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A NEW RELAXATION MODE IN FERROELECTRIC LIQUID CRYSTAL

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Abstract: Bias dependence of the dielectric permittivity in a ferroelectric liquid crystal material KCFLC 10S is studied in the frequency range of 20 Hz to 10 MHz. The complex dielectric constant was found to increase with increasing bias contrary to normal Ferroelectric Liquid Crystals. The theory is presented for the results obtained by considering the presence of new relaxation mode.
Keywords: Ferroelectric Liquid Crystals, Relaxation Frequency, Goldstone mode, New Relaxation mode.

Introduction

Meyer et al., in 1975, discovered that liquid crystalline materials exhibiting chiral smectic C (SmC*) phase show ferroelectricity [1]. These materials were found useful in display devices due to their fast switching and interesting electro-optic properties. Their use in devices demands measurements of certain physical parameters like dielectric parameters, electro-optic responses, surface properties etc. [2-8]. Dielectric investigations of ferroelectric liquid crystals (FLC) yields useful information regarding the molecular and relaxation processes of these materials and gives a measure of parameters like dielectric strength, relaxation frequency etc. The dielectric spectrum of ferroelectric liquid crystals essentially consists of four relaxation modes in the SmC* phase, two are the high frequency polarization modes and the other two are low frequency director relaxation modes (Goldstone mode and Soft mode) [9-10]. The Polarization modes occur at very high frequency and are not observable in the measureable frequency range. From director modes, Goldstone mode occurs at low frequency (from few Hz to few KHz) whereas Soft mode occurs at high frequency. Some more relaxation modes like domain mode (DM) and new relaxation mode (NRM) have also been reported by few workers [11-15]. These modes usually appear in the presence of external electric field and are noticeable in thin samples.

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In this paper, we studied the bias dependence of dielectric permittivity in a ferroelectric liquid crystal material KCFLC 10S in the frequency range of 20 Hz to 10MHz. A New relaxation mode (NRM) is observed in this material even in the absence of bias voltage which is becoming more pronounced on application of field.

Experimental Details

The liquid crystal material used in our experiment is a ferroelectric mixture, KCFLC 10S. The phase sequence of the material is

$$SmC^{*} \xleftrightarrow[64.5^{0}C]{} SmA \xleftrightarrow[99.5^{0}C]{} N \xleftrightarrow[112^{0}C]{} Iso$$

It has large spontaneous polarization (23 nc/cm^2), and large tilt angle 22°. The phase transition temperatures of this material have also been confirmed by the optical thermal polarizing microscopy and differential scanning calorimeter (Perkin-Elmer DSC-7). The cell of thickness 6 μm was used in the investigation. It was prepared by rubbing polyvinyl alcohol solution on indium tin oxide (ITO) coated glass substrates, unidirectionally, to obtain planar alignment. The material was then filled in these cells by capillary action at or above its isotropic temperature. The micro-textures of the samples were visualized through the polarizing microscope interfaced with computer. The dielectric parameters were measured in the frequency range of 20Hz to 10MHz; using LCR Meter (INSTEK 8110G) interfaced with computer for further analysis. The calibration with air and benzene enables the calculation of absolute value of dielectric constant from the measured data. The dielectric strength and relaxation frequency for the various modes is obtained by fitting the experimental data points in the Cole–Cole equation. From the circle intersection with axis in the Cole-Cole plots the dielectric strength of the material is given by

$\Delta\varepsilon_G = \varepsilon_o - \varepsilon_\infty$, where ε_o and ε_∞ are the permittivities at low and high frequency respectively. The relaxation frequency has been obtained from the peak of the loss curve or by using equation of the form

$$\frac{U}{V} = (\omega\tau)^{1-\alpha}$$

where $U = [(\epsilon - \epsilon')^2 + (\epsilon'')^2]^{1/2}$

and $V = [(\epsilon' - \epsilon_\infty)^2 + (\epsilon'')^2]^{1/2}$

A plot of $\log_{10} f$ with $\log_{10}(U/V)$ gives a straight line. The intercept of the line on the abscissa gives a measure of the relaxation frequency.

Results and Discussion

Frequency dependence of the real and imaginary part of dielectric permittivity ($\varepsilon_\perp'$,$\varepsilon_\perp''$) of KCFLC 10S material, for different bias voltages, is shown in Fig 1(a, b) respectively at room temperature. It reflects the dielectric spectrum in the form of absorption ($\varepsilon_\perp''$) [Fig 1(b)] and dispersion ($\varepsilon_\perp'$) [Fig 1(a)] curves. It is seen that $\varepsilon_\perp'$ shows dispersion at a particular frequency. The saturation in the permittivity is observed after this frequency. On the other hand, $\varepsilon_\perp''$shows a peak at this frequency. It is ~200Hz at all bias voltages. It corresponds to relaxation frequency and is associated with Goldstone Mode (GM). Fig 2 shows the relaxation process in terms of Cole-Cole plots. The Cole-Cole plots are observed to be distorted. According to theoretical studies [16] the distortion in Cole-Cole plots is a consequence of overlapping of modes. So we expect that relaxation in our case corresponds to the presence of two modes, one is Goldstone mode (GM) and other is some new relaxation mode (NRM).

Fig 1(a, b) also shows that with the increase of bias voltage, permittivity increases. The Goldstone mode, as per theory [17-18], suppresses with the application of bias thereby decreasing the magnitude of permittivity. Considering the fact, the increase of complex permittivity with bias cannot be explained on basis of Goldstone mode. It ought to be due to the presence of new relaxation mode (NRM) which becomes more pronounced with bias. So distorted shape of Cole-Cole plots and increased permittivity with application of bias confirms the presence of some new relaxation mode (NRM) in our sample. Dielectric strength and exact relaxation frequency of these relaxations could not be measured due to overlapping of modes.

Conclusions

In Summary, we have investigated the effect of bias on dielectric permittivity of ferroelectric liquid crystal KCFLC 10S and a new relaxation mode was seen in the material. With the increase of bias the permittivity of FLC material increased. This is due to presence of new relaxation mode in addition to Goldstone mode which becomes more significant with increase in bias. This consideration is supported by the distorted shape of Cole-Cole plots which corresponds to presence of two overlapping modes.

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Figure Captions

Fig.1 (a): - Behavior of real part of dielectric permittivity (ε') of pure KCFLC 10S material with frequency at different bias voltages.

Fig.1 (b): Behavior of imaginary part of dielectric permittivity (ε'') of pure KCFLC 10S material with frequency at different bias voltages.

Fig. 2: Cole-Cole Plots at different bias voltages for KCFLC 10S mixture.

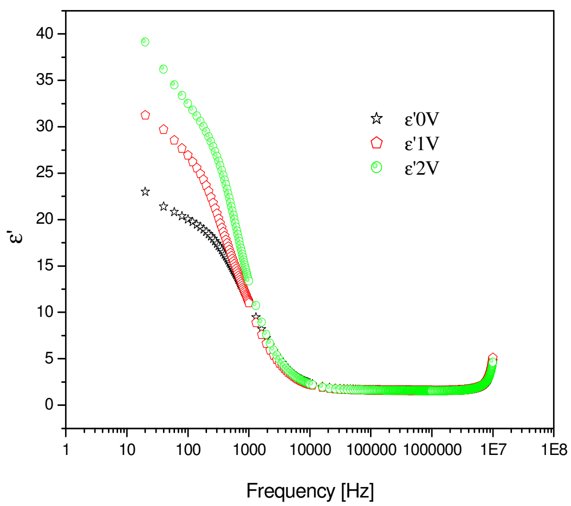

Fig. 1(a) Behavior of real part of dielectric permittivity (ε′) of pure KCFLC 10S material with frequency at different bias voltages.

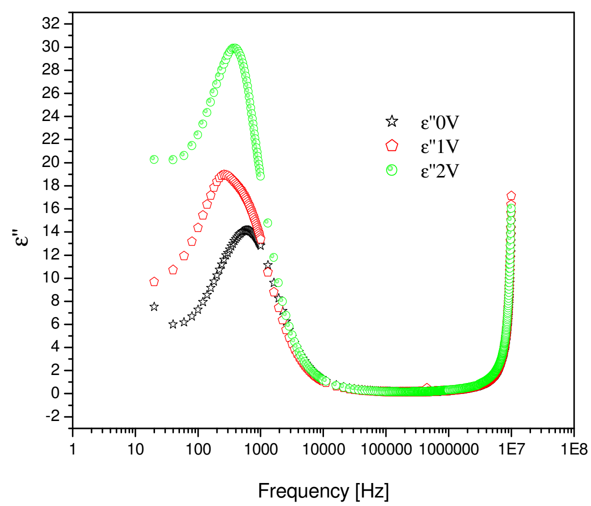

Fig. 1(b) Behavior of imaginary part of dielectric permittivity (ε'') of pure KCFLC 10S material with frequency at different bias voltages.

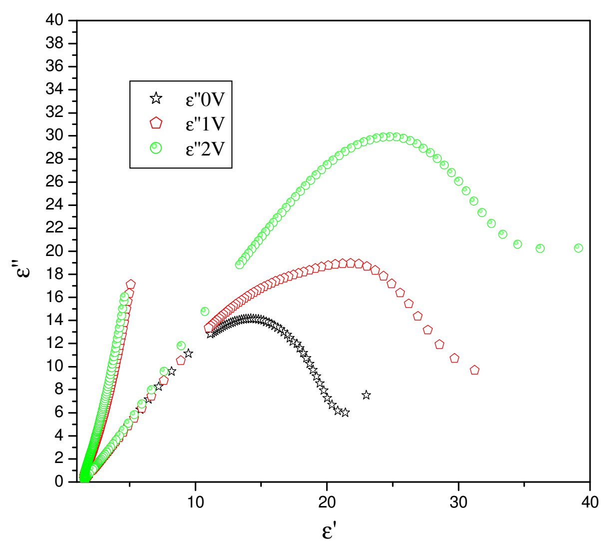

Fig. 2 Cole-Cole plots at different bias voltages for KCFLC 10S mixture.