



IONIC AND ELECTRONIC TRANSPORT OF ALKALIHALIDE CRYSTALLINE SOLIDS

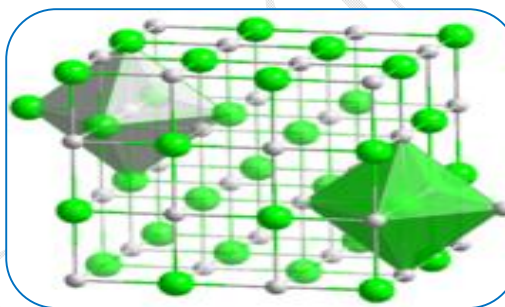
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ABSTRACT :

Single crystals of pure alkali halides, have been grown by adopting Czochralski – Kyropoulos method. The crystals are characterized by usual techniques to form non-rectifying contact in insulating solids within heterogeneous electrodes through experiment. In this paper both analytical and experimental approach has been introduced to justify the experimental fact. From the theoretical concept, it has been established to be a useful tool over the homogeneous for electron injection. The activation energy involved in the ionic zone (zone – I) and Space charge limited (SCL), zone – II injection has been performed keeping the specimen under field stress crystals. For this purpose in situ measurements were carried out to yield current density at different temperature at particular field. The activation energy values for heterogeneous electrodes depend on both electric field and temperature. These expected results indicate the non-uniformity of fields in case of the pointed cathode and is very important towards the formation of ohmic contact.



KEYWORDS : Lexical Competence, Teacher Behaviour, Socio-Demographic Variables, Secondary Level English Language Teachers.

INTRODUCTION

The electrical conductivity of all the materials differs significantly. Some are electrically good conductor, some are insulator (bad conductor) and few are in between them i.e. semiconductor. The conduction of electron depends on both electric field [1-3] and temperature. First of all the conduction process in most materials due to low electric field strength is mainly ohmic [3,4] but as the field strength is increased the conductivity becomes field dependent. The conductivity of dielectrics (insulators) may be either ionic or electronic or both.

Single crystals of pure KCl, KBr and NaCl have been grown by adopting Czochralski – Kyropoulos method and the crystals were characterized. A non-rectifying contact has been established through experiment in insulating solids within heterogeneous electrodes.

THEORETICAL DEVELOPMENT

The contact between metal and insulator exhibit either enabling or blocking carrier injection. When two materials with different Fermi levels (E_F) are brought into contact, free carriers will flow from one material into the other until an equilibrium condition is established, which is equivalent that till the Fermi levels of both the materials are aligned. The Fermi levels for electrons in both materials are equal at the contact. The net carrier flow will set up a positive space charge on one side and a negative space charge on the other side of the interface, forming an electric double layer. This double layer is

generally referred to as the potential barrier, and the potential across it is termed as the contact potential. The function of this double layer is to set up an electric field in order to stop any further flow of free carriers from one material to the other, although thermodynamically the flow of free carriers in two directions always exists but it would be quite small and equal in quantity, thereby maintaining a statistically zero net flow under a thermal equilibrium condition.

The Fermi level is sometimes termed as electrochemical potential or chemical potential and this can be considered as reference level. A state of energy equal to E_F will have the same probability ($f = 1/2$) for it to be occupied or to be vacant. This implies that the probability for a state at the level ΔE above E_F to be occupied is equal to that at the level ΔE below E_F to be vacant. Let us have a glimpse on the features of various types of potential barriers formed by some ideal contacts. Although the energy band diagrams may be effective in analyzing and predicting some consequences, the surface states, produced due to the presence of impurities and intrinsic crystallographic defects and the lattice mismatching which unavoidably exists in the interface, affect to a great extent the electrical performance of a contact. The physics of contacts by including the surface states is yet to be understood fully and also the science and technology of producing a tailored electrical contact for many applications particularly to organic semiconductors are yet to be explored.

In this section it will not be out of place to provide a resemblance of the contacting systems to indicate the reasoning behind the importance of different contacting mechanisms. The performance of the contact between an electrolyte and a non-electrolyte solid is chiefly based on an electron exchange reaction between the energy levels associated with ions in the electrolyte and the energy levels in the solid [5]. The equilibrium for such continuous exchange of charge carriers between the ions of the electrolyte and the surface of the solid is very much dynamic, and at this dynamic equilibrium both the forward and the reverse rates are equal. This type of contacts can be constructed to provide and, or hinder charge carriers to inject by selecting a right kind of electrolyte for a particular solid. Because of the wave functions or orbital of the valence electrons of atoms or molecules are overlapped to an extent in a solid due to the inter-atomic or intermolecular bonding, the injected charge carriers from a metallic or an electrolyte electrode into a solid become de-localized within the solid. Carriers produced by thermal / optical excitation inside a solid generally do not alter the electrical neutrality of the solid as a whole. In other words they may cause a net space charge of one sign in a local domain and a net space charge of opposite sign in the other region due to the difference in mobility and diffusion constant between electrons and holes even than the solid as a whole can be thought of to be electrically neutral. The injected charge carriers from a contact will produce a net space charge in the solid what is called as space-charge-limited (SCL) current under an applied electric field.

Although it may sound very inexperienced that contact is an easy affair but the nature of contact is complex one. Crystals without imperfections has been technically impossible to think about and hence there exists truly structural imperfections viz. dislocations in a crystal lattice, chemical imperfections such as impurities already inhibited intrinsically in a crystal or also due to external contaminations. Imperfections due to impurities always produce protuberances and depressions on the surface. It is impossible to avoid contamination even if the surface is cleaved in a vacuum $\sim 10^{-12}$ torr containing particles $\sim 10^4 \text{ cm}^{-3}$. When two surfaces are brought into contact, portion of surface may not be in contact with some parts in real contact, with mechanical actions and reactions between the surfaces.

A contact is basically between a metal and a non-metallic substance and essentially between a metal and a vacuum. The current flow is substantially negligible within two parallel metallic plates separated by a small distance apart under the application of small voltage across the two plates. The reason for the small current flow is because of the fact that electrons in the metal have to surmount a potential barrier, before entering the vacuum. The highest energy level of the electrons in the metal in this potential barrier is the Fermi level (E_F) and simultaneously the lowest energy level is termed as vacuum level, equivalent to work function of the metal, given by

$$\Phi = \zeta - E_F \quad \dots \quad (1)$$

where ζ , is the potential energy difference of the electrons between inside and outside of metal which is an indication about the quality of the surface and the crystalline structure.

A metal is electrically neutral. The electron distribution assumed to be non symmetrical with respect to ion cores, when a surface of it facing a vacuum, resulting the formation of double layer, equivalent to the way that of a net charge flow. This layer significantly influences the behavior of surface potential barrier due to the presence of foreign impurity atoms.

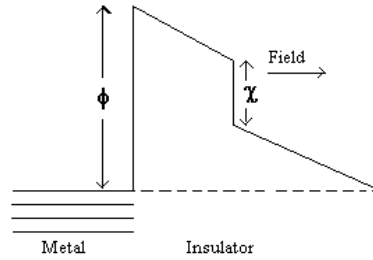


Fig. 1 Insulator in contact with metal, ϕ the work function of the metal, χ the electron affinity of the insulator with a field.

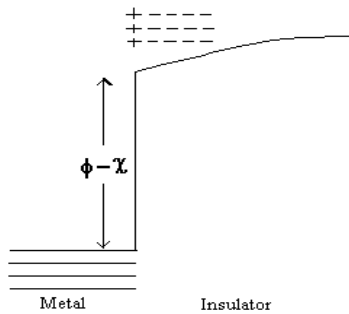


Fig. 2 Insulator in contact with a metal showing the shift in the energy levels due space charge

Let us examine from the band theoretic model, the work function and the other important parameters, which influence largely the contact problems in question. Fig. 1 show the meaning and definition of work function of (Φ) for metals, insulators and both intrinsic and extrinsic semiconductors (SC). For insulators the condition is same as that for SC excepting the fact that the energy band gap is much higher in case of insulators. There are no electrons at the E_f , so that the electrons which may be removed from the bulk of a non metallic material must be in the conduction band (or in the valence band / in the impurity levels. Minimum energy required (metal) to be imparted when electron to remove it from the metal at $T = 0$, into vacuum is the difference in energy between the Fermi level and the potential energy given by the equation (1). At $T > 0$, the F. D. distribution function appears smeared out over a distance $\sim KT$, i.e. over a small portion of an eV.

In an insulator / SC the situation is different. Only a small portion of electrons in the conduction band requires the minimum excess energy ($\sim \chi$, the electron affinity) to leave the semiconductor to

vacuum level. Electrons at impurity levels required larger energy and there in the valence band require even much higher energy to do so. On receiving an energy $> \chi$ by an electron in the conduction band and leaving the SC, the void is immediately filled by an electron either from impurity level or from valence band. Since the electron distribution inside the SC before and after the emission of an electron is quantified by the energy levels of these electrons with respect to E_f , hence the free energy required for an electron emitted from the SC to vacuum level is work function.

$$\Phi = \chi + (E_c - E_f) \quad \dots \quad (2)$$

The work function again depends upon the location of E_f (function of temperature, impurity concentration, external pressure etc.)

In insulator and SC, χ is an important parameter and is defined as the energy required for an electron to be removed from the bottom edge of the conduction band at the surface via point in vacuum just outside the SC. Materials having a positive χ readily form negative ions and are therefore considered to be electronegative, whereas those having a negative electron affinity viz. alkali elements, readily form positive ions and are electropositive. From Fig. 2 the contact potential is by definition being the difference between two dissimilar materials when both are brought into intimate contact and is basically equal to difference in work functions of the materials.

Taking metal and n-type SC contact with $\Phi_m > \Phi_s$ (the contact potential) is

$$V_d = \frac{1}{q} (\Phi_m - \Phi) = \frac{1}{q} [\Phi_m - \chi_s - (E_c - E_f)] \dots \quad (3)$$

where $(E_c - E_f)$ is sensitive to temperature and impurity concentration. V_d is a strong function of these two quantities. Fig. 3(a) clearly indicates that before contact the electrons in both isolated metal and SC experience a short range binding force exerted by the lattice of their own crystal (metal or SC). In this situation the electrons have to surmount a very high potential barrier so as to leave the solid into vacuum. By allowing electrons to flow from one solid to the other, making contact between the solids electrically as shown in Fig. 3(b). A net flow of charges from the n-type S.C. to the metal will occur, since $\Phi_s < \Phi_m$, causing a space charge near the two surfaces to quench the flow of electrons. The net flow will cease when the density of space charge achieves to such a level that the Fermi levels in the metal and the SC are aligned to the same height. However, electron flow from both sides exits due to thermal excitation and that a thermal equilibrium has been reached between these two solids. The space charge will establish an electrostatic field and hence a potential difference between the metal and the S.C. bulk, referred to as the contact potential / diffusion potential. If the separation between these solid front surfaces be decreased, the positive space charge region in the SC will enhance much into the bulk, because electrons are pushed further away from the surface due to the proximity effect, result of which the portion of the contact potential across the vacuum gap decreases, while the portion across the space charge region increases. Reducing the separation of the order of inter atomic distance, the contact appears to be an intimate one, the total contact potential will be practically across the space charge region and the portion across the vacuum gap being very small (negligible) as shown in Fig. 3(c). In general, this very thin barrier between the two surfaces is omitted in the energy level diagram, since it is transparent quantum mechanically to tunnelling of electron. The space charge region extends further into the bulk of the SC (Fig. 3(c)), since the free carrier density in the SC is much smaller than that in metal. The thin space charge in metallic side is thought of as the surface containing charge carriers equal in proportion but oppositely charged to that in SC and hence the concept of double layer comes into the picture.

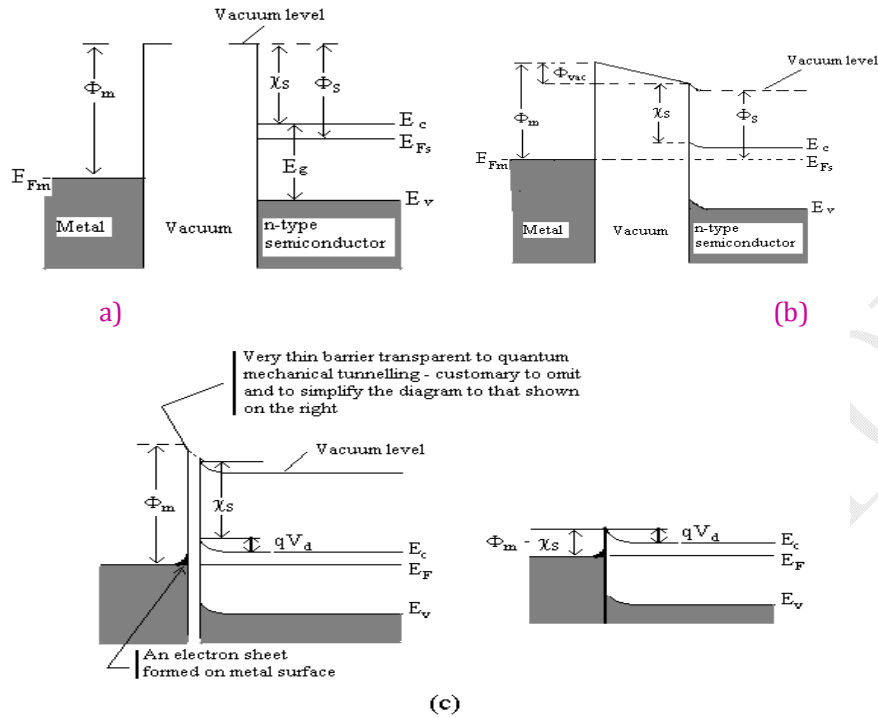


Fig. 3 Energy level diagrams for a contact between a metal and an n-type semiconductor for $\phi_m > \phi_s$ and without surface states : (a) before contact, (b) in thermal equilibrium, and (c) in intimate contact.

Analytical Expression

An ohmic contact between a metal and a SC is understood to be one having almost negligible impedance when compared with series impedance of the bulk of the SC. On the basis of energy band view point Mott and Gurney [6] made the important observation that it should be possible to obtain injection in a manner closely resembling their injection from a thermionic cathode into vacuum was studied and on injection of charge carriers from a point contact [1-3, 6]. The context of which is the following and have a bearing with this work, the importance of the contact is also exemplified.

Following the works of O’dwyer et. al. [7], the expression for the current density may be written as,

$$\begin{aligned}
 J &= en(x)\mu E - eD \frac{dn(x)}{dx} \\
 &= en(x)\mu \left[-\frac{dW(x)/e}{dx} \right] - eD \frac{dn(x)}{dx} \\
 &= -n(x)\mu \frac{dW(x)}{dx} - \mu kT \frac{dn(x)}{dx}
 \end{aligned}$$

[From Nernst-Einstein equation] ... (4)

where, E , $n(x)$, μ and D are Electric field, carrier concentration, Mobility of carrier and carrier diffusion co-efficient.

In equation (4) first part is due to drift current and second part is due to diffusion current. From equation (4) we have

$$\frac{J}{\mu kT} = - \left[\frac{n(x)}{kT} \cdot \frac{dW(x)}{dx} + \frac{dn(x)}{dx} \right]$$

$$\text{Or, } \frac{J}{\mu kT} \exp\left(\frac{W(x)}{kT}\right) = - \left[\frac{n(x)}{kT} \cdot \frac{dW(x)}{dx} + \frac{dn(x)}{dx} \right] \exp\left(\frac{W(x)}{kT}\right)$$

$$= \frac{n(x)}{kT} \cdot \frac{dW(x)}{dx} \exp\left(\frac{W(x)}{kT}\right) - \frac{dn(x)}{dx} \exp\left(\frac{W(x)}{kT}\right)$$

$$= - \frac{d}{dx} \left[n(x) \exp\left(\frac{W(x)}{kT}\right) \right]$$

... (5)

Now the potential barrier height $W(x)$ = potential energy barrier (W_0)

+ Image force which tends to attract the

emitted electrons back to crystal (W')

+ Potential energy due to the
applied field (W'')

Integrating equation (5) from x_0 to x we have,

$$\int_{x_0}^x \frac{J}{\mu kT} \exp\left(\frac{W(x)}{kT}\right) dx = \int_{x_0}^x - \frac{d}{dx} \left[n(x) \exp\left(\frac{W(x)}{kT}\right) \right] dx$$

$$= - \left[n(x) \exp\left(\frac{W(x)}{kT}\right) \right]$$

... (6)

Now correspond to minimum potential energy i.e. at $x = x_0$

$$W(x) = W_0 \quad \text{and} \quad n(x) = n_c \exp\left(-\frac{W(x)}{kT}\right)$$

$$\int_{x_0}^x \frac{J}{\mu kT} \exp\left(\frac{W(x)}{kT}\right) dx = n_c \exp\left(-\frac{W(x)}{kT}\right) \exp\left(\frac{W(x)}{kT}\right) - n(x) \exp\left(\frac{W(x)}{kT}\right)$$

$$= n_c - n(x) \exp\left(\frac{W(x)}{kT}\right)$$

$$n(x) \exp\left(\frac{W(x)}{kT}\right) = n_c - \int_{x_0}^x \frac{J}{\mu kT} \exp\left(\frac{W(x)}{kT}\right) dx$$

$$n(x) = \exp\left(-\frac{W(x)}{kT}\right) \left[n_c - \int_{x_0}^x \frac{J}{\mu kT} \exp\left(\frac{W(x)}{kT}\right) dx \right]$$

... (7)

For an injection field of $F < 10^4 \text{ Vcm}^{-1}$ in case of potassium halide crystal, $x_0 \sim 10^{-6} \text{ cm}$ and can be assumed to be zero.

Writing,

$$\frac{W(x)}{kT} = p - qx - \frac{r}{x}$$

$$\text{where, } p = \frac{W_0}{kT}, \quad q = \frac{eF}{kT}, \quad r = \frac{e^2}{16\pi\epsilon kT}$$

and $(qr)^{1/2} \ll 1$ at temperatures on or about room temperatures.

$$\begin{aligned}
 \int_{x_0}^x \exp\left(\frac{W(x)}{kT}\right) dx &= \int_0^x \exp\left(\frac{W(x)}{kT}\right) dx = \int_0^x \exp\left(p - qr - \frac{r}{x}\right) dx \\
 &= \exp(p) \int_0^x \exp\left(-\left(qr + \frac{r}{x}\right)\right) dx \\
 &= \exp(p) \left[\int_0^{\alpha} \exp\left(-\left(qr + \frac{r}{x}\right)\right) dx - \int_x^{\alpha} \exp\left(-\left(qr + \frac{r}{x}\right)\right) dx \right] \\
 &= \left[\frac{1}{q} - \frac{1}{q} \exp(-qx) \right] \exp(p) \quad \left(\text{If } x \gg \left(\frac{r}{q}\right)^{\frac{1}{2}} \quad \& \quad (qr)^{\frac{1}{2}} \ll 1 \right) \\
 &= \exp(p) \frac{1}{q} [1 - \exp(-qx)]
 \end{aligned}$$

Therefore from equation (7) we have,

$$\begin{aligned}
 n(x) &= \exp\left(-\frac{W(x)}{kT}\right) \left[n_c - \frac{J}{\mu kT} \exp(p) \frac{1}{q} \{1 - \exp(-qx)\} \right] \\
 &= \exp\left(-\frac{W(x)}{kT}\right) \left[n_c - \frac{J}{\mu kT} \exp\left(\frac{W_0}{kT}\right) \frac{kT}{eF} \left\{1 - \exp\left(\frac{eFx}{kT}\right)\right\} \right] \\
 &= \exp\left(-\frac{W(x)}{kT}\right) \left[n_c - \frac{J}{\mu eF} \exp\left(\frac{W_0}{kT}\right) \left\{1 - \exp\left(\frac{eFx}{kT}\right)\right\} \right] \\
 \text{Or, } n(x) \exp\left(-\frac{W_0}{kT}\right) &= \exp\left(-\frac{W(x)}{kT}\right) \left[n_c \exp\left(-\frac{W_0}{kT}\right) - \frac{J}{\mu eF} + \frac{J}{\mu eF} \exp\left(-\frac{eFx}{kT}\right) \right] \\
 \text{Or, } n(x) \exp\left(-\frac{W_0}{kT}\right) \exp\left(\frac{W(x)}{kT}\right) &= \left[n_c \exp\left(-\frac{W_0}{kT}\right) - \frac{J}{\mu eF} + \frac{J}{\mu eF} \exp\left(-\frac{eFx}{kT}\right) \right] \\
 \text{Or, } n(x) \exp\left(-\frac{W_0}{kT} + \frac{W(x)}{kT} + \frac{eFx}{kT}\right) &= \left[n_c \exp\left(-\frac{W_0}{kT}\right) - \frac{J}{\mu eF} \right] \exp\left(\frac{eFx}{kT}\right) \cdot \frac{J}{e\mu F} \\
 &\dots \tag{8}
 \end{aligned}$$

Now,

$$\frac{W(x)}{kT} = p - qx - \frac{r}{x} \cong (p - qx) \quad \left[\text{If } (qr)^{\frac{1}{2}} \ll 1 \right]$$

$$= \frac{W_0}{kT} - \frac{eFx}{kT}$$

$$\frac{W(x)}{kT} - \frac{W_0}{kT} + \frac{eFx}{kT} = 0$$

$$\text{Or, } \exp\left(\frac{W(x)}{kT} - \frac{W_0}{kT} + \frac{eFx}{kT}\right) = 1$$

Thus,

$$n(x) = \frac{J}{e\mu F} \exp\left(\frac{eFx}{kT}\right) \left[n_c \exp\left(-\frac{W_0}{kT}\right) - \frac{J}{\mu e F} \right] \quad \dots \quad (9)$$

The co-efficient of exponential term in equation (9) must vanish in order to avoid divergence of $n(x)$ for large x we have.

$$n_c \exp\left(-\frac{W_0}{kT}\right) - \frac{J}{\mu e F} = 0$$

$$\text{Or, } J = (e\mu F n_c) \exp\left(-\frac{W_0}{kT}\right) = A \exp\left(-\frac{W_0}{kT}\right) \quad \dots \quad (10)$$

This is the final analytical expression that can be used to verify the electronic and ionic transmissions of alkali-halides solids.

It is easy to understand that the injection of electron into an insulator on the basis of energy band diagram. The electrons in the metal set for emission are those thermally excited to energy sufficiently large to overcome the energetic barrier at the emission surface. Mott and Gurney [6] depicted that the interface dipole energy barrier at the metal-insulator contact can be quite smaller than the corresponding work function barrier for metal-vacuum contact. At room temperature sufficient number of electron available at the contact to support SCL electron were flowing into the specimen, insulator. Electron flow in the conduction band of the insulator is influenced by the frequent collisions with the thermal vibrations, chemical impurities and structural imperfection present in the insulator though the mathematical analysis of SCL current flow is different from that of corresponding flow in vacuum. Presence of localized traps can drastically interfere with the passage of injected electrons particularly at sufficiently low temperatures where the capture of injected electrons would be assumed to be stable. Rose had developed the work on SCL injection and formulated a theory about the form and magnitude of the reduction in injected current arising from localized trapping of the injected carriers. Lampert and Mark [5] discussed the transients for the case of ohmic contact.

EXPERIMENTAL DESIGN AND CHARACTERIZATION

The experimental verification of equation (10) analogous to electron emission in vacuum tubes envisages that these injection experiments might give us some insight in qualifying transport kinetics in insulators like alkali-halides.

Following are the experiments conducted with the alkali halide specimen.

- a) Methodology of Single crystal growth.
- b) Sample preparation for carrying present experiments.
- c) Characterization of the grown Crystals.

a) Methodology of Single Crystal Growth

The most suitable method for growing a large single crystal of high purity is achieved by melt growth process. The Czochralski - Kyropoulos method is one of the best method known which is used in the present work. A microprocessor controlled dedicated furnace (pid controller model No. HS 1500-C) indigenously modelled and fabricated in the laboratory. Powdered pure material (analar grade 99.99) is used under argon atmosphere in a platinum crucible rotating from below. The rate of rotation was synchronized with the pulling rate of seed from the melt, so as to maintain a good mechanical stability of the entire system to produce quality crystal.

1. Crystal growth furnace

The furnace is made up of silicon carbide rods as heating elements. The silicon carbide rods have an overall length of 55 cm and the hot zone consists of 15 cm x 1.2 cm and nine resistances of 1.3

Ω are used in three phase. The furnace covers a total volume of 55 cm (length) x 50 cm x 51 cm. The hot zone has a measure of 20 cm x 20 cm x 15 cm. The heater power supply consists of S C R which are operated both manually and automatically with power control using p i d based controller MPC – 500. A cylindrical quartz muffle (30 cm in length, 3 mm gauge and 10 cm in diameter) is inserted vertically at the center of the furnace. This will enable a uniform heating of the melt and appropriate argon charging during the growth process. A step down transformer of 7.5 KVA is used to convert 440 V, 50 Hz to 80 V, through phase to phase primary delta and secondary star connections. Power controller is 1 % to 99 % proportional by SCR mounted on metallic aluminium heat sink. A Pt: Pt – Rh (13 %) thermocouple is used to measure the inside temperature of the furnace. The output signals are compared with the set point in MPC – 500. The temperature control accuracy in the hot zone is $\pm 1^{\circ}$ C and temperature uniformity in the hot zone is $\pm 0.5^{\circ}$ C. All controlling circuits are housed in an instrument cabinet and the panel meters and other accessories are grafted in front of the cabinet.

2. Preparation of the single crystalline specimen:

High purity material in the form of powder was taken in a quartz tube and heat treated at about 500° C in order to remove water vapor and other occluded absorbed gases or volatile compounds. Single crystals of alkali-halide material [pure KCl, KBr, NaCl {E-mark powder 99.99%}] were grown by Czochralski - Kyropoulos method. Typical rotation speed was generally maintained at ~ 5 to 8 rpm and pulling rate $\sim 120 \mu\text{m min}^{-1}$. Variable sizes of the crystals had been achieved by changing the rotation speeds. Molten mass temperature was fixed in accordance with the melting point of the solids and is in general slightly higher than the melting point. Typical data for this regulation is summarized in Table – 1.

Some of the laboratory grown crystals are shown in Fig. 4 The Laue photographs under X-ray exposure (not shown) were observed to verify the purity of the grown crystals.

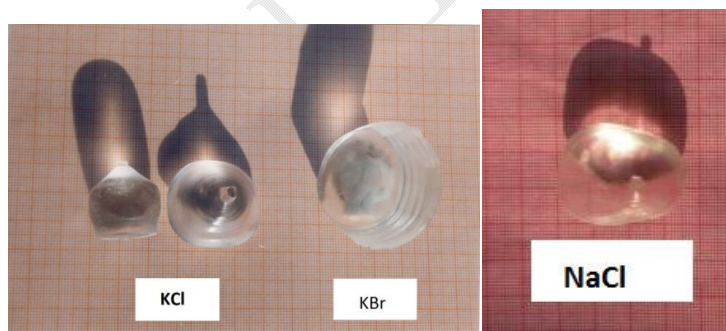


Fig. 4 : Grown Crystals by Czochralski-Kyropoulos method
Table - 1: Maintenance of the furnace Temperature

Specimen	Furnace Temperature(K)
Pure KCl	1065
Pure KBr	1045
Pure NaCl	1110

b) Sample Preparation for Experimental works

Rectangular shaped block of crystal of was cleaved from the grown crystal. The surfaces of the cleaved crystal were polished by stripping a thin layer of surface with a moist chamois leather. In the process the surface defects were reduced significantly as these class of crystals are soluble in water. The water polished cleaved specimen were dried and polished further by a dry chamois leather and is made ready for carrying experiments.

c) Characterization of the Grown Crystals

A rectangular furnace is needed for heat treatment and performance of electron injection. A cleaved sample is placed between two electrodes and housed inside the furnace. A flat platinum anode and flat brass cathode i.e. both flat electrodes homogeneous contacts of corresponding materials have been used.

1. Measurement of Temperature.

A chrome – alumel thermocouple is inserted within the furnace from the topside to measure the temperature of the treatment in a manner such that the thermocouple tip is very near to the crystal surface to avoid the temperature lag. The temperature of the furnace is controlled with the help of an electronic controller within $\pm 2^\circ\text{C}$.

2. Measurement of Current

A polished cleaved specimen is placed between the electrodes and the temperature of the furnace is increased. As the stable desired temperature is achieved the electric field is applied for injection purpose. In the first phase, the injection has been made at various temperatures for a particular field and the process has been truncated before the advent of the second zone. In the second phase the injection has been performed on the same specimen at a higher field under different temperatures.

The current conducted through the specimen during the process is obtained by measuring the voltage drop across the external resistance and is recorded with the use of one pen of Bausch and Lomb series 5000 strip chart recorder having two pen in it.

RESULTS & DISCUSSIONS

Current growth curves (Fig. 5) for single crystals of KBr, KCl and NaCl indicate the effect of temperature for particular fields of 500 Volt cm^{-1} and 700 Volt cm^{-1} .

From the theoretical approach [equation 10] the ionic current density does not depend on the shape of electrodes given by

$$J = A \exp.(-W_0 / KT)$$

where, W_0 is the activation energy for the ionization.

Activation energy for ionization has been calculated from $\ln J$ vs. $1/T$ graph plot (Fig. 6) in both the cases. Results for different specimen have been shown in the Table – 2. It is clear from the table that W_0 values for heterogeneous electrodes are field effective in nature. These expected results indicate the non-uniformity of fields in case of the pointed cathode.

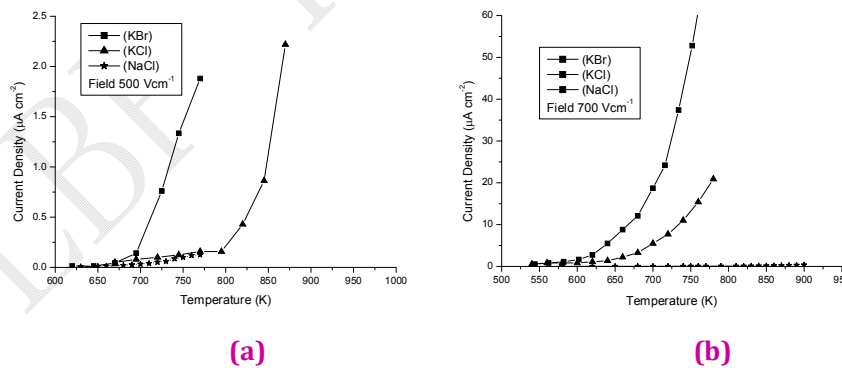
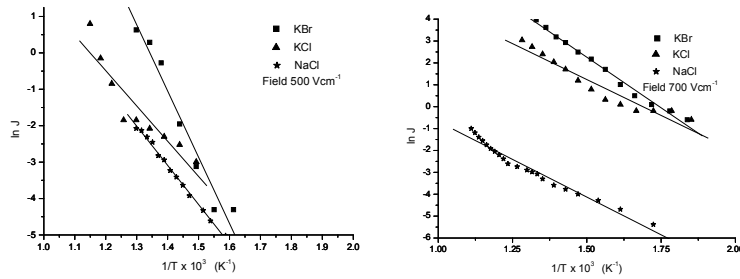


Fig.5: Ionic current growth at various temperatures under injection field of a)500 Vcm⁻¹b) 700 Vcm⁻¹



(a) **(b)**
Fig.6. Logarithm of current density (ln J) as a function of reciprocal of temperature under injection, field a) 500 Vcm⁻¹ and b)700 Vcm⁻¹

Table - 2: Estimated activation energy values for KCl, KBr and NaCl.

Sample	Activation Energy in eV	
	Field 500 Volt cm ⁻¹	Field 700 Volt cm ⁻¹
KCl	1.56	0.79
KBr	0.83	0.56
NaCl	0.93	0.59

In ionic solids like alkali halides, the electric current under electrolysis is begin to flow by the motion of the ions and these ions are enhanced thermally. Due to the process of electrolysis the anion reaches the cathode and the cation on to the anode. The ions will be piling up under the influence of the metal field and the metal surface potential be raised to an extent to lead the electrons on the negative ions to the Fermi level of the metal anode or to lower the holes on the positive ions to the Fermi level of the metal cathode so that the charges of both types of ions can be transferred to the metal electrodes.

The activation energy connected to the formation of the contact has a correlation with the Galvani voltage. The Galvani voltage type barrier must be overcome to have an adequate ionization current. Thus the activation energy (W_0) under ionic process is at the most be equal to eV_c .

The cessation of this thermo dynamical process is consequent upon the formation of ideal contact and under inhomogeneous geometry of contact copious amount of electrons undergo to commence the process of space charge current necessary for trapping the carriers (general feature of alkali halide crystals towards the formation of color centres).

From the results of the activation energy, it is clear that the heterogeneous geometry is effective in deriving the electrons in stage 2 under the influence of SCL current and also the basic demand for injection to be continued. The ideal condition of contact is confirmed with a heterogeneous cathode – anode contacting system which is a prerequisite for the electronic current to flow beyond the ionic zone.

CONCLUSIONS

Study of the electrical properties of ion crystals by electron injection revealed a transient response of the current which is characteristic of four zones [8-11] The electron transport is responsible for the conduction in zone II and zone III, while the first-zone current is due to ionic conductivity [4, 13]. For a given electric field, first-zone current does not change with time. However, due to nonlinearity and in-homogeneity of the contact [3], ionic current is initially constant until the deposition of alkali metal causes the formation of a secondary cathode, which acts as a reservoir of free carriers. Hence, the electron injection gets a boosting. The formation of such contact is the prerequisite for the flow of SCL current through the crystal and it is a precursor for the growth of the color canters [11-15].

Electrons on their way through the crystal get trapped in anion vacancies and form color centers. The coloring of a specimen may be varied by incorporating impurities of different vacancies which may act as good traps or may have a deteriorating effect on F center formation.

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