CURRENT-VOLTAGE (I-V) MEASUREMENTS OF BOAB AND H$_x$OAB NEMATIC LIQUID CRYSTALS
INTRODUCTION:

Defects states and impurity in insulators, predominantly influence their electrical and optical properties. This makes it possible to use these properties to gain the information about the nature of the states. Also an ionic impurity causes complex behavior in liquid crystals. Particularly, it poses a significant problem in application of the liquid crystals to display devices or other electronic devices. Therefore, it is necessary to elucidate the ion behavior in liquid crystals. Moreover knowledge of the ion behavior is important for understanding the electric (ion) conduction in liquid crystals as a dielectric material. A lot of theoretical work is available in the literature, however, little work in the experimental part on electrical conduction mechanism seems to have been done. A few reports discuss ion behavior in liquid crystals, but not much information seems to be available in this direction. To establish the ion behavior, measuring current flow in liquid crystals is the simplest and most effective method. The current can be divided into a transient and a steady-state current. The transient current measurement has been reported by several authors. In contrast the steady state current or leakage current in liquid crystals has not yet been investigated, except for one report on nematic liquid crystal (5CB) and other on cholesteric liquid crystals to the author's knowledge.

In view of above considerations in mind the author has carried out the measurements of current-voltage (I-V) behavior on two nematic liquid crystals, namely 4,4'-Dibutoxyazoxybenzene (BOAB) and 4,4'-Bis (hexyloxy) azoxybenzene (HxOAB). The samples supplied by Eastman Kodak Co. (USA) were used directly without further purification as the purity of the samples as quoted by the manufacturer was 99%.
Method:

Details of the experimental technique adopted for the current-voltage measurements are discussed under chapter-II 'Experimental' (2.11).

Results and Discussion:

Conduction in organic molecules in particular liquid crystals is often characterised by the carrier mobility and density and their temperature dependence. The carrier mobility and its temperature dependence in these materials is usually obtained by current-voltage (I-V) measurements depicting non-ohmic currents. In this method for a material exhibiting non-ohmic currents, the most accurate and direct method of obtaining mobility and its temperature dependence and the carrier density and its temperature dependence can be determined from the I-V characteristics. The I-V curves are interpreted in terms of a model proposed by Mott and Gurney,5 Rose2 and Lampert1 for the injection of space charge into an insulator by ohmic electrodes.

The current-voltage curves depicted in Fig 7.1 and 7.3 for BOAB and HxOAB clearly illustrate the I α V and I α V² regions predicted by SCLC theory. This theory will be used to analyse the I-V curves and their temperature dependence. The ohmic behaviour below 8 volts and the 'modified Child's law' behaviour above 12 volts can be described by equation (2.67) and (2.68) discussed under chapter - II 'experimental'. The current behaviour in this latter region strongly suggests the injection of space charges by ohmic contacts and dominates conduction for applied fields greater than 60V/cm.

The variation of I-V² curves with temperature for BOAB and HxOAB are presented in Figs 7.2 and 7.4 respectively. An effective drift mobility and
its temperature dependence, $\mu_{\text{eff}}(T)$, can be calculated from Child's law, and the slope of the I versus $V^2$ curves. The variation of the I-V$^2$ curves with temperature indicates that effective mobility is strongly dependent on temperature. The effective mobilities for BOAB vary from $3.3 \times 10^{-4}$ to $6.5 \times 10^{-2} \text{ cm}^2/\text{v-s}$ in the temperature range 90$^0$C to 135$^0$C and for HxOAB, the effective mobilities are in the range of $1.0 \times 10^{-4}$ to $9.10 \times 10^{-2} \text{ cm}^2/\text{v-s}$ in the temperature range of 64$^0$C to 130$^0$C. These mobilities are comparable with the mobility values for most of the dielectric liquids.

The temperature dependent slopes in Fig 7.2 and 7.4 indicate that the effective drift mobility increases with temperature. The I-V curves in Figures 7.1 and 7.3 retain the same form with little change in transition voltage $V_{tr}$, in passing from the solid to the liquid crystal state and from the liquid crystal to the isotropic liquid state. The increase in mobility with temperature indicates that the conduction is likely to be electronic.

The similarity in shape, slope and transition voltage, $V_{tr}$ in the I-V curves in Fig 7.1 and 7.3 indicates that the same majority carriers (electrons or holes) are present in the solid, liquid crystal and isotropic liquid states in BOAB and HxOAB. No discontinuous or erratic behaviour on passing through a phase transition which could correspond to a change in conduction mechanism was observed. The same behaviour in the I-V curves for BOAB and HxOAB further suggests that the same conduction process is present, in all three states of these two samples under study.
Fig. 7.1  I-V Characteristics for BOAB in the solid, liquid crystal and isotropic liquid states
Fig. 7.2 Variation of I with $V^2$ for BOAB at different temperatures.
Fig. 7.3 I-V Characteristics for HxOAB in the solid, liquid crystal and isotropic liquid states.
Fig. 7.4 Variation of I with $V^2$ for HxOAB at different temperatures.
The thermal equilibrium carrier density, $N_0$, obtained from equation 2.69 (Chapter - II) and the values of $V_{tr}$ obtained from Figures 7.1 and 7.3 agree well with the literature values. The thermal equilibrium carrier density $N_0$, scattered from $6.10 \times 10^{10}$ to $9.23 \times 10^{10}$ for the temperature range of $90^0c$ to $145^0c$ for BOAB and $6.10 \times 10^{10}$ to $4.46 \times 10^{10}$ for the temperature range of $64^0c$ to $145^0c$ for HxOAB. This may be due to the uncertainty in the value of $V_{tr}$. Hence the exact temperature dependence of $N_0$ could not be determined. Some average values of $N_0 = 9.39 \pm 1.0 \times 10^{10}/cm^3$ between $90^0c$ to $145^0c$ for BOAB and $5.68 \pm 1.0 \times 10^{10}/cm^3$ between $64^0c$ to $145^0c$ for HxOAB are given. The values of $N_0$ obtained are in fair agreement with the literature values. The carrier density obtained here suggest that the space charge limited currents are predominant.

With the above discussion, in both the liquid crystals, ohmic ($I \alpha V$) and Child's law ($I \alpha V^2$) behaviour was observed. Due to the lack of enough experimental facilities we could not go for higher voltages and hence it was not possible to detect the linearity at the higher voltages which is the property of the liquid crystal or $V_{TPL}$. However from the present I-V curves it may be concluded that the same majority carriers are present in both liquid crystals under study in soild, liquid crystal and isotropic liquid state.
References

5. Mott, N.F. & Gurney, R.W.; "Electronic process in Ionic crystals" Oxford
14. Chutia, J. and Baruk; "Indian J of pure & Appl. Physics, 19, 12, 1210.