

## THEORETICAL BEHAVIOR ABOUT THE FREDERICKSZ TRANSITION IN POLYMER DISPERSED ANTIFERROELECTRIC LIQUID CRYSTALS (PDAFLC)

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### ABSTRACT

We have studied the Fredericksz transition of polymer dispersed antiferroelectric liquid crystals (PDAFLCs) utilizing Landau-Ginzburg (LG) equation. Low frequency in-phase mode and high frequency anti-phase mode in the region of Fredericksz transition influenced by the polymer cross link chain strength has been discussed. Dielectric characteristics have been investigated in detail both in in-phase and anti-phase motions in the region of the Fredericksz transition in PDAFLCs. We theoretically noticed the modulation of the dielectric functions in the region of Fredericksz transition depending on the variation of polymer cross link chain strength due to the introduction of polymer molecules in AFLCs.

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## INTRODUCTION

Antiferroelectric liquid crystals (AFLCs) belonging to the class of smectic phase having helical structure and the spontaneous polarization of them because of helical structure are oriented oppositely from layer to layer [1-5]. Such orientation is inducing the *c*-director in the adjacent layers almost antiparallel [6]. Due to the application of electric field there are different types of configuration geometry can be arranged depending on the magnitude of the applied field [7]. The smectic layers can be rotated and arranged the molecules with a fixed angle because of the application of a sufficiently large amount of electric field. Since our work is confined within the region of Fredericksz transition in AFLC a very low value of the electric field is required which is associated with the Fredericksz transition for finite dimensional liquid crystal molecules [8]. It was reported earlier that a energetic contribution can be introduced in the dielectric nature in the liquid crystals because of the interaction between polymer network and liquid crystal molecules, surface anchoring strength and volumetric strength of the free volumes [9-10]. We also reported earlier about the variation of dielectric functions in the region of Fredericksz in AFLCs [11]. In this paper, we are attempting to provide the information of dielectric functions in PDAFLCs within the region of Fredericksz transition.

### Theoretical results

#### In-phase motion

The expected free energy in our present theoretical model including polymeric cross-link can be written as [10-12]:

$$F = -EP \cos \phi_a \cos \phi_b + \gamma \cos^2 \phi_b + 2EV_0 \cos(2\phi_a) + \frac{1}{2} K \left( \frac{\partial \phi_a}{\partial x} - \frac{2\pi}{p} \right)^2 - \frac{\epsilon_0 \Delta \epsilon \sin^2 \theta_0}{2} E^2 \sin^2 \phi_a + W(z) \sin^2 \phi_a + \frac{1}{2} \Gamma \left( 1 - \frac{r(\theta)}{R} \cos \phi_a \right) - \lambda P^2 \left( \frac{\partial \nabla \psi}{\partial P} \right) \cos^2 \phi_b \quad (1)$$

After minimization with respect to  $\phi_b$  for the stable condition and after simplification we get

$$F = -\frac{E^2 P^2}{4\gamma} \left( 1 + \frac{\lambda P^2}{\gamma} \left( \frac{\partial \nabla \psi}{\partial P} \right) \right) \cos^2 \phi_a + 2EV_0 \cos(2\phi_a) + \frac{1}{2} K \left( \frac{\partial \phi_a}{\partial x} - \frac{2\pi}{p} \right)^2 - \frac{\epsilon_0 \Delta \epsilon \sin^2 \theta_0}{2} E^2 \sin^2 \phi_a + W(z) \sin^2 \phi_a + \frac{1}{2} \Gamma \left( 1 - \frac{r(\theta)}{R} \cos \phi_a \right) \quad (2)$$

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The Landau-Ginzburg equation which gives the connection between the viscosity and the antiferroelectric ordering can be written as [10-12]:

$$-\frac{\eta_a p^2}{K} \frac{\partial \phi_a}{\partial t} = \frac{p^2}{K} \left[ \frac{E^2 p^2}{4\gamma} \left( 1 + \frac{\lambda P^2}{\gamma} \left( \frac{\partial \nabla \psi}{\partial P} \right) \right) - 4EV_0 - \frac{\epsilon_0 \Delta \epsilon \sin^2 \theta_0}{2} E^2 + W_P(\theta) \right] \sin(2\phi_a) - \frac{p^2 \Gamma r(\theta)}{2KR} \sin \phi_a - \frac{\partial^2 \phi_a}{\partial T^2} \tag{3}$$

Consider the trial solution to find out the solution for the Landau-Ginzburg equation as follows [10-12]:

$$\phi_a = 2\pi T + (a + b \exp i\omega t + c \exp 2i\omega t) \sin(4\pi T) \tag{4}$$

The solution is like as [10-12]:

$$\phi_a = 2\pi T - \delta(\omega) \sin(4\pi T) \tag{5}$$

Where  $\delta(\omega)$  is like as follows [10-12]:

$$\delta(\omega) = \left\{ A \left( E_b^2 + \frac{E_0^2}{2} \right) \left( 1 + \frac{\lambda P^2}{\gamma} \left( \frac{\partial \nabla \psi}{\partial P} \right) \right) - \frac{16\gamma V_0}{P^2} E_b + \frac{4\gamma W_P(\theta)}{P^2} + \frac{\gamma \Gamma r(\theta)}{P^2 R} \right\} + \left\{ 2E_b E_0 A \left( 1 + \frac{\lambda P^2}{\gamma} \left( \frac{\partial \nabla \psi}{\partial P} \right) \right) - \frac{16\gamma V_0}{P^2} E_0 \right\} \frac{\exp i\omega t}{1+i\omega\tau_a} + A \frac{E_0^2}{2} \left( 1 + \frac{\lambda P^2}{\gamma} \left( \frac{\partial \nabla \psi}{\partial P} \right) \right) \frac{\exp 2i\omega t}{1+2i\omega\tau_a} \frac{P^2 p^2}{64\pi^2 K \gamma} \tag{6}$$

Term,  $A = \left( 1 - \frac{2\gamma\epsilon_0\Delta\epsilon\sin^2\theta_0}{p^2} \right)$  and  $\tau_a = \frac{\eta_a p^2}{16\pi^2 K}$  is the time constant for  $\phi_a$  relaxation. So, the dielectric permittivity of the liquid crystal medium can be obtained as follows

$$\epsilon = \frac{P^2}{4\epsilon_0\gamma} \left( 1 + \frac{\lambda P^2}{\gamma} \left( \frac{\partial \nabla \psi}{\partial P} \right) \right) \left[ 1 + \left\{ A \left( E_b^2 + \frac{E_0^2}{2} \right) \left( 1 + \frac{\lambda P^2}{\gamma} \left( \frac{\partial \nabla \psi}{\partial P} \right) \right) - \frac{16\gamma V_0}{P^2} E_b + \frac{4\gamma W_P(\theta)}{P^2} + \frac{\gamma \Gamma r(\theta)}{P^2 R} \right\} + \left\{ 2E_b^2 A \left( 1 + \frac{\lambda P^2}{\gamma} \left( \frac{\partial \nabla \psi}{\partial P} \right) \right) - \frac{16\gamma V_0}{P^2} E_b \right\} \frac{1}{1+i\omega\tau_a} \right] \frac{P^2 p^2}{64\pi^2 K \gamma} \tag{7}$$

By comparing the real and imaginary components of dielectric permittivity the real component of the permittivity is

$$\epsilon_r = \frac{P^2}{4\epsilon_0\gamma} \left( 1 + \frac{\lambda P^2}{\gamma} \left( \frac{\partial \nabla \psi}{\partial P} \right) \right) \left[ 1 + \left\{ A \left( E_b^2 + \frac{E_0^2}{2} \right) \left( 1 + \frac{\lambda P^2}{\gamma} \left( \frac{\partial \nabla \psi}{\partial P} \right) \right) - \frac{16\gamma V_0}{P^2} E_b + \frac{4\gamma W_P(\theta)}{P^2} + \frac{\gamma \Gamma r(\theta)}{P^2 R} \right\} + \left\{ 2E_b^2 A \left( 1 + \frac{\lambda P^2}{\gamma} \left( \frac{\partial \nabla \psi}{\partial P} \right) \right) - \frac{16\gamma V_0}{P^2} E_b \right\} \frac{1}{1+\omega^2\tau_a^2} \right] \frac{P^2 p^2}{64\pi^2 K \gamma} \tag{8}$$

The imaginary component of the permittivity is

$$\epsilon_i = \frac{P^2}{4\epsilon_0\gamma} \left( 1 + \frac{\lambda P^2}{\gamma} \left( \frac{\partial \nabla \psi}{\partial P} \right) \right) \left[ 1 + \left\{ 2E_b^2 A \left( 1 + \frac{\lambda P^2}{\gamma} \left( \frac{\partial \nabla \psi}{\partial P} \right) \right) - \frac{16\gamma V_0}{P^2} E_b \right\} \frac{\omega\tau_a}{1+\omega^2\tau_a^2} \right] \frac{P^2 p^2}{64\pi^2 K \gamma} \tag{9}$$

Therefore, the dielectric strength written as

$$\Delta\epsilon = \frac{P^2}{4\epsilon_0\gamma} \left( 1 + \frac{\lambda P^2}{\gamma} \left( \frac{\partial \nabla \psi}{\partial P} \right) \right) \left[ 2E_b^2 A \left( 1 + \frac{\lambda P^2}{\gamma} \left( \frac{\partial \nabla \psi}{\partial P} \right) \right) - \frac{16\gamma V_0}{P^2} E_b \right] \frac{P^2 p^2}{64\pi^2 K \gamma} \tag{10}$$

**Anti-phase motion**

The Landau-Ginzburg equation can be written as [10-12]:

$$-\eta_b \frac{\partial \phi_b}{\partial t} = EP \cos \phi_a \sin \phi_b - \gamma \left( 1 - \frac{\lambda P^2}{\gamma} \left( \frac{\partial \nabla \psi}{\partial P} \right) \right) \sin 2\phi_b \tag{11}$$

The average polarization is [10-12]:

$$\langle P_z \text{ at } \omega \rangle = \frac{E_0 \exp i\omega t}{1+i\omega\tau_b} \frac{P^2}{4\gamma} \left( 1 + \frac{\lambda P^2}{\gamma} \left( \frac{\partial \nabla \psi}{\partial P} \right) \right) \left[ 1 + \left\{ A \left( E_b^2 + \frac{E_0^2}{2} \right) \left( 1 + \frac{\lambda P^2}{\gamma} \left( \frac{\partial \nabla \psi}{\partial P} \right) \right) - \frac{16\gamma V_0}{P^2} E_b + \frac{4\gamma W_P(\theta)}{P^2} + \frac{\gamma \Gamma r(\theta)}{P^2 R} \right\} \frac{P^2 p^2}{64\pi^2 K \gamma} \right] \tag{12}$$

So, the dielectric permittivity of the liquid crystal medium is

$$\epsilon = \frac{1}{1+i\omega\tau_b} \frac{P^2}{4\epsilon_0\gamma} \left[ \left\{ 1 + \left( A E_b^2 + A \frac{E_0^2}{2} - \frac{16\gamma V_0}{P^2} E_b + \frac{4\gamma W_P(\theta)}{P^2} + \frac{\gamma \Gamma r(\theta)}{P^2 R} \right) \frac{P^2 p^2}{64\pi^2 K \gamma} \right\} + \left\{ 1 + \left( 2A \left( E_b^2 + \frac{E_0^2}{2} \right) - \frac{16\gamma V_0}{P^2} E_b + \frac{4\gamma W_P(\theta)}{P^2} + \frac{\gamma \Gamma r(\theta)}{P^2 R} \right) \frac{P^2 p^2}{64\pi^2 K \gamma} \right\} \frac{\lambda P^2}{\gamma} \left( \frac{\partial \nabla \psi}{\partial P} \right) \right] \tag{13}$$

The real component of the permittivity is

$$\epsilon_r = \frac{1}{1+\omega^2\tau_b^2} \frac{P^2}{4\epsilon_0\gamma} \left[ \left\{ 1 + \left( A E_b^2 + A \frac{E_0^2}{2} - \frac{16\gamma V_0}{P^2} E_b + \frac{4\gamma W_P(\theta)}{P^2} + \frac{\gamma \Gamma r(\theta)}{P^2 R} \right) \frac{P^2 p^2}{64\pi^2 K \gamma} \right\} + \left\{ 1 + \left( 2A \left( E_b^2 + \frac{E_0^2}{2} \right) - \frac{16\gamma V_0}{P^2} E_b + \frac{4\gamma W_P(\theta)}{P^2} + \frac{\gamma \Gamma r(\theta)}{P^2 R} \right) \frac{P^2 p^2}{64\pi^2 K \gamma} \right\} \frac{\lambda P^2}{\gamma} \left( \frac{\partial \nabla \psi}{\partial P} \right) \right] \tag{14}$$

The imaginary component of the permittivity is

$$\varepsilon_i = \frac{\omega\tau_b}{1+\omega^2\tau_b^2} \frac{P^2}{4\varepsilon_0\gamma} \left[ \left\{ 1 + \left( AE_b^2 + A \frac{E_0^2}{2} - \frac{16\gamma V_0}{P^2} E_b + \frac{4\gamma W_P(\theta)}{P^2} + \frac{\gamma I\dot{r}(\theta)}{P^2 R} \right) \frac{P^2 p^2}{64\pi^2 K\gamma} \right\} + \left\{ 1 + \left( 2A \left( E_b^2 + \frac{E_0^2}{2} \right) - \frac{16\gamma V_0}{P^2} E_b + \frac{4\gamma W_P(\theta)}{P^2} + \frac{\gamma I\dot{r}(\theta)}{P^2 R} \right) \frac{P^2 p^2}{64\pi^2 K\gamma} \right\} \frac{\lambda P^2}{\gamma} \left( \frac{\partial \nabla \psi}{\partial P} \right) \right] \quad (15)$$

Therefore, the dielectric strength is

$$\Delta\varepsilon = \frac{P^2}{4\varepsilon_0\gamma} \left[ \left\{ 1 + \left( AE_b^2 + A \frac{E_0^2}{2} - \frac{16\gamma V_0}{P^2} E_b + \frac{4\gamma W_P(\theta)}{P^2} + \frac{\gamma I\dot{r}(\theta)}{P^2 R} \right) \frac{P^2 p^2}{64\pi^2 K\gamma} \right\} + \left\{ 1 + \left( 2A \left( E_b^2 + \frac{E_0^2}{2} \right) - \frac{16\gamma V_0}{P^2} E_b + \frac{4\gamma W_P(\theta)}{P^2} + \frac{\gamma I\dot{r}(\theta)}{P^2 R} \right) \frac{P^2 p^2}{64\pi^2 K\gamma} \right\} \frac{\lambda P^2}{\gamma} \left( \frac{\partial \nabla \psi}{\partial P} \right) \right] \quad (16)$$

In absence of bias field, the dielectric strength becomes as:

$$\Delta\varepsilon = \frac{P^2}{4\varepsilon_0\gamma} \left[ \left\{ 1 + \left( A \frac{E_0^2}{2} + \frac{4\gamma W_P(\theta)}{P^2} + \frac{\gamma I\dot{r}(\theta)}{P^2 R} \right) \frac{P^2 p^2}{64\pi^2 K\gamma} \right\} + \left\{ 1 + \left( AE_0^2 + \frac{4\gamma W_P(\theta)}{P^2} + \frac{\gamma I\dot{r}(\theta)}{P^2 R} \right) \frac{P^2 p^2}{64\pi^2 K\gamma} \right\} \frac{\lambda P^2}{\gamma} \left( \frac{\partial \nabla \psi}{\partial P} \right) \right] \quad (17)$$

By putting the value of A,

$$\Delta\varepsilon = \frac{P^2}{4\varepsilon_0\gamma} \left[ \left\{ 1 + \left( \left( 1 - \frac{2\gamma\varepsilon_0\Delta\varepsilon\sin^2\theta_0}{P^2} \right) \frac{E_0^2}{2} + \frac{4\gamma W_P(\theta)}{P^2} + \frac{\gamma I\dot{r}(\theta)}{P^2 R} \right) \frac{P^2 p^2}{64\pi^2 K\gamma} \right\} + \left\{ 1 + \left( \left( 1 - \frac{2\gamma\varepsilon_0\Delta\varepsilon\sin^2\theta_0}{P^2} \right) E_0^2 + \frac{4\gamma W_P(\theta)}{P^2} + \frac{\gamma I\dot{r}(\theta)}{P^2 R} \right) \frac{P^2 p^2}{64\pi^2 K\gamma} \right\} \frac{\lambda P^2}{\gamma} \left( \frac{\partial \nabla \psi}{\partial P} \right) \right] \quad (18)$$

### Critical unwinding field

The critical unwinding field for the system of polymer dispersed AFLCs can be obtained from the expression of free energy reported earlier [10, 13] as given below:

$$E_{Critical} = \frac{\pi^2}{P} \left( \frac{K}{\frac{P^2}{2\gamma} \left( 1 + \frac{\lambda P^2}{\gamma} \left( \frac{\partial \nabla \psi}{\partial P} \right) \right) - \frac{8V_0}{E_{Critical}}} \right)^{1/2} \quad (19)$$

The critical unwinding field with the region of Fredericksz transition for the system of PDAFLCs can be obtained from the expression of free energy (Eqn. 2) as given below [11, 13]:

$$E_{Critical} = \frac{\pi^2}{P} \left( \frac{K}{\frac{P^2}{2\gamma} \left( 1 + \frac{\lambda P^2}{\gamma} \left( \frac{\partial \nabla \psi}{\partial P} \right) \right) - \varepsilon_0 \Delta\varepsilon \sin^2\theta_0 - \frac{8V_0}{E_{Critical}}} \right)^{1/2} \quad (20)$$

## DISCUSSION

Figure 1 shows the variation of dielectric constant( $\varepsilon_r$ ) with the variation of polymer cross link gradient ( $G = \left( \frac{\partial \nabla \psi}{\partial P} \right)$ ) for both in-phase and antiphase motion within the region of Fredericksz transition. For both in-phase and anti-phase motion, dielectric constant is roughly constant with the increase of G. It is clearly indicating that the dielectric constant of both phase motion does not depend with the effect of polymer cross link chain in the region of Fredericksz transition.

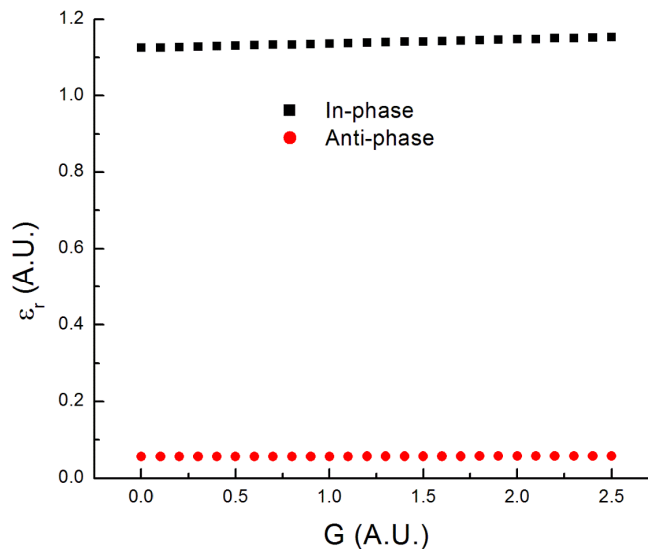


Figure 1

Variation of dielectric constant ( $\epsilon_r$ ) of polymer dispersed antiferroelectric liquid crystals with the variation of polymer cross link chain strength ( $G = \left(\frac{\partial \nabla \Psi}{\partial P}\right)$ ). The values are taken for the graphs are  $A=1$ ,  $E_0=1V$ ,  $E_b=0.5V$ ,  $\omega\tau_a=1$ ,  $\omega\tau_b=1$ ,  $\frac{P^2}{4\epsilon_0\gamma} \approx 1.125$ ,  $P \approx 80$  nC/cm<sup>2</sup>,  $\gamma \approx 1.6 \times 10^4$  J/m<sup>2</sup>,  $K \approx 2.5 \times 10^{-11}$  N,  $\frac{P^2 p^2}{64\pi^2 K \gamma} \approx 2.53 \times 10^{-13}$ ,  $\lambda \approx 2.5 \times 10^8$ .

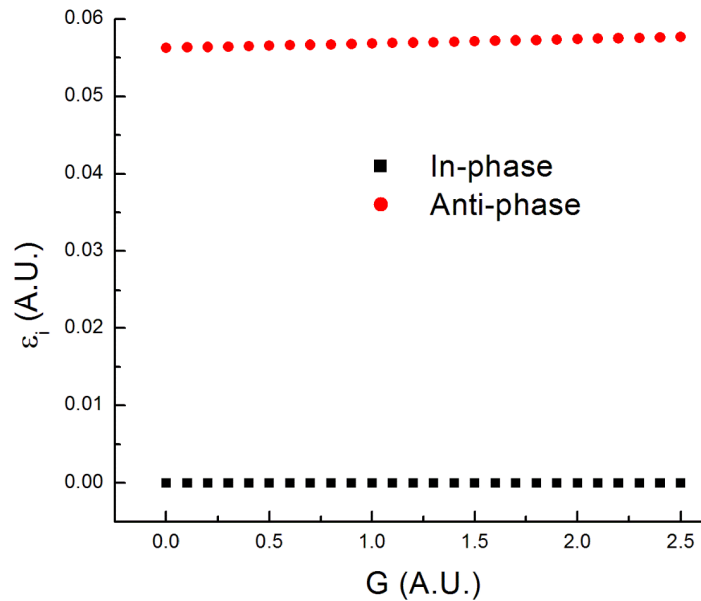


Figure 2

Variation of dielectric loss ( $\epsilon_i$ ) of polymer dispersed antiferroelectric liquid crystals with the variation of polymer cross link chain strength ( $G = \left(\frac{\partial \nabla \Psi}{\partial P}\right)$ ). The values are taken for the graphs are  $A=1$ ,  $E_0=1V$ ,  $E_b=0.5V$ ,  $\omega\tau_a=1$ ,  $\omega\tau_b=1$ ,  $\frac{P^2}{4\epsilon_0\gamma} \approx 1.125$ ,  $P \approx 80$  nC/cm<sup>2</sup>,  $\gamma \approx 1.6 \times 10^4$  J/m<sup>2</sup>,  $K \approx 2.5 \times 10^{-11}$  N,  $\frac{P^2 p^2}{64\pi^2 K \gamma} \approx 2.53 \times 10^{-13}$ ,  $\lambda \approx 2.5 \times 10^8$ .

Figure 2 shows the variation of dielectric loss ( $\epsilon_i$ ) in the region of Fredericksz transition with the variation of polymer cross link gradient ( $G = \left(\frac{\partial \nabla \Psi}{\partial P}\right)$ ) in PDAFLCs. The in-phase dielectric loss does not vary with the variation of  $G$  and the value of it is very low. But, the anti-phase dielectric loss is slowly increasing with the increase of  $G$  and the value of it is roughly greater than 0.055. Figure 3 shows the variation of dielectric strength ( $\Delta\epsilon$ ) polymer cross link gradient ( $G = \left(\frac{\partial \nabla \Psi}{\partial P}\right)$ ) in PDAFLCs for both in-phase and anti-phase motions. The dielectric for in-phase motion does not vary with the polymer cross link chain and it is very low. But, the dielectric strength for anti-phase motion is slowly increasing with the increase of polymer cross link chain strength and its value is greater than 1.15. The critical field for PDAFLCs within the region of Fredericksz is strongly depending on the both polymer cross link chain strength and dielectric anisotropy.

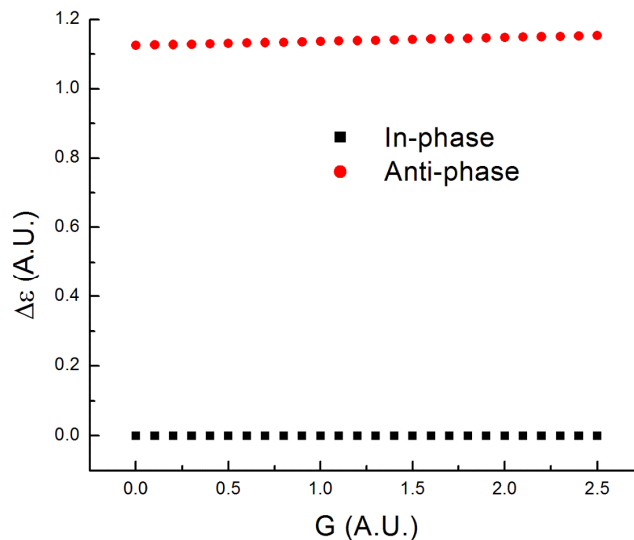


Figure 3

Variation of dielectric strength ( $\Delta\epsilon$ ) of polymer dispersed antiferroelectric liquid crystals with the variation of polymer cross link chain strength ( $G = \left(\frac{\partial \nabla \Psi}{\partial P}\right)$ ). The values are taken for the graphs are  $A=1$ ,  $E_0=1V$ ,  $E_b=0.5V$ ,  $\omega\tau_a=1$ ,  $\omega\tau_b=1$ ,  $\frac{P^2}{4\epsilon_0\gamma} \approx 1.125$ ,  $P \approx 80$  nC/cm<sup>2</sup>,  $\gamma \approx 1.6 \times 10^4$  J/m<sup>2</sup>,  $K \approx 2.5 \times 10^{-11}$  N,  $\frac{P^2 p^2}{64\pi^2 K \gamma} \approx 2.53 \times 10^{-13}$ ,  $\lambda \approx 2.5 \times 10^8$ .

## CONCLUSIONS

The theoretical works is clearly indicating that the polymer cross link chain does not make any influence on the relaxation dynamics of AFLCs within the region of Freedericksz transition of PDAFLCs. But, the critical field is strongly influenced due to the polymer cross link chain strength and dielectric anisotropy of the medium of PDAFLCs.

## References

1. H. Takezoe, E. Gorecka, M. Cepic, *Rev. Mod. Phys.* 82 (2010) 897.
2. A. D. L. Chandani, Y. Ouchi, H. Takezoe, A. Fukuda, K. Terashima, K. Furukawa, A. Kishi, *Jpn. J. Appl. Phys.* 28 (1989) L1261.
3. A. Roy, N. V. Madhusudana, *Eur. Phys. Lett.* 41 (1998) 501.
4. H. Furue, H. Kuramochi, D. Kakinuma, *Jpn. J. Appl. Phys.* 47 (1008) 7638.
5. A. D. L. Chandani, E. Gorecka, Y. Ouchi, H. Takezoe, A. Fukuda, *Jpn. J. Appl. Phys.* 28 (1989) L1265.
6. S. T. Lagerwall, *Ferroelectric and Antiferroelectric Liquid Crystals*, Wiley-VCH, Weinheim (1999).
7. K. Hiraoka, A. D. L. Chandani, E. Gorecka, Y. Ouchi, H. Takezoe, A. Fukuda, *Jpn. J. Appl. Phys.* 29 (1990) L1473.
8. X. Y. Wang, T. Kyu, A. M. Rudin, P. L. Taylor, *Phys. Rev. E* 58 (1998) 5919.
9. T. Lahiri, T. Pal Majumder, *J. Appl. Phys.* 109 (2011) 114109.
10. D. Das, T. Pal Majumder, *Science Letters* 4 (2015) 99.
11. P. Mandal, D. Das, T. Pal Majumder, *J. Molec. Liq.* 215 (2016) 170.
12. L. A. Parry-Jones, S. J. Elston, *J. Appl. Phys.* 92 (2202) 449.
13. P. de Gennes, *Solid State Commun.* 6 (1968) 163.

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