows the variation of dc conductivity vs temperature for nano carbon filled polyester gradient composites sample2. This plot shows that up to 100°C there is no increase in dc conductivity. After 100°C there is a sudden increase in dc conductivity with increase of temperature. At 150 °C the dc conductivity of nano carbon filled polyester sample was $1.94\text{x}10^{-10}$

Fig. 3 shows the variation of dc conductivity vs temperature for nano carbon polyester gradient sample3

It has been observed that dc conductivity suddenly increases after 86°C. Increase of dc conductivity appeared at 126°C and a peak was found at 128°C.It goes on increasing up to 150°C. At 150 °C the dc conductivity of nano carbon filled Polyester sample was $2.77\text{x}10^{-10}$

Fig 4 shows the variation of dc conductivity vs temperature for HAF carbon filled polyester gradient composites sample4.dc conductivity increases from 84°C then there is peak at 92°C there is a increase in dc conductivity. At 150 °C the dc conductivity of HAF carbon filled Polyester sample was $4.61\text{x}10^{-10}$

It was investigated that the resistance caused by phonon scattering freezes out at a temperature of half of their frequency [11]. At low temperatures the interparticle gaps are uniformly distributed but at higher temperature, the average gap width increases and it increases the resistivity also [12].It was observed in the case of carbon black filled polymers that carbon black could be more conductive because of its high surface are and small aggregate size [13]

Fig 6-9 shows the variation of ln dc conductivity vs temperature for sample 1 to sample4 respectively.

It was investigated that value of percolation threshold depends on the porosity, shape, size and aggregation of the fillers and dc conductivity follows scaling law [14]:

$\sigma = \sigma_0(p-p_c)^t$

The ln σ versus T^{-1}plots in the case of nano carbon filled polyester gradient composites studies by us can be best expressed by the equation:

$\sigma = A \exp(-W_E/KT)$

Where A and W_E are two constants having different values for the regions above and below the softening temperature of the sample.

Table 2 lists the activation energy values of different samples. The observed variation of σ with T is due to the combined effect of change in conductivity with temperature and the distribution of nano carbon in polyester gradient composites.

At higher concentration of filler the activation energy of the sample 4 decreases, which can be explained as there is increase in the number of conduction paths created in the sample. At higher filler concentration, the temperature independence of the electrical conductivity is attributed to the tendency of filler particles to form aggregation paved direct pathway for the charge carriers, The same conclusion has been reported in different experiments on polymer- metal composites [15].

V. Conclusion

a) Increase of dc conductivity value from sample 1 to sample 4 shows the existence of graded structure.
b) Increase of nano carbon content increases the dc conductivity value.
c) dc conductivity of copper filled polyester gradient sample increased with increase of temperature.
d) Activation energy decrease with increase of nano carbon content

References

[1] Wiriya Thongruang,Richard J. Spontak and C. Maurice Balik Correlated electrical conductivity and mechanical property analysis of high-density polyethylene filled with graphite and carbon fiber Polymer 43 (2002), pp.2279-2286.

[2] Zdenka Rimska,Vojtech Kresalek and Josef Spacek ac conductivity of carbon fiber- polymer matrix composites at the percolation threshold Polymer composites 23 (2002).

[3] P.Kathirgamanathan, P.N. Adams,K.Quill and A.E. Underhill,J.Mater.5 (1993),pp 281.

[4] C. A Harper,. Handbook of Plastics, Elastomers; McGraw-Hill: New York, (1975).

[5] VA Beloshenko, AP Borzenko, VN Varyukhin, VV Shapranov. Polymer compsite material and a method to produce articles with shape memory effect. Patent No. 43593 A, Ukraine; (2000).

[6] Harper, C. A. Handbook of Plastics, Elastomers and Composites, 2nd ed.; McGraw-Hill: New York, 1992.

[7] Edenbaum, J. *Plastics* Additives and Modifier Handbook; Van Nostrand Reinhold: New York, (1992).

[8] F. Lux J. Mater. Sci. 28 (1993), pp. 285

[9] A.salmi,s.Benfarhi,J.B. Donnet and c. Decker European Polymer Journal 42 (2006) pp.1966-1974.

[10] Navin Chand and SAR Hashmi, Indian Patent NF 438/03.

[11] 11. M. Weger and D. Schweitzer, Freezeout of the electrical resistivity of $(BEDT–TTF)_2I_3$, Synth Met 70 (1995), pp. 889–894.

[12] K.ohe,Y.Natio,Jpn.J.Appl.Phys.10 (1971), 99.

[13] Ling Du and Sadhan c. Jana journal of power sources 172 (2007), pp.734-741.

[14] S. shekhar, v. Prasad and S.V. subramanyam Carbon 44 (2006) pp334-340

[15] F.A.Hussain, and A.M. Zihlif, J. Thermoplastic Composite Material.6,120,(1993).

AUTHORS

First Author – Archana Nigrawal, Advanced Materials and Processes Research Institute, Bhopal (CSIR) (formerly RRL Bhopal), Habibganj Naka, Bhopal -462026, INDIA, E-mail: archananigrawal@gmail.com

Second Author – MANIT Bhopal
Third Author – RGPV Bhopal

Correspondence Author – Author name, email address, alternate email address (if any), contact number.

Table1. Density of the samples

S.No.	**Density** **(g/cc)**
Sample 1	**1.25297**
Sample 2	**1.26196**
Sample 3	**1.26249**
Sample 4	**1.26289**

Table 2 Activation energy (ev) of the Samples

Sample	**Activation energy (eV)**
Sample1	**1.190**
Sample 2	**1.187**
Sample3	**1.053**
Sample4	**1.03**

Figure captions

Fig.1 shows the Variation of dc conductivity vs temperature for HAF carbon filled polyester sample 1

Fig. 2 shows the variation of dc conductivity' vs. temperature for HAF carbon filled polyester sample 2

Fig. 3 shows the variation of dc conductivity vs. temperature for HAF carbon filled polyester sample 3

Fig. 4 shows the variation of dc conductivity vs. temperature for HAF carbon filled polyester sample 4

Fig. 5 shows the variation of ln dc conductivity vs. temperature for HAF carbon filled polyester sample1

Fig. 6 shows the variation of ln dc conductivity vs. temperature for HAF carbon filled polyester sample2

Fig.7 shows the variation of ln dc conductivity vs. temperature for HAF carbon filled polyester sample3

Fig.8 shows the variation of ln dc conductivity vs. temperature for HAF carbon filled polyester sample4.

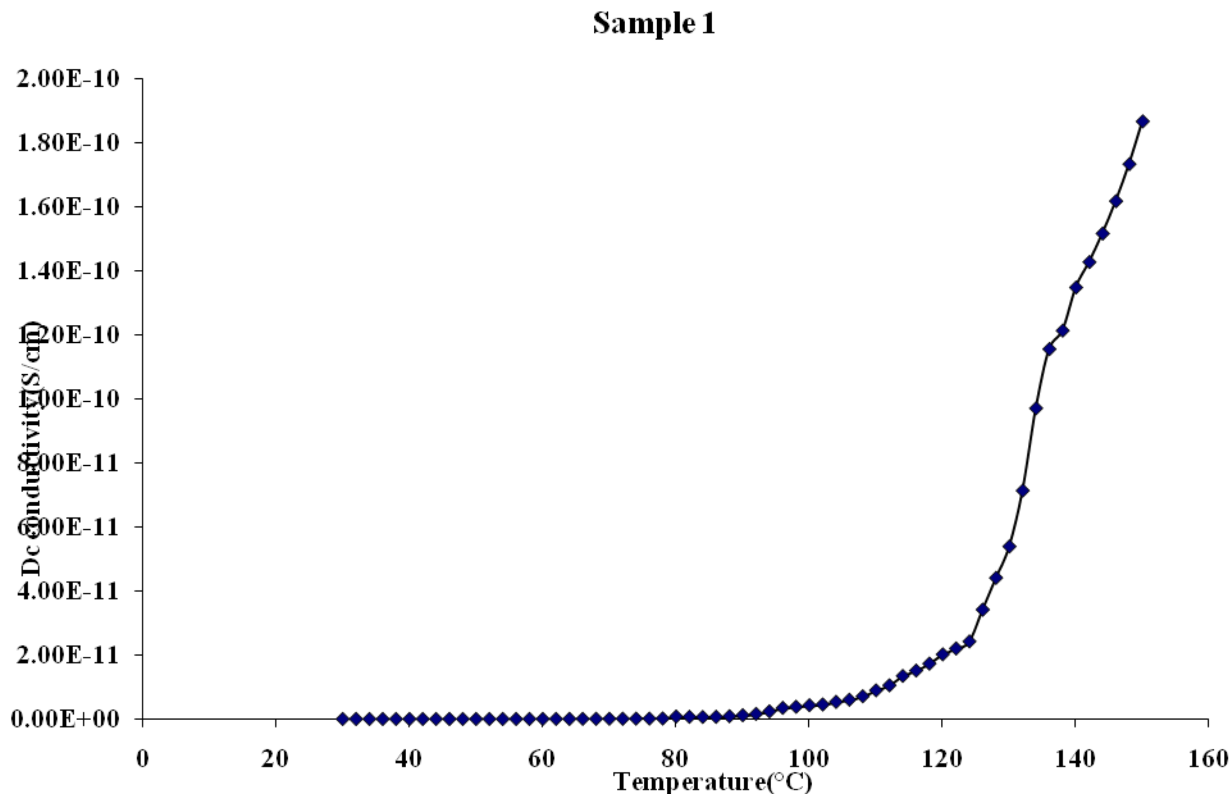
Sample 1
2.00E-10
1.80E-10
1.60E-10
1.40E-10
1.20E-10
1.00E-10
8.00E-11
6.00E-11
4.00E-11
2.00E-11
0.00E+00
0
20
40
60
80
100
120
140
160
Temperature(°C)
Dc conductivity (S/cm)

Fig.1

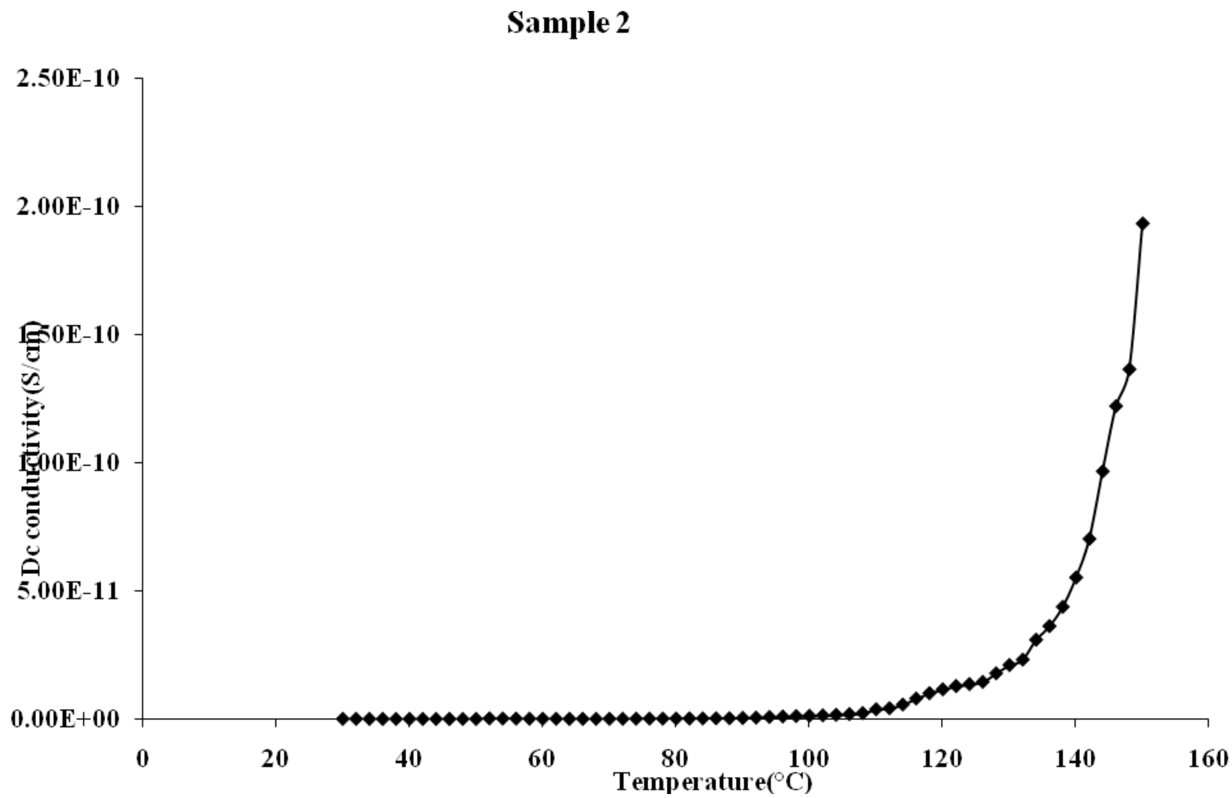
Sample 2
2.50E-10
2.00E-10
1.50E-10
1.00E-10
5.00E-11
0.00E+00
0
20
40
60
80
100
120
140
160
Temperature(°C)
Dc conductivity(S/cm)

Fig.2

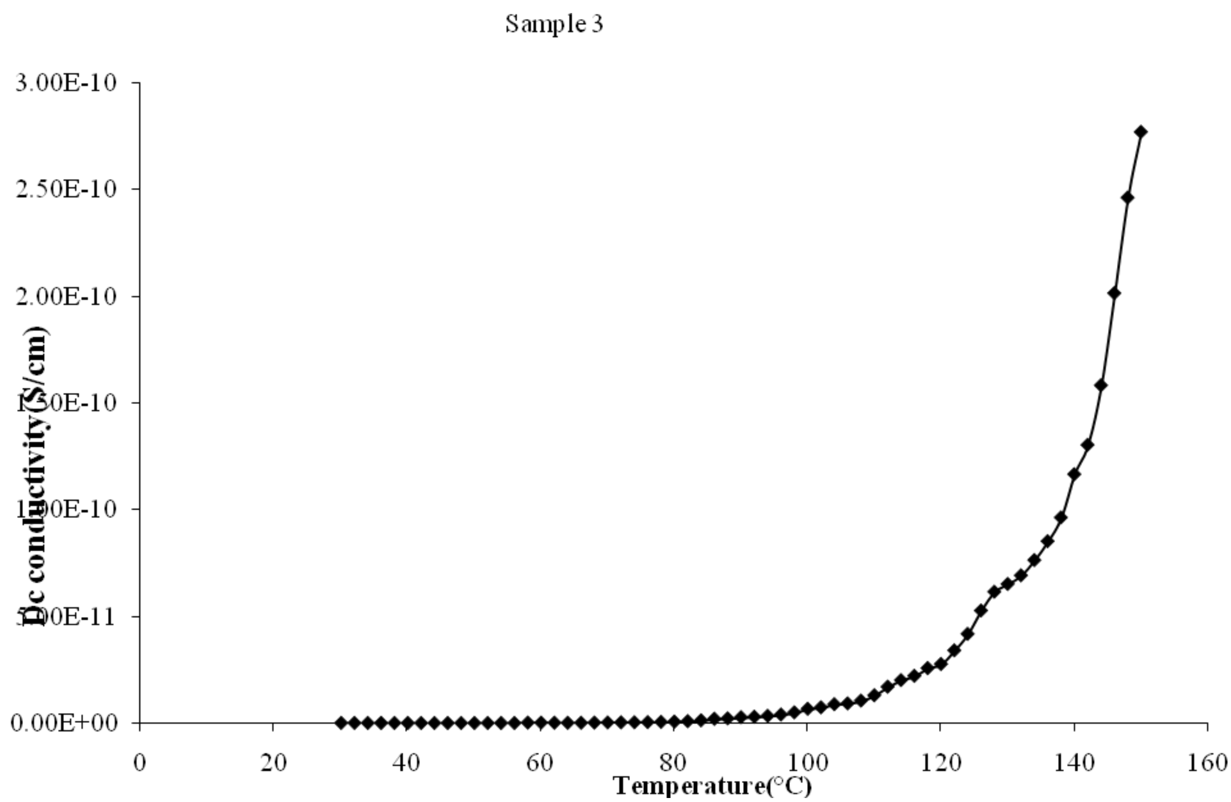
Sample 3
3.00E-10
2.50E-10
2.00E-10
1.50E-10
1.00E-10
5.00E-11
0.00E+00
0
20
40
60
80
100
120
140
160
Temperature(°C)
Dc conductivity(S/cm)

Fig.3

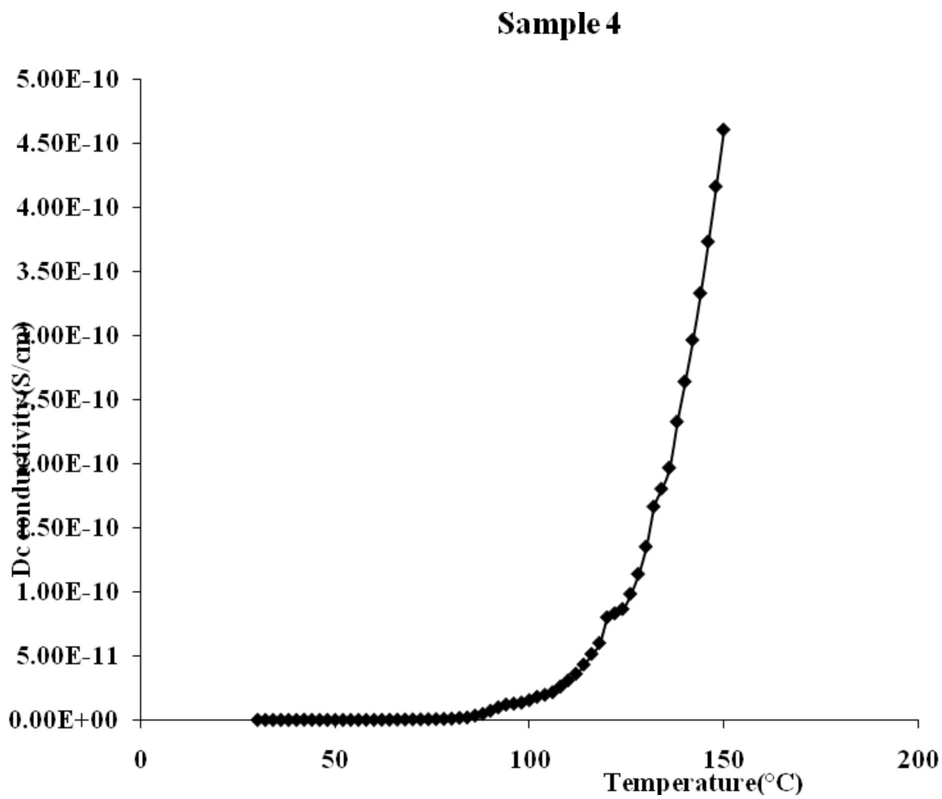
Sample 4
5.00E-10
4.50E-10
4.00E-10
3.50E-10
3.00E-10
2.50E-10
2.00E-10
1.50E-10
1.00E-10
5.00E-11
0.00E+00
Dc conductivity (S/cm)
0
50
100
150
200
Temperature(°C)

Fig.4

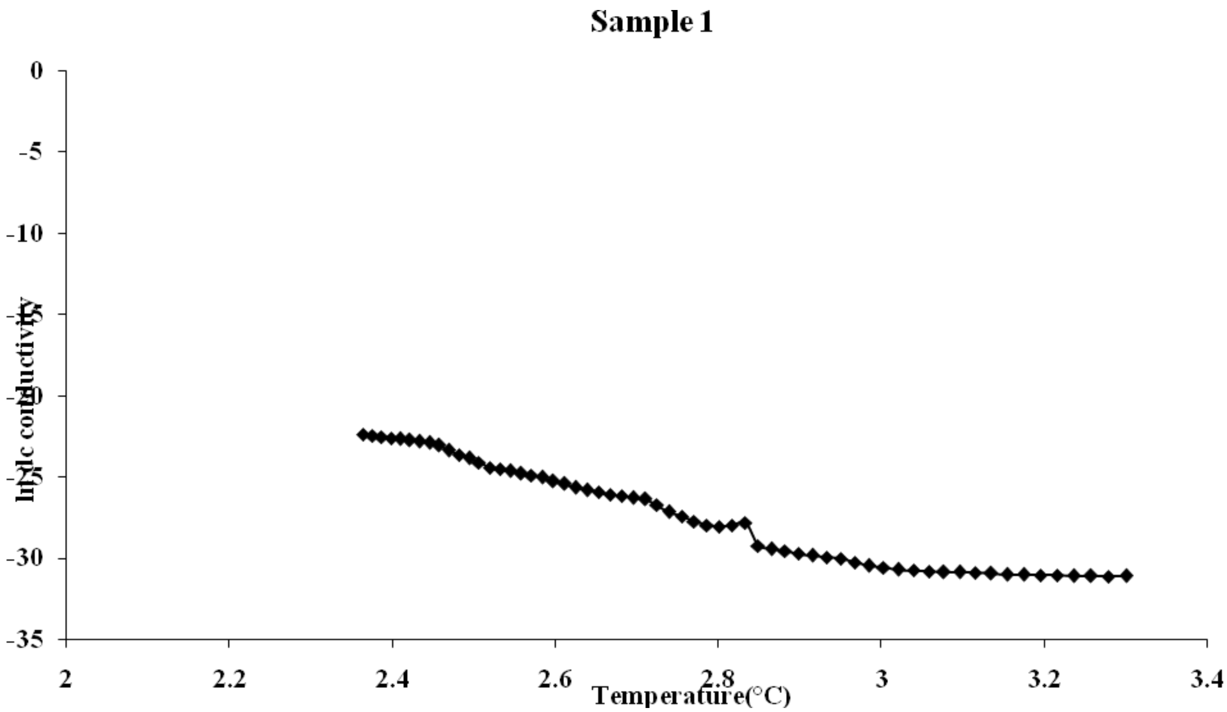
Sample 1
ln dc conductivity
Temperature(°C)
0
-5
-10
-15
-20
-25
-30
-35
2
2.2
2.4
2.6
2.8
3
3.2
3.4

Fig.5

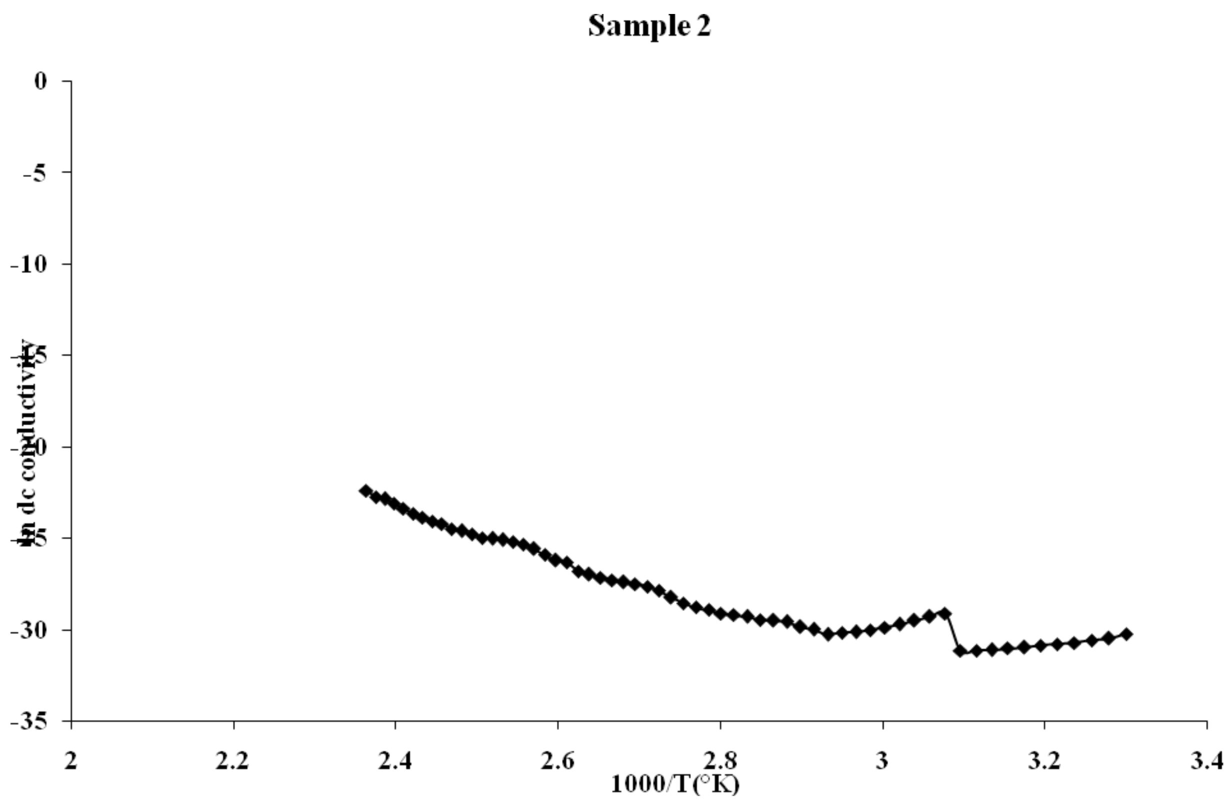
Sample 2
ln dc conductivity
1000/T(°K)
0
-5
-10
-15
-20
-25
-30
-35
2
2.2
2.4
2.6
2.8
3
3.2
3.4

Fig.6

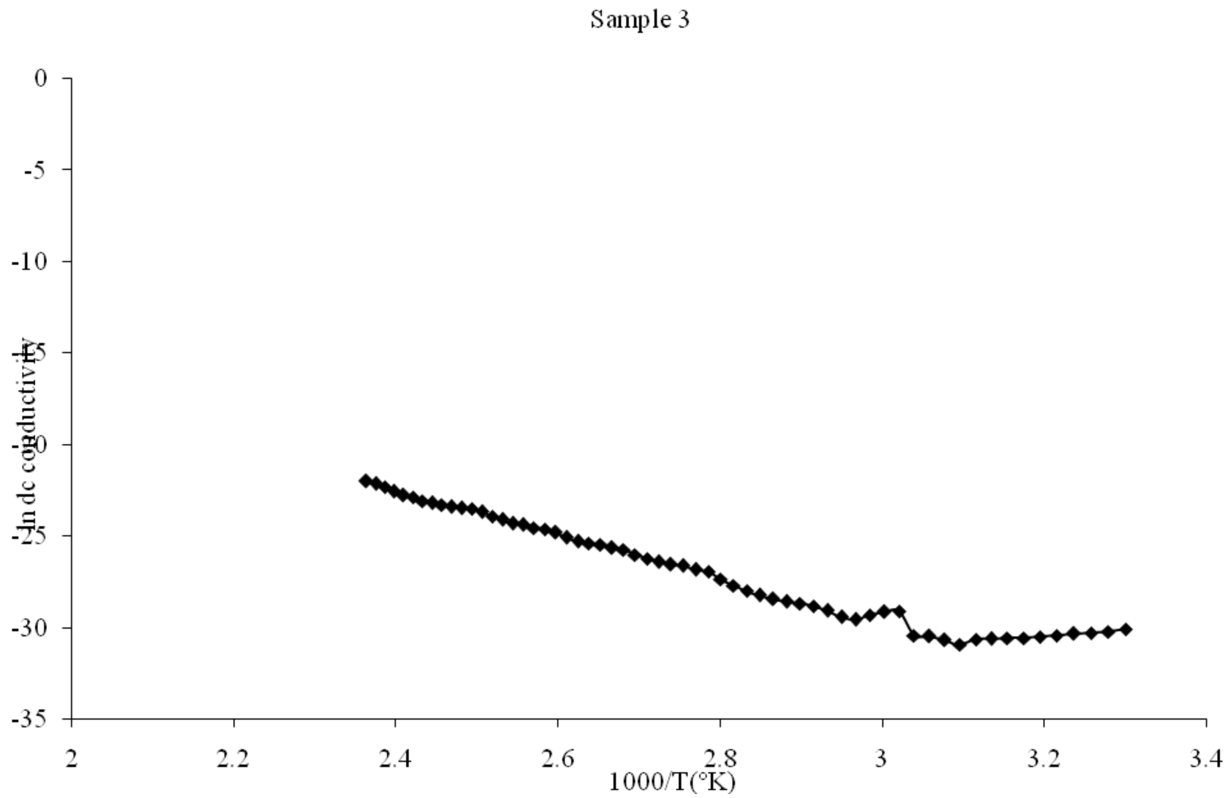
Sample 3
0
-5
-10
-15
-20
-25
-30
-35
ln dc conductivity
2
2.2
2.4
2.6
2.8
3
3.2
3.4
1000/T(°K)

Fig.7

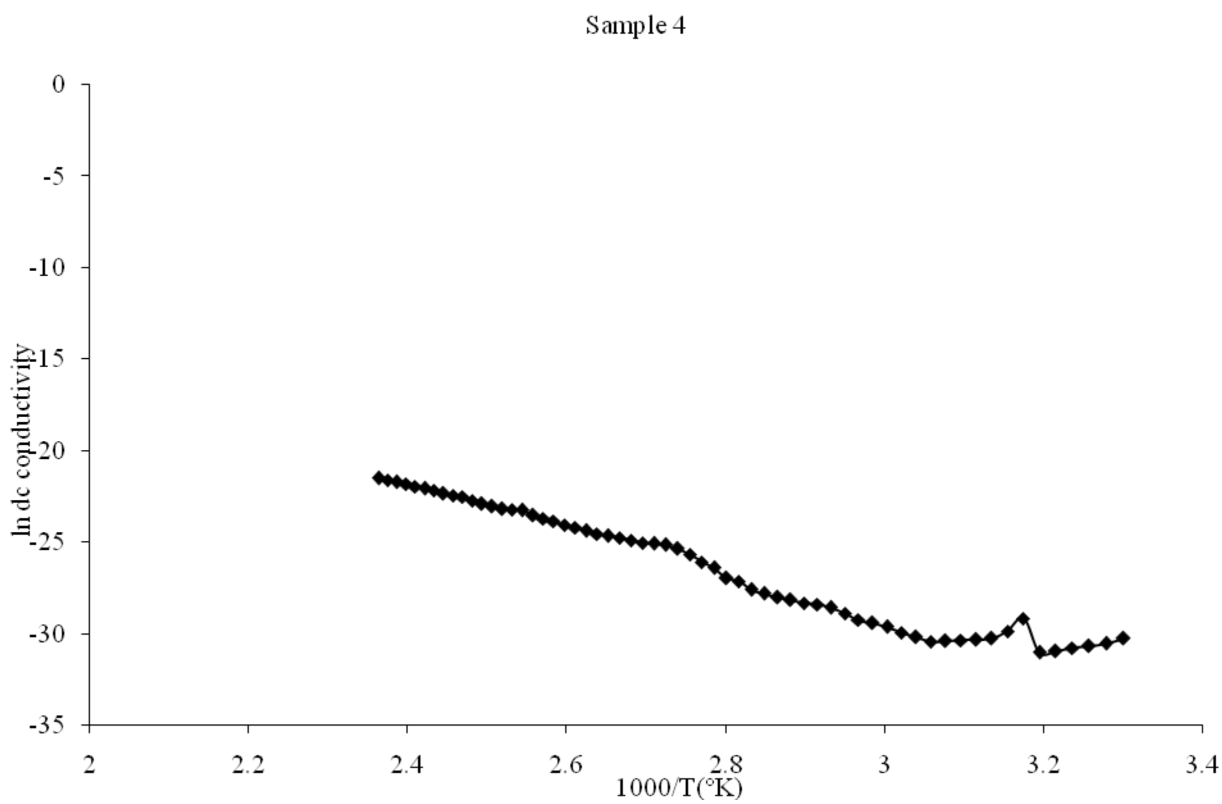
Sample 4
0
-5
-10
-15
-20
-25
-30
-35
ln dc conductivity
2
2.2
2.4
2.6
2.8
3
3.2
3.4
1000/T(°K)

Fig.8