Electrical Conductivity Properties of Iodine doped Polystyrene Films (PS) in Electret State

Abstract

Polystyrene films (PS) is reportedly one of the most widely used high molecular weight compounds. Polystyrene and its applications are quite attractive for both academic and industrial researchers. Electrical Conductivity Properties of iodine doped Polystyrene films (PS) thin film using transient current at 50^{o}C for different concentration. The trapping capability of Polystyrene (PS) can be greatly modified by doping it with certain impurities. The describes transient behaviour of current, current-voltage characteristics and temperature dependence of current in iodine doped Polystyrene films (PS).

Keywords: Polystyrene(PS), Iodine, Electrical Conductivity, Transient Current,Schottky Effect, Spelling and Grammar are Correct

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Introduction

Most of the polymers are considered to be insulators because they show low conductivity, low dielectric loss and high break strength. [1]. A good amount of work has been reported on electrical conduction in polymeric materials and various mechanisms such as ionic conduction [2], Schottky emission [3], space charge limited conduction [4], tunnelling [5],Poole Frenkal mechanism.[6].The trapping capability of a polymer can be greatly modified by dopping it with certain impurities [7]. Electrical conductivity of dielectric is generally investigated either by heating the sample over a temperature range at a constant rate and keeping the applied voltage constant or by applying a voltage over a rang keeping the temperature constant .Polystyrene (PS) doped with iodine has been chosen for the present investigation.

In Polystyrene (PS) polymer when H-atoms in the backbone chains are replaced by larger aromatic groups with π-electrons, the highest filled and the lowest empty molecular orbits are formed from the substituent and the charge transfer occurs within the pendent groups where charge carrier density is higher due to higher affinity to electrons or holes [8-11]. The role of backbone chain is less important.

The trapping capability of Polystyrene (PS) can be greatly modified by doping it with certain impurities [12]. Carrier mobility in polymeric materials is increased by small molecules such as ionic [13]. Doped Polystyrene (PS) with several impurities and found that the conductivity of polymer is greatly enhanced due to doping of the matrix with iodine [14].The enhanced conductivity of the polymer has been interpreted in terms of charge-transfer complexes.

This paper describes transient behaviour of current, current-voltage characteristics and temperature dependence of current in iodine doped Polystyrene films (PS).

Experimental Details

The sample polarization and transient current measurements have been carried out in a cell using and assembly which is dry, rigid and well established. The cell and assembly have the following properties (i) high insulating resistance (ii) freedom from picking up of spurious potentials and induced charges due to physical motion of the system and (iii) negligible leakage current and less micro phonic. To achieve the required degree of precision every consideration of perturbing parameters was taken into account while taking the measurement. All the efforts have been made to minimize the any type of experimental errors. The electrometers is specially designed to measure very small direct current, low DC potentials from high impedance source, small charges and high resistance. The temperature of the sample was recorded with a calibrated thermocouple attached in close neighbourhood of the sample. The samples thickness was of the order of 25µm.

Results and Discussion

The transient current vs time in iodine doped Polystyrene films (PS has been investigation over a period of time 01 -1000 sec. Figure 1 show log I vs log t plots for charging mode at temperature 50^oC at applied voltage 9V and 99V. It is represented iodine doped Polystyrene films (PS) causes current which is found to decreases first rapidly and then slowly. The s thickness of the samples is 25µm.Transient behaviour of current was investigated in 20 µm thin films of PS, I_1 and I_3. At 50^oC, I_1 gives ten times more current than PS, I_3. Current also depends upon applied voltage but the temperature dependence is more pronounced.

Current (J) versus time (t) on a double log plot yielded a straight line. The current may be described by

$$J(t) = A(T)\,t^{-b}$$

Where b is an exponent and A (T) a temperature dependent factor. Figure show that the exhibits effect of temperature, voltage and iodine concentration on transient behaviour of current. It is show that the decaying current obeys the usual t^{-b} law before reaching a steady state. Voltage dependence of current may be described by

$$J(t) = K(t)\,V^p$$

Where p is an exponent and K is a decay factor independent of voltage. Transient current was also found to depend upon electrode material.

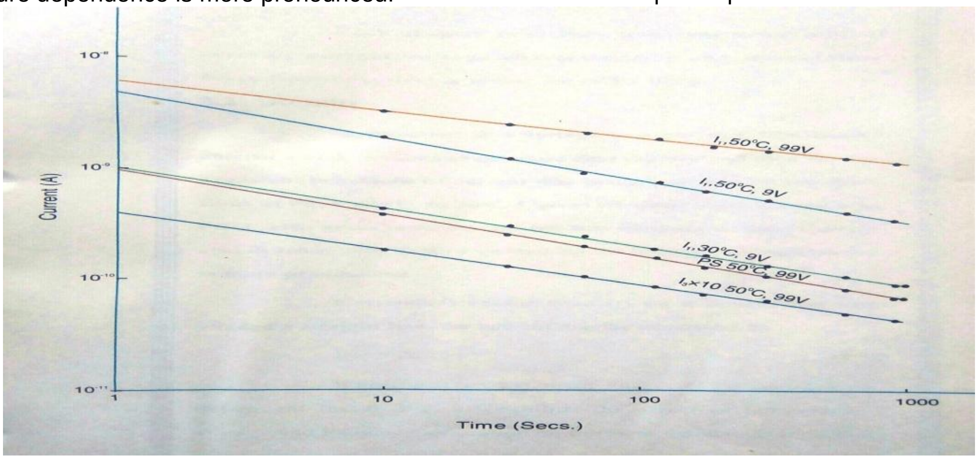

Figure No. 1: Effect of temperature, voltage and iodine concentration on transient current in PS

Constant provide an important source of carrier injection in poly-meric materials. To investigate the role played by constants, steady state current-voltage (J-V) characteristics were traced at 50^oC for I_1 in the configuration Al-PS- metal. Al, Cu, Ni and Zn metals were employed to obtain a range of work function. The peplots of J-V in the form of J-$\sqrt{V}$ (Schottky plots) are show in Figure.2. The figure also shows the effects of concentration and temperature .The plots when extrapolated in the backward direction seem to originate from the same point, therefore electrode dependence is rather weak.

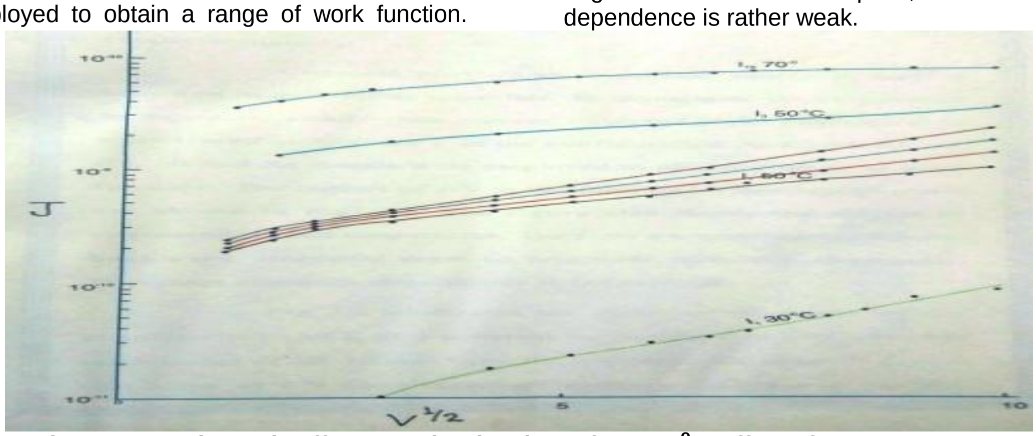

Figure No 2: Electrode effect on schottky plots of I_1 at 50^oC, effect of temperature on J-$\sqrt{V}$ Plots of I1 and effect of iodine concentration on J-$\sqrt{V}$ plots at 50^oC

Figure no. 3 illustrates the effect of thickness on J-V characteristics of I_1 at a constant temperature of 50 ^oC. For the thickness of 20, 10 and 5 µm the J-V plots are linear. It is seen that slpoe of J-V plots increases with the decrease in the film thickness. Current density at the same voltage plotted against reciprocall thickness cube of the film gave straight line.

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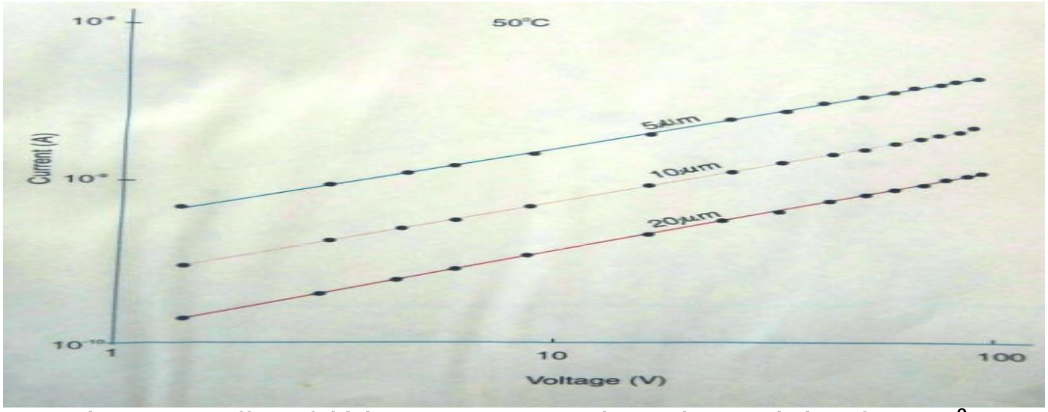

Figure No 3: Effect of thickness on Current-Voltage Characteristics of I_1 at 50^{o}C

Figure No.4 shows these plots for the applied voltages 1.5, 4.5,9,45 and 90 V. Current – Voltage characteristics are linear. When the charge carriers are supplied from the electrode and all of them are transported Ohmic law holds and the current is proportional to the voltage. The current in the case is limited by the electrode. When the electric field is low, the mobility of the carriers or the presence of traps can limit the current observed in the system. In the absence of traps only mobility limits the current and one has a super linear J-V curves.

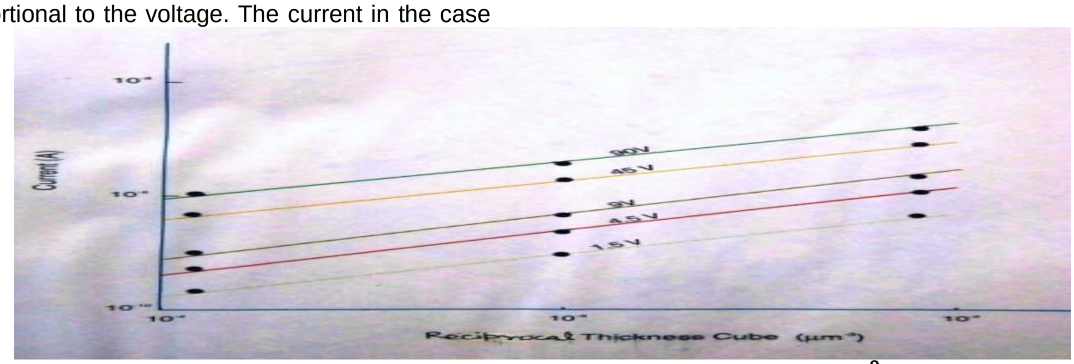

Figure No 4: Current vs reciprocal thickness cube of I_1 at 50^{o}C

Figure No.5 compares the steady state conduction currents obtained by applying a voltage in the range 3-99 V at a temperature of 50^{o}C to the PS, I_1, I_2, I_3, I_5 and I_{10} films. They are all linear on double log scale. Currents and hence the conductivities of the doped films are greater than those of pure PS film at all the voltages applied. At a particular voltage, as the iodine concentration is increased, the current is also increased. Slope of pure PS plot is greatest and it is decreased with the increase in iodine concentration. At a lower voltage the current differ more than at higher voltage i.e. as the voltage is increased, the difference in the currents of various samples become smaller and smaller.

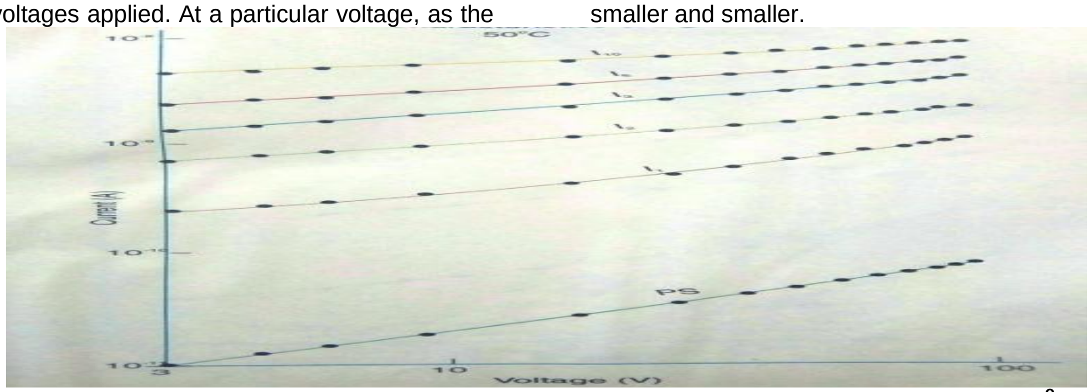

Figure No 5: Effect of iodine concentration on Current –Voltage Characteristics of PS at 50^{o}C

Current voltage characteristics of I_1 at 30,40,50,60 and 70^{o}C have been plotted in figure no 6. Similar plots were also obtained for other concentrations of iodine. Slopes of these lines are seen to decrease with the increase in temperature. The diirence in current at various temperatures is greater at smaller voltage and is smaller at greater voltages.

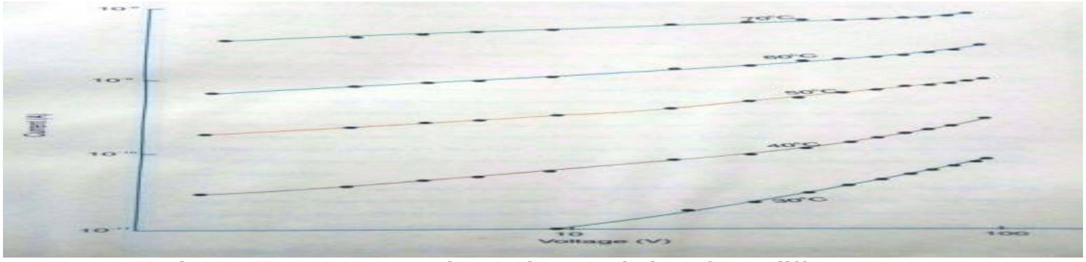

Figure No.6 Current – Voltage Characteristics of I_1 at different temperature

The temperature variation of current in the range 30-100°C was studied by heating the film at a constant rate of 1°C/min and applying a voltage of 18 V. The conductivity was evaluated from the measured value of current. The conductivity of PS film increases linearly with temperature from 30°C to about 70°C beyond which a strong bend is observed. At all temperature, conductivity of doped film is greater that that of pure PS. Due to increase in iodine concentration, the conductivity is further enhanced. Activation energy E was calculated from

$$\sigma = \sigma_0 \exp (E/kT)$$

Where k= Boltzmann's Constant

The value of activation energy energy is noted on the corresponding plot. The value of activation energy decreases due to doping which is further decreased due to increase in iodine concentration. The behaviour of absorption current in iodine doped PS is observed to be similar to that of polypropylene. A sudden increase in voltage causes the current to transiently increase to high values. In a matter of minutes, the current subsides to a much smaller stationary value. The interpretation is that the sudden increase in voltage forced a corresponding increase of charge in the conduction band. The inflection on J (T) curve does not necessarily correspond to the glass transition temperature of the polymer, even though the inherent conductivity becomes a predominating component in the vicinity of glass transition [15-18]. The Conductivity is enhanced considerably, which may be associated with the increase in mobility due to doping. The strong concentration dependence of conductivity of the polymer helps to interpret that transport in iodine doped PS films occurs via a hopping process among sites associated with the dopant molecule [19]. A rather detailed theoretical background exists for hopping transport with discrete activation energy. Theoretical refinements are in progress to include distribution of hopping energies and to describe alternative transport mechanisms such as multiple trapping and trap controlled hopping, although these extensions of the theoretical concept will narrow the range of possible interpretation, would require the experimental modifications of materials parameters specific to the proposed transport model, such as the densities of hopping or trapping sites.

Conclusion

The Transient current decays according to t^{-b} law before reaching a steady state. The observed magnitude of b and the lack of thickness and electrode material dependence of transient current indicate carrier hopping process. Electrode effect on current-voltage characteristics of the films indicates the Schottky thermionic emission of charge carriers. Temperature dependence of conductivity of pure and iodine incorporated films reveals that doping of the PS matrix with iodine enhances the conductivity of PS polymer. The increase in conductivity is due to the increase in mobility of charge carriers due to impregnation of the matrix with iodine. Iodine is a strong electron acceptor impurity. It forms charge transfer complexes (CTC) and so the conductivity is enhanced.

Endnotes

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