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DIELECTRIC PROPERTIES NEAR THE SMECTIC-C*- A PHASE TRANSITION OF FERROELECTRIC LIQUID CRYSTALLINE STATE AT DIFFERENT VOLTAGES

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ABSTRACT: We report the results of dielectric studies was measured near the Smectic-C*-Smectic-A liquid crystal phase transition for ferroelectric liquid crystal. The two relaxation modes, the soft mode and the Goldstone mode have been observed. The dielectric strengths as well as the corresponding relaxation frequencies of the dielectric modes were determined. In the Sm-A, phase the relaxation frequency and the inverse dielectric strength of the soft mode decrease linearly when approaching the critical temperature. We conclude that, we have a fairly good understanding of the behavior of the complex dielectric constant in the whole Sm-C*-Sm-A transition range.

KEYWORDS: Ferroelectric liquid crystal mixture, Soft mode, Goldstone, dielectric strength.

I. INTRODUCTION

The ferroelectric smectic-C* liquid crystal phase provides a system which has gained an increasing amount of interest during the last several years and much effort has been devoted to characterizing the basic thermodynamic properties of the system[1-3].

In order to understand the physics and material properties of ferroelectric Smectic C (SmC*) liquid crystals, theoretical and experimental investigations have been carried out by various research groups on materials having small and large spontaneous polarization, helix pitch and rotational viscosity to explore their use in electro-optic displays [4-8]. Dielectric spectroscopy has also been studied over a wide frequency spectrum to understand the static and dynamic properties of these materials. It also gives information about various collective and molecular processes observed in the broad frequency range. [9-12]. we have evaluated dielectric parameters like relaxation frequency, dielectric strength of various collective dielectric processes experimentally [13-14].

In this paper, we report on the observation of the various relaxation processes under various bias conditions in a room temperature, high and above room temperature spontaneous polarization ferroelectric liquid crystal mixture.

II. EXPERIMENTAL

Dielectric spectroscopy studies have been carried out in FLC. Its phase sequence is given by:

$$Cryst \xrightarrow{70^0 C} SmC* \xrightarrow{138^0 C} N* \xrightarrow{182^0 C} Isotropic$$

This material has a wide temperature range of ferroelectric (SmC*) liquid crystalline phase. The phase sequence and transition temperatures were studied using the differential scanning calorimeter (DSC-) and optical polarization thermal microscopy method both have good agreement. The sample cells consist of conducting Indium Tin Oxide (ITO) coated glass substrate pre-treated with the polyamide (spin coating ~ 1000 rpm) at the surfaces. The distance between the plates was kept around 10µm by means of a Mylar spacer. The cell was first calibrated using air and benzene as standard references, which allowed us to calculate the absolute value of real and imaginary parts of complex dielectric. The device was assembled in the planar complex dielectric. The device was assembled in the planar orientation. The FLC material was introduced into the cell by means of the capillary action in its isotropic phase. The cell temperature was controlled using a temperature programmer interfaced to hot stage (LINKAM model TP94 and THMS 600) with an accuracy of ± 0.1ºC. The orientation of molecule was observed through polarizing microscope (OLYMPUS BX 5.P). The complex dielectric permittivity was measured in planar orientation using a programmable automatic RCL meter (FLUKE PM 6306) in the frequency range 50 Hz

to 1 MHz. The measurements were fully automated. The temperature, frequency, and bias field dependences of real and imaginary parts of the complex dielectric permittivity have been studied for FLC mixture.

III THEORETICAL BACKGROUND

The Smectic-C liquid crystal phase represents the spatially modulated layered structure. The tilt of the long molecular axis processes helicoidally around the layer normal while going from one smectic layer to another. Because of the chirality's, there is in-plane transverse polarization $P = P_X X + P_Y Y$ perpendicular to the direction of the tilt [9-10]. In SmC* phase the order parameter and the polarization can thus be written as:

$\square_{\square}\square_0$ Cos (qZ), $\square_{\square}\square_0$ Sin (qZ) (1)

$P_X = -P_0(\text{Sin } qZ)$, $P_X = -P_0(\text{Sin } qZ)$ (2)

Where $\square_0$ and P_0 are the magnitude of tilt angle and the spontaneous polarization respectively q is the helical wave vector.

In the absence of an external DC bias and at low frequency, phase fluctuations occur giving rise to GM while at high frequency due to amplitude changes in the tilt angle, a SM near Tc* shall appear. The external DC bias disturbs the helix in two ways:

(i) Magnitude of the tilt and the direction of the phase with weak external DC bias changes. The net induced polarization will increase and the tilt decreases.

(ii) At critical field E_C, the tilt is disturbed in such a manner that the liquid crystal molecules nearly become parallel to the layer normal and a mono domain structure starts appearing. The relaxation mode due to the domain formation known as the Domain mode "DM" can further be splitted into Bulk domain mode "BDM" and Surface domain mode "SDM" ($x = \square_{BDM} + \square_{SDM}$), while the SM appears near $T_C{}^*{}_A$ at higher frequency. At higher bias, the SDM is expected to be dominant as compared to the BDM due to the strong surface energy.

IV. RESULT AND DISCUSSION

Here we shall discuss results of temperature and frequency dependence of the complex permittivity of a ferroelectric liquid crystal mixture in the frequency range 50 Hz to 1 MHz under DC bias conditions. On the basis of our results indicated in the absence of an external field, the dielectric permittivity in the SmC* phase is dominant at low frequencies due to the Goldstone mode "GM" contribution which comes from the phase fluctuations of the azimuthally orientation of the director. However on the application of the bias field the GM dielectric increment decreases due to the suppression of the helix. The GM contribution in the form of absorption and dispersion curves at 35ºC (T<Tc*) is shown in Fig.-1 and Fig.-2 respectively. The Cole-Cole plot reflected in Fig.-3 shows one more relaxation process above 100 kHz. This mode could not be suppressed even at a field of 0.67 V/mm whose dielectric increment is very small as compared to the GM [18].

The Cole-Cole plot of Fig. 3 shows that a new mode whose relaxation frequency is ~ 113 kHz is observable. The GM is observed in the Hz region while SM is observed above 10 kHz. Here GM and SM are simultaneously reflected which can be varied from the Cole-Cole plot. In the SmA phase, only SM term is considered.

Intermediate Field ($E \sim E_C$)

In the result, we found that at zero bias the dielectric increment of the GM was quite high which got suppressed when we applied a bias voltage up to 0.6 V/□ m, but this bias Fig.-4 and Fig.-5 was not sufficient to suppress the GM and to study other collective processes. A DC bias nearly equal to E_C i.e. 1.3 V/□ m was applied to suppress the GM in order to study other relaxation processes. We can say that the multi domain texture changes into the mono-domain texture due to the formation of ferroelectric domains.

V. CONCLUSIONS

From the dielectric spectroscopy measurements carried out in the FLC mixture is it found that:

i) The GM exists at E<Ec while at E >□ □Ec DM appears with the suppression of the GM dielectric increment. DM can be further splitted into the BDM and SDM. NFM is also observable at E < Ec in SmC* phase whose relaxation frequency is above 100 kHz.
ii) At E > Ec, it is found that the SDM is more dominant as compared to the BDM.
iii) Curie-Weiss law is obeyed by SM at all the bias varying up to 2V/□ m. The values show good agreement with theory.
iv) Dielectric strength and the relaxation frequency of SDM is more as compared to that of BDM.

VI. REFERENCES

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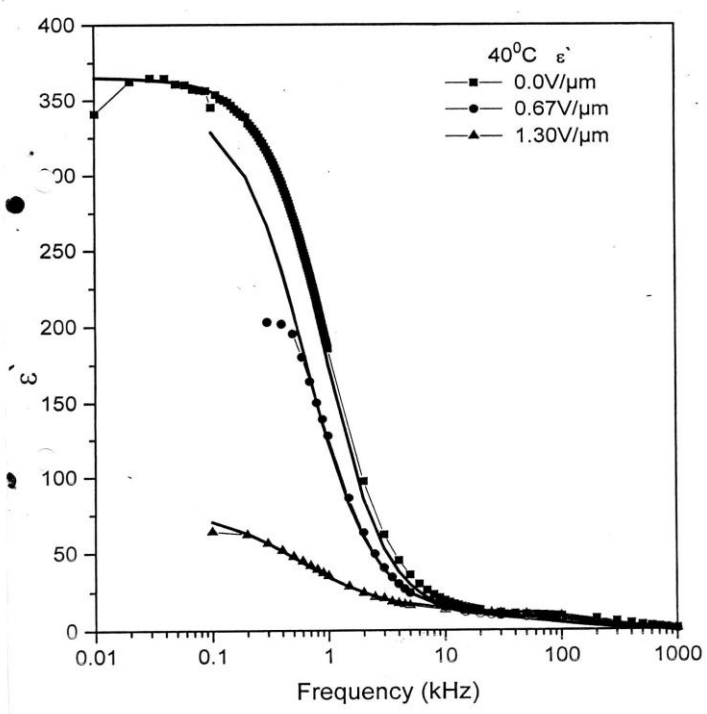

Fig.-1: Frequency Dependence of Dielectric Permittivity at 40°c and Different Voltages

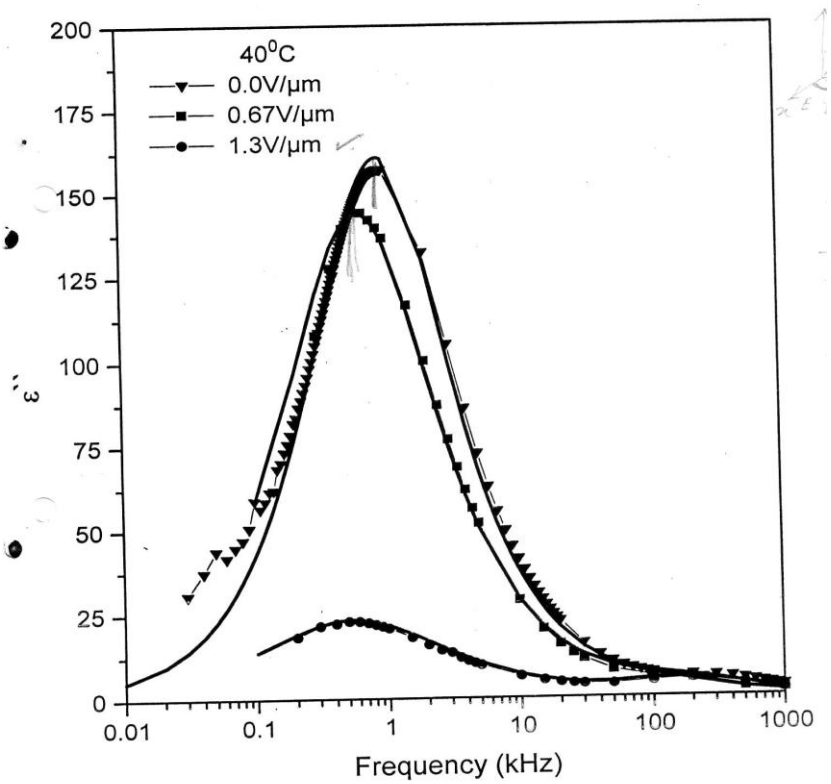

Fig.-2: Frequency Dependence of Dielectric Losses at 40°c and Different Voltages

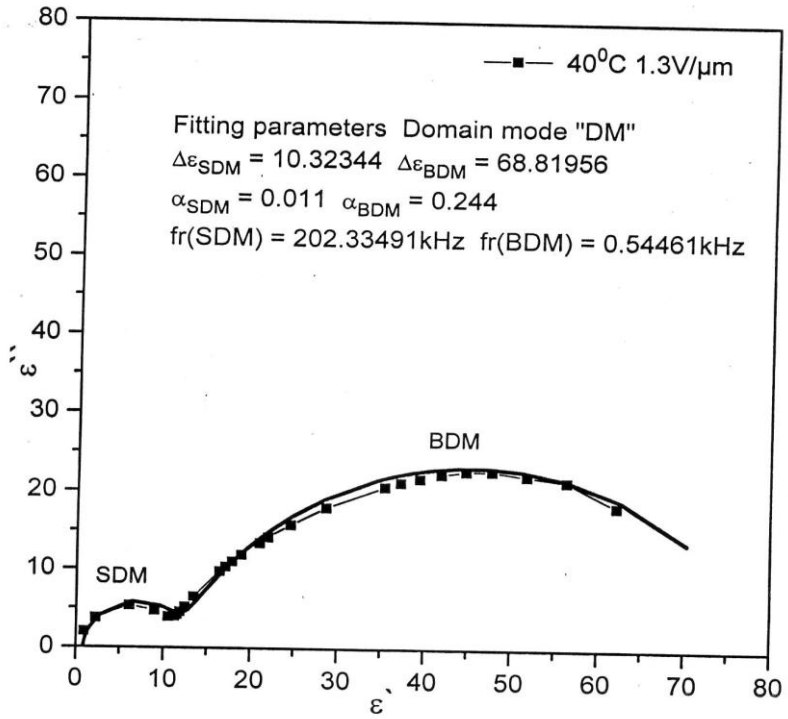

Fig.-3: Cole-Cole Representation in Different Mode At 40°c

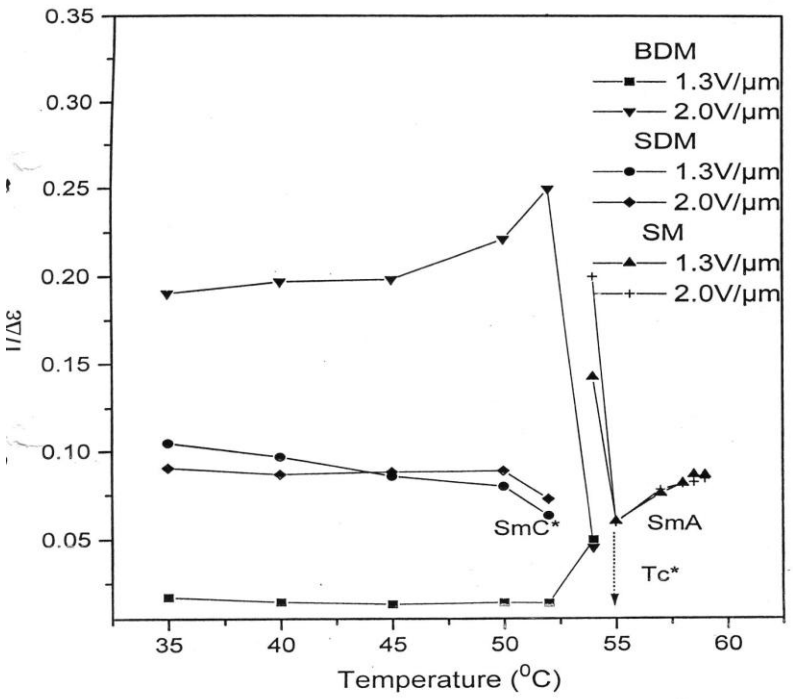

Fig.-4: Temperature Dependence of Dielectric Strength

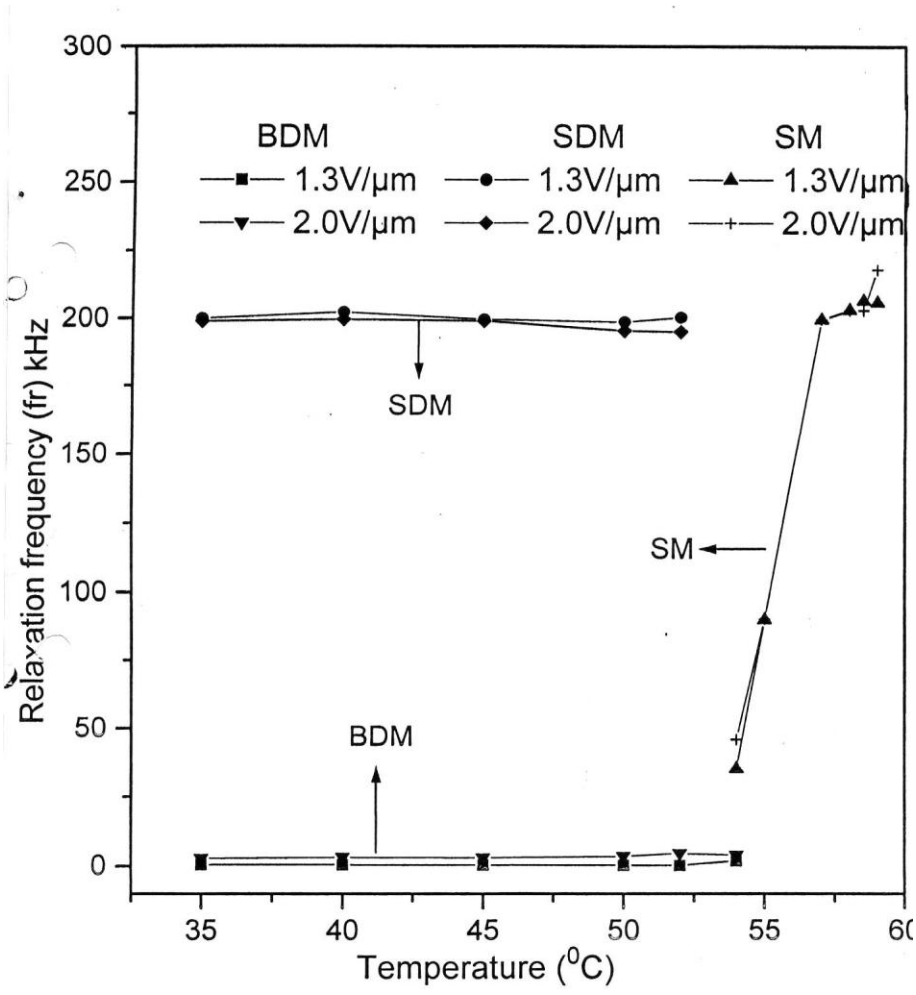

Fig.-5: Temperature Dependence of Relaxation Frequency in Different Phases