CHAPTER I

INTRODUCTION
1.1 DIELECTRICS AND SEMICONDUCTORS

On the basis of electrical conductivity, solids are classified in three categories. They are (i) conductors (ii) semiconductors (iii) insulators.

Dielectric is the second name of insulators. An ideal dielectric is a medium in which a moderate electric field once established may be maintained without loss of energy. It is an insulator containing no free charges. Actual dielectric may be slightly conducting and the line of demarcation between insulators, dielectrics and conductors is not sharp.

Dielectrics are not narrow class of so-called insulators, but the broad expanse of non-metals considered from the standpoint of their interaction with electric, magnetic or electromagnetic fields. Thus we are concerned with gases as well as with
liquids and solids, and storage and dissipation of electric and magnetic energy in them. Under certain conditions a dielectric may function as a semiconductor. Generally dielectric materials are divided into three classes.

(i) Non-Polar
(ii) Polar
(iii) Di-Polar

In all dielectrics consisting of a single type of atoms, whether they form gases, liquids, or solids, an electric field produces elastic displacement of electrons only. These dielectrics come under the category of non-polar dielectrics. Substances which come under the polar dielectrics, are capable of infra-red as well as optical polarisation. They may contain dipolar groups of atoms but these groups must show only elastic displacement.

The last and the third class of dielectrics consists the substance in which there are several equilibrium positions for the dipole.

Substances which have intermediate resistivities of $10^{-2}$ to $10^9$ ohm-cm. and certain distinctive characteristics are known as semiconductors. The difference in the nature of the chemical bond of these substances from the others in detail, are more complicated. One of the way in which they differ from metallic conductors is that they exhibit a negative temperature coefficient of resistance. A perfect crystal of most pure semiconductors would have the characteristics of an insulator at absolute zero of temperature. Semiconductor substance may be inorganic and organic. An organic semiconductor may be defined
as a solid containing an appreciable number of carbon-carbon bonds which is capable of supporting electronic conduction. The study of electrical properties of organic semiconductor has long been a "Step Child" of solid state physics.

The distinction between an insulator and semiconductor is more of quantitative rather than a qualitative nature (1). According to the band model (2), in the case of an insulator where there are no effective free electrons all the bands up to the valence band, are full and topmost band called conduction band, is completely empty and separated from the valence band by a large forbidden gap. If the forbidden gap is small, the materials may exhibit semiconductor behavior. Addition of an appropriate impurity to an insulator can make it behave like a semiconductor showing what is known as impurity conductivity.

1.2 Electrical Conductivity

The semiconducting properties are invariably brought out by thermal agitation, lattice defects or impurities. Properties of highly purified substances are called "intrinsic properties" thus the conductivity of highly purified substances is called "intrinsic conductivity" and that of impure substances is called "extrinsic conductivity." Extrinsic conductivity depends on the impurity contents to a very large extent.

Kittel (2) applied the energy band model in explaining the electrical properties of solids. This model consists of two bands, one normally filled band is known as "Valence Band" and
the second normally unoccupied band is known as "Conduction Band". These two bands are separated by forbidden zone. In the case of an insulator, the forbidden zone is so large that the electron can not jump from the valence band to the conduction band at room temperature. Where as in semiconductors the phonon interaction is sufficient for such a transition to take place. When an electron jumps from valence band to conduction band, the vacancy left behind in the valence band known as "hole". Electron and hole both will contribute to conductivity. Thus the conductivity depends on the concentration and on the mobility of these two types of charge carriers. Frenkel (3) and Schotky (4) type of defects give rise to localised levels in forbidden gap. Impurity also introduces localised levels (5). The localised levels due to impurities lie either immediately below the conduction band or just above the valence band. Levels localised near the conduction band are known as "donor levels" and that near valence band are known as "acceptor levels".

The variation of conductivity with temperature is expected of the type exp (-E/kT). Where E is "activation energy" which is equal to be half of the band gap. The Fermi levels lies in the middle of forbidden gap. But the activation energy for the most organic semiconductor is not equal to half the band gap. Thus the energy band model can not apply to such organic substances.

Although the \( \pi \) - electron theory has enabled to rationalise the search for semiconducting properties of organic
solids. It only offers a conducting field in molecular dimensions. Several attempts have been made to search for some suitable theory. Thus the "ground triplet state" was searched out which could possibly be involved in the conductivity. Triplet state has an energy somewhat close to double the dark current activation energy.

Triplet states of a molecule can be combined into a Bloch orbital which would serve as a conduction band (6). Optical excitation throw the molecules in their first excited singlet state, from which they would then thermally degenerate into the triplet conduction band. According to Rosenberg (7), this requires one or more quanta of vibrational energy to account for the variation of photo-conductivity with temperature.

In similar way, Aley (8), Nelson (9) and Wilk (10) considered the tunnelling possibility of an electron from some excited state to an excited states of next molecules. After the electron transfer, a positive molecular ion is next to a negative molecular ion. A coulomb attraction force acts between these two ions, which prevents the electron from travelling further on in the crystal unless it is given some additional energy. The relation between triplet state energy and activation energy for the conductivity, is lost and tunnelling model is considerably diminished. If all triplet states are involved, it again lead back to the triplet band as proposed by Tarenin (6).

A new theory of semi-conduction in organic solids was suggested by Brown and Aftergut (11) and this theory is based on
the overlap of molecular orbitals of neighbouring molecules. This theory is qualitative one and lack rigour.

After the study of relevant theories it is evident that there is no theory which explains satisfactorily the mechanism of semiconduction in the organic solids treating conductivity as an intrinsic property of the organic solids. Theoretical calculations on the band structure and transport properties of anthracene by the Le Blan (12) and the similar work of Thaxton et al (13) and Katz et al (14) on naphthalene and other evidences have been collected to confirm the idea that the dark conductivity is extrinsic in organic semiconductors.

Lyon's (15) calculations predicted the possibility of the dependence of the dark current, activation energy on the electrode material to some extent. Numerous workers (16 - 23) reported the variation of dark current, and activation energy with electrode material.

1.3 POLARISATION OF DIELECTRICS

When any non-conducting material (dielectric) is introduced into an electric field the electrons and atomic nuclei under go displacements from their equilibrium position, with the result that an internal field is set up in such a sense as to oppose the applied field. The material is then said to be polarised. Although for all dielectrics whether solid, liquid or gaseous, this effect is particularly pronounced when the material contains dipolar molecules which are capable of rotation. These
tend to orient themselves in such a sense such as to oppose the applied field and consequently enhance the internal field arising from the electron and nuclear displacement. Polarisation depends on the atomic and molecular structure of the dielectric.

The term polarisability ($\chi$) used to express the extent to which the polarisation takes place and is defined as the induced dipole moment per molecule per unit electric field. The total polarisability may consist of any one or all of the following components:

(a) A component of polarisability ($\chi_e$) is due to the displacement of the electrons in each constituent atom relative to their nuclei under the action of an external electric field. Such polarisation is called electronic or optical polarisation, the latter term being used because the natural frequencies of oscillation of the electron bound to the nucleus are usually in the optical region.

(b) A component due to ionic displacements within the molecule such as charges in bond angle and interatomic spacings. This component is called ionic or atomic polarisability.

(c) In polarisation due to the orientation of permanent dipoles, the constituent molecules of the dielectric may each have a permanent dipole moment $\mu$ which may be partly aligned by an external field.

On the basis of the above classification dielectrics may be grouped thus:
Those showing electronic polarisation only are called non-polar dielectrics.

Those possessing both electronic and atomic polarisation are called polar, such dielectrics may be subdivided into those possessing very small or very large atomic components of polarisation.

Those possessing in addition to electronic and atomic polarisation, a permanent dipole moment are called dipolar dielectrics.

1.4 ELECTRICITY:

Sir Oliver Heaviside (24) was the first who used the term "electret" to specify a permanently electrified insulating substances in 1885. These electrified substances are parallel to an electrical condenser. The main difference between the two is that no current can be drawn from electrets but a condenser is enable to give such a current. There is a long gap between this theoretical prediction and the actual preparation of electrets. M. Suuchi (25) was the first who prepared the electret with a mixture of equal parts of resin and carnauba wax in which a little amount of bees wax was added. This mixture was heated above the melting point and then allowed to solidify and cool down to room temperature under the influence of strong electric field (10 kV/cm). It was found that -

(1) If an electret is cut in two or three parts between its pole, then each part will behave like a perfect electret (like magnet).
(ii) It is found that short circuiting of both pole is an essential requirement for the long life of electret (like magnet).

(iii) On heating or remelting, the electret was destroyed (like magnet).

On the basis of above fact an analogy between the electret and magnet has been confirmed by Aldridge (26). But this analogy can not be carried very far.

In the case of magnet there are no free magnetic charges but the spontaneously ordered Weiss domains and the role of the external field in magnetisation consists simply in aligning these domains. On the other hand in the case of electrets, one has to do with free electric charges, mixtures of dipoles, neutral interaction, thus it is clear that the absence of free magnetic charges in contrast to free electronic charges, is the main cause of limitation in analogy between the two.

Different workers have defined the electret in different ways (27). No agreed definition could be made due to the lack of literature on persistent internal polarisation and semiconductors. A definition which appears to be fairly appropriate was given by Robillard (28). In his words "An electret is a dielectric which can give rise to a sensibly permanent external electric field".

Since the electret can be formed by various agencies thus they are classified according to the process by which they are formed.
(B) HOMOCHARGES AND HETEROCHARGES:

Surface charges which have the same polarity as that of the corresponding polarising electrodes are called homo-charges, those having opposite polarity are called hetero-charges. This terminology is due to Gemant (29). Different theories are behind the formation of homo and hetero-charges. Gemant (30) considered hetero-charges as ionic effect and homo charges due to piezoelectric effect experienced by dipoles transverse stress. Gross et al. (30, 31) considered, hetero-charges due to all process of charge absorption in a dielectric while homo-charge is due to break down of the interface between the dielectric and electrode.

In certain cases the reversal of polarity is obtained. This phenomenon was explained on the difference in the rate of decay of the two type of charges.

1.5 CLASSIFICATION OF ELECTRET:

Electrets are prepared under the influence of electric field and other treatment of various types. Thus electrets are classified according to the process by which they are formed. They are as follows:

(a) Electro-electret: The term "electro-electret" was used by Gubkin and Skanavi (32) for those electret which are prepared only under the influence of an electric field without any other treatment like special heating or illumination. This phenomenon was found by Mikola (33). Some ceramic dielectric and phosphors able to provide electro luminescence are called electro-electret.
(b) Thermo-Electret:  Hguchi (34) prepared the thermo-electret first in 1922. He used a mixture of waxes as a base and polarized under the influence of an electric field and thermal treatment. Thus the electrets prepared by a combined electric and thermal treatment are called thermo-electret. The usual organic waxes and their mixtures are known as classical electret materials. Many organic and inorganic substances have capability in this direction. Polymers (35), Ceramics (36 - 38) and other materials (39 - 42) are known as a suitable material for thermo-electret formation.

(c) Photo-electret:  In 1937 Nadjakoff (43-44) prepared an electret by illuminating solid sulphur disc, under the action of an electric field. The name photo-electret for such electrets was proposed by Nadjakoff. Photo-electrets are such electrets which hold in possession their charges only in darkness. Though poly and mono crystalline sulphur are classical material but after a long experience various other materials came in the light which are suitable to form the photo-electret e.g. anthracene, phenanthrene, chrysene, CdS, ZnS, HgS, (Zn, Cd)S, amorphous Se, Silicon, ZnSe, HgI₂, AgCl, Tl₂Se, As₂Se₃ etc. (45-48). Photo-electrets are used mainly in electro-photography.

(d) Radio-electret:  Electrets prepared under the simultaneous action of high energy radiation and an electric field are called Radio-electret. The term radio-electret is due to Murphy (49) but they were first prepared by Myazdrikov (50). Murphy prepared radio-electret of carnauba wax by the simultaneous
action of electric field and $\beta$-rays from a Sr$^{90}$ source. Numerous workers (51-56) observed this effect and interse polarisation in many electret forming dielectrics, has been reported in recent years.

(a) Cathodo-electret: Cathodo-electrets were prepared first by Lyubin and Fomina (46) who produced electret state in Tl$_2$Se, As$_2$Se samples, exposing them to the beam of fast electrons under the action of an electric field and called them "Cathode-electret state". The possibility of achieving persistent internal polarisation in dielectrics by electron bombardment, has been reported by Gibbons (57).

(f) Magneto-electret: Electrets prepared under the simultaneous action of temperature and magnetic field instead of an electric field are called Magneto-electrets (58). Magneto-electrets were prepared by Bhatnagar C.S. In recent years this effect has been observed in a number of waxes and other dielectric materials (59,60).

1.6 Thermo-electrets:

Theoretical explanation of thermo-electret state has been given by various workers. They explained also the reversal of charge. Various theories proposed by different workers will be discussed in the chapter "Surface charge measurement of thermo-electret". A large number of materials are available which have a tendency in the direction of thermo-electret state. A short description about such materials and the type of polarisation is considered under the different headings.
(a) **Substances capable of permanent polarisation**

Many workers have done a lot of work on thermo-electret in order to find out the substances which are capable to form thermo-electret and to contribute the satisfactory explanation for their formation and decay mode. Just after Kuchu almost entire work was done on the carnauba wax and its mixtures with rosin and bees wax.

Nikola (33) was the first who classified the substances according to the nature of substances, whether they aquire homo-charge, hetero-charge or exhibit no electret behaviour and gave two different results.

(i) High conductivity electrets yielding hetero-charges.
(ii) Low conductivity electrets yielding homo-charges.

Wax, ester and alcohols except cetyl alcohol were found to develop homo-charge. Glass resin and acidic compounds developed hetero-charge. Hydrocarbons also tended to develop homo-charges if the compound has a finite dipole moment, but non polar hydro-carbons e.g. paraffin wax cannot be used for preparing the electrets (29). Balskus (30) worked on naphthalene and got success in the preparation of thermo-electret of naphthalene which is a non-polar material. A worker of our laboratory, Singh(61) also prepared the thermo-electret of Naphthalene.

Plastic electrets were prepared from nylon, perspex and lucite (35). Thermo-electrets from P.V.C. were prepared by Binder (62). Talwar (63) also prepared thermo-electret from
P.V.C. Johnson and Carr (64) have prepared thermo-electret from molten sulphur.

In the inorganic field ceramic materials like titanates of barium, calcium and strontium and other inorganic material like glasses, quartz were found suitable for thermo-electret preparation (65,36,37,38,60). Dickinson (67) was the first worker who worked in this direction.

Linden (41), Polovikov (40), Wisemann and Feaster (42) and others got success in the formation of thermo-electret. From a vast study of thermo-electret state in various types of dielectrics by different workers, no over all criteria for selecting suitable materials for electret behaviour could be established except a high volume resistivity greater than $10^{14}$ ohm-cm. as concluded by Nikola (33). All electrically absorptive insulator could be made to exhibit typical electret behaviour to greater or smaller extent.

(b) **Polarisation of thermo-electrets**

Asuchi observed that if an electret is divided into two parts by cutting between its pole, each parts was a complete electret. On the basis of above fact Asuchi (26,68-70) explained that the polarisation of thermo-electrets was a volume phenomena and not a surface effect. His statement was confirmed by Jaeger (71) and Namakura (72).

According to Theissen, Winkel and Herrmann (73) the central region of the thermo-electret appears essentially
charge free. Thus they concluded that the polarisation is confined to electrode layers. But the investigation by Will (74) and Gross and Demoraes (75) proved and have established beyond doubt that polarisation of thermo-electret is a volume effect. This idea was confirmed by the measurements of depolarisation current, recently by many workers (76, 77, 78-81). The same was also reported earlier by Frei and Grotzinger (82).

1.7 THermo-ELEcTrIc STUDIES

All measurements useful in giving data to establish mechanism of thermo-electret state may be termed as thermo-electret studies. Different measurements are given below:

(a) **Discharge current measurement**: It is a indirect method of surface charge measurement. Integration of discharge current with time gives surface charges (82, 83).

(b) **Surface charge**: The knowledge of surface charge helps in knowing polarity, nature of charges and mobility (84).

(c) **Piezo-electric properties**: Adam (85) was the first who observed piezo-electric effect in wax thermo-electret. But other workers (29, 73, 86, 87) did not observe this effect. A clear sign of piezo-electric effect in ceramic thermo-electrets was reported by Gubkin (88, 89).

(d) **Thermal conductivity**: High thermal conductivity is reported along the direction of polarisation (90). Earlier Frei and Grotzinger (82) found that the thermal conductivity of gases
and liquids with polar molecules increase in a constant field. Groetzinger (90) found a considerable increase in thermal conductivity in the direction of polarisation in the case of bees wax, a small rise in the case of cable impregnant. In the case of non polar paraffin, no effect was observed at all. The alteration in thermal conductivity supposed to be due to oriented dipoles in thermo-electrets. Groetzinger concluded that this change was more typical than their external or internal fields, since such fields might be compensated by a finite conductivity of dielectric or the medium surrounding it.

According Vanbalker (91) the internal conductivity of waxes changes by polarisation in molten state and the change depends on the field strength. He found also a difference in the behaviour of A.C. and D.C. field. The change in conductivity was explained on the basis of the presence of water which disappears by dehydration and later difference on the basis of a model, which takes into account the deformation of the water droplets which have been "frozen-in" in the wax under the influence of the applied field.

Other associated effects are summarised below:-

(a) Effect of alternating field (92, 93).
(f) Ultrasonic (26).
(g) Irradiation (70, 94-99, 48, 60, 66).
(h) Value of permittivity and loss angle (tan δ)(78, 100-102).
(i) Depolarisation (78, 80, 82, 92, 103, 104).
(j) Pyro-electric effects (82).
(k) Noise in thermo-electrets (26,63,106-109).
(l) Magnetic susceptibility (110, 111).

The following studies are not mentioned for electret studies, but they may give useful information.

(i) Optical anisotropy studies with polarising microscope (112).

(ii) Mobility studies (113).

(iii) Electron spin resonance spectrum (E.S.R.) studies (114).

(iv) Ionic thermo current studies (I.T.C.) (115).

1.8 Dielectric constant and loss angle tangent (\(\tan \delta\)):

Tangential and specific inductive capacity are synonymous with dielectric constant. It can be defined as the ratio of the capacity of a condenser, the region between whose plates is completely filled with the dielectric in question to the capacity when a vacuum exists between the plates. All dielectric materials have a constant value of dielectric constant \(> 1\). When A.C. field is applied instead of D.C. field the current would lead the voltage by \(90^\circ\). However in a capacity containing a solid dielectric the phase difference is somewhat less than \(90^\circ\), say \((90-\delta)\). The angle is known as loss angle.

Since it is reported by many workers (116-122) that dielectric constant of a material depends strongly on the frequency of applied potential and on the temperature. But the study of the variation of the dielectric constant and loss angle (\(\tan \delta\)) of electret formed material on polarisation is still in infancy.
Reports, which are available in literature are conflicting. Polarised and unpolarised samples of carnauba wax were studied by Wikstrom (78). No change in the value of dielectric constant and loss angle tangent was obtained by the investigator (123).

Chatterji and Bhadra (100a) found the value of permittivity (or dielectric constant) of carnauba wax thermoelectret to be three times greater than that of unpolarised samples. A rise in value of loss angle tangent has also been obtained by Chatterji and Bhadra. Bhadra (100b) also measured the permittivity along and at right angle to the direction of polarisation and obtained that the value of permittivity when measured at right angle was greater than that of unpolarised sample and lesser than that along the direction of polarisation. They studied also the variation of dielectric constant and loss angle tangent of polarised (thermo-electrets) sample with time. It was found that dielectric constant rises for first 10-12 days, then it rises to a high value for 90 days. After 90 days a sudden fall is obtained, similar phenomenon was obtained in the case of loss angle tangent (tan θ).

Gubkin and Skanavi (124) could not find any change for a period of twenty days in the case of CaTiO₃ and SrTiO₃.

An isotropic change in the value of dielectric constant of polarised and unpolarised sample was obtained by McHohan (125) in the case of some organic materials.

Elgard (126) studied the dielectric properties of ferroelectrics subjected to an electric field and found the
function $\varepsilon = f(\theta)$ and $\tan \theta = f(\theta)$ in the direction of the field differ considerably to that of in perpendicular direction. The value of dielectric constant passes through maximum in case of strong field.

1.9 Persistent Internal Polarisation:

When a photoconductor is subjected to an external field during illumination and in some cases even there after, a separation of charges occurs in the interior of sample. These separated charges can be frozen-in when they are trapped. These traps are produced either by vacancies or by impurities. This internal polarisation is found in all materials which contain traps. It can be studied under two headings (1) Barrier Polarisation (ii) Bulk Polarisation. In other words we can say that internal polarisation can be of two types. Production of free charges due to illumination and separation of free charges by electrical field, are the two essential points in all types of polarisation.

1. Barrier Polarisation:

The layers with high resistance giving rise to internal polarisation are close to the electrodes and this polarisation is independent of mode of excitation whether uniform or non-uniform. But in latter case a longer period is required for the application of external field to reach the steady state. Fig 1.1 (a,b,c) describe schematically the charge and field distribution, and charge release in Barrier polarisation.

Selective discharge and internal field measurements are the two investigation which can give a general information
about Barrier polarisation. When a sample is excited through one or the other electrode after the removal of polarising field, the result of this action is the production of free charges that move under the influence of the internal field in such a way as to cancel the persistent polarisation. In the presence of strong Barrier polarisation the accumulation of charge occurs in such thin layers that any excitation producing free charge mostly in the interior $D_2$ region, and the current which is produced by excitation, flows in reverse direction of original polarising current. Thus field strength in this region can be determined with the help of above model and it was found to be of the same order as polarising field with opposite polarity.

The speed of discharge was also studied and was found greatest when the internal field moves the more mobile charge carriers through the bulk of the sample under the condition when the releasing excitation is restricted to a narrow layer close to an electrode.

(2) Bulk Polarisation:

It occurs under the following conditions:

1) The sample must be non-uniformly excited and the resistance of the layers near the electrode should not be too high.

2) The mobility of charge carriers of one sign must be smaller or more rapidly trapped than the charge carriers of other sign.
Fig. 1.2 (a, b, c) describe schematically the charge and field distribution and charge release for the Bulk polarisation. In the Bulk polarisation the less mobile charges may be distributed over a large distance as shown in fig. 1.2 (b) \( D_3 > D_1 \). Release of polarisation through electrode A and through electrode B are discussed below separately.

1) When the release of polarisation takes place through electrode A adjacent to which the more mobile carriers are accumulated the releasing radiation produces carriers in the \( D_2 \) region and again a release current is obtained in opposite direction to polarising current.

2) When the release of polarisation takes place through electrode B. The excitation takes place within \( D_3 \) region because of its large value and the direction of current being the same as that of polarising field. Curve (1) is obtained when the polarising period is very long, during which the less mobile charge has accumulated in a thin layer, curve (2) is obtained when the polarising period is not long and less mobile charges have not reached a thin layer. Curve (3) is obtained in the case when the charges are rather far from the B electrode.

It was found that the charges are almost neutral for barrier polarisation where as for bulk polarisation the less mobile charge is always in excess. This means more fast mobile
FIG. 1.2 (a, b, c)
charges have been removed from the sample than the less mobile charges.

All the results of barrier and bulk polarisation were confirmed by field measurement inside the various regions.

The effects of internal polarisation supply us with several important kinds of information which could not be as easily obtained otherwise. An relevant discussion of the effect of internal polarisation is useful in the phenomenon of photo-conduction. Many workers have worked on this topic (126-130) and they discussed the results which they obtained in details.

1.10 STATEMENT OF PROBLEM

Many theories were proposed to explain the polarisation in dielectrics in the literature. In the phenomenon of polarisation two type of charges were obtained i.e. homo-charge and hetero-charge. According to Gross view, homo-charges are due to the transfer of charges in the inter space between the dielectric and the electrode and this view is quite adequate, where as hetero-charge is assumed due to the dipole orientation and the migration of the oppositely charged ions present in the dielectrics. Gross' theory of hetero-charges does not agree with the evidences (109, 131-133). In addition, the thermo-electret state in non-polar dielectrics (36, 124, 134) could not be explained in terms of dipole orientation mechanism.

Hetero-charge has also been reported in non-polar substances, which is a evidence against the dipole hypothesis.
There are many evidences in the support of trapping of electrons in deep traps as a cause of hetero-charge. Naphthalene is a non-polar substance, which is able to produce hetero-charges. Baldus' explanation (39) as freezing in of induced dipoles produced by polarising field and that of Belyaev (136) as electron trapping for the hetero-charge in naphthalene thermo-electret are contradictory.

A lot of work has been done since last fifteen years in our laboratories on thermo-electret and associated effects. The study was confined mainly to conventional waxes, plastics and mixture of organic and inorganic substances like sealing wax till recently (136-141). Sufficient progress has not been observed in the field of organic substances since 1920. There had been some progress in the field of organic substance after 2nd world war. But the study of electret state in organic substances is still in infancy. Keeping these facts in consideration organic molecular crystals have been chosen for the study of persistent internal polarization and electrical conductivity in the present work.

The outstanding properties of organic solids is that in most of the cases their conductivity is low and consequently the solids are either insulator or semi-conductor. Electrical conductivity has been of considerable importance in explaining some of the most important results of thermo-electret formation. It was with this point in view that the study of mechanism of electrical conduction and persistent internal polarisation in organic material has been chosen in the present work.
From the conductivity data one can understand the structural changes in a dielectric as these changes lead to a variation in the conductivity with temperature. Moreover the density of centres at surface, recombination, the energy levels and capture probability of electrons or holes by the centres can be determined by studying the variation of conductivity with field. Persistent polarisation and change in the value of dielectric constant on polarisation also give important informations about the structure of substance.

Organic solids fall into two major categories molecular crystal and polymers. The classical example of a molecular crystal is anthracene which is probably the most extensively studied organic semiconductor. Enough experimental evidence has accumulated to show that some of the transport properties of anthracene are not unlike those familiar inorganic semi-conductors like silicon and Germanium.

The experimental results have been explained on the basis of modified band model for organic materials because of small overlap which gives rise to narrow bands. But the situation so far as the band model for organic semi-conductor is concerned, is far from satisfactory. Interpretation of experimental conductivity, activation energy in terms of band model, energy gap are not yet justifiable. This situation demands experimental data on many organic molecular crystals which show semiconducting properties.

It is with this end in view that $\beta$-Naphthol, on which data are not complete has been chosen for the present work.
The experimental work has been divided in the following parts:

i) Study of variation of electrical conductivity with temperature at different fields.

ii) Study of variation of electrical conductivity with field at different temperatures.

iii) Study of space charge limited current.

iv) Study of persistent internal polarisation under thermal treatment with electrical stress on.

v) Study of persistent internal polarisation in the presence of field when the substance has been exposed to light.

vi) Study of variation of dielectric constant with temperature.

vii) Study of variation of dielectric constant of polarised (thermo-electret) sample with time.

The above mentioned experimental studies can be grouped as direct and indirect probe in the material in order to understand the charge transport mechanism in organic molecular crystals. This has been done to understand the roles played by charges originating at the surface and in the bulk of the material in the transport mechanism.

The results of persistent internal polarisation when
correlated with the results of electrical conductivity and
dielectric constant can also enable us to understand the relationship between electrical properties and structural properties of the substance under investigation.
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