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Conducting effect on spectroscopy of dielectric material

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ABSTRACT

The Indium tin oxide layers are broadly used for making electrodes in case of measuring cells as these layers are transparent and various investigations can be performed by using the cells. It was observed during the measurement of dielectric spectroscopy, performed for smectic liquid crystalline mixture at the frequencies higher than 200 khz. The measuring does not permit to measure the relaxations, as its own dielectric behaviour covers the dielectric response of a liquid crystal phase. In this article, the theoretical model was discussed, that indicate how to determine relaxations related to liquid as well as filled measuring cell.

INTRODUCTION

The ferroelectric properties of tilted smectic liquid crystals is established on the basis of experimental and theoretical investigations [1,2]. From structural point of view, the ferroelectric SmC* phase shows layered structure and appears through the formation of an incommensurate structure in which the molecular director moved helically while moving from one layer to another layer. To understand the material properties of ferroelectric smectic C (SmC*) liquid crystals, theoretical as well as experimental study have been performed by number of workers on the materials having large and small spontaneous polarisation, rotational viscosity and helix pitch to explore their application in electro optic display units [2-8]. The spectral study of dielectric have been done to understand the static and dynamic properties of ferroelectric liquid crystal and their mixtures too [9-12]. It also provides the information about different molecular and collective process found in the broad frequency range. Appearance of goldstone mode and soft mode occurs due to the phase fluctuations of azimuthal angle and the amplitude of tilt angle. They have been studied by good number of researchers [12-13]. At the SmC* -SmA, only the SM is observable because of the fact that both the amplitude and tilt angle fluctuations become undisguisable near SmC* -SmA transitions. Bersnew et al [14-17] have reported that, the director reorientation can be explained in terms of the real part of [$\varepsilon'(\omega, T)$] and imaginary part of [$\varepsilon''(\omega, T)$] of the complex dielectric permittivity [$\varepsilon^*(\omega, T)$]. These are given as follows –

$$\varepsilon^*(\omega,T) = \varepsilon'(\omega,T) - i\varepsilon''(\omega,T) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where $\omega = 2\pi f$ is the angular frequency of the applied electric field and T is the temperature, f is the characteristic frequency related with the relaxation mechanism that contribute to $\varepsilon^*(\omega,T)$. It is given in the following manner-

$$\varepsilon^*(\omega,T) = \varepsilon_\infty(T) + \sum_i . \frac{[\delta\varepsilon_{BDM}(T)]}{1+(j\omega\tau_{BDM})(1-\alpha_{BDM})} + \frac{(\delta\varepsilon_{SM})}{1+(j\omega\tau_{SM})(1-\alpha_{\alpha SM})} + \frac{A_1}{\omega^n} - \frac{j\sigma_{(50Hz)}}{\varepsilon_o\omega} - jA\omega^m$$

…..…………………….. (2)

Where Ɛ’(∞) is the relative permittivity in the high frequency range, δƐ, α and τ are the dielectric strength, symmetric distribution parameter ($0 \leq \alpha \leq 1$) and relaxation time or reciprocal of angular relaxation frequency of the i^{th} mode respectively. The third and fourth term in above equation represent the contributions of the electrode capacitance and ionic conductance at low frequencies respectively. The imaginary part $A\omega^m$in above equation shows partially the effect of indium tin oxide coating. A_1, n, A and m are the physical constants while σ is the ionic conductance. The term $\varepsilon_o$is the permittivity of free space.

In the present article we are reporting the dielectric relaxation processes in the FLC mixtures. In has been observed that collective dielectric techniques like bulk domain mode are shown in the SmC* medium. The dielectric parameters of such mode have been determined. The effect of biasing field on the collective dielectric techniques has been investigated and explained in the present study [16-17].

The frequency dependence of the complex dielectric permittivity (Ɛ = Ɛ’ - j Ɛ”) has been investigated at different temperature range in the ferroelectric liquid crystal mixture of SCE-4. Both conducting glass plates of the dielectric cell are separated through Mylar spacer of 10 micrometre thickness. The sample were filled through capillary action at the isotonic temperature of the liquid crystal. After that it is cooled slowly at the rate of 0.1^o C/minute. The cell consisted of two indium tin oxide coated glass substrates. A thin layer of polyamide was spin coated of about 1000 rpm on these substrates to encourage planar orientation. The alignment was verified through viewing the cell by polarizing microscope interfaced to LINKAM-TP94 and THMS600 temperature programmer coupled to hot stage with in an accuracy of ±0.1^{o}C. The dielectric measurements were carried out using a programmer and automatic RCL meter in the frequency range 50 Hz to 1 MHz. The cell was calibrated by using air and benzene as standard references. The temperature, frequency and the bias voltage dependence of the real and imaginary parts of the complex dielectric permittivity has been determined. Instrumental uncertainty in the basic measurement of the capacitance as well as conductance in the frequency range concerned is less than 0.2 percentage and thus uncertainty in the determination of permittivity (Ɛ’) and loss (Ɛ”) from the capacitance and conductance is less than ±1 percentage.

RESULTS AND DISCUSSION:

The effect of frequency on the imaginary part of the dielectric investigations is shown in figure 1.

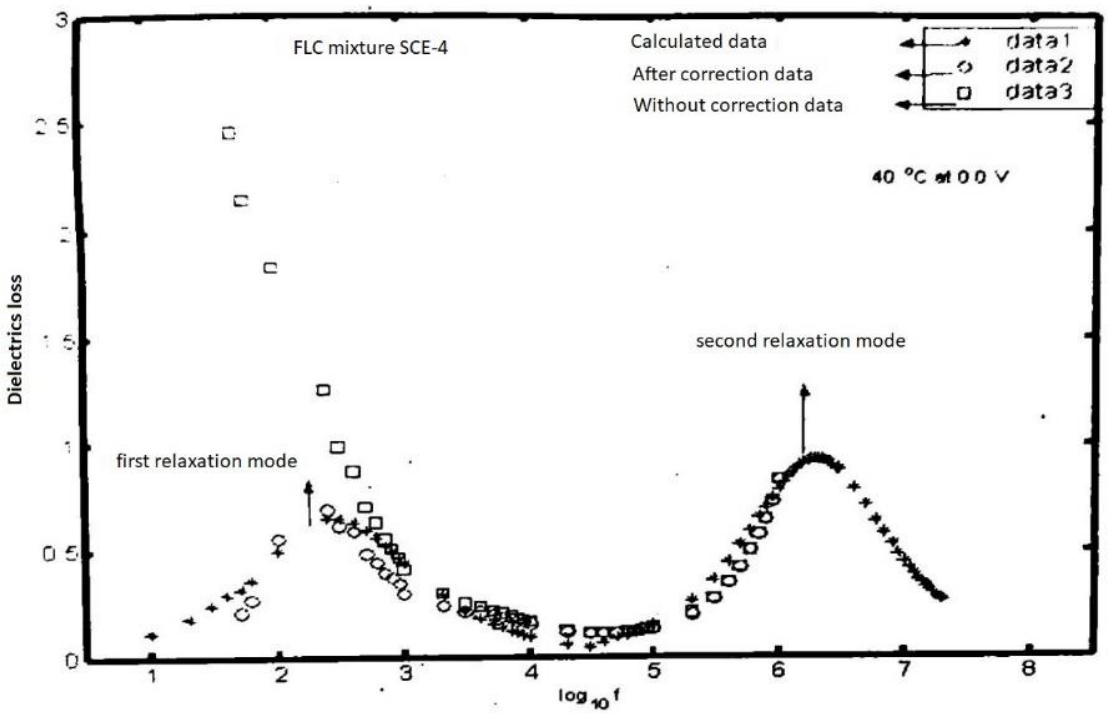

Figure 1

The dielectric loss (Ɛ'') increases from 0.2 at 15 Hz attains a maxima of 0.8 (~300 Hz) in the lower frequency range and in case of higher frequency range 0.2 (at 500 kHz) and ~1.0 at 40°C for the experimental sample SCE-4. At higher frequencies, second loss peak has been found. It is supposed to have been formed the other relaxation mode. We found that the other relaxation mode originates as a result of surface effects because of change accumulation phenomena between the alignment layer and the ferroelectric liquid crystal. Figure indicates, the effect of frequency on real part of permittivity (Ɛ') at the temperature 40° C. The permittivity decreases exponentially up to a frequency of 300 Hz for SCE-4. The response of FLC material for increasing the filed strength, helix deforms continuously and then at some field (E < V/d), the internal disclination line is formed. It is a surface disclination. At critical field (E = Vc/d), the helix unwinds completely and the whole structure becomes almost uniform. Such field suppresses the goldstone mode and the residual permittivity will give the other modes also like BDM and NRM etc. [17-19]. It has been observed that the permittivity corresponding to NRM becomes more dominant at higher bias voltage. From these, the relaxation frequency (f_r) can be determined. The standard form of the Fuoss-Kirkwood relation for practical evaluation is given as follows [17] -

$$Cosh^{-1}\left(\frac{\varepsilon''_{max}}{\varepsilon'}\right) = 2.303\ \beta(\log f_{max} - log f) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

This method eliminates the requirement for Ɛ' value and so it is specifically useful when they are not certain. For the Fuoss-Kirkwood plots, the factor $Cosh^{-1}\left(\frac{\varepsilon''_{max}}{\varepsilon'}\right)$ was determined. After that it was plotted against $\log_{10}f$, as a result a straight line is observed. The intercept on the abscissa gives the magnitude of relaxation frequency.

In this article, we have done a detailed study of dielectric properties of FLC mixtures has been performed. The observed result shows that –

1) The real and imaginary part of FLC mixtures falls with the bias voltage.
2) The imaginary part of dielectric parameter effective on lower and higher frequency side indicate significant contribution of conductivity effect in SmC* phase.

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