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Indium Tin Oxide (ITO) Conducting Effect on Dielectric Spectroscopy without Biasing Voltage in Liquid Crystal Mixture

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ABSTRACT:

In dielectric study we have use Indium tin oxide (ITO)coated glass plate. The ITO layers are widely used to make electrodes in measuring cells, because these layers are transparent and investigations can be performed by using the cells. It was found during the dielectric spectroscopy measurements, performed for smectic liquid crystalline mixture, that it is not possible to detect some important dielectric relaxation modes for SmA*and SmC*ferroelectric liquid crystal mixture for the frequencies higher than 200 kHz. The measuring cell does not allow to measure relaxations, because its own dielectric behaviour covers the dielectric response of a liquid crystalline medium. One can observe the contribution for high frequency part of the dielectric spectrum, due to the finite resistance of ITO layers. In this paper theoretical model was introduced, which shows how to calculate relaxations related to liquid crystals from dielectric response of the empty and filled measuring cell. The proof of strong influence of cell properties on effective values of dielectric permittivities was shown.

KEYWORDS: liquid crystal mixture, dielectric spectroscopy, relaxation modes, dielectric strength, relaxation frequency.

INTRODUCTION:

The existence of ferroelectric properties in tilted smectic liquid crystals (SmC*, SmF*, SmI*) is firmly established on the basis of experimental and theoretical investigations [1-2]. From structural view point, the ferroelectric SmC* phase exhibits layered structure and appears by the formation of an incommensurate structure in which the molecular director precesses helicoidally while going from one layer to another. In order to understand the physics and material properties of ferroelectric smectic C (SmC*) liquid crystals, theoretical and experimental investigation 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 [3-8]. Dielectric spectroscopy has been carried out to understand the static and dynamic properties of ferroelectric liquid crystals (FLCs) and their mixtures [9-12]. It also gives information about various collective and molecular process observed in the broad frequency range. Appearance of Goldstone mode "GM" and the soft mode "SM' which occur due to the phase fluctuations of azimuthal angle (□) and the amplitude of tilt angle have been demonstrated by several researchers [13-15] At the SmC*-SmA, only the SM is observable due to the fact that both the amplitude and tilt angle fluctuations become indistinguishable near the SmC*-SmA transition. Wrobel et al. explained that the large dielectric increment of the GM hinders the detailed investigations of other collective processes. The complex permittivity of the SmC* phase is dominated by the DM [16, 18] ; however it can be suppressed by application of a bias field resulting in the unwinding of the helicoidal structure. Bersnew et al. [19-22] and Wrobel et al. [15] have reported. The director reorientation can be described in terms of the real $[\varepsilon'(\omega,T)]$ and imaginary $[\varepsilon''(\omega,T)]$ part of the complex dielectric permittivity $[\varepsilon^*(\omega,T)]$ which is given as

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

Where $\omega = 2\pi f$ is the angular frequency of the applied electric field and T is the temperature. f is the characteristic frequency connected to relaxation mechanisms which contribute to $\varepsilon^*(\omega,T)$ and is given by [17]

$$\varepsilon^*(\omega,T) = \varepsilon_\infty(T) + \sum_i \frac{(\delta\varepsilon_{BDM}(T))}{1+(j\omega\tau_{BDM})^{(1-\alpha_{BDM})}} + \frac{(\delta\varepsilon_{SM})}{1+(j\omega\tau_{SM})^{(1-\alpha_{SM})}} + \frac{A_1}{\omega^n} - \frac{j\sigma_{(50Hz)}}{\varepsilon_0\omega} - jA\omega^m \quad \ldots (2)$$

where $\varepsilon'(\infty)$ is the relative permittivity in the high-frequency limit and $\delta\varepsilon$, τ and α are the dielectric strength, the relaxation time (inverse of angular relaxation frequency) and symmetric distribution parameter $(0 \le \alpha \le 1)$ of i^{th} mode respectively. The third and fourth terms in equation (2) represent the contributions of the electrode capacitance and ionic conductance at low frequencies. The imaginary term $A\omega^m$ in equation (2) takes into account partially the effect of ITO coating. A_1, n, A and m are constants. σ is the ionic conductance and ε_0 (= 8.85 p F/m) is the free space permittivity. In this paper, we report on the detailed investigations of dielectric relaxation processes in FLC mixtures. It has been found that collective dielectric processes such as the bulkdomain mode and soft domain mode are present in the SmC* phase. The dielectric parameters of this mode have been evaluated. The influence of biasing field on collective dielectric processes has been studied and discussed in the proceeding sections.

The frequency dependence of the complex dielectric permittivity $(\varepsilon^* = \varepsilon' - j\varepsilon'')$ has been studied at different temperatures ferroelectric liquid crystal mixture SCE-4. The two conducting glass plates of the dielectric cell were separated by mylar spacer of 10 μm thickness and the sample was filled by capillary action at the isotropic temperature of the liquid crystal and then cooled slowly at 0.1 ºC/min. The cell consisted of two indium tin oxide (ITO) coated glass substrates. A thin layer of polyamide was spin coated (~ 1000 rpm) on these substrates to encourage planar orientation. The alignment was confirmed by viewing the cell through the polarizing microscope (OLYMPUS BX-51P) interfaced to LINKAM-TP94 and THMS600 temperature programmer coupled to hot stage at an accuracy of ± 0.1ºC.

The dielectric measurements were carried out using a programmer and automatic RCL meter (FLUKE PM 6306) in the frequency range 50 Hz to 1 MHz. The cell was calibrated using air and benzene as standard references. The temperature, frequency and bias voltage dependence of the real and imaginary parts of the complex dielectric permittivity have been made. Instrumental uncertainty in the basic measurement of capacitance and conductance in the frequency range concerned is less than 0.2% and hence uncertainty in the determination of permittivity (ε') and loss (ε'') from capacitance and conductance is less than ± 1%.

RESULTS AND DISCUSSION:

Figs. 1 shows the effect of frequency on the imaginary part of the dielectric study the dielectric loss (ε'') increases from 0.2 (at 15 Hz) attains a maxima of 0.8 (about 300 Hz) in lower frequency range and in case of higher frequency range 0.2 (at 500 kHz) and ~1.0 at 40 Cº for sample SCE-4 .

At higher frequencies, second loss peak have been observed. It is expected to have been formed the other relaxation mode. We believe that the other relaxation mode originates as a consequence of surface effects due to the charge accumulation phenomena between the alignment layer and the ferroelectric liquid crystal materials.

Fig. 2 shows the effect of frequency on real part of permittivity (ε') at the temperature 40ºC. The permittivity decreases exponentially up to a frequency of 300 Hz for SCE-4 . The typical variation of the ε' and ε'' as a function of frequency is shown in figure. The response of our FLC material to increasing the field strength, helix deforms continuously and then at some field (E < V/d) the internal disclination line is form this is a surface disclination. At critical field (E = Vc/d) the helix unwinds completely and the whole structure becomes almost uniform. This field suppresses the GM and the residual permittivity shall give rise to other modes like BDM and NRM [17]. The permittivity corresponding to NRM becomes more dominant at higher bias voltages.

The relaxation frequency (f_r) can be evaluated, the usual form of the Fuoss-Kirkwood relation for practical evaluation is[21].

$$\cosh^{-1}(\varepsilon''_{max}/\varepsilon') = 2.303\,\beta\,(\log f_{max} - \log f) \qquad \ldots (3)$$

This procedure eliminates the need for ε' value and so it is particularly useful when they are uncertain.

For the Fuoss-Kirkwood plots, the factor $\cosh^{-1}(\varepsilon''_{max}/\varepsilon')$ was calculated then it was plotted against $\log_{10} f$, as a result a straight line, the intercept on the abscissa gives the magnitude of relaxation frequency. Relaxation frequency as a function of temperature shown in Fig. 3 for SCE-4.The gradient of straight line, in Fuoss-Kirkwood plots gives the numerical factor (β).

CONCLUSIONS:

A detailed analysis of dielectric properties of FLC mixtures has been carried out. Our results indicate that:

1. The imaginary part of dielectric data effective on lower and higher frequency side show significant contribution of conductivity effect in SmC* phase.
2. The real and imaginary part of FLC mixture decreases with bias voltage.
3. The real part (permittivity) is decreases with increasing temperature frequency in SmC* phase and permittivity increase with temperature in SmA and again decrease with temperature in N* phase.

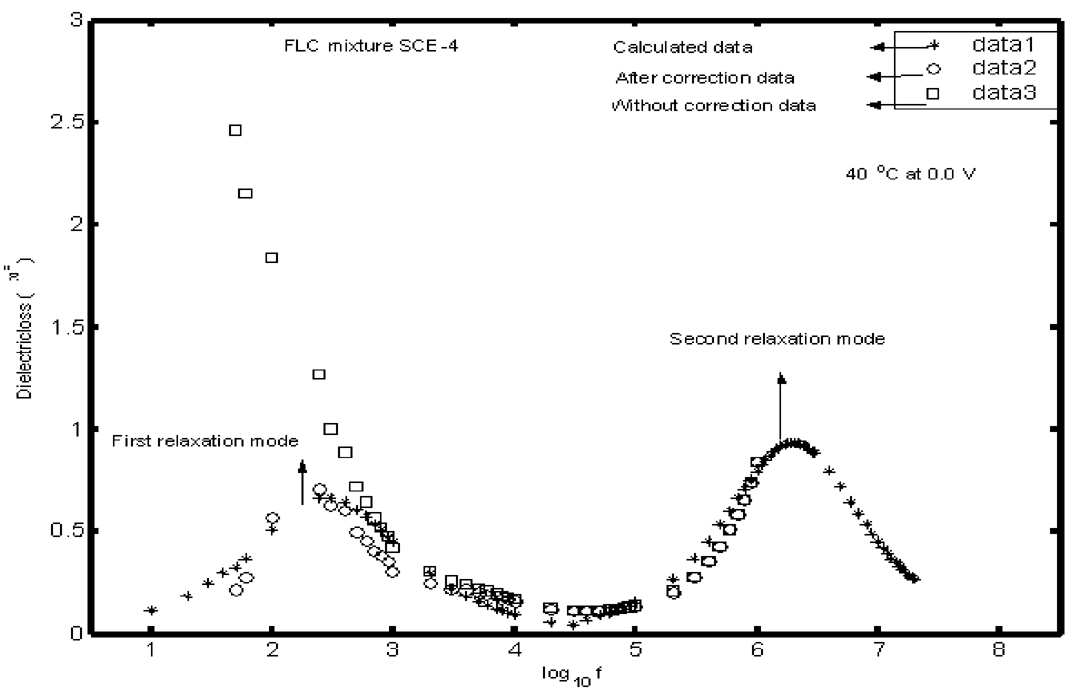

Fig.1

Frequency dependence of measured loss (ε′′) - □ for SCE-4 (FLC) at 40 °C. After subtracting correct data and theoretically calculated values of ε′′- o and ε′′- * are also shown

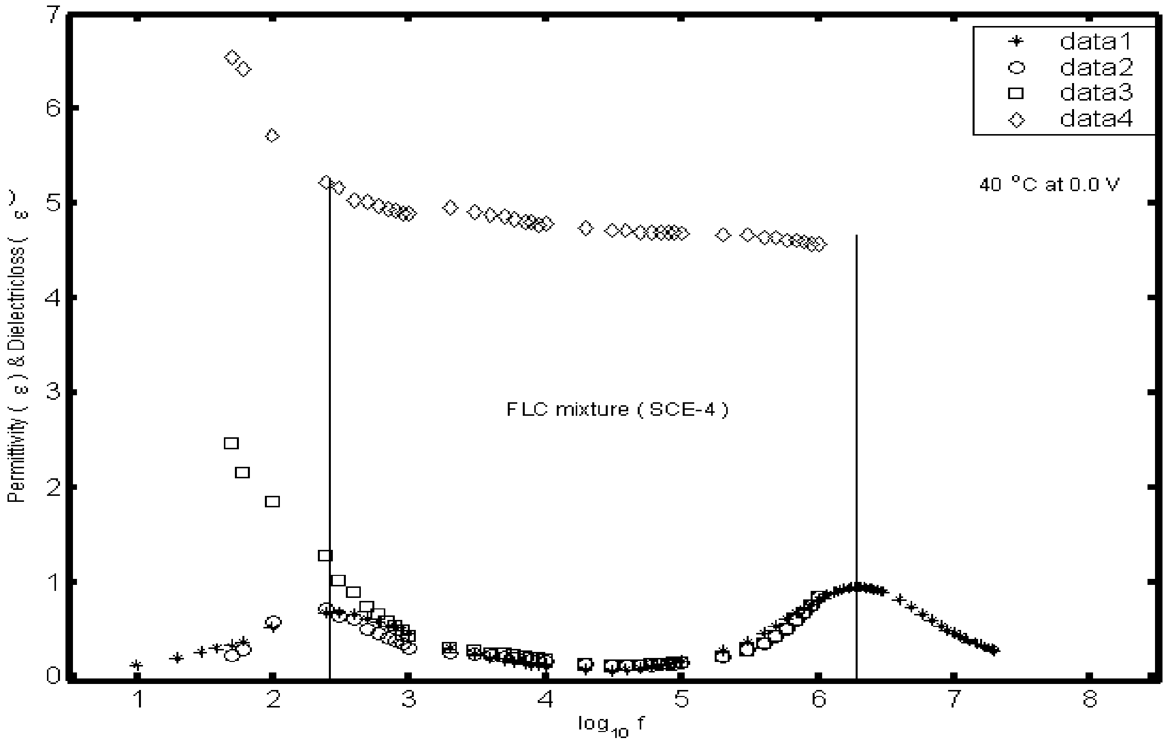

Fig.2

Frequency dependence of measured permittivity (ε′) - ◊ and loss (ε′′) - □ for SCE-4 at 40 °C. After subtracting correct data and theoretically calculated values of ε′′- o and ε′′- * are also shown.

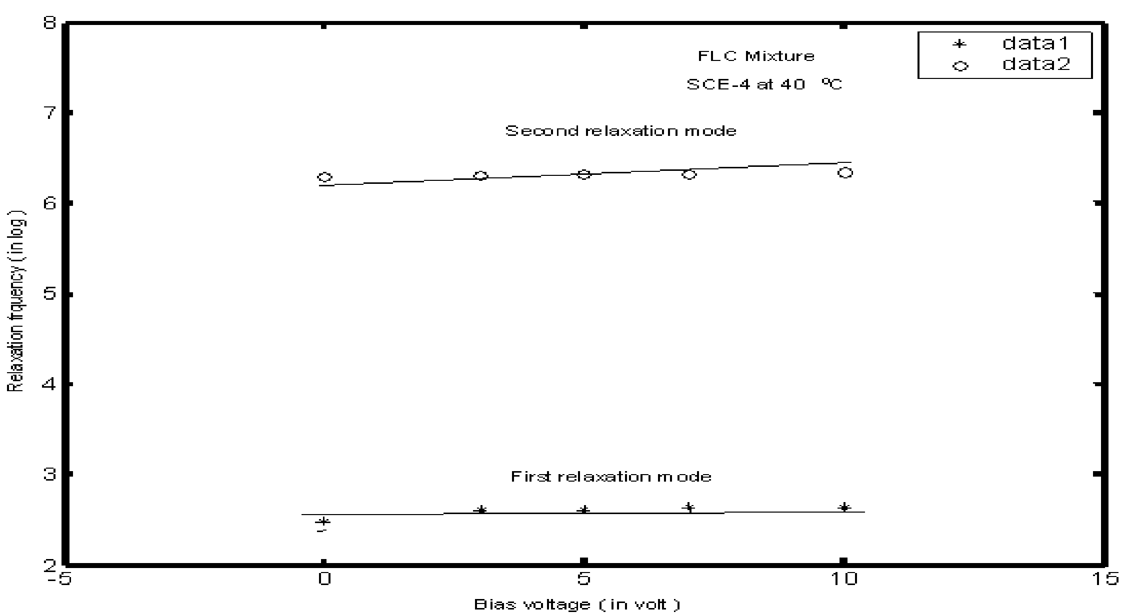

Fig. 3

Relaxation frequency as a function of applied electric field for SCE-4.

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