

D.C. Electrical Conductivity of Iodine Doped Polystyrene Thin Film

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Abstract—Conducting polymers represent a transformative class of materials that bridge the gap between conventional plastics and metals. Their unique ability to combine the mechanical flexibility and processability of polymers with the electrical conductivity of semiconductors makes them indispensable for next-generation electronics. In the present work, polystyrene was used as the host polymer and iodine as the dopant to measure DC conductivity. Measurements were conducted using iodine concentrations ranging from 1 wt% to 10 wt% at temperatures of 348 K, 343 K, 338 K, 333 K, 328 K, and 323 K. It was observed that for each temperature, conductivity increased linearly, suggesting ohmic conduction where the current is directly proportional to both the applied voltage and temperature. The results indicate that the conduction is not space-charge limited. The electrical conductivity of the polystyrene films increased with doping concentration. For a specific doping level, conductivity reached a maximum; beyond this point, conductivity decreased. The current in the polystyrene material is controlled by thermally generated carriers. Upon examining the activation energies across different doping percentages, it was found that the activation energy reaches a minimum at the same doping level where conductivity is maximized. This relationship suggests that minimum activation energy is a prerequisite for achieving peak conductivity in these films.

Index Terms—Activation energy, Charge carriers, Conducting polymers, DC conductivity, Ohmic conduction.

I. INTRODUCTION

In recent years, the demand for conducting polymers has surged significantly, driven by their unique ability to combine the electrical properties of metals with the mechanical flexibility and processability of traditional plastics. Unlike conventional polymers, which act as

insulators, conducting polymers feature a conjugated backbone—a system of alternating single and double bonds—that allows for the movement of charge carriers. The characteristic property of semiconductor is electrical conductivity which is given by Pohl (1962) lies between 10^{-2} to 10^{-12} ohms⁻¹ cm⁻¹ at room temperature for polymeric semiconductor. The electrical conductivity of substance used as insulator is vary from 10^{-12} to 10^{-14} ohms⁻¹ cm⁻¹ for organic compound and 10^{-16} to 10^{-19} ohms⁻¹ cm⁻¹ for polystyrene. Organic material with a conductivity less than 10^{-12} to 10^{-13} ohms⁻¹ cm⁻¹ are designated as dielectrics while those with a conductivity more than 10^{-11} ohms⁻¹ cm⁻¹ as semiconductor. Is taken to be 10^{-15} ohms⁻¹ cm⁻¹ (My Nilkov 1968) plastics are used in electrical engineering and electrical as insulating material on accounts of their dielectric properties with high specific resistance 10^{-12} to 10^{-19} ohms⁻¹ cm⁻¹ in 1958-1960 polymer with more conductivity falling in range 10^2 to 10^{-11} ohms⁻¹ cm⁻¹ possessing semi-conducting properties were 1st prepared (Ya. M. Pauskhln et al 1970). During last few decades, research on polymeric semiconductor and conducting oxide glasses (Austin and mott,1969, Chaudhury,1995, Denton et al,1954, Mott,1968, Sayer and Mansing,1972) has been discussed which have induced conductivity by techniques using such doping, heat treatment, irradiation etc.

II. MATERIAL AND METHODS

2.1. Preparation of sample

For the preparation of sample, we take 1grams of polystyrene (supplied by Suprime Chemicals), which is, add in 5 ml of Xylene taken in test-tube. Shake the mixture for 2-3 hour and stand it for 24 hours. After

that clear, transparent and viscous solution is formed which can be utilized for preparation of pure film

In present work we used 1 Wt%, 2 Wt%--10Wt% Iodine for doping

- To prepare the 1Wt% of iodine doped polystyrene solution, we take 1grams of polystyrene which is dissolved in 5ml Xylene and in other test tube take 0.01grams of iodine add 5ml of Xylene and shake well to dissolved it then mix both solution and stands the solution 24 hours
- Similarly, for 2Wt%, 3Wt%, ----- 10Wt%, take 0.02,0.03, ----- 0.1 grams of iodine, conduct the same procedure. Finally, we get required doped solution, which can be used, for the preparation of pure, 1Wt%, 2Wt%-----10Wt% of doped film respectively

In present work the Solution Casting or Drop Casting method is used, which is one of the most straightforward ways to prepare thin films of conducting polymers on a glass substrate?

2.2. Substrate Preparation

Before any polymer is applied, the glass plate must be chemically cleaned. Any contaminants like oils or dust will cause "pinholes" or poor adhesion.

2.3. Cleaning:

The plate is usually cleaned in an ultrasonic bath using a sequence of deionized water, acetone, and isopropanol.

2.4. The Casting Process

Here we use Drop Casting: A specific volume of the solution is "poured" or dropped onto the center of the glass plate. It is ensured that the polymer solution spreads evenly. The solvent evaporates, leaving the polymer film behind. While simple, it can lead to the "Coffee Ring Effect," where the edges are thicker than the center.

2.5. Controlled Evaporation and Annealing

Once the liquid is on the plate, the solvent must be removed the plate is placed in a leveled environment (often under a petri dish cover) to slow down evaporation, which prevents cracking.

III. MEASUREMENT OF D.C. ELECTRICAL CONDUCTIVITY

The D.C electrical conductivity of polystyrene thin film was measured by finding its resistance. The resistance of sample was measure by using method adopted by Yawale et.at. (1996,1997) the electrical circuit for D.C. resistance measure is shown in fig. 3.1 The circuit consists of D.C. regulated power supply of 5 volts and digital D.C. microvoltmeter (systronic 412) having input impedance of 10 mho also it consists of digital Pico ammeter having accuracy of 1 pA by measuring voltage across the sample, the resistance can directly be calculated by using ohms law

The circuit used for this purpose is shown in fig

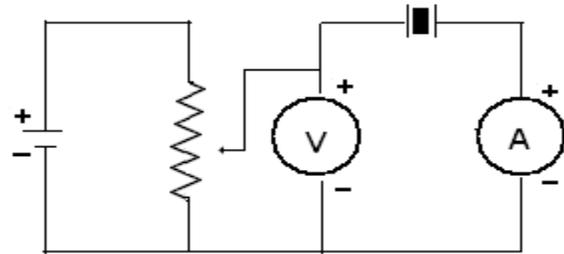


Fig no 1 Circuit for to Find Resistance OF Sample

IV. RESULT AND DISCUSSION

4.1. D C Conductivity

For the study of d c electrical conductivity of polystyrene thin films, the V-I characteristics of 6 films with 5, 6, 7, 8, 9-wt % iodine doped and one pure film of different thickness i.e., 0.003, 0.0048, 0.0049, 0.0074, 0.005 and 0.004 were studied. The plots of V-I characteristics of these films at six different temperature 348 K, 343 K, 338 K, 333 K, 328 K, 323 K are represented in figures 4.1, 4.2, 4.3, 4.4, 4.5, 4.6, respectively

It is seen that, the curve for each temp has, linear increase with temperature where thought conduction is ohmic V-I characteristics indicates that current is directly proportional to temperature of the and voltage applied to film

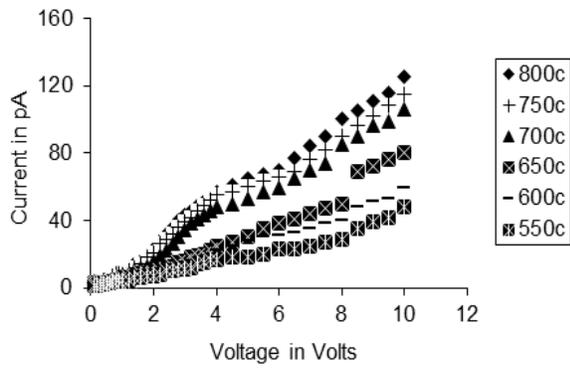


Fig no 2 - V-I Characteristics of pure polystyrene

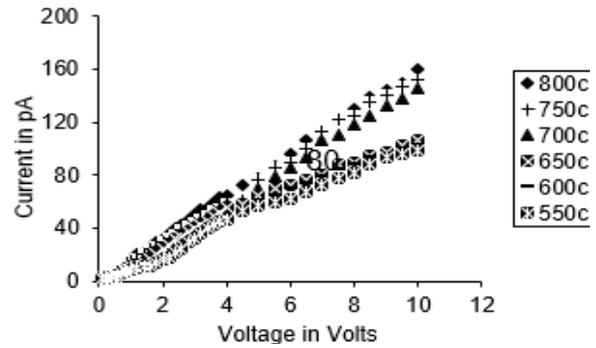


Fig no 6 - V-I Characteristics of 8 Wt% of Iodine

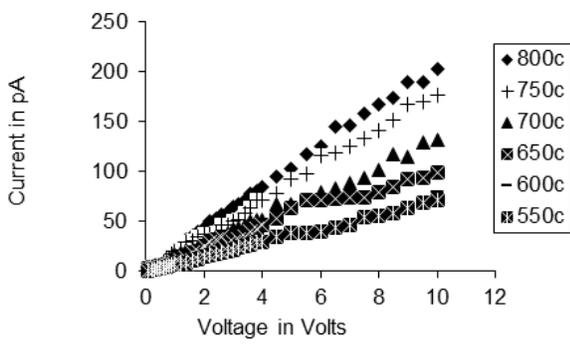


Fig no 3 - V-I Characteristics of 5 Wt.% of Iodine

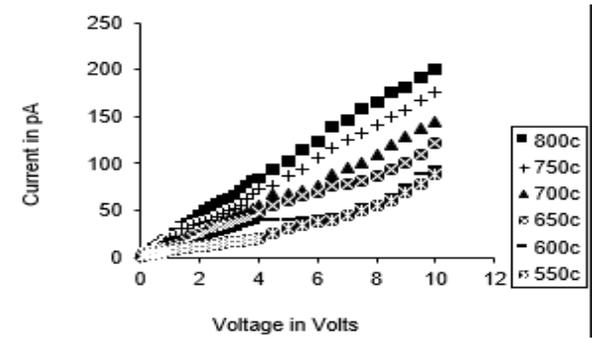


Fig no 7 - V-I Characteristics of 9 Wt% of Iodine

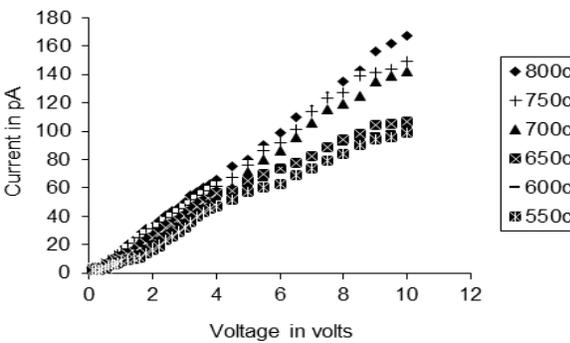


Fig no 4 - V-I Characteristics of 6 Wt% of Iodine

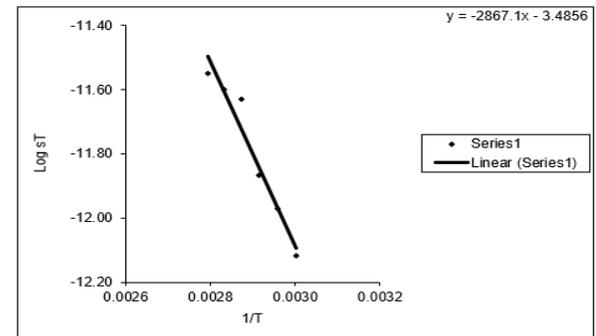


Fig no 8 - The variation of conductivity ($\log \sigma T$) with temperature ($1/T$) at 8 volts Pure Polystyrene

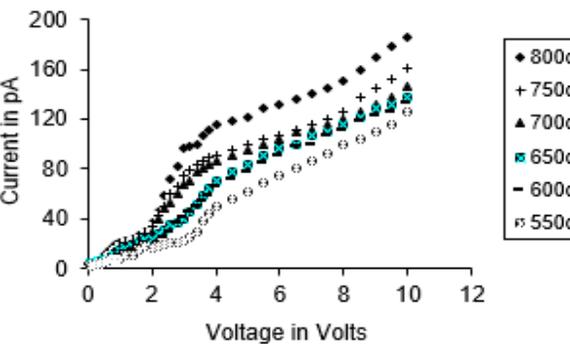


Fig no 5 - V-I Characteristics of 7 Wt% of Iodine

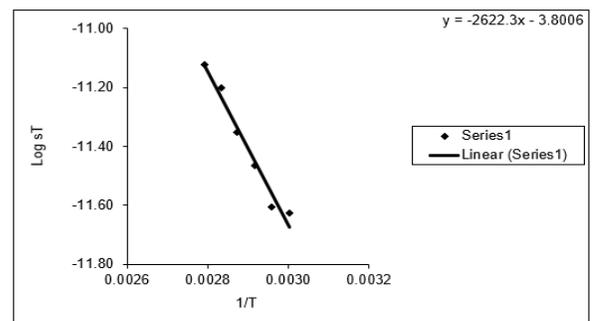


Fig no 9 - Variation conductivity ($\log \sigma T$) with temperature ($1/T$) for 5-wt % iodine doped Polystyrene at 8 volts

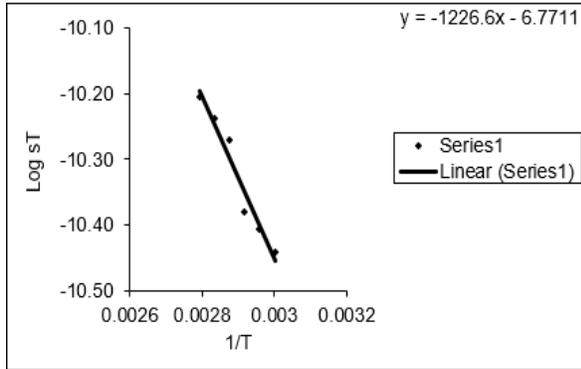


Fig no 10 - Variation conductivity ($\log \sigma T$) with temperature ($1/T$) for 6-wt % iodine doped Polystyrene at 8 volts

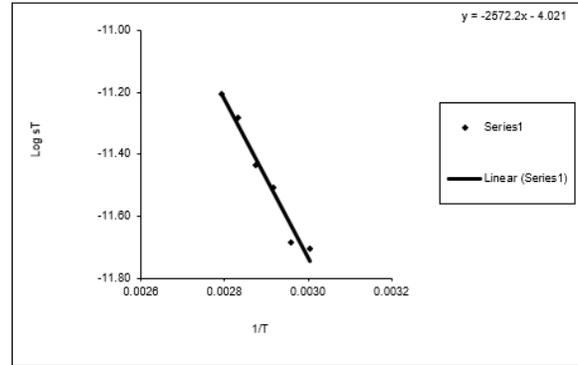


Fig no 13 - Variation conductivity ($\log \sigma T$) with temperature ($1/T$) for 9-wt % iodine doped Polystyrene at 8 volts

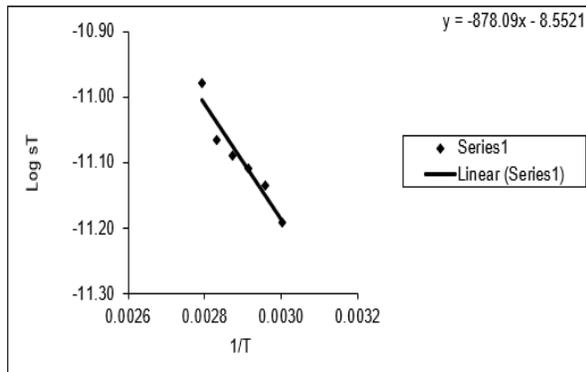


Fig no 11 - Variation conductivity ($\log \sigma T$) with temperature ($1/T$) for 7-wt % iodine doped Polystyrene at 8 volts

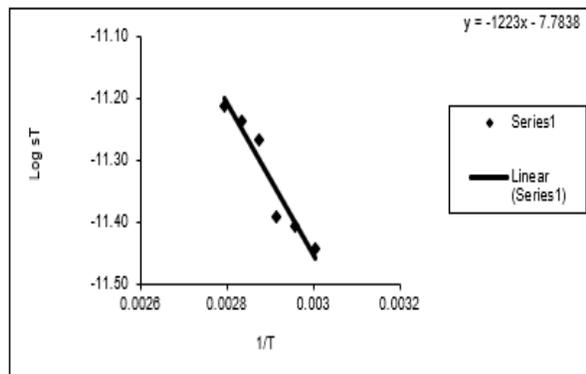


Fig no 12 - Variation conductivity ($\log \sigma T$) with temperature ($1/T$) for 8-wt % iodine doped Polystyrene at 8 volts

The entire fig shows straight line with different slopes this indicates that the conduction is not space charge conduction. The activations energies in eV with different doping percentage is tabulated as below

Table no. 1 For eV and doping percentage

S. NO.	Wt % Of Iodine	Activation Energy in eV
1	0	0.2470
2	5	0.2259
3	6	0.1057
4	7	0.0756
5	8	0.1054
6	9	0.2216

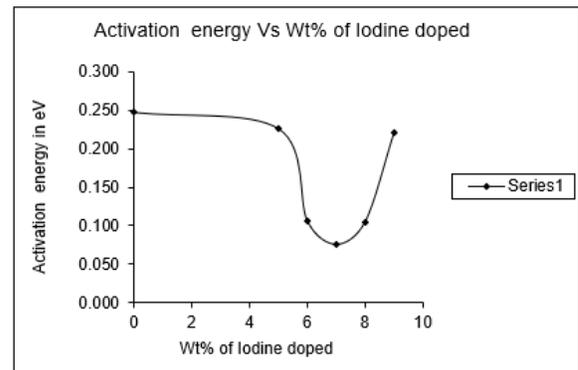


Fig no 14 - The graph for variation of activation energies vs. different wt % of doping

From the above figure it is seen that the minimum activation energy is found for 7-wt % of iodine and of maximum for pure polystyrene 0.2216 eV

This shows that conductivity increases with doping up to certain extent and further doping gives raises the decrease in conductivity

V. CONCLUSION

The conduction in V-I characteristics is not a space charge limited the electrical conductivity of polystyrene film increases with increase in doping. For particular doping, conductivity is found to be maximum other than that; it is below the maximum point. The current in polystyrene material is controlled by thermally generated carries the activation energy reported in literature (Ghosh and Chudhury,1986, Kulkani et al,1984, nassar,1982, Syayer and Mansing,1972, Singh and Trsikka,1988) it is also observed that the electric conduction is electronic (Karimi and Gupta,1987) as activations energy is less than 1 eV.

While we examine the activation energies at different dopping percentage, we found that at particular doping the activation energy is found to be minimum. For other case it is somewhat greater than minimum value this entire discussion predicts that once there is minimum activation energy, we have maximum conductivity or vice-versa.

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