CHAPTER V
CHAPTER V.

CHARGE MEASUREMENT OF ELECTRETS
PREPARED IN DIFFERENT METAL ELECTRODES.

1. Introduction

There is enough literature available, giving the dependence of nature of the charge and general properties of electrets, on the electric field used in electret preparation (1,2,3,4). Good quality electrets were obtained when the specimen was subjected to high voltage in the molten state (5). Froiman and Fridkin (6) have observed that the polarising temperature affects the magnitude of heterocharge. Tiku (7) in his investigations observed a decrease in the electrification when the field was maintained for a longer time after solidification or if switched off before complete solidification of wax. Cooling period of the dielectric under electric stress is also an important factor influencing the electret behaviour (8,9). According to Wiseman and Feaster (10), all solid dielectrics are capable of acquiring surface charge and volume polarisation, provided they are subjected to proper conditions;
hence all solid insulators can exhibit electret effect. The
effect of thickness of the specimen also plays an important
role in determining the general behaviour of the electrets,
such as nature of charge, period of charge reversal, and other
properties of the electrets (11).

In general there are two ways of getting charged
samples, firstly the charge acquired by friction, and secondly
as exhibited by electrets. But there is a marked difference
in these charge acquiring processes. The charge acquired by
friction is purely a surface charge effect while the charge
acquired upon breaking the bond between metal and insulator
is a volume charge distribution. In the case of electrets a
volume charge distribution is obtained. An electret is a
dielectric which can maintain a permanent electric field.
Electrets are obtained by subjecting the dielectric to an
electric stress at high and even at room temperatures (12).
In practice, heterocharge appears first, and in due course
of time changes into homocharge, which lasts for a longer
time (13).

To establish the correlation between the observed
surface charge of the electret and their various properties,
a number of workers have measured the surface charge. The
maximum value of the surface charge observed by Sheppared and
Stranathan (14) was 10 e.s.u/cm², while Theissen and others (15) have observed a value of 8 e.s.u/cm², and Geimant (13) found 4.6 e.s.u/cm² only. In plastic electrets Wieder and Kaufmann (16) have reported surface charge densities as 16.5 e.s.u/cm² whereas in ceramic materials values of 3-6 e.s.u/cm² or even more have been reported (17,13). It has been found that Barium-titanate yields electrets having the maximum charge, which is retained for a longer period. Geimant and others (19, 20) have measured the field at various distances above the electret surface and have discovered that the values of the field decreases exponentially with distance. Surface charge of electrets were measured at various pressures in the range of 10 to 223 cm Hg pressure, and it was found that the density of charge is proportional to the pressure (14). At 150 cm Hg pressure, the density of charge attains nearly a constant value of about 15 e.s.u/cm². It is therefore presumed that at such high pressures the polarising field is not sufficient to produce an electrification, which can give surface potential equal to the breakdown strength of air at that pressure.

Frei and Groetzinger (21) have found that in the remelting process of the electrets a discharge current appeared which was of the order of 10⁻³ amp/cm², but no current was observed when the complete molten state was attained. Paraffin wax which is a non polar substance, shows
a discharge current that remains the same whether the substance is polarised in the solid or molten state. The discharge current has been observed even at temperatures below the melting point (22).

Electret properties of the high polymers have been studied by very few workers (16,23); their surface charge measurements under different physical conditions (24) were also done. It has been reported that there is a charge transfer from metal to the surface of high polymers, when the contact between the two is broken (25,26). The charge thus attained by the high polymer does not respond to any surface treatment (27). X-ray work made in the previous chapters of this thesis clearly show that there is some mechanism taking place which gives rise to enhancement in the orientation in the 110 and 200 diffraction rings, at 110°C. Hence the purpose of the studies in this chapter is to examine the properties of the electrified sample of Polyethylene and especially to know whether there is any correlation between the surface charge developed and the orientation obtained at 110°C.
2. **Description of the apparatus**

   (i) Electret holder -

   The electret holder used for electret preparation was the same as that described in Chapter III, and shown in fig. 3.1.

   (ii) D.C. High Voltage Source -

   The required number of 90 volts Eveready Minimax dry batteries were connected in series. The positive potential was applied to the upper electrode, and the negative to the lower electrode (fig.3.1). Every time the voltage was tested by a KV meter.

   (iii) Temperature Control -

   A thermostat was utilised, which has already been described in Chapter II.

   (iv) Charge measuring electrode assembly -

   An apparatus designed in the solid state Physics Laboratories of the Physics Department of this University was used for charge measurement. The underlying principle of the apparatus is the same as was used by Gemant and Gross (13,28). The complete assembly and its cross sectional sketch has been given in figs. 5.1 and 5.2 respectively. It consists of three major parts.
Fig. 5.1 Complete Charge Measuring Electrode Assembly.
Fig. 5.2 Charge Measuring Electrode Assembly (Cross-sectional View)

(a) - Flexible hanger
(b) - Beakhead
(c) - Clamps
(d) - Collarless brass cylinder
(e) - Brass rod
(f) - Spring
(g) - Clamping screw
(h) - Brass screws
(i) - Brass nuts
(j) - Upper electrode
(k) - Lower electrode
(l) - Rubber ring
(m) - Lunate cylinder
(n) - Window
(o) - Ring with screw
(p) - Upper spring
(q) - Cash terminal
(a) Lower fixed electrode

(b) Upper electrode and its moving system

(c) Body of the assembly.

(a) Lower fixed electrode (Fig. 5.1-g) -

It is a plane circular disc of 5.0 cm diameter having a thickness of 4.0 mm, fitted in the centre of a wooden base (not shown in the diagram). The electrified sample is kept over it and then is connected to the earth terminal.

(b) Upper electrode and its moving parts (Fig. 5.1-h) -

This is a brass electrode having a surface area of 0.6 sq. cm and a stem 1.2 cm long (Fig. 5.1-o). The other end of the stem is threaded and fitted in an ebonite cylinder (Fig. 5.1-d) which acts as an insulator for the rest of the system. This ebonite piece along with the electrode is connected to a moving system (Fig. 5.2-a), in such a way that it is made to touch the upper surface of the electret placed on the fixed lower electrode and then it is lifted to a constant height for the measurement of induced charge.

The moving part is operated by an ebonite handle (Fig. 5.2-a), and the lifting of the electrode is done by a spring mechanism. A bracket made of copper strip of
width 0.8 cm and length 12.0 cm is fixed just below the ebonite handle. It is bent four times to form the shape given in Fig. 5.2-b. The height of the bracket is 4 cm and its breadth is 2 cm. The remaining 2 cm of the length is bent below on either side i.e. 1 cm each projecting on opposite sides. The two clamps (Fig. 5.2-c) fitted in the upper lid have been provided to arrest the bracket. A collared brass cylinder (Fig. 5.2-d) is fitted in the centre of the upper lid. This collared brass cylinder has got a hole of diameter slightly greater than 5 mm, so that a brass rod of 5 mm diameter and 16 cm long (Fig. 5.2-e) can move freely through the hole. Two springs are mounted on this rod which are on either side of the collared brass cylinder. At the top end an ebonite holder has been fastened which rests on the collar of the brass rod. The lower end of the rod is screwed in an ebonite cylinder of 1.75 cm diameter and 2.5 cm length (Fig. 5.2-m), to which the upper electrode is fitted. The lower spring is kept separated from the ebonite block by a ring (Fig. 5.2-o) inserted and screwed on the brass rod. The expansion and compression of the spring (Fig. 5.2-f) is controlled by the ring. If the ring is pushed upwards, the electrode moves further down because of the pressure of the spring and if the ring is pushed down, the electrode moves less in the downward direction; thus the pressure of the upper electrode on the electret can
be adjusted.

The terminals for carrying the charge of the electrode are fitted in the body of the apparatus (Fig. 5.2-i & h). An insulating ebonite screw (Fig. 5.2-g) has been fixed in the brass cylinder and a brass terminal (Fig. 5.2-h) is fitted in the centre of the ebonite screw. The upper electrode is connected to this terminal, and the connecting wire is tied with the ebonite block by a rubber band, in such a way that the movement of the upper electrode is not restricted.

(c) Body of the assembly (Fig. 5.1-p) -

The body is made of a hollow brass cylinder of 16 cm length, 4 mm. thickness, and 10 cm diameter. Both the ends of the cylinder are closed. From the lower part of this cylinder a window has been cut for inserting the electret (Fig. 5.2-n).

The electret along with the mica holder is placed over the lower electrode (Fig. 5.1-g) which is permanently connected to the earth. The measuring upper electrode (Fig. 5.1-h) is connected to a specially prepared key having mercury contact, and which can be connected to the electrometer or earth. For charge measurement the bracket is pressed down and is arrested by the clamp (Fig. 5.1-c). This compresses
the spring (Fig. 5.1-m) making it ineffective. The lower weaker spring (Fig. 5.2-f) expands, resulting in a proper contact between electrode and the electret surface. In this position the upper electrode is also earthed for one minute i.e. the electret is short circuitted. Then the bracket is released from its clamp, where the stronger spring pushes the upper electrode assembly upwards, till this upward movement is stopped by the lower spring. The electrode terminal is connected to the electrometer immediately, where due to sharing of charge, the electrometer needle receives an impulse producing a deflection depending on the amount of the charge.

(v) Lindemann Electrometer -

The surface charge measurement of the electrets was done by Lindemann electrometer manufactured by Cambridge Instrument Ltd. The diagram of the electrometer is given in Fig. 5.3. On the electrometer body two terminals A and B are provided which are connected to the quadrants. The needle of the electrometer is connected to terminal C. The terminal D is earthed. A chamber E has been provided for placing the drying materials. For earthing the needle a pneumatically operated earthing device has been used which is operated by pressing a small rubber bulb, connected to the instrument with the help of rubber tubing. This electrometer assembly has been
Fig. 5.3 Lindemann Electrometer (Schematic Diagram)
mounted on the stage of a microscope having suitable magnification. The eye-piece of the microscope carries a scale by which the deflection of the needle is recorded. The capacity of the electrometer is less than 3 cm., which makes the leakage insignificant in dry atmosphere.

(vi) Circuit used for charge measurement with the Electrometer -

The circuit which consists of two parts has been given in Fig. 5.4.

(1) Main part; (2) auxiliary part.

(1) Main Part -

It consists of a potentiometer arrangement \( R_1, R_2 \), and having a combination of two resistances \( R_1 & R_2 \) of equal value (1000 ohms.). The current is supplied through circuit having an ammeter \( A \), key \( K_1 \) and a rheostat \( R_{th} \), a 10 volts accumulator \( E_1 \). The finer adjustment of the quadrant potential is done with \( R_1 & R_2 \) of two rheostats connected in series, having the values of 5600 ohms each. The potential drops across \( R_1 \) and \( R_2 \) are added to the potentials from the dry batteries \( E_2 \) and \( E_3 \). The positive and negative potentials are applied to the quadrants through the key \( K_4 \) having mercury contacts. In series with the dry cell, \( S_1 \) and \( S_2 \) the safety resistances have been provided in each branch of
Fig. 5.4 Circuit Diagram used with Electrometer for Charge Measurement.
quadrant circuit. The common points of the resistances $R_1$ and $R_2$ and that of $S_1$ and $S_2$ are earthed. The body of the quadrant electrometer i.e. the terminal $L$ is also earthed. Q.Q. and $N$ are the terminals for the quadrants and needle respectively. A special type of key $K_5$ made of paraffin wax, and having a mercury contact is used to connect the needle with the terminals 2, 3 and 4. At terminal 1 the needle is connected. Terminals 2, 3 and 4 are connected to the auxiliary circuit, the earth, and the measuring electrode respectively.

(2) Auxiliary Circuit —

It is used to supply an equivalent charge to the needle to give the corresponding deflection as desired. This is shown in the lower part of the circuit diagram given in Fig. 5.4. This circuit consists of a potentiometer $T$, fed by a 90 volts dry battery in which a reversing key $K_3$ has been included. The variable terminal is connected to one side of the condenser $C$. The charge through the condenser $C$ is communicated to the needle of the electrometer. The magnitude of the charge is given by the product of the micro capacity $C$, kept at 50 $\mu F$, and the voltage through which the slider of $T$ has been moved. The voltage drop across the
earthed and variable terminals of the potentiometer can be measured by voltmeter V. The key K_2 is always kept open except when the voltage measurement is to be made. The auxiliary circuit is kept separate from the main circuit by insulating point 2 of the key K_5.

(3) Details of the different electrets prepared for charge measurement -

Three series of samples were prepared at 110°C, and their surface charge was measured. The first series was prepared between non-metallic plates like Glass and Perspex, without applying any electrical field. They were heated at 110°C for three hours and then cooled for six hours. The details of specimens are given in Table 25. Table 26 shows the details of the electrets prepared between different metal electrodes at 110°C in the absence of an electric field. The details of the third series are given in Table 27. In this case electrets were prepared at 110°C and by applying an external field of 10 kV/cm for nine hours i.e. 3 hours heating and 6 hours cooling. The fourth series of electret specimens were prepared at 90°C, with Tin electrodes, and at 0 and 10 kV/cm fields (Table 23).
### Table 25.

**Detail of electrets prepared at 110°C in non-metallic electrodes at 0KV/cm field.**

<table>
<thead>
<tr>
<th>Series No.</th>
<th>Sample No.</th>
<th>Electrode used</th>
<th>Thickness of electret</th>
<th>Time of heating</th>
<th>Time of cooling</th>
<th>Voltage applied</th>
<th>Field in KV/cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 II</td>
<td>Glass</td>
<td>1 mm</td>
<td></td>
<td>3 hrs.</td>
<td>6 hrs.</td>
<td>0 volt</td>
<td>0 KV/cm</td>
</tr>
<tr>
<td>1</td>
<td>Perspex</td>
<td>1 mm</td>
<td></td>
<td>3 hrs.</td>
<td>6 hrs.</td>
<td>0 volt</td>
<td>0 KV/cm</td>
</tr>
</tbody>
</table>

### Table 26.

**Detail of electrets prepared at 110°C in metallic electrode at 0KV/cm field.**

<table>
<thead>
<tr>
<th>Series No.</th>
<th>Sample No.</th>
<th>Electrode used</th>
<th>Thickness of electret</th>
<th>Time of heating</th>
<th>Time of cooling</th>
<th>Voltage applied</th>
<th>Field in KV/cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 II</td>
<td>Sn 110</td>
<td>Tin</td>
<td>1 mm</td>
<td>3 hrs.</td>
<td>6 hrs.</td>
<td>0 volts</td>
<td>0 KV/cm</td>
</tr>
<tr>
<td>II</td>
<td>Al 110</td>
<td>Aluminium</td>
<td>1 mm</td>
<td>3 hrs.</td>
<td>6 hrs.</td>
<td>0 volts</td>
<td>0 KV/cm</td>
</tr>
<tr>
<td>III</td>
<td>Pb 110</td>
<td>Lead</td>
<td>1 mm</td>
<td>3 hrs.</td>
<td>6 hrs.</td>
<td>0 volts</td>
<td>0 KV/cm</td>
</tr>
</tbody>
</table>
Table 27.
Detail of electrets prepared at 110°C, in metallic electrode at 10kV/cm field.

<table>
<thead>
<tr>
<th>Series</th>
<th>Sample No.</th>
<th>Electrode used</th>
<th>Thickness of electret</th>
<th>Time of heating</th>
<th>Time of cooling</th>
<th>Voltage applied</th>
<th>Field in KV/cm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10ESn110</td>
<td>Tin</td>
<td>1 mm</td>
<td>3 hrs.</td>
<td>6 hrs.</td>
<td>1 KV</td>
<td>10 KV/cm</td>
</tr>
<tr>
<td>III</td>
<td>10EAl110</td>
<td>Aluminium</td>
<td>1 &quot;</td>
<td>3 &quot;</td>
<td>6 &quot;</td>
<td>1 &quot;</td>
<td>10 &quot;</td>
</tr>
<tr>
<td></td>
<td>10EPb110</td>
<td>Lead</td>
<td>1 &quot;</td>
<td>3 &quot;</td>
<td>6 &quot;</td>
<td>1 &quot;</td>
<td>10 &quot;</td>
</tr>
</tbody>
</table>

Table 28.
Detail of electrets prepared at 90°C, in Tin electrode at 0kV/cm and 10kV/cm field.

<table>
<thead>
<tr>
<th>Series</th>
<th>Sample No.</th>
<th>Electrode used</th>
<th>Thickness of electret</th>
<th>Time of heating</th>
<th>Time of cooling</th>
<th>Voltage applied</th>
<th>Field in KV/cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>IV</td>
<td>Sn90</td>
<td>Tin</td>
<td>1 mm</td>
<td>3 hrs.</td>
<td>6 hrs.</td>
<td>0.0 volts</td>
<td>0 KV/cm</td>
</tr>
<tr>
<td></td>
<td>10ESn90</td>
<td>&quot;</td>
<td>1 &quot;</td>
<td>3 &quot;</td>
<td>6 &quot;</td>
<td>1.0 KV</td>
<td>10 KV/cm</td>
</tr>
</tbody>
</table>
(4) Measurement and calculation -

(1) Measurement of charge:

Before starting the charge measurement, the electrometer has to be properly adjusted. To do this the electrometer is disconnected from the circuit by opening key $K_4$. Key $K_1$ of battery $E_1$ is closed, which creates a voltage drop across $E_1$ and $E_2$. These tapped voltages are added to $E_2$ and $E_3$ which are applied to the quadrants. The temporary connection between 1 and 3 of key $K_5$ is made resulting in earthing of the needle. Now the key $K_4$ is closed and potential is applied to the quadrants. The connection between 3 and 1 of key $K_5$ is broken and 3 and 4 are connected, which earths the upper electrode also.

The sample whose charge is to be measured is placed on the lower electrode (Fig. 5.1-g), at its centre. By mechanical operation, already explained, the upper electrode is allowed to touch the upper surface of the electret under test. Under these conditions the sample is short circuited, because both upper and lower electrodes are earthed. This state is maintained for one minute which is sufficient to restore the normal charge on its surface. Now with the help of the pneumatic switch the needle is earthed. The connection between 3 and 4 is broken when the upper electrode is lifted
immediately 1 and 4 are connected and the charge transfer from upper electrode to the needle takes place. Charge opposite to that on the surface of the sample is induced on the electrode; hence the nature of the charge recorded in the electrometer is opposite to that of the sample. The needle deflection is seen in the microscope which has got a scale in its eye-piece.

In order to determine the absolute value of the charge the auxiliary circuit is used. Before taking measurement connections were made as follows. 1 and 2 of key K₅ are connected, and the key K₃ is closed and the variable terminal of potentiometer T is adjusted so that the induction through the condenser C gives the same deflection in the electrometer as that recorded in the case of sample. A reversing key K₃ in battery circuit is provided to record the deflections corresponding to homo-charge and hetero-charge. Voltage drop across the sliding terminal T and the earthed terminal is measured. The measuring electrode area is 0.5 sq.cm, hence the charge on the sample per sq.cm is \(2V \times 50 \times 10^{-12}\) coulomb/cm\(^2\) or \(V \times 10^{-10}\) coulomb/cm\(^2\).

Soon after taking out the sample (with mica frame) from the cassette the charge measurement on both sides is made and then the sample is indexed by pasting a label on
that side of the mica frame which was facing the upper electrode during preparation. Wild and Stranathan (29) have shown that humidity plays a very important role in electret preparation, and preservation; hence the samples were kept in a dessicator containing dry calcium chloride. The charge on the electrets decays if they are kept without short circuiting for a long time (30), hence the electrets are wrapped in a Tin foil. The pressing of the Tin foil on the two faces of the sample is done by keeping the mica frame with sample between two ebonite plates. A thin layer of cotton was kept between the mica frame and the ebonite plates, and a small weight was kept on the ebonite plate, in order to keep them compressed for proper contacts.

(ii) Measurement of current during the polarisation:

A simple circuit is made for the current measurement. This consists of a suitable current sensitive galvanometer (Multiflex Galvanometer of sensitivity $5.6 \times 10^{-10}$ amp/mm) and a source of potential across the sample which is applied by connecting twelve Eveready dry batteries (90 volts) in series. The complete circuit is given in Fig. 5.5.

The mica cavity in the electret cassette is packed with Polyethylene and is kept between any one of the Sn, Al,
Fig. 5.5  
Circuit for Current Measurement

E - 90 VOLT BATTERIES  
T - THERMOSTAT  
C - ELECTRET CASSETTE  
G - MULTI-FLEX GALVANOMETER  
K - KEY
and Pb electrodes. This cassette is kept in the thermostat adjusted at 160°C. Fifteen minutes later the field (10 KV/cm) is applied across the sample kept in the thermostat. The sample is heated for three hours in this state. After three hours the deflection in the galvanometer is recorded and then the thermostat is switched off. In the process of cooling the deflection corresponding to the temperature recorded by the thermostat is noted till the thermostat acquires 30°C temperature. This process was repeated for the different electrodes (Tin, Aluminium, and Lead) which are used in electret preparation. The graph between temperature and the current flowing through the galvanometer during the electret formation is plotted for the different electrode materials. These are given in the Fig.5.6.

(5) Results and Conclusions –

Immediately after the preparation of the samples surface charge was measured on both its upper and lower sides. The upper side of an electret prepared in electric field is the anode side and lower side is the cathode side, charge measurement was continued for one month once after every 24 hours. In this way the value of the charge retained by the samples and their decay mode was studied. Decay curves of all the samples prepared between different electrodes were
Fig. 5.6 Current flowing through Polyethylene during Electret formation between different Metal Electrodes.
drawn by plotting the time in days and the charge coul/cm².

Fig. 5.7 shows the decay curves of samples prepared between Glass Plates and Perspex plates at 110°C in the absence of field. Upper half of the graph shows the decay mode of the upper surface of the sample, whereas the lower graph is for the lower surface of the sample. The sign of the charges observed on either side of the samples were the same i.e. negative. Initially the rate of decay is very fast, but later on it remains fluctuating and finally settles down to a constant value. The final charge on upper surfaces of Glass and Perspex is 16 and 12 coul/cm² and on the lower surface 23 and 16 coul/cm² respectively. Final charge in the case of Glass plate series remains greater than in the case of Perspex plate series. The magnitude of the final charge remains greater in the lower surface of the sample.

The decay curves of samples prepared at 110°C, but with different metal electrodes (Tin, aluminium, and Lead) are given in Figs. 5.8 and 5.9. In Fig. 5.8 the decay curve of upper surface of the sample is plotted whereas the decay curve of the lower surface is given in Fig. 5.9. In the upper half of the graph, positive charge density and in the lower half, negative charge density is plotted. The decay curves of both the surfaces of the sample is given separately, because in some cases the curves are overlapping and hence create confusion.
Fig. 5.7 Decay mode of Polyethylene Electrets prepared at 110°C with 0kV/cm. Field using different Non-metal Electrodes.
Fig. 5.8 Decay mode of Polyethylene Electrets prepared at 110°C with 0kV/cm. Field using different Metal Electrodes.
Fig. 5.9 Decay mode of Polyethylene Electrets prepared at 110°C with 0kV/cm. Field using different Metal Electrodes.
The upper surfaces of the samples prepared with Aluminium and Lead electrodes show initially, positive charge. After four days Aluminium electrode samples show negative charge whereas the sign of the charge in Lead electrode sample remains unchanged till the end of the month. The charge of the Tin electrode sample remains negative throughout the period of study. After twenty two days the magnitude of the charge became constant, (i.e. 3, 20, 24 coul/cm$^2$ on Tin, Aluminium and Lead electrode samples respectively), but earlier to it, it remained fluctuating. On the lower surface, the sign of charge was found to be similar, i.e. negative, in case of all the metal electrodes used. On this side also the magnitude of the charge acquired a constant value after the twenty second day (i.e. 16, 24, 20 coul/cm$^2$ Tin, Aluminium, and Lead electrode samples respectively), and prior to it, the charges continued changing.

The samples prepared between metal electrodes also show that the magnitude of the final charge is always greater on the lower surface of the sample than on the upper surface. The magnitude of final charge is found to be maximum in the case of Aluminium electrode and minimum in the case of Lead electrode, whereas Tin comes in between, but very near to that of Aluminium electrode.
The decay curves of electrets prepared at 110°C between different electrodes, and at 10KV/cm field are given in Figs. 5.10 and 5.11, while Figs. 5.10 and 5.11 show the decay curves of anode and cathode surface respectively. The electrets prepared with aluminium and Tin electrodes initially show hetero-charge on the anode surface which remains hetero even after one month, and its final magnitude attains a constant value, 13 and 16 coul/cm² respectively. The electret prepared with Lead electrode initially shows homocharge on anode surface and it remains homo throughout the entire study. The magnitude of final charge remains 4 coul/cm².

On the cathode surface, in all three cases homocharge was found initially. This homocharge decays at a faster rate and finally it attains a constant value, 16, 20 and 15 coul/cm² on Tin, Aluminium and Lead electrodes respectively.

The magnitude of the final charge was found to be greater on the cathode side than on the anode side for the electrets prepared with all the metal electrodes (Sn, Al, and Pb) used. On comparing the magnitudes of the final charge it was found that the Aluminium electrode shows the maximum charge (20 coul/cm²), and then comes Tin electrode (16 coul/cm²) and with Lead electrode it has got the minimum value (15 coul/cm²).
Fig. 5.10 Decay mode of Polyethylene Electrets prepared at 110°C with 10kV/cm Field using different Metal Electrodes.
Fig. 5.11 Decay mode of Polyethylene Electrets prepared at 110°C with 10kV/cm. Field using different Metal Electrodes.
The decay curves of the two electrets prepared between Tin electrodes at 90°C are shown in Figs. 5.12 and 5.13. One was prepared at 10KV/cm field and the other without any field. The upper surfaces of the sample prepared in the absence of field showed zero initial charge, but on the next day it acquired charge which kept on changing its value, and ultimately it became zero. The anode surface of the electret prepared at 10KV/cm shows an initial heterocharge which decays and finally remains heterocharge with a constant value of 12 coul/cm². The lower surface of the electret prepared at field F=0 shows a negative charge initially which changes its value with time and finally attains the initial value and remains constant (i.e. 12 coul/cm²). The cathode surface of the electret prepared at 10KV/cm shows homo-charge which in due course of time decays to attain a constant value of 16 coul/cm² with the same sign.

In this study it was found that the magnitude of the final charge is greater for the electret prepared at 10 KV/cm, than for the one prepared at 0KV/cm. Like previous cases the value of the charge on the cathode side is greater than that on the anode side.

Polyvinyl-chloride samples when heated above the softening point and then cooled to room temperature show
Fig. 5.12 Decay mode of Polyethylene Electrets prepared at 90°C with 0kV/cm. and 10kV/cm. Fields using Tin Electrodes.
Fig. 5.13 Decay mode of Polyethylene Electrets prepared at 90°C with 0kV/cm. and 10kV/cm. Fields using Tin Electrodes.
electrical charges having opposite sign on opposite surfaces (31). The asymmetry noted in the charges on both sides can be explained on the basis of polar group orientation. Here in the case of Polyethylene, which is a non-polar substance, like charges were observed on either side, in the case of Glass, Perspex and Tin electrodes. Asymmetry in electrical charges were observed wholly in the case of Lead electrode and partly in the case of Aluminium electrode. With Aluminium electrode, like electrical charges were recorded after four days of decay figs. 5.7, 5.8, 5.9, 5.12, and 5.13.

Such charges are also observed on a solid dielectric, when the contact between it and metallic electrode is broken (25,26). The present study also appears to favour the above view. Here, in addition to Tin electrode, Aluminium electrode was also found to be equally good.

The orientation of polar group in the crystalline phase of Polyethylene at high electrical field is possible (32). Under prolonged intense electric field at room temperature dielectric absorption is expected which can give rise to heterocharge. A similar effect is also produced by heat treatment (33). The sign of the charge depends upon thermal conditions (34). In inducing the dipole moment in polyethylene, the electronic polarisability of CH₂ molecule will make significant contribution. The possibility of
internal polarisation in dielectrics is chiefly based on the following three phenomena (1) Ionic displacement over microscopic distances i.e. negative ions displaced towards positive electrode and vice versa, (2) Polar group orientation in crystalline phase, and (3) Induced dipole moment, on account of electronic polarisation.

Ionic conduction in Polyethylene has been reported by Mayburg and others (35). This has been confirmed recently in this laboratory also (24). The other two phenomena were also observed to some extent. The possibility of dipole orientation in plastics has been excluded by Wieder and Kaufmann (16), whereas antennen (36) accounts for it in terms of ionic space charge only.

When external polarisation occurs, the positive ions deposit on the positive electrode and negative ions on the negative electrode. This process has been presumed to take place by the two given processes (i) by migration of charges from electrodes and (ii) on account of breakdown between the dielectric and the electrode, spraying of charge takes place. According to Gross's (33) theory the measurement of charge of electrets is to determine the difference between the charges resulting from internal polarisation and external polarisation. Hence the observed heterocharge means that the charges due to external polarisation are being over-compensated by the charges arising from internal polarisation.
Heterocharge was observed on the anode side of the Polyethylene electrets which were prepared at 110°C and 10KV/cm field, using Tin and Aluminium electrodes, whereas on the cathode side homocharge was found. But in the case of Lead electrode, only homocharge was observed on both the sides (Figs. 5.10, 5.11, 5.12, and 5.13). Appearance of homocharge suggests that the charges due to internal polarisation are being over-compensated by the charges arising from external polarisation.

The polarising current for different electrodes, observed during the cooling process in electret formation for different temperatures has been given in Fig. 5.6. It clearly shows that among the three different metal electrodes used (Aluminium, Tin, and Lead), Aluminium is the best electrode showing more current than any other electrode. Tin comes next to Aluminium, and Lead comes last. The X-ray studies of electrets prepared with different metal electrodes given in Chapter IV also suggest that the choice of the metal electrodes regarding orientation is in the same order as above. Hence it is evident that electrode material plays a very important role in polarisation of dielectrics and in determining the orientation of molecules in the electrets.

From the above studies it can also be stressed that the orientation of molecules in the dielectric will increase with the polarising current.
References.

11. Mathew, A.C. - Thesis accepted for Ph.D. degree of Saugar University, Sagar (1960).