CHAPTER - 6

THERMALLY STIMULATED DISCHARGE CURRENT
6.1 **INTRODUCTION** :-

Many kinds of polymer films (351-395) polarized in a high d.c. field at an elevated temperature and cooled in that field, have semi permanent charges which exist for many years at room temperature. Depolarization currents at room temperature are frequently too small to be easily measured. To increase them one must speed up the depolarization process by heating the electret upto or above the polarization temperature. The ensuing current has been called thermally stimulated current (TSC), since it is produced by heating without an external voltage (396). TSC is now generally considered as particularly well suited to the study of dielectric relaxations (397-425). This is mainly because this technique is characterized by a very low equivalent frequency as compared to the dielectric loss method and consequently leads to a better resolution of the different relaxation processes (426).

As a matter of fact, the $\alpha,\beta$ relaxations arising from the conformational motions of main chain segments and from the local motions of main chain or side groups respectively are more or less superimposed at the common measurement frequencies of a few hertz and thus the values of the characteristic parameters determined from the loss curves are often hybrid values (427). Much uncertainly results from this and numerous discussions are found in the literature especially concerning the detailed mechanism of the motions involved (427,428), the discrete or continuous nature of the possibly
associated distribution of relaxation times (398) and the physical significance of such a distribution (414). With these last problems in view, the TSC technique appears also very useful, owing to its component peaks by techniques such as thermal cleaning or partial polarization (430).

A wide literature (428-497) is available on TSC in polymers. The technique has been widely used in the study of trapping parameters in luminescent and photo conducting materials. Lilly et al (498) investigated TSC in mylar and teflon. Stupp and Carr (499) suggested an ionic origin for high temperature discharge currents in poly acrylic nitrile. Guillet and Seytre (500) conducted a detailed study of the complex relaxation modes observed in poly-L-Proline. Takeda and Naito (501) studied temperature change of dielectric constant of polystyrene using TSC measurement. TSC in corona charged polymers have been investigated by Perlman (436) and those in electron beam irradiated, polymers have been investigated by Sessler (502). Ong and Turnhout (397) have concluded in favour of the existence of a continuous distribution of relaxation times. Recently similar conclusions have been inferred by Fischer and Rohl (503) and Hino (504) from studies on secondary peaks of polyethylene and polyethylene terephthalate respectively. Chaitan et at (431), however, have found in polyamides that the low temperature peaks could generally be decomposed in several discrete Debye processes.

It has been shown by theoretical argument and by experiments (505) that only is the case of a first order kinetics, polarization do the TSC peaks occur invariably at a fixed temperature. Otherwise, their position is
shifting in a characteristic way with changing initial polarization. In the case of a space charge release, for example, the peak temperature is increasing with polarization temperature and with polarizing time. Thus peak position data for varying polarization conditions allow one to decide in particular whether a peak is due to a first order depolarization process e.g. complex reorientation or to the release of a space charge.

TSC of polar materials (506) shows several bands or peaks. 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 a space charge caused by mobile carriers accumulated at the electrodes. But there are still other processes which cause TSC peaks and have not yet been identified. It is one of the fundamental problems of any TSC investigation to relate the observed peaks to specific depolarization processes. TSC 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 polarization. The determination of activation is a delicate task if the peaks overlap too much, possibly no meaningful value can be obtained at all. Dependence of peak position on initial polarization provides information on the depolarization process.

TSC spectra are unique to the material under study. They are fingerprints of them and are sensitive to impurities, additives discharges, humidity i.e., to any chemical or morphological change. They provide a sensitive analytical tool that could be used to guide the production of
materials with fixed electrical properties. TSC is an electrical spectroscopy and has practical application to electrical quality control. Recently several workers (507,508) have used TSC technique to investigate changes produced in polymers due to doping of them with suitable impurities. Gupta and Tyagi (507) doped polyvinyl fluoride with rhodamine, alizarine, dichloro- flutecein and iodine and utilized TSC to find out the changes produced by doping. Srivastava et al have reported relaxation parameters by doping polystyrene with copper-phthalocyanine, ferrocene, anthracene, pyrene, iodine (139) and chloranil (508).

Mehendru et al (509) have reported TSC in PVAC films. They observed three TSC Peaks at 53, 116 and 195°C and studied the effect of film thickness on TSC spectra of PVAC. The 53°C peak was found to grow slightly with thickness. The magnitude of 116°C peak was observed to increase with film thickness and 195°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 volume polarization in PVAC. Effect of iodine doping on TSC spectra of PVAC has been considered by Mehendru et al (510).

This chapter reports TSC in pyrene doped PS films by varying polarizing temperature, polarizing field, pyrene concentration and electrode materials.

6.2 Theory :-

According to Creswell and Perlman (511), the instantaneous
The value of depolarization current \(i(T)\) when the sample is heated at a rate of \(\beta = dT/dt\) (\(T\) being the temperature and \(t\), the time) in terms of an activation energy \(H\) of the process involved, may be written as:

\[
i(T) = A \exp\left[-\frac{H}{kT} - B \int_{\tau_0}^{\tau} \exp\left(-\frac{H}{kT}\right) dT\right]
\]

Where \(H\) is given by:

\[
\tau = \tau_0 \exp\left(\frac{H}{kT}\right)
\]

The temperature dependent expression in brackets is the same as obtained by Bucci et al (512), for the dipolar decay. The values of \(A\) and \(B\) for trapping near the surface are:

\[
A = (N_o e \delta^3) (\mu \tau) / 2 \varepsilon d \tau
\]

\[
B = 2 / \beta \tau
\]

and for dipolar decay, they are

\[
A = N p^2 E_f / 3 kT_f \tau_0
\]

\[
B = 1 / \beta \tau
\]

Where \(N_o\) = initial charge density in traps.

\(\mu \tau\) = Charge mobility free life time product.

\(\delta\) = Penetration depth of charge.

\(\varepsilon\) = Dielectric permittivity.

\(d\) = Sample thickness

\(e\) = Electronic charge

\(N\) = Dipole Concentration.

\(p\) = Dipole Moment.

\(E_f\) = Electret forming field.

\(T_f\) = Electret forming temperature.
\[ k = \text{Boltzmann's Constant.} \]

\[ \tau_o = \text{Inverse of the trap escape frequency} \]

and\( \ T_o = \text{The temperature at which the heating is started.} \)

Eqn. 6.1 shows a maximum at a temperature \( T_m \) given by

\[ \tau_o = \frac{kT_m^2}{H \exp (H/kT_m)} \]

The current initially just above \( T_o \) in eqn 6.1 can be shown to have the form
\[ \log i(T) = \text{Constant} - \frac{H}{kT} \]

The activation energy \( H \) for the discharge process responsible for a peak, can be obtained from a plot of \( \log i(T) \) Vs \( 1/T \). This is the initial rise method of Garlick and Gibson (513). It may also be calculated from Gross Weiner's formula (514).

\[ H = \frac{1.3 \times 10^{-4} T_m T_h}{T_m - T_h} \]

\( T_h \) is the temperature corresponding to the half height of the peak on the lower temperature side of the curve. The attempt to escape frequency \( \nu = 1/\tau_o \) can be calculated from eqn. 6.5. The capture cross-section (\( \sigma \)) could also be estimated from the relation (492).

\[ \sigma = \frac{\nu}{2.9 \times 10^{24} T_m^2} \]

Total charge released = \( \int i(t) \, dt \)

Using an approximation to the integral in eqn. 6.1. It is possible to write

\[ i = A \exp \left[ -\frac{H}{kT} - B \left\{ \exp \left( -\frac{H}{kT} \right) \right\} \left( \frac{H}{kT} \right)^2 \right] \]
Fig 6.1 TSC spectra of 1g/l doped PS polarizing temperature noted on the curve. Polarizing voltage being 54 V.
Fig 6.2 Initial Rise plots of TSC spectra of fig 6.1 activation energy noted on the plot
Using the Cowell and Woods (516) curve fitting technique with an initial low guess of \( H \), then increasing it in small steps, it is possible to determine \( H \) and \( \tau_o \). The eqn. 6.1 can also be written in the form

\[
N = \left[ \int_0^P \frac{d\Phi}{d\Phi} dt \right] = \log \left( \frac{1}{B} \right) + H/kT \]

The parameters \( H \) and \( \tau_o \) may be determined from a straight line plot of the remaining charge divided by the current at a particular temperature versus the inverse of that temperature. This method is referred as the modified Bucci (or BFG) plot.

6.3 RESULTS :-

To study the build-up of polarization with the polarizing (Poling) temperature, 1glt-doped PS films were employed. The polarizing voltage was 54 V. Fig 6.1 shows the TSC, spectra of films polarized at 70, 80 and 90\(^{\circ}\)C. When the film is polarized at 70\(^{\circ}\)C, only one peak is observed. It occurs at 80\(^{\circ}\)C. When the film is polarized at 80\(^{\circ}\)C, the thermogram exhibits two peaks at 90 and 148\(^{\circ}\)C. When the film is polarized at 90\(^{\circ}\)C, again two peaks are observed at 95 and 165\(^{\circ}\)C. At low polarizing temperature, only one peak is observed. As the polarizing temperature is increased, besides the first peak, another peak arises which is intensified with the increase in poling temperature. Due to increase in poling temperature the temperature at which TSC ends, is also increased. Initial rise plots of TSC thermograms of fig 6.1 have been plotted in fig 6.2. The value of activation energy is noted on the plot. There is a slight change in activation energy due to change in polarizing temperature but it seems that this change in activation energy is not regular.
Fig 6.3 TSC spectra of $1 \text{g l}^{-1}$ doped PS polarizing voltage noted on the curve polarizing temperature being $100^\circ C$. 
Fig 6.4 Initial Rise plots of TSC spectra of fig 6.3 activation energy noted on the plot
Fig 6.5 Peak current & charge released Vs poling temperature for low temperature peak
Fig 6.6 Peak current Vs square root voltage for low temperature peak
Fig 6.7 TSC spectra of pyrene doped PS. Doping concentration noted on the curve polarizing voltage = 54V polarizing temperature = 100°C
Fig 6.8 TSC spectra of pyrene doped PS. Doping concentration noted on the curve polarizing voltage = 54 V, polarizing temperature = 100°C
Insert shows peak current & charge released Vs doping concentration.
To study the build up of polarization with the polarizing voltage, 1gl⁻¹ doped PS films were used and were poled at 100°C by 9, 18 and 36 V. The thermograms obtained are shown in fig 6.3. Each spectra exhibits two peaks at 95 and 170°C. With the increase in polarizing voltage, peak current of both the peaks is increased. This increase in peak current is more pronounced for second peak. Initial rise plots of TSC spectra of fig 6.3 have been drawn in fig 6.4. The activation energy is noted on the plot. No regular change in activation energy is found due to change in polarizing voltage. Charge released was calculated by integrating current versus temperature (time) curve. Peak current and charge released versus poling temperature have been plotted in fig 6.5 for low temperature peak. The plots are seen to be linear. No such variation was observed for high temperature peak. Fig 6.6 shows the peak current versus, square root polarizing voltage for low temperature peak. It is a straight line graph. No such variation was found for high temperature peak.

To investigate the effect of pyrene concentration on TSC spectra of PS, films incorporating pyrene in different concentrations were employed. All the electrets were formed at 100°C by a voltage of 54 V. TSC spectra of films incorporating pyrene in 1, 2, 3 and 5 gl⁻¹ concentrations are shown in fig 6.7 while those of 0.1, 0.5, and 0.8 gl⁻¹ concentrations are shown in fig 6.8. For the sake of comparison, TSC spectra of pure PS film under the same thermoelectric history is also shown in fig 6.7. The insert of fig 6.8 shows the variation of peak current and charge released under the low temperature peak with pyrene concentration. TSC thermogram of PS con-
Fig: 6.9 charge released under both the peaks Vs doping concentration
Fig 6.10 Initial Rise plots of TSC spectra of fig 6.8 activation energy noted on the plot
Fig 6.11 Initial Rise plots of TSC spectra of fig 6.7 activation energy noted on the plot
Fig 6.12 Electrode effect on TSC spectra of 1g/l doped PS polarizing voltage = 54V polarizing temperature = 100°C
sists of a single peak at 105°C. Due to doping this peak shifts to a lower temperature of 95°C (fig 6.7 and 6.8). The position of this peak is seen to be unaltered due to change in pyrene concentration. Peak current and charge released are enhanced with the increase in pyrene concentration and shows a sort of saturation (insert of fig 6.8). Incorporation of pyrene in PS gives rise to a second peak which is observed in between 160-170°C for different concentration of pyrene. This peak is intensified due to increase in pyrene concentrations. At a concentration of 2gl⁻¹, low temperature peak becomes a shoulder. For still higher concentration low and high temperature peaks, degenerate into one. Total charge released under both the peaks has been plotted against pyrene concentration in fig 6.9. The plot is seen to be a straight line. Initial rise plots of TSC spectra of fig 6.8 and 6.7 have been plotted in fig 6.10 and 6.11 respectively. The activation energy is noted on the plot. No regular variation in activation energy is observed with the increase in pyrene concentration. The attempt to escape frequency (ν) and the capture cross-section (σ) for pure PS were calculated to be 10¹⁷ S⁻¹ and 10⁻¹⁵ m². These parameters for doped films (on average) were calculated to be 10¹³ S⁻¹ and 10⁻¹⁷ m² for low temperature peak and 10¹⁷ S⁻¹ and 10⁻¹³ m² for high temperature peak. Due to doping attempt to escape frequency and capture cross section are decreased.

Electrode effect on TSC spectra was investigated by employing 1gl⁻¹ doped films grown on Cu, Ni and Zn. Electrets were formed at 100°C by 54V. The spectra are shown in fig 6.12. Each spectra consists of two peaks. The position of low temperature peak is found to be unaltered due
Fig 6.13 Initial Rise plots of TSC spectra of fig 6.12 activation energy noted on the plot
to change in electrode forming material. High temperature peak arises at 180, 170 and 160°C for Cu, Ni and Zn respectively. It may by argued that due to increase in metal work function, the high temperature peak is shifted towards higher temperature side of the spectrum. Peak current increases with the decrease in metal work function. Initial rise plots of TSC spectra of fig 6.12 are shown is fig 6.13. The activation energy is noted on the plot. There is a slight increase in activation energy due to decrease in metal work function for low temperature peak. However, the activation energy of high temperature peak is increased due to decrease in metal work function.

6.4 DISCUSSION:-

Application of an electric field always produces a small movement of charges within the atoms of a dielectric, displacing the negative electronic cloud relative to the positive nucleus and thus temporarily generating a small dipole moment and a consequent atomic or deformation polarization. This effect occurs within very short-time. Its time scale can not be changed from outside. Thus its influence on the persistent polarization of the electret can be disregarded. Many dielectrics, including polymers, contains molecules that have an electric moment. An applied field tends to align these elementary dipoles along its own direction and thus produces an electric moment of the whole body giving rise to dipole polarization, essentially a volume effect.

All dielectrics contains a small number of free charge carriers, ions or electrons or both. An electric field tends to separate positive from
negative charges and to move them toward the electrode. The structure of many polymers is not homogeneous, there exist microscopic domains or grains separated by highly resistive interfaces. In this case the charge carriers can move relatively freely only with single grains, piling up along the barriers which they are unable to surmount as they lack the necessary energy. Alternatively, when the dielectric contains many irregularly distributed traps with widely different well depths, carriers might move in the direction of the field until they fall in to deep traps from which they do not have enough energy to escape unless reactivated by a temperature increase. Both these interfacial polarization effects constitute again a volume polarization.

Ionic conduction currents in homogeneous dielectrics usually lead to the formation of space charge clouds in the electrode regions. The effect results in a macroscopic space charge polarization of the dielectric.

The sources of the internal polarization described so far have been charges originating from and remaining within the dielectrics, but a polarization can also be caused by the deposition or injection of charge carriers from outside. Deposition of equal and opposite charges on opposing surfaces of a dielectric produces an external polarization. The distinction between internal and external polarization is due to Mikola (9). Charges can also be shot into the dielectric using penetrating electron beams. Such electron charged dielectrics now are also called electrets, a rather loose use of the term.

The degree of polarization and its rate of decay depend on the
nature of the dielectric and the experimental conditions, in particular the
temperature. A dielectric becomes an electret when the rate of decay can be
slowed down so much that a significant fraction of the field induced po-
larization is preserved long after the polarizing field has been removed.

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 an electric
field at a high temperature. If the dielectric is cooled and the field removed
only after a low temperature has again been reached, dipoles return to the
original disordered state very slowly because rotation is hindered by strong
viscous forces. The polarization is thus frozen-in. A similar behaviour is
found in the case of space-charge and interfacial polarization.

The mobility of charge carriers is very low at room temperature,
but increases strongly with temperature. Thus the previous reasoning ap-
plies here too. Space charge clouds and charges accumulated along inter-
faces can be frozen-in.

All types of internal polarization lead to surface charges which
have the opposite polarity to that of the corresponding polarizing
electrodes. Therefore, heterocharge formation should be and is, a very gen-
eral effect. Every decrease of the internal polarization due to rotation of
dipoles or recombinations of ions within the dielectric frees image charges
which flow back through the external circuit where a discharge current is
recorded. Analogously every increase of polarization gives a charging cur-
rent. Therefore, build up and dissipation of internal polarization can be
investigated by means of current measurement. Current peaks are observed at temperatures where dipole orientation or carrier release from traps is activated.

The processes taking place during discharge are similar to those occurring during charging. Generally speaking, they only behave in an opposite way. The net charge of an electret usually arises from aligned dipoles and space charge. The later are excess charges which cause the electret to be not locally neutral. However, before the electret formation the neutral polymer already contained free charges, they manifest themselves in a conduction current, when a field is applied. So in addition to the excess charges there are free equilibrium charges in the electret. These do not contribute to its ohmic conductivity. In heteroelectrets the excess charges are intrinsic and bipolar. They originate from those charges that first take part in conduction and were accumulated near the electrode during formation. This field motion is opposed by diffusion. Moreover, during their transport a part of the charges is lost by recombination with opposite carriers.

The decay of the charge of an electret during TSC results from dipole reorientation, excess charge motion and ohmic condition. 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. The excess charges will eventually
recombine either with thier opposed image charges or with opposite excess charges with in the polymer. Whichever, is the case, their gross motion should generate a discharge current opposed to the charging current (170).

The temperature dependence of the dipole reorientation can be differed from the motion of excess charges. The later will confirms closely to that of ohmic conduction, from which the charges often originate. In particular, we may expect the current maxima for dipole reorientation to occur at lower temperature than that of the excess charge motion. The first process requires only a rotational motion of molecular groups, whereas the later process involves a motion of molecular groups (ions) over macroscopic distances. The activation energy predicted theoretically by Raddish (518) for the relaxation process resulting from the local twisting of the main chain or the orientation of the side groups in a polymer is about 0.2eV.

Polyblends which are mixtue of two homopolymer are charac- terized by two peaks (519,520). In co-polymer well defined complex and partial phase segregation depending on molecular mass are observed (521). Saraf et al (522) have discussed the effect of heating rate, polarizing temperature and electrode material on TSC spectra (522). A study of charge storage and relaxation process in polymide flurocarbon polymer has been done. In electron beam irradiated polymer films the depth increases with increasing injected charge density (523). Origin of high temperature peak in polymide films has been attributed to the space charge (524). The relationship between activation energy and pre-exponential
factor of the relaxation time has been discussed(525).

Only one TSC peak at 105°C is observed for pure PS film. It is near the glass-transition temperature of PS. Wada et al. (128) observed a temperature-transition at 110°C in the main relaxation region of PS in dilatometric and acoustic measurement. So the 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 95°C due to doping of PS with pyrene. It may be argued that pyrene facilitates the segmental motion of the main chain of PS. In addition to α-peak, the TSC-spectra of doped films consist of another peak arising well above the glass transition temperature of PS. This peak originates due to the charges which take part in the conduction and is called the ρ-peak. The charges may be ions or electrons and they may originate from dissociation of impurity. The forming field drives positive carriers to the cathode and negative carriers to the anode. This field drift is weakened by diffusion, while a part of the moving charge is lost by recombination with opposite charges. Never the less, the field drift dominates and the excess charges are built-up in the vicinity of the electrodes where they are frozen-in during the cooling phase. The occurrence of such a space-charge polarization requires that there be enough carriers of sufficiently high mobility. This condition is satisfied only if the conductivity is reasonably high. Hence it may be inferred that a significant space charge polarization is most likely to occur at forming temperatures near the glass-transition temperature of the polymer. During TSD, the frozen in excess
charges are thermally activated and mobilized. They then start to move under their own field towards the shorted electrodes.

6.4(a) POLARIZING TEMPERATURE:-

By varying polarizing temperature, one can detect that a heteroelectret contains a distributed dipole polarization or not. For a single dipole relaxation the current is lowered as polarizing temperature is lowered, but the position of its maxima will remain the same. For a distributed polarization maxima will shift, when polarizing temperature is low, only the fast sub-polarizations will be filled and the TSC will be cut off on the high temperature side, because of the unactivated slow polarization. When polarizing temperature is raised more sub-polarizations are activated and the current maxima will rise and simultaneously shift to a higher temperature. When all the sub-polarizations are filled the current maxima appears at the glass-transition temperature. Linearity of peak current and charge released with polarizing temperature (fig 6.5) shows that this peak originates due to dipole reorientation. No such variation for ρ– peak was observed.

6.4 (b) POLARIZING VOLTAGE :- Dipole re-orientation and charge detraping 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 (528) allow one to decide in particular whether a peak is due to dipolar process or due to the release of a space charge. Dipolar peaks increase linearly with field. Space charge peaks
increase non linearly with field. However, the deviations from linearity will not be very large. Linear plot for peak current versus square root polarizing voltage for α–peak (fig 6.6) shows that in addition to dipole, this peak arises due to displacement of charges through microscopic distances. Gerson and Rohrbough (39) have suggested that in some dielectrics, charges suffer microscopic displacement during polarization and are trapped. On heating these charges are released and recaptured. The value of activation energy is close to the values expected on the basis of ionic traps. No such variation is observed for ρ peak.

6.4 (c) PYRENE CONCENTRATION :-

Increase in pyrene concentration has an effect of enhancing the peak current of α and ρ–peaks. This magnification is much more pronounced for ρ-peak. Pyrene 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 doped film may possess more structural defects i.e. more trapping sites. When the conductivity of film is increased sufficiently the α and ρ peaks degenerate into one. Total released charge under both the peaks increases linearly with the dopant concentration (fig 6.9). So the build up of polarization is uniform with the dopant concentration. The decrease in activation energy due to increase in pyrene concentration may be associated with the increase in carrier mobility.

6.4 (d) ELECTRODE EFFECT :-

Variation in electrode forming material exhibits changes in TSC spec-
tra of pyrene doped PS films. The position of α-peak remains unaltered due to change in electrode material but the peak current is changed. For the metal of 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 (170). 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 detrapping of a space charge built-up due to carriers injected from the electrodes 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 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. The first stage of charging is carrier injection and the second stage is the entrapment of these charges in the border layer.

6.5 CONCLUSIONS:-

TSDC of pyrene doped PS films has been investigated as a function of polarizing temperature, polarizing voltage, pyrene concentration, and electrode material.
The study enables to draw the following conclusions.

1. Pyrene facilitates the segmental motion of main chain of the polymer shifting \( \alpha \)-relaxation of PS to a lower temperature.

2. Addition of pyrene in the polymer enhances greatly the intensity of \( \alpha \)-peak and creates the \( \varphi \)-peak.

3. Dipolar and ionic polarization are responsible for \( \alpha \)-relaxation peak.

4. Space charge polarization is responsible for \( \varphi \)-peak.

5. More and more space charge is accumulated due to increase in pyrene concentration.

6. Mobility of charge carriers is increased due to increase in pyrene concentration.

7. Electrode variation reveals that charge carrier injection decreases with the increase in metal work function.