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Dielectric spectroscopy near the smectic C* phase ferroelectric liquid – crystalline material

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Abstract
The frequency and temperature dependence of the complex dielectric spectroscopy was measured near the semectic C* phase liquid crystal with a large spontaneous polarization. The dielectric strengths as well as the corresponding relaxation frequency were determined. Due to large polarization, we were able to resolve the contribution of different modes. The Significant contribution of conductance effect at lower frequency side in experimental data have to showed.

1. Introduction

The ferroelectric properties in titled smectic liquid crystals (SmC*, SmF*, Sml*) 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 [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 electrooptic 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]. They evaluated dielectric parameters like the spreading factor i.e. the distribution parameter, relaxation frequency, dielectric strength of various collective dielectric processes experimentally and theoretically with a good agreement in both the values [13-14].

2. In this paper, we report on the observation of the various relaxation processes under various bias conditions in a room temperature and above room temperature, high spontaneous polarization ferroelectric liquid crystal mixture FLC-6430.

2. Experimental

The frequency and temperature dependence of the complex dielectric permittivity as a function of bias voltage has been studied. We carried out measurements in a 7.5□m thick sample sandwiched between two conducting Indium tin oxide coated glass substrates (LUCID, UK). These substrates have been pre-treated with the polymide coating. The liquid crystal was filled in these cells by the capillary action at 66ºC, the isotropic phase of the sample. The sample was then cooled into the SmA phase @ 0.1ºC/min. in a LINKAM TP90 and THS600 temperature programmer cum hot stage. The thermal polarizing microscopy of the sample was studied .The complex electric permittivity was measured in the frequency range 50Hz to 1MHz at varying temperature . The cell was calibrated using air and benzene as standard reference media.

3.Theoretical Background

The chiral SmC 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, 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 :

□□□$_0$ Cos (qZ), □□□$_0$ Sin (qZ)

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

Where □$_0$ 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.

4.Results and Discussions

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. 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 azimuthal 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(a,b). The Cole-Cole plot reflected in Fig. 1(b) shows one more relaxation process above 100 kHz. This mode dielectric increment is very small as compared to the GM [16-18]. could not be suppressed even at a field of 0.67 V/mm whose

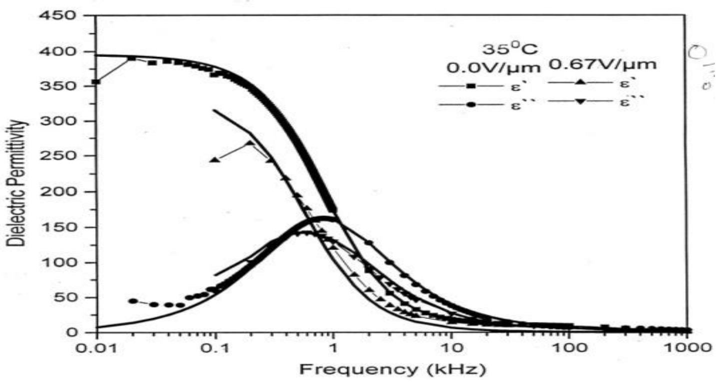

Fig. 1(a) Dielectric spectra as a function of frequency at 35ºC without bias and at E = 0.67 V/□m bias.

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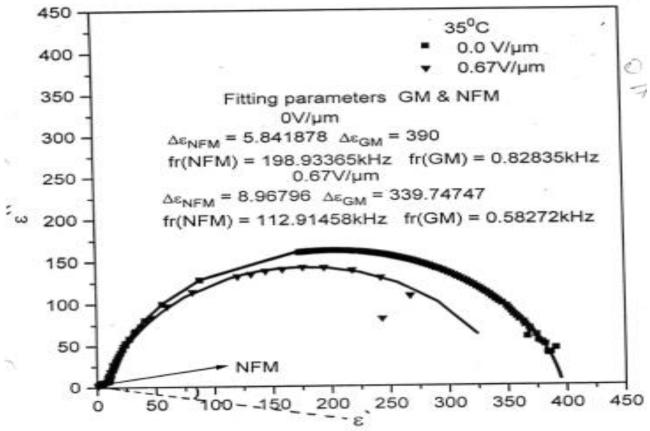

Fig. 1(b) Cole-Cole plots of GM and NFM in the SmC* phase

5. 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.

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 upto 2V/μm. The values show good agreement with theory.

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