# Thermally Depolarisation Current (TDC) of Iodine doped Polystyrene films (PS) in Electret State

**Manoj Kumar Tiwari**
Assistant Professor,
Dept. of Physics
Mathura Prasad Degree College,
Konch (U.P.) India

### Abstract

Thermally depolarisation current (TDC) of polarised samples of Iodine doped Polystyrene films (PS) films of about 20 μm thickness has been recorded as a function of temperature, electric field, heating rates and storage times. Two current maxima in positive direction and found around (60 ± 10) and (110 ± 10) $^{o}$C for doped sample with Polystyrene films (PS) .Thermal sampling technique showed that the relaxation is distributed. Differentia thermal analysis gave a second-order transition at bout 345K because of good correlation between both thermal techniques it is concluded that the TDC peak is associated with glass transition of the polymer, and therefore it involves the motion of large parts of the polymer chains.

**Keywords:**TDS, Iodine doped, Polystyrene (PS),  SCLC, Charge Transfer Complex Grammar and Spelling are Correct.

## Introduction

Thermally depolarisation Current (TDS) of polar materials shows several bands or peaks [1]. TDC have been widely used to determine the trapping parameters, i.e., the density, depth and energy distribution of traps in polymers [2,3]. This indicates that the depolarization is realized by several different processes. Two such processes are well known, the relaxation of aligned dipoles and the relaxation of space charge caused by mobile carriers accumulated at the electrodes. But there are still other processes which cause TDC peaks and have not yet been identified [4]. It is one of the fundamental problems of any TDC investigation to relate the observed peaks to specific depolarization processes [5]. TDC peak may be characterized by the maximum positions, the magnitude of the peak and the slope of initial rise of the peak. The magnitude of the peak is eventually a measure of the number of defects causing the polarisation.TDC is an electrical spectroscopy and has practical application to electrical quality control [6-8].TDC is find out the changes produced by doping [9]. Researchers have reported relaxation parameters by doping polystyrene with copper-phthalate-cyanine, ferrocene, anthracite, pyrene, iodine [10] and chloranil [11]. They observed three TDC peaks at 53,116 and 195$^{o}$C and studied the effect of film thickness on TDC spectra of doped polymer. The 53$^{o}$C peak was found to grow slightly with thickness. The magnitude of 116 $^{o}$C peak was observed to increase with film thickness and 195 $^{o}$C remained uninfluenced with the thickness. Total charge under all the three peaks grew linearly with the film thickness which led them to conclude uniform polarization in doped polymer.

## Aim of the Study

This paper reports TDC in iodine doped Polystyrene films (PS) films by varying, polarizing field, iodine concentration and electrode materials.

## Experimental Details

Commercial Polystyrene films (PS) always contains impurities, such as acrylic acid.  PS was dissolved in cyclohexanone. 100 mg of iodine was dissolved in 100 ml cyclohexanone. Purification has to be done to remove diacrylate and acrylic acid.  Film (20 μm) of  iodine doped Polystyrene prepared by immersion technique.  The thickness of the film was extrapolated by measure its capacitance at 10 KHz and talking the permittivity equal to 3. The subtract acted as an electrode and the other of Al 1 cm$^{2}$ in area was pressed on to the film. EA 815 electrometer amplifier specially designed to measure very small direct current, low DC potentials from high impedance sources, small charge and high resistances.

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## Results & Discussion

Polystyrene (PS) films no TSC. Iodine doped films were found to give TSC.TSC spectra $I_1, I_2, I_3, I_5$ and $I_{10}$ are shown in figure no.1.Peak current vs iodine concentration has been plotted in figure no.2. The plot is linear up to about $I_5$ then shows a strong saturation. Initial rise plots of TSD spectra are shown in figure no.3. It may be said that the activation energy decreases with the increase in concentration. The effect of polarizing voltage on $I_1$ samples is shown in figure no.4.

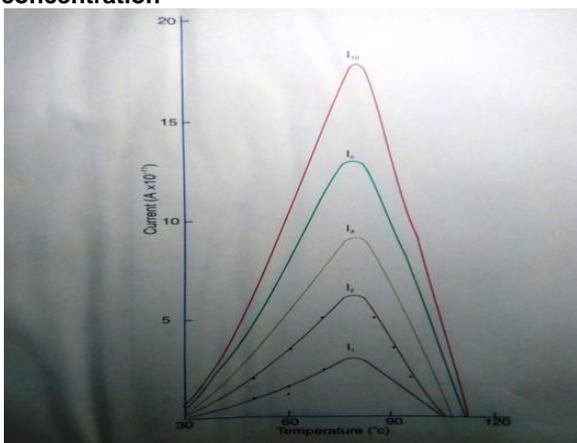**Figure no. 1: Unpoled TSC vs iodine concentration**
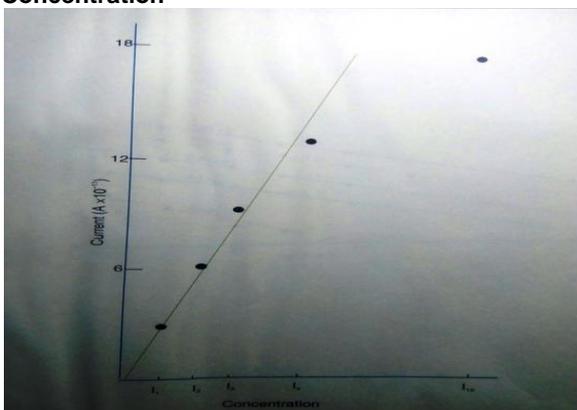


**Figure no. 2: Peak Current vs Iodine Concentration**



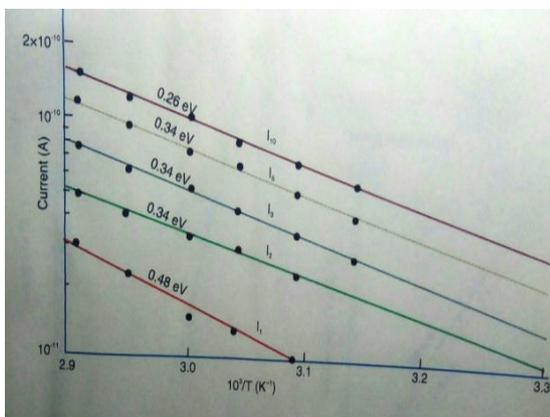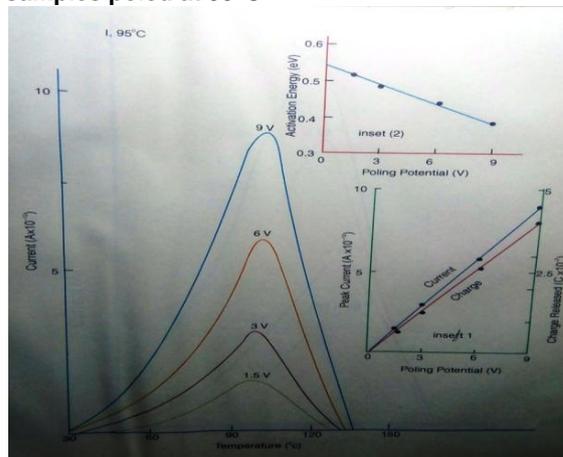**Figure no. 3: Initial rise plots of figure no.1**



**Figure no. 4: Effect of polarizing potential on $I_1$, samples poled at 95°C**



The voltage applied is 1.5,3,6,9 volts. Peak current and charge released increases with the voltage while activation energy decreases. (Table no.-1) Figure no.5 compares TSC spectra of PS, $I_1$, $I_5$ and $I_{10}$ under the identical thermo electric history. $I_1$ is hundred times greater than PS. Increase in concentration of iodine has less effect ($I_5$ and $I_{10}$). Figure no.6 is initial rise plots of TSC. Incorporation of iodine has an effect of shifting the TSC peak of PS from 105°C to 100°C. Due to increase in concentration shifting is less. Figure no. 7 show the effect shows the effect of electrode material Cu, Ni and Zn on TSC spectra of $I_1$ under the identical conditions of polarization. All the spectra consist of two peaks. Low temperature peak is α-peak and high temperature peak is ρ–peak. Initial rise plots of these peaks are shown in figure no.8 . For α-peak it seems that the activation energy decreases with the increase in metal work function. It is not observed so for ρ–peak.

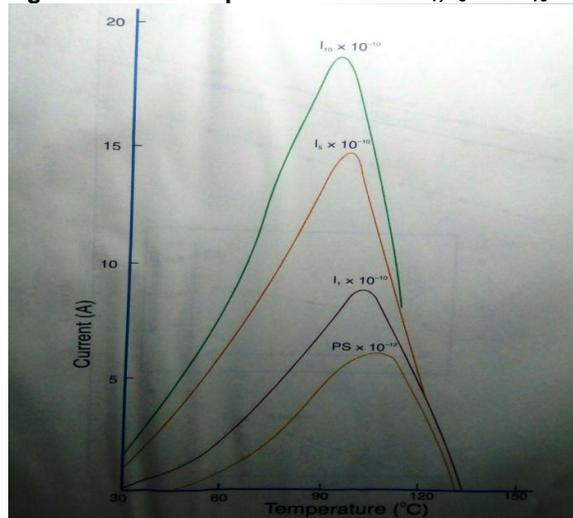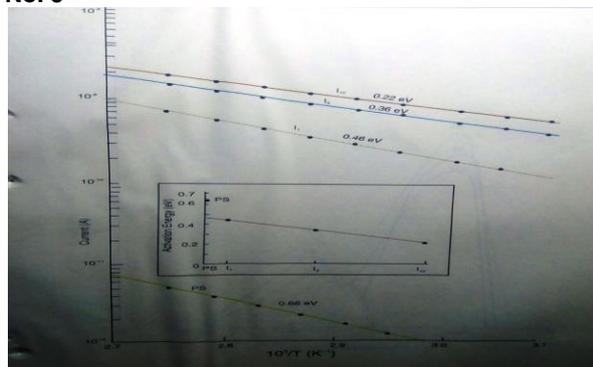**Figure No.5: TDC Spectra of PS and $I_1$, $I_5$ and $I_{10}$**

**Figure No.6: Initial rise plots of TDC spectra of fig. No. 5**



**Samples under the Identical Thermoelectric**
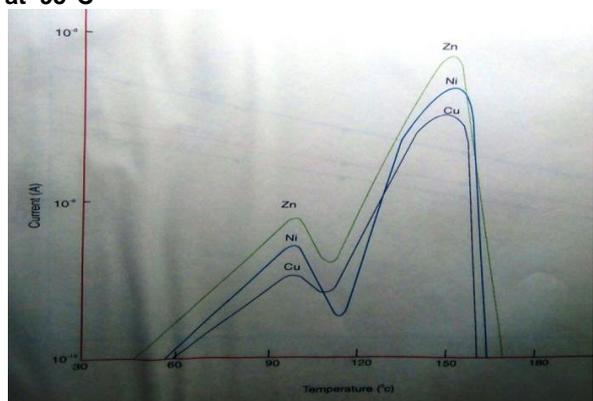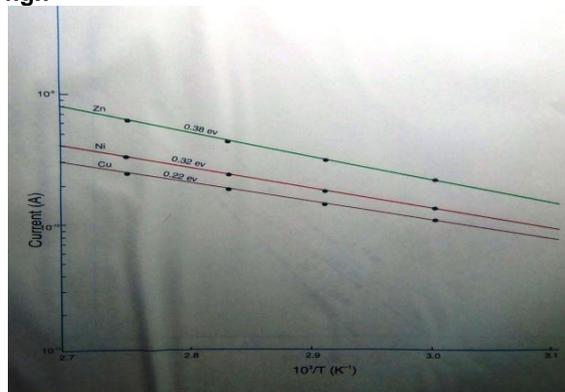**Figure No.7: Electrode effect on I₁ Samples ploted at 95°C**



**Figure No.8: Initial rise plots of TDC spectra of fig.7**



Dipole orientation is strongly temperature dependent; at high temperature the forces opposing rotation are lessened. Thus a high degree of polarization can be achieved in a short time by application of electric fields at a high temperature. The decay of the charge of electrets during TSC results from dipole reorientation excess charge motion and ohmic conduction. The first process will be clear; the thermal agitation will reorient the aligned dipoles at random. The motion of excess charge originates from space charge limited drift and diffusion. The decay of the charge of electrets during TSC results from dipole reorientation excess charge motion and ohmic conduction. The first process will be clear; the thermal

agitation will reorient the aligned dipoles at random. The motion of excess charges originates from space charge limited drift and diffusion. The first motion is due to the local electric fields forcing the mobilized excess charges to drift towards opposite charges; where by electric neutrality is restored.

Only one TSC peak at 105°C is observed for pure PS film, it is clear glass-transition temperature of PS [12]. Temperature-transition at 110°C in the main relaxation region of PS in dilatometric and acoustic measurement. So peak may be identified as the α-peak intimately connected with the molecular chain-motion of the polymer. The value of the activation energy also supports this view. The α-peak is shifted to 100°C due to doping of PS with iodine. It may be argued that iodine facilitates the segmental motion of the main chain of PS.

Iodine doped PS films give unpoled TSC. It is due to formation of charge transfer complexes (CTC).As the concentration of iodine is increased more CTC are formed.CTC formation may have low activation energy.

Dipole re-orientation and charge dettraping mechanisms are generally invoked to explain the occurrence of a TSC spectrum. TSC spectra are generally interpreted in terms of dipole re-orientation or in terms of release of a space charge peak position data for varying polarizing voltage [13]. Linear plot for peak current versus polarizing voltage for α-peak show that in addition to dipole, this peak arises due to displacement of charges through microscopic distances [14].

Increase in iodine concentration has effect of enhancing the peak current. Iodine is dipolar and semiconductive. With the increase in dopant concentration conductivity of the film is increased. Hence, more space charge is accumulated during formation. Moreover, the dopant film may possess more structural defect i.e. more trapping sites. The build uo of polarization may be uniform with the dopant concentration. The decrease in activation energy due to increase in iodine concentration may be associated with the increases in carrier mobility.

Variation in electrode forming material exhibits changes in TSC spectra of iodine doped PS films. The position of peak remains unaltered due to change in electrode material but the peak current is changed. For the metal oh higher work function, peak current and activation energy is smaller. The ρ–peak occurs at different temperature for different metal contact. Peak current and activation energy are also changed. The values are lower for a metal of higher work function. Dipolar peaks remain uninfluenced by the choice of electrode material [15-17]. Therefore, the origin of α-peak is not purely dipolar. Ionic polarization is also responsible for this peak. The interpretation of ρ–peak appears to be reasonably possible in terms of charge deterapping of a space charge built-up due to carriers injected from the electrode into the film and are then trapped. It is only at temperatures above the glass transition of PS that the molecular chains are sufficiently agitated to release the charges. The amount and the sign of charge injected depend on the relative work function

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of the metal polymer interface. The various metal polymer interfaces possess different charge exchange rates which change the space charge storage and the current released by diffusion [18]. The first stage of charging is carrier injection and the second stage is the entrapment of these charges in the border layer.

**Conclusions**

TDC of iodine doped PS films has been investigated as a function of polarizing voltage, iodine concentration and electrode material. Iodine facilitates the segmental motion of main chain of the polymer shifting α- relaxation of PS to a lower temperature. Addition of iodine in the polymer enhances greatly the intensity of α-peak. Dipolar and ionic polarization is responsible for α- relaxation peak. Space charge polarization is responsible for ρ–peak. Electrode variation reveals that charge carrier injection decreases with the increases in metal work function.

**Endnotes**

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**Table – 1: Depolarization kinetic data for Iodine doped PS samples**
**Experimental Setup & Characterization Techniques**

| Concentration | α-peak | | | | | ρ–peak | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Peak Current (Amp.) | Peak Temp. ($^{o}$C) | Activation Energy (eV) | Relaxation Time(τ) (sec) | Charge Released Coul.(Q) | Peak Current (Amp.) | Peak Temp. ($^{o}$C) | Activation Energy (eV) | Relaxation Time(τ) (sec) | Charge Released Coul.(Q) |
| $I_1$ | $0.66 \times 10^{-12}$ | 50 | 0.34 | $1.2 \times 10^7$ | $1.1 \times 10^{-9}$ | $1.03 \times 10^{-12}$ | 100 | 0.70 | $5.4 \times 10^7$ | $2.2 \times 10^{-9}$ |
| $I_3$ | $1.31 \times 10^{-12}$ | 50 | 0.33 | $9.8 \times 10^6$ | $7.5 \times 10^{-9}$ | $1.19 \times 10^{-12}$ | 120 | 0.68 | $4.2 \times 10^7$ | $6.3 \times 10^{-8}$ |
| $I_{10}$ | $0.65 \times 10^{-12}$ | 60 | 0.35 | $1.7 \times 10^7$ | $8.5 \times 10^{-9}$ | $0.79 \times 10^{-12}$ | 120 | 0.67 | $7.2 \times 10^7$ | $7.6 \times 10^{-8}$ |