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Dielectric Measurement for 1MC1EPOPB and 1BC1EPOPB Ferroelectric Liquid Crystals of Large Spontaneous Polarization

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Abstract: Dielectric measurements have been carried out using impedance analyzer for two ferroelectric liquid crystals R - 4' (1' –methoxycarbonyl –1 - ethoxy) phenyl 4 - (4 - octyloxy phenyl) benzoate (1MC1EPOPB) and R - 4' (1 – butoxycarbonyl -1- ethoxy) phenyl 4 - (4 - octyloxy phenyl) benzoate (1BC1EPOPB). The two samples have large spontaneous polarization, +170 nC/cm^2 for 1MC1EPOPB and +240 nC/cm^2 for 1BC1EPOPB. The permittivity and dielectric loss have been measured at different temperatures in the range 70.0°C to 110.0°C for 1MC1EPOPB and 45.0°C to 80.0°C for 1BC1EPOPB in the frequency range 2 Hz to 2 MHz. Both of the ferroelectric liquid crystals, 1MC1EPOPB and 1BC1EPOPB show a new phase smectic X along with smectic C* and smectic A phases. The work reported in this paper is new and is very useful in understanding their application in switching devices.

INTRODUCTION

The dielectric spectroscopic technique [1-4] has been used by various workers for the study of systems in different phases. This method [5-6] has been found to be one of the best ones to make measurement of permittivity and dielectric loss with high accuracy and sensitivity. In this paper we have chosen R - 4' (1 –methoxycarbonyl –1 - ethoxy) phenyl 4 - (4 - octyloxy phenyl) benzoate (1MC1EPOPB) and R – 4' (1 - butoxycarbonyl - 1 - ethoxy) phenyl 4 - (4 - octyloxy phenyl) benzoate (1BC1EPOPB), smectic ferroelectric liquid crystals, which are relatively of large spontaneous polarization +170 nC/cm^2 and +240 nC/cm^2 respectively. These ferroelectric liquid crystals were synthesized by Yoshino et al [7-8]. The dielectric spectroscopic technique has been used to measure permittivity ($\varepsilon'_\perp$) and dielectric loss ($\varepsilon''_\perp$) at frequencies 2 Hz to 2 MHz in the temperature range 70.0°C to 110.0°C for 1MC1EPOPB and 45.0°C to 75.0°C for 1BC1EPOPB. We have plotted graphs of permittivity and dielectric loss for the purpose to see the variation in the selected range of frequencies and temperatures. The dielectric strength ($\Delta\varepsilon$) and relaxation frequencies in the corresponding temperature ranges are also plotted for the two ferroelectric liquid crystals under study.

EXPERIMENTAL DETAILS

The experimental arrangement for dielectric technique consists of an impedance analyzer model Solartron 1260 (10 μHz to 32 MHz), hot stage model METTLER FP82HT and central processing unit model METTLER FP90 connected with a computer. The sample is filled in a planar oriented cell in isotropic phase using the principle of capillary action. The planar oriented cell with thickness 48 μm is used for 1MC1EPOPB and 33 μm for 1BC1EPOPB for dispersion studies. Dispersion measurements are carried out on impedance analyzer, which is connected with a computer. The uncertainty in the measurement is ± 100 ppm with stability of ± 10 ppm in 24 hrs within 1°C. The resolution varies from 10 μHz to 32 MHz. The planar oriented cell filled with material is kept in the hot stage. The computer program has been developed to run at different points of equal intervals in the log frequency scale for the measurement of capacitance in parallel to the conductance. We have set the range of the frequency measurements for the two samples under investigation with the temperature variation in the steps of 0.2 to 5°C near the phase transition and away from it. The impedance analyzer has adjustable oscillator signal but the signal is kept at 1 V in different runs in the present work. The central processing unit model METTLER FP90 is used to control the temperature of the hot stage.

RESULTS

The observed data of dielectric permittivity ($\varepsilon'_\perp$) as a function of frequency in the log-log plot in approximately the mid temperatures of smectic A (106.0°C), smectic C* (90.0°C) and smectic X (75.0°C) phases for 1MC1EPOPB and smectic A (71.0°C), smectic C* (60.0°C) and smectic X (50.1°C) phases for 1BC1EPOPB are given in Figure 1 and 2 respectively. While the data observed for dielectric loss ($\varepsilon''_\perp$) as a function of frequency in the log-log plot in approximately the mid temperatures of smectic A (106.0°C), smectic C* (90.0°C) and smectic X (75.0°C) phases for 1MC1EPOPB and smectic A (71.0°C), smectic C* (60.0°C) and smectic X (50.1°C) phases for 1BC1EPOPB are given in Figure 3 and 4 respectively. Figure 1 makes it evident that at very large frequency of 2000 kHz the permittivity plots with frequency for 106.0°C, 90.0°C

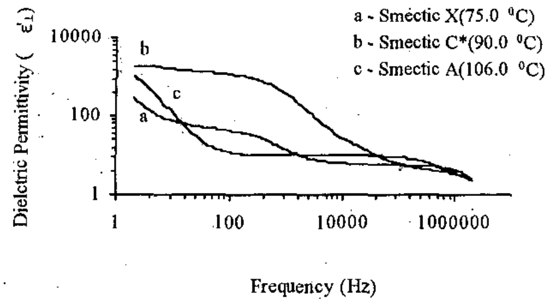

Figure 1 - Variation of dielectric permittivity ($\varepsilon'_\perp$) with frequency at different temperatures in smectic A(106.0°C), smectic C*(90.0°C) and smectic X(75.0°C) phases for 1MC1EPOPB.

and 75.0°C coincide giving a permittivity independent of temperature. The plots of $\varepsilon'_\perp$ for 106.0°C and 90.0°C have one point of intersection with $\varepsilon'_\perp$ = 9.54 at 42.4 kHz. The permittivity plot for smectic X at 75.0°C has 3 points of intersections with the permittivity plot for smectic A at 106.0°C around 409 kHz, 1.59 kHz and 0.0152 kHz. The plot of $\varepsilon'_\perp$ with frequency for smectic X at 75.0°C has one common point with the same plot for smectic C* at 90.0°C at about 118 kHz. The plot of $\varepsilon'_\perp$ with frequency for smectic A at 106.0°C shows that the decrease in the value of $\varepsilon'_\perp$ is very sharp and almost linear from 1120 at 0.002 kHz to 16.1 at 0.047 kHz as the frequency is increased and then it is almost independent of frequency till 9.38 at 66.8 kHz. On further increase in frequency it decreases again to the value 2.3 at 2000 kHz. The plot of $\varepsilon'_\perp$ decreases from 1960 at 0.002 kHz to 922 at 0.259 kHz and then decreases to 2.3 at 2000 kHz much faster for smectic X at 90.0°C as the frequency increases. The plot of permittivity for smectic X has the smallest value 290 of $\varepsilon'_\perp$ out of the three phases under investigation at 0.002 kHz.

From Figure 2 it is clear that the permittivity plots with frequency for 71.0°C, 60.0°C and 50.1°C coincide giving a

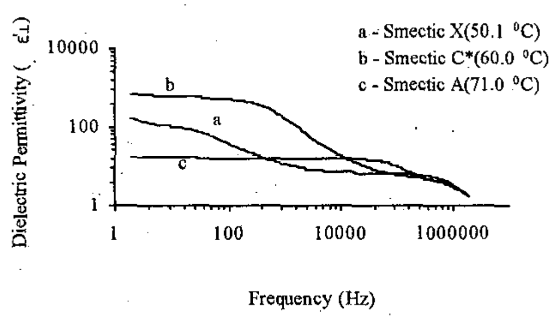

Figure 2 - Variation of dielectric permittivity ($\varepsilon'_\perp$) with frequency at different temperatures in smectic A(106.0°C), smectic C*(90.0°C) and smectic X(75.0°C) phases for 1BC1EPOPB.

permittivity independent of temperature at very large frequency of 2000 kHz. The curve for smectic C* and smectic X have one more point of intersection at about 83.7 kHz while the curves for smectic C* and smectic A intersect around 10kHz. Also there are two points of intersection for smectic A and smectic X at about 165 kHz and 0.400 kHz. The smectic C* has largest value 680.77 of $\varepsilon'_\perp$ out of the three phases under investigation at 0.002 kHz. As the frequency increases the value of $\varepsilon'_\perp$ decreases from 680.77 to 365.1 at 0.363 kHz slowly and then the variation in the value of $\varepsilon'_\perp$ is steeper. The smectic X has the value of $\varepsilon'_\perp$ 177.11 at 0.002 kHz and decreases to 96.25 at 0.015 kHz with increase in frequency. As the frequency is further increased from 0.015 kHz, the $\varepsilon'_\perp$ falls sharply to 7.76 at 4.4 kHz and then it is almost independent of frequency up to 260 kHz and hereafter it decreases at increasing rate. The permittity plot with frequency for smectic A has nearly constant value $\varepsilon'_\perp$ = 16.42 up to 22.7 kHz before it has sharp decrease.

Figure 3 shows that the plots of dielectric loss with frequency for smectic A at 106.0°C, smectic C* at 90.0°C and smectic X at 75.0°C have a common value about 2.67 at 2000 kHz. The plot of $\varepsilon''_\perp$ for smectic A intersects the plot for smectic C* around at 0.004 kHz and 409 kHz. It also has two points of intersection with the similar plot for smectic X at about 0.206 kHz and 33.8 kHz. The plot of dielectric loss for smectic A has the value of 1790 at 0.002 kHz, which is largest of the three plots. As the frequency is decreased the value of dielectric loss decreases linearly till 0.741 at 17.1 kHz from there it changes the sign of the slope and starts rising to 3.56 at 365 kHz and then again starts decreasing on further increase in frequency till 2000 kHz. The similar plot for smectic X decreases from 663 at 0.002 kHz to 0.716 at 105 kHz and then the slope is reversed and the dielectric loss starts increasing with frequency till 2000 kHz.

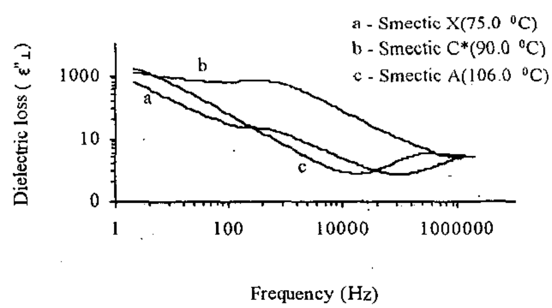

Figure 3 - Variation of dielectric loss ($\varepsilon''_\perp$) with frequency at different temperatures in smectic A(106.0°C), smectic C*(90.0°C) and smectic X(75.0°C) phases for 1MC1EPOPB.

Figure 4 reveals that at 2000 kHz all the three curves for variation of $\varepsilon''_\perp$ with frequency corresponding to smectic A, smectic C* and smectic X have nearly equal values. The plot,

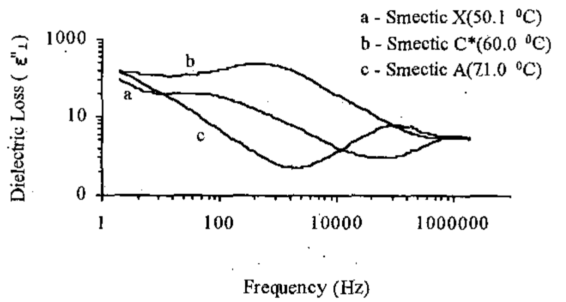

Figure 4 - Variation of dielectric loss ($\varepsilon''_{\perp}$) with frequency at different temperatures in smectic A(106.0°C), smectic C*(90.0°C) and smectic X(75.0°C) phases for 1BC1EPOPB.

showing the changes in $\varepsilon''_{\perp}$ with frequency for smectic A at 71.0°C, intersects the similar curves for smectic C* and smectic X around 85 kHz and 10 kHz respectively in log-log plot. But smectic C* and smectic X curves do not intersect each other within the frequency range from 2 Hz to 2 MHz of measurement. The smectic A curve for dielectric loss with frequency decreases with nearly a constant slope from 140 at 0.002 kHz to 0.65 at 0.880 kHz and attains a minima with $\varepsilon''_{\perp}$ = 0.49 at 1.9 kHz. The lowest loss amounts to least possibility of dispersion for smecic A phase at 71.0. On further increase in frequency the direction of slope reverses and dielectric loss increases with constant slope to 4.09 at 40.2 kHz and attains a peak at 104 kHz having the value $\varepsilon''_{\perp}$ = 5.82 after which the slope again reverses its direction. The curve for smectic C* has the value $\varepsilon''_{\perp}$ = 149.58 at 0.002 kHz and has very slow decrease to 114.02 at 0.014 kHz with the increase in frequency. Now it starts increasing and after attaining a maximum value $\varepsilon''_{\perp}$ = 229 at 0.511 kHz it decreases. After 1 kHz the $\varepsilon''_{\perp}$ decays with a constant slope up to 232 kHz and then it is nearly constant. The smectic X curve has value 88.2 for $\varepsilon''_{\perp}$ at 0.002 kHz and then decreases with the increase in frequency up to 37.5 at 0.012 kHz and after that small variations with a constant slope are found. This slope changes sign after 59.6 kHz.

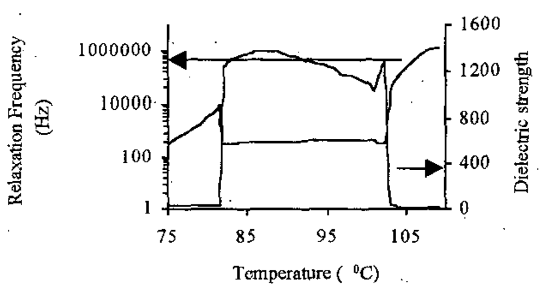

Figure 5 - Variation of relaxation frequency and dielectric strength ($\Delta\varepsilon$) with temperature for 1MC1EPOPB.

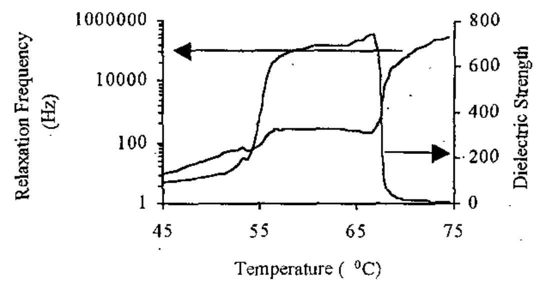

Figure 6 - Variation of relaxation frequency and dielectric strength ($\Delta\varepsilon$) with temperature for 1BC1EPOPB.

The variation of relaxation frequency and dielectric strength ($\Delta\varepsilon$) with temperature for 1MC1EPOPB and 1BC1EPOPB are plotted in figure 5 and 6 respectively. From figure 5 and 6 it is evident that the dielectric strength is largest in the smectic C* phase and decreases sharply in smectic X and smectic A phases for both the samples. The relaxation frequency is maximum in the smectic A phase but it is almost constant for both the samples under study.

CONCLUSION

The measurements reported in this work are new and they are fruitful for understanding molecular collisions, structure and change of the phase as a function of temperature and dielectric behaviour at different frequencies. These observations for smectic ferroelectric liquid crystal considered may help in understanding its applications.

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