The D.C Electrical Properties of magnesium Filled Polymer Composites

Zainab Al-Ramadhan[1], Ahmed Hashim[2], Marwa Abdul-Muhsien[3], Hussein Talib[4]

[1, 3]Al-Mustansiriyah University, Iraq

[2, 4]Babylon University, Iraq

Abstract: ***In this paper the effect of filler content on D.C electrical properties of polyvinylchloride filled with magnesium powders has been investigated. For that purpose, the polyvinylchloride samples with magnesium additive prepared with different percentages and different thickness. The experimental results showed that the D.C conductivity of such composites increases suddenly by several order of magnitude at a critical weight concentration. The D.C electrical conductivity changed with increasing of temperature. Also the activation energy change with increasing filler concentration.***

Keywords: electrical properties, percolation threshold, polyvinylchloride, conductivity

1. Introduction

Filled polymer composites have a wide range of industrial applications-they are used in anti-static materials, self regulating heaters, over current and over temperature protection devices, and materials for electromagnetic radiation shielding [1].The electrical insulating behavior of most polymeric materials is well known. However, conductive fillers can be incorporated as a second phase in to these matrices, leading to an increase in the conductivity of the resulting composites. the properties of these composites are mainly varied with the filler content. Polymeric composites are traditionally used as electrically insulating materials and generally known to have many structural applications, but their use in electronics has been relatively limited. In order to make the polymeric materials have electrical conduction, continuous pathways by electrical fillers must be established [2]. In order to make the polymeric materials have electrical conduction, continuous pathways by electrical fillers must be established [2]. The percolation theory is the most adequate for modeling conductivity of conducting polymer composite materials(CPCM). It involves convergence of particles to distances at which the probability of transfer of current carriers between them becomes higher than zero. The so-called percolation threshold ϕc, i.e. the lowest concentration of conduction particles at which continuous conducting chains are formed, is easily determined from the experimental dependence of conductivity on the filler concentration. It is a very useful tool to probe the filler distribution within a polymer matrix [3]. Ahmed and Marwa, in(2010) [4] studied the effect of filler content on D.C electrical properties of polyvinylchloride filled with tin powders. The experimental results showed that the conductivity of such composites increases suddenly by several order of magnitude at a critical weight concentration. The D.C electrical conductivity changed with increasing of temperature. Also the activation energy change with increasing filler concentration The present work deals with the effect of magnesium additive on the D.C electrical properties of polyvinylchloride composite.

2. Materials and Methods

The material used in the paper is polyvinylchloride as matrix and magnesium (particle size 70-80 micron) as filler. The electronic balanced of accuracy 10^{-4} have been used to obtain a weight amount of magnesium powder and polymer powder. These mixed by Hand Layup and the Microscopic Examination used to obtain homogenized mixture. The weight percentages of magnesium are (0, 20,40,50 and 55) wt.% The Hot Press method used to press the powder mixture. The mixture of different magnesium percentages has been compacted at temperature 150^{o}C (glass transition temperature 85^{o}C) under a pressure 100 bar for 10 minutes. Its cooled to room temperature, the samples were disc shape of a diameter about 15mm and thickness ranged between (1.05-1.42)mm. The coating unit (Edward coating System E3C6A) has been used for deposition of thin film Aluminum electrode on both sides of each sample. The resistivity was measured over range of temperature from (30 to 80)^{o}C using Keithly electrometer type (616C).The volume electrical conductivity σ_v defined by :

$$\sigma_v = \frac{1}{\rho_v} = \frac{L}{RA} \quad \text{..................(1)}$$

Where:
A = guard electrode effective area.
R = volume resistance (Ohm).
L = average thickness of sample (cm).
In this model the electrodes have circular area A= $D^2\pi/4$ where D= 0.5 cm^2.

3. Results and Discussion

Figure (1) shows electrical volume conductivity as function of the concentration of magnesium at a temperature of 30^{o}C, the conductivity increases with increasing magnesium additive concentration. The increase of conductivity with increasing of concentration of magnesium due to increases the charge carriers which increased with increasing filler contact where the magnesium particles at a low concentrations are represented by small darker regions and become large when the magnesium content increases and the network will be connected to each other containing the overlapping paths to allow the charge carriers to pass through, where the charge carriers with routes through which the electrical resistance be less [1,5,6].

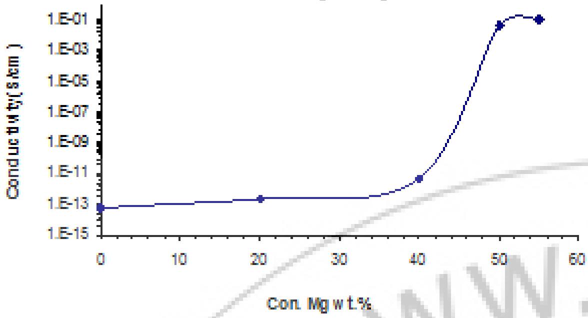

Fig. (1) variation of D.C electrical conductivity with Mg wt% concentration for (PVC-Mg) composite.

The source of the conductivity enhancement is the electrical contacts generated from the filler networks as illustrated in the microscopic photographs in figure (2) taken for samples of different concentrations.

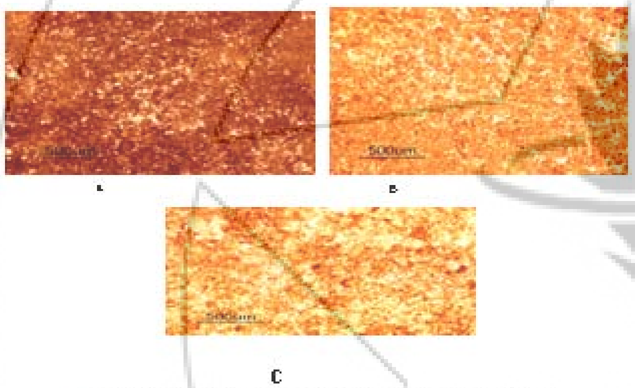

Fig.(2) Photomicrographs for PVC-Mg composite
(a) for pure,(x50) . (b) for 20 wt.% Mg ,(x50)

Figure (3) shows the variation for $\sigma_{D.C}$ of (PVC-Mg) composites at different temperature. The D.C conductivity increases with increase of the temperature($\Phi < \Phi_c$), the increment in temperature provides an increase in free volume and segmental mobility. These two entities then permits free charges to top from one site to another thus increase conductivity. The conductivity increases so as temperature indicates more ions and electrons gained kinetic energy via., thermally activated hopping of charge carriers between trapped sites, which is temperature dependence. The sharp increase of D.C conductivity can be attributed to large heat energy absorbed by the samples and thus induce mobility of electrons.

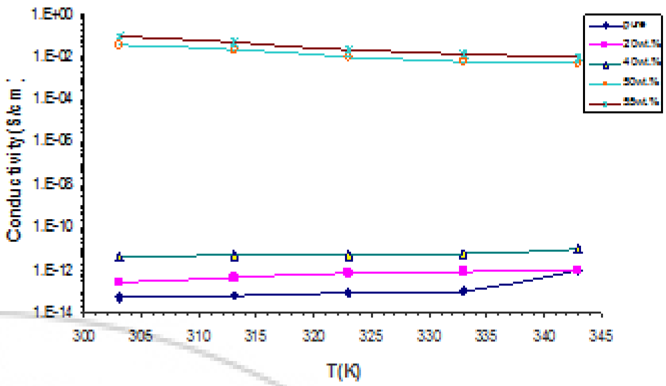

Fig. (3)Variation of D.C electrical conductivity with temperature for (PVC-Mg) composite

It is suggested that in this region, the hand gap between valence band and conduction band is reduce significantly and provide easiness for electrons to hopping from valence band to conduction band [5,7]. Figure(4) shows the relationship between the ln(conductivity) and inverted absolute temperature of the PVC-Mg composites, using equation $\sigma = \sigma_o \exp(-E_a/k_BT)$ was calculate activation energy, the high activation energy values for neat sample and low Mg concentration sample can be attributed to the thermal movement of the ions and molecules, whereas the low activation energy values for the samples of higher Mg content can be attributed to the electronic conduction mechanism which is related to the decreasing of the distance between the Mg particles [8]. The electrical conductivity decreases with increasing temperature($\phi > \phi c$) that any of this material has a positive thermal coefficient of resistance(conductive material).

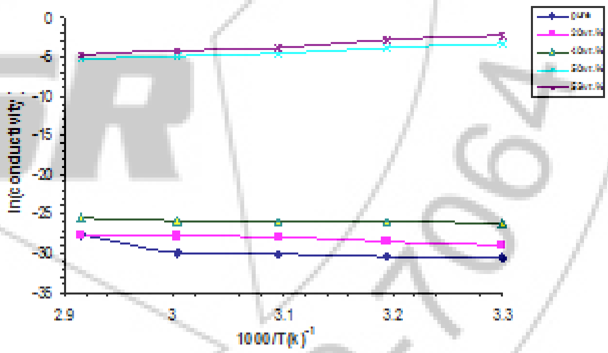

Fig.(4)Variation of D.C electrical conductivity with reciprocal absoute temperature for(PVC-Mg) composite.

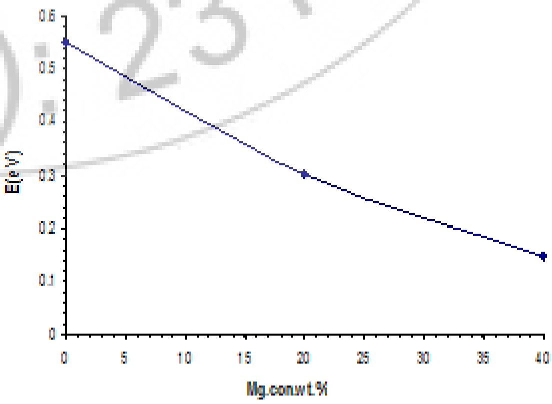

Fig.(5) Variation activation energy for D.C electrical conductivity with Mg wt. % concentration for PVC-Mg composite

The concentration increasing of magnesium less the result of the activation energy as shown in the figure (5) of PVC- Mg composites for ($\Phi < \Phi_c$) which is a reasonable support for the above discussion [7].

4. Conclusions

1. The D.C electrical conductivity of the polyvinylchloride increases by increasing the magnesium concentrations and the temperature.
2. The activation energy of D.C electrical conductivity decreases by increasing magnesium concentrations.

References

[1] Bhattacharya S., Sachdev V.K. and Tandon, 2008,"Electrical properties of Graphite filled polymer composites", 2nd National Con R.P. ference Mathematical Techniques: Emerging Paradigms for Electronics and IT Industries, 100-101.
[2] Shi-hong wn, Toshiaki Natsuki, and Qiog-Qiog Ni, 2008, Electrical conduction and percolation behavior of carbon nanotubes/UPR nancomposites", IEEE Transaction, 15(6) : 214-220.
[3] Younis Khalaf, 2008, The dielectric properties of polyvinylchloride-nickel composites, J. of physics, 3: 529-536.
[4] Ahmed H. and Marwa A., 2010, "The D.C Electrical Properties of Polyvinylchloride- tin Composites", International Conference on Mathematical Applications in Engineering, 3-5 August, 360-362.
[5] He X. JDu., J. H. and Ying Z. , 2005, " positive temperature coefficient effect in multwalled carbon nanotube high – density polyethylene composite", J. Appl. Phys. Letters, 86(6) :112-114.
[6] Srivastava N. K. and Mehra R. M. , 2009," Study of electrical properties of polystyrene / foliated graphite composite", J.Materials Science- Poland, 27(1): 110-122.
[7] Ahmed M. S. and Zihilif A. M., 1992, “The electrical conductivity of polypropylene and Nickel- Coated carbon Fiber composite ",J. Mater. Sci. 25(706): 53-57.
[8] Hamzah M., Saion E., Kassim A. and Yousuf M. , 2008, "Temperature dependence of AC Electrical conductivity of PVA-PPy-FeCl3 composites polymer Films", Malaysian Polym. J., 3(2) : 24-31.