CHAPTER VI

PHOTO DEPOLARIZATION OF ACENAPHTHENE PHOTOELECTRET

6.1 INTRODUCTION

One of the most interesting aspects of the studies of electret characteristics of organic solids, is the relationship of these properties of their chemical structure, although much work still remains to be done to establish a definite correlation between the electronic properties and the chemical structure. One of the earlier investigations showed that electrical resistivity and energy gap decrease with increasing number of condensed aromatic rings and with greater number of electrons in the hydrocarbons. However, different workers in this field have observed significant differences in their results. A widely scattered data about the electronic conductivity and band gaps are available for naphthalene, anthracene and pyrene.

Among the substances (Zn : Cd)S and anthracene were used most extensively. Measurements are reported on the effect of ultra-voilet, visible and infrared light, gamma and beta rays on the production and removal of polarization. The increase of polarization with time is initially rapid and then shows saturation. It is almost a logarithmic function of the exciting radiation intensity and a linear function of the polarizing voltage over a wide range.
Recently Pillai et al.\textsuperscript{319} reported the effect of reversed field on anthracene and Srivastava and Saraf\textsuperscript{320} also studied the effect of field reversal on pyrene photoelectrets. Persistent internal polarization effects in photoconductive materials have been discussed by Freeman et al.\textsuperscript{321}. An important aspect of their work is the comparison of internal polarization effect in inorganic and organic photoconductors. In the organic materials the positive charges are mobile carriers, whereas in inorganics the negative ones are more mobile. For photopolarization one type of carriers must be trapped strongly in the materials otherwise the charge would either move out of the sample after termination of the excitation or recombine.

\textbf{RECIROCITY LAW: -}

The theory of reciprocity law which was developed by Adirovich and Fridkin\textsuperscript{322,323} play an important role in clarifying the kinetics of electron process that leads to the photoelectret state formation.

The reciprocity law states that the photoelectret charge is a junction of depolarization exposure 'Et', where \( E \) is the irradiance and \( t \) is the exposure time. It was observed that most of the photoelectret forming materials obey the reciprocity law. Departures from the reciprocity law in monocristalline anthracene were reported by Belyeev et al.\textsuperscript{126} who used ultraviolet radiation to prepare the photoelectrets. The reciprocity\textsuperscript{126} law in monocristalline
anthracene was obeyed when $\gamma$-rays were used.

The studies of the use of photoelectrets in electrography showed that the reciprocity law has a single physical sense: the optical density of a developed electrographic image depends only on the product of irradiance and time of exposure$^{324}$.

6.2 GENERAL METHOD OF PREPARATION OF PHOTOELECTRETS

Fridkin and Zheludev$^8$ have used polycrystalline samples in their preliminary investigations. Kallmann and Rosenberg$^{87}$ considered a method for the preparation of photoelectrets by melting a quantity of a substance on a conducting glass plate. The material solidified in polycrystalline form was found to be disadvantageous since the thickness could not be made constant in different samples. Silver$^{120}$ has suggested a modified method. A hole of desired size and thickness was cut in a teflon sheet which was placed on a glass plate. The material in powder form was filled in the hole and heated. A sample of desired size and thickness was obtained by this technique.

These techniques of preparation by melting and solidifying are successful with organic hydrocarbons which have low melting points. In case of inorganic photoconductors, a polycrystalline sample was made either by compressing the powder or by using a binder to the finely grained powder$^{324}$. 
6.3 PRESENT METHOD OF INVESTIGATION

The apparatus for the preparation and measurement of polarization and depolarization currents of photoelectrets is designed and made in the university workshop fig. 6.1

The assembly consists of a metallic cubic hollow box with dimension of one foot. A window of size 4" x 4" is made from a vertical side for the convenience to change the source of excitation. The source of excitation is placed at the bottom of the box. A lens system is arranged in the middle of the box and movable in the vertical direction with a threaded rod. A small circular portion is cut out at the centre of the top level. The box is painted black inside so that there may be no reflection of light.

Another brass rectangular box having electrode arrangement is adjusted at the centre on the top of hollow box. The lower fixed electrode is made up of transparent conduction fine mesh of steel wires. The contact from the upper surface is taken by a metal suspended electrode provided with a spring arrangement. The whole arrangement was fixed inside a brass rectangular box and was electrostatically shielded. A circular cut in upper box of the size equal to the cut at the top of hollow box is made in the middle of the lower surface. A plate is used to cut off the illumination from the sample, between the space of two boxes.
Fig. 6.1 Current Measuring Assembly.
In the present investigation sample of acenaphthene of the size 0.065 cm. thickness and 1 sq.cm. area of cross-section prepared with the same procedure as described in chapter 2nd were used.

(1) Dark Polarization :-

The electrets are polarized and depolarized in the absence of light for different values of polarization field and polarization time. After application of the field for desired time, the field is switched off and electrodes are short-circuited. The polarized sample is stored for 30 sec. in darkness under short-circuited conditions and then the decay of depolarization current is recorded for 30 minutes.

(2) Photo Polarization :-

Photoelectrets are formed by the simultaneous application of field and light. The light of milky and mercury lamp is made to fall on the sample parallel to the polarization field. After application of polarizing field for desired time in presence of light the photoelectret is stored in dark for 30 sec. under short circuited condition. The photodepolarization current measurements are carried out while reilluminating the photoelectret with the same illumination intensity as used during polarization process.
(3) Field Reversal Polarization :-

The polarization with the application of reverse field in presence of light is studied in the following two ways.

(i) For the study of reverse field effect, the sample is photopolarized by the application of polarization field with illuminated electrode at positive polarity. After desired polarization time the field is removed and then reapplied in reverse direction with illuminated electrode at negative polarity. The time of application of field in both direction is of equal duration.

(ii) In the second case, the condition of polarization remains the same as in (i) using opposite polarity first i.e., -ve. field is applied on the illuminated electrode and then for equal time positive field applied.

In this investigation the polarization time is doubled with respect to photo and dark depolarization.

6.4 METHOD OF CURRENT MEASUREMENT

An electrometer and D.C. field is connected in series with the sample. The polarity of the applied field can be changed with the help of double way key. The polarization processes have been carried out at different polarizing field, polarizing time and illuminating source. The photoelectrets are prepared for 1 minute, 3 minutes, 5 minutes and 10 minutes at fields 4.35 kV/cm., 9 kV/cm.,
12.9 kV/cm. and 17 kV/cm. with illuminating source a Milky bulb 100 watt, 220 volt, Mercury vapour lamp 125 watt, 220 Volt and at dark, in both the polarities of field reversal.

6.5 RESULTS

(a) Effect of polarizing field

Photodepolarization currents observed at different polarization fields in dark and in presence of different illuminating source are shown in figures 6.2. The following results can be drawn.

(1) Depolarization current decreased at a rapid rate for first 10 minutes then slowly for next 10 minutes and becomes constant.

(2) The magnitude of depolarization current increases with increase of polarizing field from 4.35 kV/cm. to 12.9 kV/cm. and within the field region 12.9 kV/cm. to 17 kV/cm. very slight increase is observed.

(3) The decay of depolarization current at polarization fields 12.9 kV/cm. and 17 kV/cm. are the same after very short time.

(4) The initial photodepolarization currents observed as a function of polarization fields. Initial photodepolarization currents observed after 30 sec. increases with forming field and no saturation has been observed.
Fig. 6.2 Depolarization current characteristics of acenaphthene photoelectrets at polarizing time 3 min. at different forming field strength.
(5) The final depolarization currents are shown in figure 6.3. Final photodepolarization currents observed after 30 minutes increase with the increasing of the forming field.

(6) No current reversal is obtained in any case.

(7) The decay of photodepolarization current is regular for all time.

(8) The initial photodepolarization current increase with the increase of polarizing field and tends to saturation. The saturation is different for different intensity of polarizing field.

(9) On extrapolation of the graph of initial depolarization current for different fields on same polarizing time and photo (illumination) condition shows that the intial depolarization current at zero field will be zero (figure 6.4).

(b) Effect of Polarizing time

The characteristic decay curves of depolarization current at polarizing time 1 minute, 3 minutes, 5 minutes and 10 minutes for all fields in presence of milky bulb light and mercury light and in dark are plotted. Graph (fig. 6.5) show the nature of the curves, Following results are obtained.

(1) The decay of photodepolarization current is
Fig. 6.3 Final depolarization current of acenaphthene photoelectret variation at different polarizing field.
Fig. 6.4 Initial depolarization current of acenaphthene photoelectret variation at different polarizing field.
Fig. 6.5 Depolarization current characteristics ofacenaphthene photoelectret at polarizing field 17 kV/cm. for different polarizing time.
regular with time.

(2) Approximately 75% value of initial depolarization current is decayed within 5 minutes.

(3) No current reversal is observed during period of decay.

(4) The magnitude and persistent photo-depolarization current increase with the increase of polarization time.

(5) The magnitude of initial photodepolarization current increase with the increase of polarization time for all fields and photo condition are shown in figure 6.4. The initial value of photodepolarization current tends to saturation is obtained on increase of duration of polarization time.

(6) The final photodepolarization current increase by very small quantity with the increase of polarizing time in all mode of photo condition.

(7) Mostly the photodepolarization current becomes almost constant after 10 minutes of its decay.

(c) Effect of Polarizing field reversal

The photodepolarization current decay characteristics for different polarization fields at different polarizing time in the presence of mercury light for both the above mentioned field reversal are shown in
figure 6.6 to 6.9.

Following results obtained by the two polarization processes are:

(A) Field reversal  $+\text{ve}$ to $-\text{ve}$.

(1) A negative current is observed when the sample is polarized keeping first $+\text{ve}$ at its illuminated surface and then reversing the field.

(2) The polarity of current is changed from negative to positive within minutes and attains almost a constant value of depolarization current approximately in 7 minutes.

(3) The rate of change of depolarization current in the case of field reversal from $+\text{ve}$ to $-\text{ve}$ increases with the increase of polarizing field and also with polarizing time.

(4) The value of initial negative depolarization current increases with the increase of polarization field. The initial $-\text{ve}$ depolarization current is obtained in the order of $10^{-12}$ to $10^{-11}$ amp.

(5) The time of change of polarity increases with increase of polarization field and polarization time but it is more effective with field strength change.

(6) The final current obtained in the case of all polarization time and field strength is approximately same in magnitude.
Fig. 6.6 Depolarization current characteristics ofacenaphthene photoelectret ($R_1$) polarized at polarizing field 4.35 kV/cm, 9 kV/cm, 12.9 kV/cm, and 17 kV/cm, for different polarizing time.
Fig. 6.7 Depolarization current characteristics of acenaphthene phoeelectrets ($R_1$) polarized at polarizing time 1 min., 5 min., 5 min., and 10 min. for different polarized field.
Fig. 6.8 Depolarisation current characteristics of acenaphthene phoebeclectrets (Rg) polarized at polarizing time 1 min., 3 min., 5 min. & 10 min. for different polarizing field.
Fig. 6.9 Depolarizing current characteristics of acenaphthene photoelectrets $E_2$ polarized at polarizing field 4.35 kV/cm, 9 kV/cm, 12.9 kV/cm, and 17 kV/cm for different polarizing time.
(B) Field reversal -ve to +ve.

(1) No depolarization current reversal is recorded during decay period.

(2) The magnitude of depolarization current increases with the increase of polarization field and polarization time.

(3) The depolarization current decay very fast in initial 3 minutes and within 5 minutes it decayed approximately 90%.

(4) The initial value of depolarization current increase with the increase of polarization field and polarization time.

(5) The final depolarization current value increases approximately with the increase of polarization field and polarization time.

(C) Comparative Results

The photoelectrets of acenaphthene, for decay characteristic studies, were prepared under the followings conditions of illumination and polarity of applied field.

(1) Keeping the illuminated surface at -ve polarity for the entire duration of illumination.

(2) Keeping the same as (1) with polarity of field changed to +ve.
(3) Keeping the illuminated surface at -ve polarity for the first half of the duration of illumination and then reversing it to +ve polarity for the remaining half of the duration of illumination. (This case is referred to as \( R_1 \) in the figures).

(4) The same as (3) with polarity of field changed from +ve to -ve. (This case is referred to as \( R_2 \) in the figures).

The decay characteristics of these photoelectrets are shown in figure 6.8 and 6.9.

(a) The initial depolarization current recorded in the cases (1) to (3) is of the same polarity except in the case (4) where the polarity is reversed (\( C_F R_2 \)).

(b) The magnitude of the depolarization current is higher when the illuminated surface has -ve polarity than when it has +ve polarity of applied field.

(c) Initial depolarization current is obtained under different condition is in the following order of increasing magnitude:
+ve to -ve field reversal (\( R_2 \)) < -ve to +ve field reversal (\( R_1 \)) < dark polarization < photo polarization by ordinary milky lamp < photo polarization by mercury lamp.

(d) Final depolarization current recorded is of the same polarity in the following order for different
condition of preparation. Photopolarization by mercury photopolarization by milky > dark polarization.

In both the types of field reversals the magnitude observed is approximately equal to the magnitude of depolarization current under photopolarization by mercury lamp.