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Study of The Electrical Conduction Mechanism of Poly (Vinyl Chloride) (PVC) /Poly (Ethylene Oxide) (PEO) Blend Films

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Abstract

In this the study, Blend of poly (vinyl chloride) (PVC) /poly (ethylene oxide) (PEO) was prepared by solution casting technique and the electrical conduction mechanism has been studied at room temperature. The results presented in the form current-voltage characteristics as function of PEO concentrations. Analysis has made in the light of Pool-Frenkel, Fowler-Nordheim and Schottky-Richardson mechanism. It observed that, Pure PVC and PVC/PEO blend samples with PEO <50% has schottky conduction mechanism. Meanwhile Pool-Frenkel conduction mechanism is the predominant mechanism for PVC/PEO blend sample with PEO (50%).Also the results indicating the absence of F-N mechanism.

Keywords: poly (vinyl chloride) (PVC) /poly (ethylene oxide) (PEO), electrical conduction mechanism

1. Introduction

In polymer with chemically saturated structures. It is difficult to observe any electronic conductivity at all, and what conductivity there is usually depends on the movement of adventitious ions. Consequently, any improvement in the quality of insulation generally won by careful preparation and purification, so to avoid as much as possible the presence of ionic impurities. Useful levels of conductivity can achieved by making composite material in which a conducting additive dispersed in an insulating polymer. The highly conductive additive is dominant in the conduction process with the insulating polymer limiting the overall conductivity by forming barriers between the particles. Electronic transition is possible in polymers with chemically unsaturated structures. (1,2)

Electrical conduction in polymers has been study extensively during the past two decades to understand the nature of charge transport in these materials.

In the case of organic solids, whose conductivity due to electrons excited from the valence band to the conduction band is negligible (3), a complex conduction behavior has usually been explained usually in terms of electron emission from the cathode (Schottky-Richardson mechanism) (4) or electron liberation from the traps in the bulk of the material (Pool-Frenkel mechanism) (5), the possibility of tunneling (Fowler-Nordheim mechanism) (6), and space charge-limited conduction (7). More recently, considerable interest has been show on the effect of doping and blending on the transport properties of polymer. (8,9,10)

Depending on their chemical nature and the way in which they react with the nost matrix, the doping substances as well as blending polymer alter the transport properties to different degrees.

In the present study, an attempt made to investigate the conduction mechanism of polyvinyl chloride (PVC)-polyethylene (PEO) blend films.

Polyvinyl chloride polymer (PVC) have excellent electrical insulation property (11) and Polyethylene polymer (PEO) have high ionic conductivity, it achieved at the temperature range of (80-100 ^{0}C), while at low temperature, it exhibits low conductivity. (12)

Many studies been conducted regarding Polyvinyl chloride polymer (PVC) and effecting addition of suitable materials on their properties:

R.S. GULAKARI et al (13) studied the electrical conduction mechanism of polyvinyl chloride (PVC) –polymathic methacrylate (PMMA) blend film.

P. D. Burghate and D. K. Burghate (14) studied the electrical conduction mechanism of (0.2%) Polyaniline doped PVC-PVAs polymer blends.

L. A. Sharma and D.K. Burghate (15) studied the electrical conduction mechanism of polyaniline doped PVC-PS blend.

A.JOY Singh (16) studied the conduction mechanism in (Zno/PVC) polymer.

2. Experimental

2-1. Preparation of sample

In this study solvent casting technique employed, prepare the PVC-PEO blend polymer. Different weight ration of PVC-PEO dissolved separately in tetra hydro furan (THF) and these solutions then mixed at room temperature to obtain a homogenous mixture. The solution was then poured into a petri dish and allowed to evaporate at room temperature. Then the samples placed inside vacuum oven to remove any traces of solvent. The compositions of films were PVC (100%)-PEO (0%), PVC (90%)-PEO (10%), PVC (80%)-PEO (20%), PVC (70%)-PEO (30%) and PVC (50%)-PEO (50%).

The samples were in circular forms of (0.052-0.058 cm) thick and (0.45 cm) in diameter. The two opposite faces of the film coated with a thin layer of silver paste. Copper wires fixed on both surfaces and the specimen mounted on a sample holder.

2-2. The measurements

The D.C measurements were taken by using Kethley 485 auto ranging Pico ammeter at room temperature (300K) and the dielectric measurements were carried out using an auto balance bridge (typ. GM Instek LCR-821 meter) in frequency 10^5 Hz.

The dielectric permittivity (ε') calculated by using the relation:

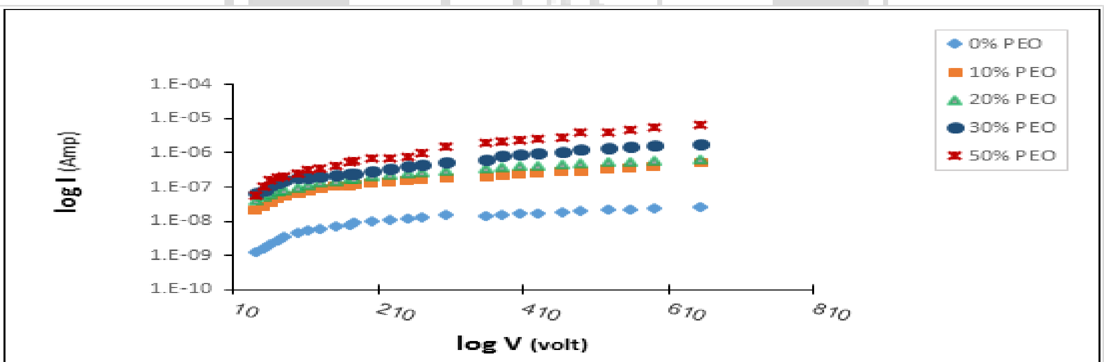
$$(\varepsilon' = \frac{d}{\varepsilon_o A} * C)$$

Where:

C: capacitance of the sample, d: thickness of the sample and A: area of the coated surface.

3. Results and discussion

The current (I) flowing through pure PVC polymer and PVC-PEO composites as a function of applied voltage (V) was measured whilst maintaining the sample at room temperature (300 k) see Figure (1).



Figure(1): Represent the (I-V)characteristice curves of PEO/PVC blends at room temperature (300K).

Fig (1)

At low voltages, the current increased gradually with applied voltage and at higher voltage, the rate of increase was slower. This behavior can explained in terms of the charge-transport mechanism operating in PVC-PEO composites in the different voltage ranges.

The mechanism operative in the present case discussed in the light of Schottky-Richardson, Pool-Frenkel and Fowler-Nordheim mechanism.

1. Schottky –Richardson mechanism

Schottky emission is a conduction mechanism that if the electrons can obtain enough energy provided by thermal activation, the electrons in the metal would overcome the energy barrier at the metal-dielectric interface to go to dielectric. The energy barrier height at the metal-dielectric interface may be lowered by image force.(4)

The Schottky-Richardson current-voltage relationship expressed as:

$$J = AT^2 \exp[\frac{-\emptyset_\beta}{KT} + \beta_{SR} E^{1/2}]$$

Where A is the Richardson constant(=120 Amp.cm^{-2}.k^{-2}) ,ϕ_B :the schottky barrier height ,K :The Boltzmann constant ,T is the absolute temperature and β_{SR} being the field lowering constant given by :

$$\beta_{SR} = \frac{e}{KT}[\sqrt{\frac{e}{4\pi\varepsilon_o\varepsilon'}}]$$

So that the S-R mechanism is characterized by the linearity of (lnJ) versus (E$^{1/2}$) plots with a positive slope.

In the present case of PVC-PEO thin films the (lnJ) versus (E$^{1/2}$) plots in Figure (2) . The plots are straight line with positive slopes indicates that the Schottky-Richardson mechanism is applicable to conduction process in PVC-PEO blend films.

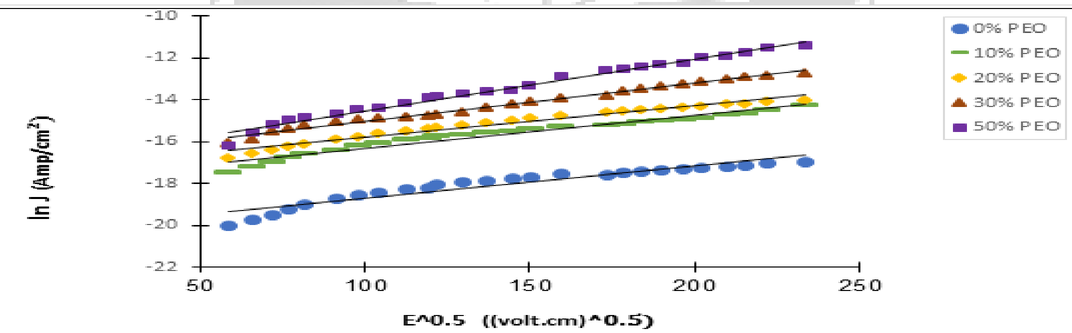


Figure (2) : Represent the (lnJ) versus E^0.5) plots for all PEO/PVC blened samples.

Fig (2)

2. Pool-Frenkel mechanism

In (P-F) emission, the thermal excitation of electrons may emit from traps into the conduction band of dielectric. Therefore, P-F emission is sometimes called the internal Schottky emission. Considering an electron in a trapping center, the coulomb potential energy of the electron can be reduced by an applied electric field across the dielectric film. The reduction in potential energy may increase the probability of an electron being thermally excited out of the trap into the conduction band of the dielectric. (5)

The current –voltage relationship for P-F mechanism is expressed as:

$$J = J_{\circ} \exp[\frac{-\emptyset_{T}}{KT} + \beta_{PF}\ E^{1/2}\ ]$$

Where:

Φ_T: the trap energy level and β_{PF} being the field lowering constant given by:

$$\beta_{PF} = \frac{e}{KT}[\sqrt{\frac{e}{\pi\varepsilon_{\circ}\varepsilon'}}]$$

The P-F mechanism predicts a field dependent conductivity as

$$\sigma = \sigma_{\circ} \exp[\frac{\beta_{PF}E^{1/2}}{2KT}]$$

So that the P-F mechanism is characterized by the linearity of (lnσ) versus($E^{1/2}$) plots with a positive slope.

In the present case of PVC-PEO thin films. It can be inferred from P-F plots in Figure (3). that the mechanism does not contribute significantly to the conduction as (ln σ) does not show appreciable dependence on ($E^{1/2}$) axis indicating absence of P-F mechanism exception (PVC (50%)-PEO (50%)) sample.

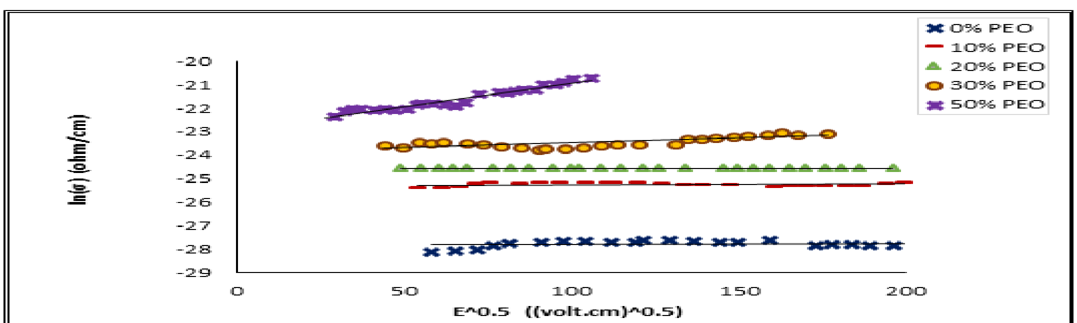


Figure (3) : Represent the (lnσ) versus E^0.5) plots for all PEO/PVC blened samples

Fig (3)

3. Fowler-Nordheim tunneling

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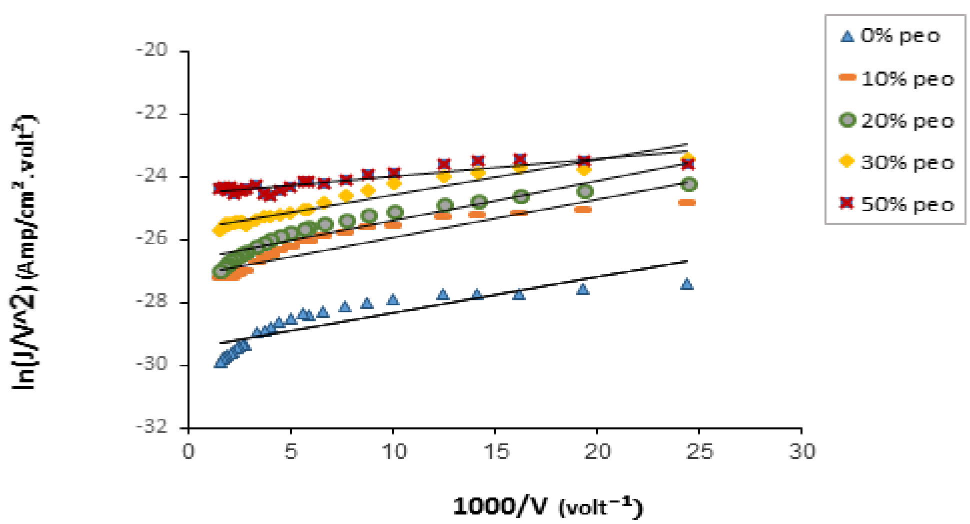
F-N tunneling occurs when the applied electric field is large enough so that the electron wave function may penetrate through the triangular potential barriers in to the conduction band of the dielectric. (6)

The Fowler-Nordheim relation for current density (J) can be expressed as:

$$ln\frac{J}{V^2} = lnA - [\frac{\emptyset}{V}]$$

So the (ln $[J/V^2]$) versus (1000/v) plots are expected to be a linear relation with negative slope.

In the present case of PVC-PEO thin films the (ln $[J/V^2]$) versus (1000/v) plots in Figure (4). The plots are nearly straight lines with positive slopes indicating the absence of F-N mechanism.



Figure(4) Represent the (ln(J/V^2) versus (1000/V) plots for all PEO/PVC blend samples

Fig (4)

The linear behavior with positive slope of (ln J) vs. ($E^{1/2}$) plots in present study points to an electronic- type conduction mechanism. Here, the charge carriers released by thermal activation over a potential barrier. The physical nature of such a potential barrier can interpreted in two ways. It can be the transition of electrons over the barrier between the cathode and the dielectric (Schottky emission). Alternatively, the charge carriers can released from traps into the dielectric (Pool-Frenkel effect).

In order to differential between these two, the values of β at constant temperature calculated from the slopes of (ln J) Vs. ($E^{1/2}$) plots for all samples.

The theoretical value of β can calculated separately for either the Schottky or Poole Frenkel mechanism be use of the following respective equations:

$$\beta_{SR} = \frac{e}{KT}\left[\sqrt{\frac{e}{4\pi\varepsilon_{\circ}\varepsilon'}}\right]$$

$$\beta_{PF} = 2\beta_{SR}$$

Where: $\varepsilon_{\circ}=8.85*10^{-12}$ F/m , $e=1.602*10^{-19}$ C and $K_B=1.3806*10^{-23}$ JK^{-1}

The experimental as well as the theoretical values of β for both the Schottky and Pool-Frenkel mechanism are shown in table (1)

Table 1

PEO content (wt %)	ε´	β_{exp}	β_{SR}	β_{PF}
0%	11.0435	0.0154	0.0169	0.0338
10%	11.73133	0.0156	0.0163	0.0327
20%	12.95839	0.0151	0.0156	0.0312
30%	13.85507	0.0182	0.0150	0.0301
50%	19.85507	0.0247	0.0126	0.0252

It is evident from the table about pure PVC and PVC/PEO blend samples with PEO <50% has schottky conduction mechanism. Meanwhile Pool-Frenkel conduction mechanism is the predominant mechanism for PVC/PEO blend sample with PEO (50%)

Conclusion

D.C-Conduction through PVC/PEO blend films was studied to identify the mechanism of electrical conduction. Heavy reliance has been made on the measured slope (Ln J) versus ($E^{1/2}$) for the interpretation of the experimental data. Pure PVC and PVC/PEO blend samples with PEO <50% has schottky conduction mechanism. Meanwhile Pool-Frenkel conduction mechanism is the predominant mechanism for PVC/PEO blend sample with PEO (50%).

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