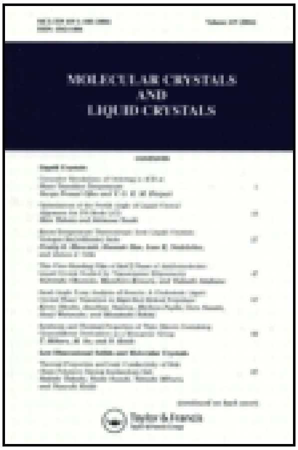

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Influence of Stabilizing Magnetic Field on the Domain Formation in Nematic Liquid Crystal Materials with Positive Dielectric Anisotropy

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The influence of magnetic field on the homogeneously aligned nematic liquid crystal materials with positive dielectric anisotropy to exhibit williams domains as threshold effect is theoretically investigated. These investigations indicate three types of positive dielectric nematics known as weakly positive, moderately positive and strongly positive. The plot of stabilization term for domain formation with dielectric anisotropy clearly indicates the three regions. Frequency dependence of threshold voltage at different values of magnetic field and dielectric anisotropies has been calculated which agrees with the earlier results. The effects of dielectric anisotropy on the existence of domain formation in the positive $\Delta\epsilon$ nematitics and the variation of threshold voltage with $\Delta\epsilon$ are numerically calculated and compared with experimental results

Keywords: Positive dielectric anisotropy; williams domains; stabilizing magnetic field; threshold field

INTRODUCTION

The presence of electro-hydrodynamic instability in the form williams domains (WD) in the nematic liquid crystal materials with positive dielectric anisotropy has been widely investigated (1-12). The ability of nematic liquid crystal material with positive dielectric anisotropy to exhibit williams domains as threshold effect is mainly dependent on the dielectric and conductivity anistropies, in addition to the sample thickness and the stabilizing magnetic field. The effect of all the above parameters on WD in positive nematics has been reported in our earlier publications (1-3). WD and their stability have been related to the competing influence of conduction and dielectric torques(1-2, 5). The effect of stabilizing magnetic field on the domain formation is to increase the range of $\Delta\epsilon$ up to which WD exist as reported (3,9) . The present work is to investigate theoretically the effect of stabilizing magnetic field on the positive dielectric nematics to show WD as threshold effect and to compare this with the experimental results. The effect of dielectric anisotropy on the formation of WD has also been studied.

EXPERIMENTAL

For experimental results, the methods adopted in our earlier publications (1-3) have been used. Moderate sample thickness of 250 μm employed for experimental investigations. The mixtures of MBBA (4 methoxy benzylidence –4^{1}- n - butylaniline)and EBCA (ethoxy benzylidence - 4^{1} - Cynoaniline) have been used to obtain various values of positive $\Delta\epsilon$ as reported (1-2). The ac conductivities of the mixtures are of the order of 10^{-10} ohm^{-1} cm^{-1}.

RESULTS NAD DISCUSSION

The results obtained regarding the effect of stabilizing magnetic field and the dielectric anisotropy on the presence of WD in the positive $\Delta\epsilon$ nematics have been discussed using numerical calculations and compared with experimental results.

THE EFFECT OF MAGNETIC FIELD

Figure-1 shows the variation of threshold voltage with frequency at different values of the magnetic field strengths for $H \perp E$ and $\Delta\epsilon$=0.4. The threshold voltages have been calculated theoretically from the equations reported in our previous publication(3). The graph evidently indicates that the stabilizing magnetic field may cause positive dilectric nematics to exhibit WD which does not normally show WD. The frequency range at which WD are observed increases with the strength of the magnetic field, which agrees with the experimental values reported (3,9).

THE EFFECT OF DIELECTRIC ANISOTROPY

Figure-2 shows the variation of theoretically calculated thresold voltage with frequency at different values of the dielectric anisotropy in $H \perp E$ condition, H=5.7 KG. The curved part of the curve corresponds to the domain formation and linear part to the Freedericksz deformation or otherwise called re-orientation. Figure-3 indicates the variation of calculated threshold voltage with frequency at different values of $\Delta\epsilon$ at H=0, which indicates the existence of WD for values of $\Delta\epsilon < +0.5$

THE EFFECT OF MAGNETIC FIELD AND DIELECTRIC ANISOTROPY

To study the effect of stabilizing field and dielectric anisotropy on the existence of WD in the positive $\Delta\epsilon$ nematics, the following

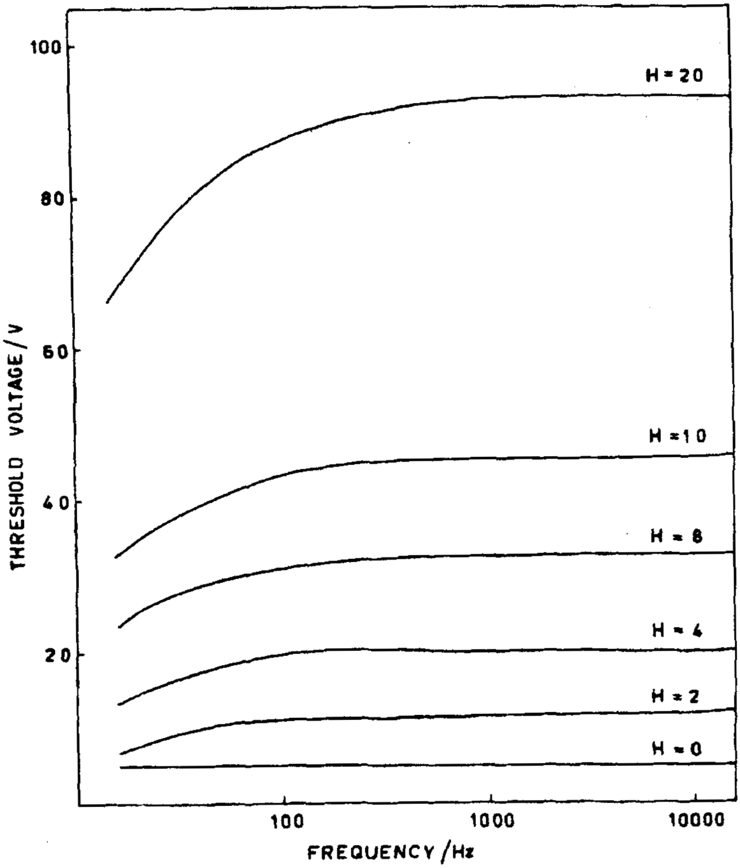


Figure 1. Frequency dependence of the calculated *threshold voltage at different values of magnetic* field strength in KG for MBBA-EBCA mixtures. $\Delta\epsilon$=+0.4 , T=32°C, sample thickness=250μm H⊥E.

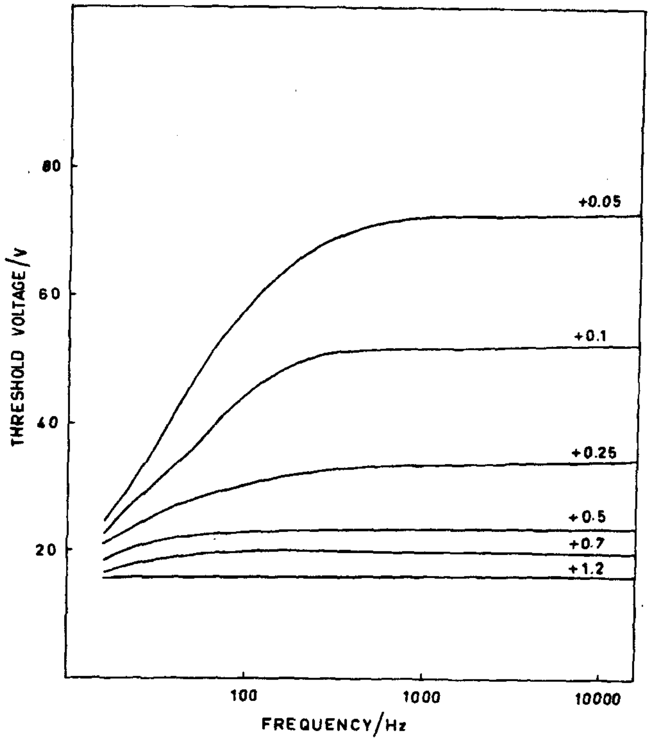
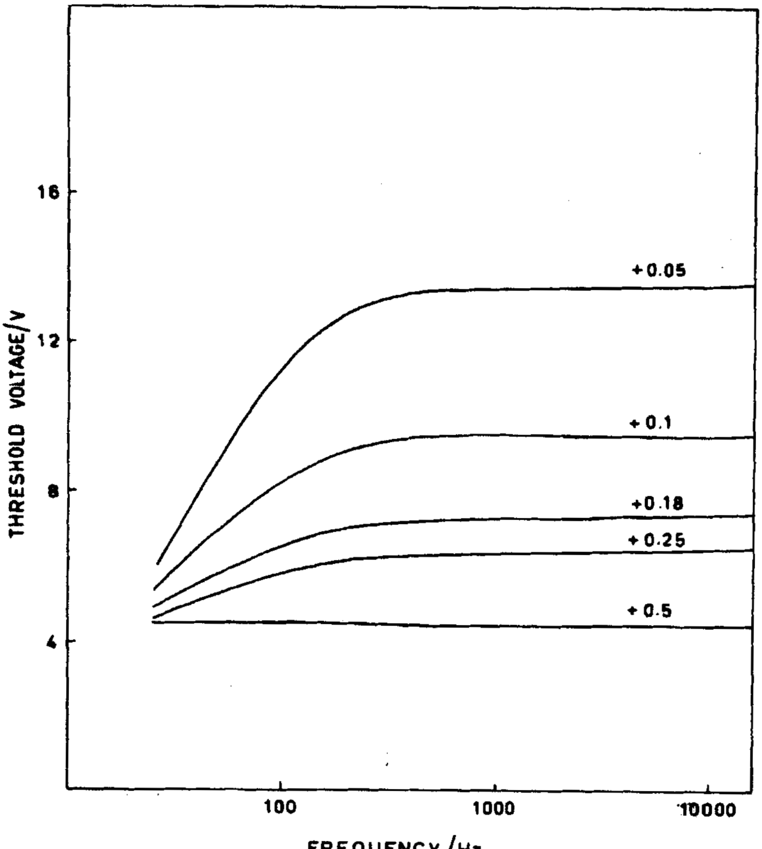


Figure 2. Frequency dependence of the calculated threshold voltage at different values of the dielectric anisotropy for MBBA-EBCA mixtures.H=5.7 KG, T=32°C and sample thickness=250μm. H⊥E.



Fihure 3. Frequency dependence of the calculated threshold voltage at different values of the dilecric anisot ropy for MBBA-EBCA mixtures. H=0, T=32°C sample thickness-250 μm.

threshold field equations (3,6) have been used for WD and dielectric alignment.

$$(E)^2 = 4\pi \frac{\epsilon_{\parallel}}{\epsilon_{\perp}} \left(\Delta\chi H^2 + K_{33} \frac{\pi^2}{d^2} \right) \frac{1 + \omega^2 \tau^2}{\Delta\epsilon\, \omega^2 \tau^2 + \theta_H}$$

$$(E')^2 = \frac{4\pi}{\Delta\epsilon} \left(K_{11} \frac{\pi^2}{d^2} + \Delta\chi H^2 \right)$$

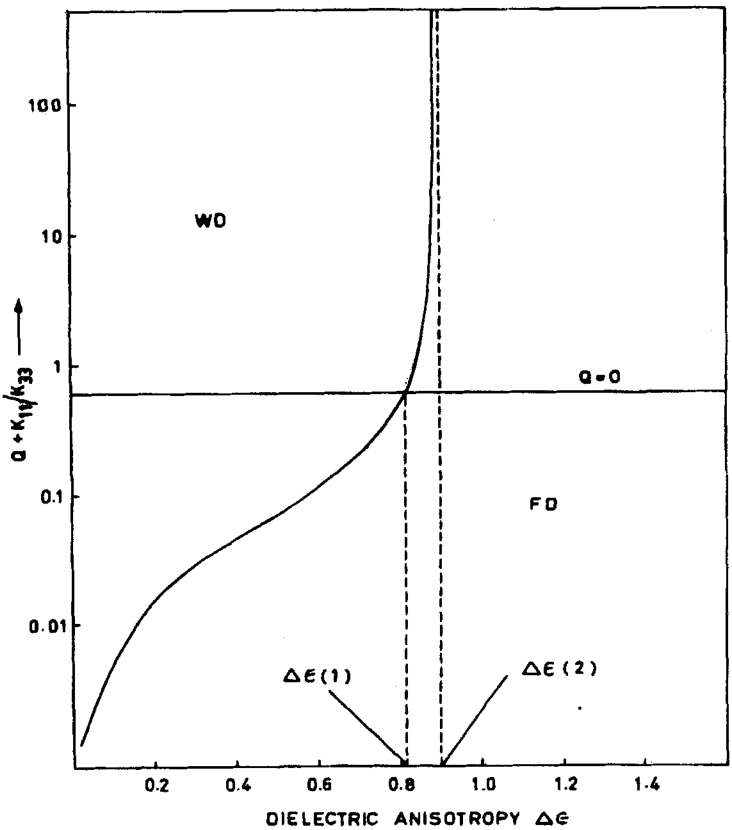
The values of E and E' will be same at the transition region from conduction mode to dielectric mode in the positive $\Delta\epsilon$ nematics for specific values of H and $\Delta\epsilon$. By equating the above equations and putting the values of S and Q as specified below:

$$\frac{1 + \omega^2 \tau^2}{\Delta\epsilon\, \omega^2 \tau^2 + \theta_H} \Delta\epsilon \frac{\epsilon_{\parallel}}{\epsilon_{\perp}} = S$$

$$\frac{\Delta\chi H^2 d^2}{K_{33} \pi^2} = Q$$

$$Q + K_{11} / K_{33} = \frac{S}{S-1} \left(\frac{K_{11}}{K_{33}} - 1 \right)$$

Q is called the stabilization term needed for the formation of WD. The values of S have been calculated at 40 Hz as per the method specified in our earlier publication (3). For theoretical calculations, some of the physical constants have been taken from the earlier publications on MBBA (8,11-12). The ratio of K_{11}/K_{33} is 0.82. The



Firgure 4. Dielectric anisotropy dependence of the minimum stabilization term Q +K_{11}/ K_{33} needed for the system to form WD.

dielectric constant for MBBA-EBCA mixtures have been taken from the data by Meyerhofer (13).

Firgure-4 shows the variation of the stabilization term $Q+K_{11}/K_{33}$ needed for WD with dielectric anisotropy. The region above the curve corresponds to WD conditions and the region below the curve corresponds to Freedericksz deformation(F-D) threshold. Figure-4 suggests that there exists a value of $\Delta\epsilon(1)$ below Q=0 line named as weakly positive, indicating that the application of a destabilizing magnetic field quench the formation of domains . The moderately positive, that is between $\Delta\epsilon(1)$ and $\Delta\epsilon(2)$ which do not normally form WD, but to do so under the action of stabilizing magnetic field. Strongly positive, which do not form WD whatever may be the applied magnetic field is above the value of (2) . The calculated values of $\Delta\epsilon$ upto which WD exisits is nearly agrees with the experimental values reported in our earlier publication(3) but differs with the values reported theoretically by zenginoglou et al (9).The WD in positive $\Delta\epsilon$ nematics can also be explained by considering the values of S. When the value of $S<1$ corresponds to the existence of WD and the value of $Q+K_{11}/K_{33}$ is positive. When S=1, $Q+K_{11}/K_{33}$ tends to infinity where WD do not exist. For $S \geq 1$ $Q+K_{11}/K_{33}$ is negative which is strongly positive.

$S<1$ below Q=0 line, weakly positive
$S<1$ above Q=0 line, moderately positive
$S\geq 1$ above Q=0 line strongly positive

As reported earlier (14), the strong positivity condition is. $\epsilon_\perp / \epsilon_\parallel - \sigma_\perp / \sigma_\parallel > 0$. The strong positivity condition may also be obtained by solving $S \geq 1$ equation, and given as follows

$$\omega\tau \geq (\theta_H \epsilon_\perp - \epsilon_\parallel \Delta\epsilon)^{1/2} / \Delta\epsilon$$

Figure-5 shows the variation of threshold voltage for WD V_{th} and the dielectric alignment V_F with $\Delta\epsilon$ for $H \perp E$ for MBBA-EBCA mixtures, sample thickness 250 μm. Line 1 represents variation of V_{th} with dielectric anisotropy at 40-Hz. Curve 2 illustrates the variation of V_F at 3 KHz with positive $\Delta\epsilon$. curves 3 and 4 show the variation of threshold voltage for domain formation and dielectric alignment calculated using the above mentioned equations as reported in our previous publication (3).

CONCLUSIONS

The effect of stabilizing magnetic field on the WD formation in positive $\Delta\epsilon$ nematics is studied theoretically, these investigations indicate three classes of positive $\Delta\epsilon$ nematics under the influence of magnetic field to show WD as threshold effect. The relative effectiveness of stabilizing magnetic field and dielectric anisotropy for the WD formation has been estimated by considering the stabilization term. The previous results regarding stabilization term are in qualitive agreement with our results except difference in numerical values. The results of these investigations give rise to a new condition for strongly positive $\Delta\epsilon$ nematics.

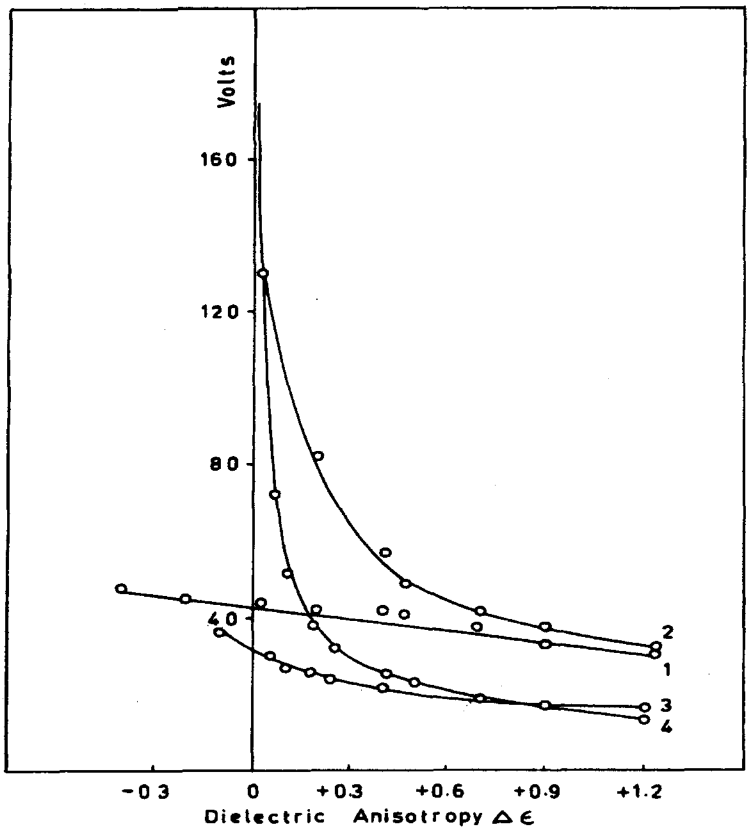


Figure 5. The threshold voltage for domain formation and dielectric alignment for MBBA-EBCA mixtures as a function of the dielectric anisotropy Δ∈. H=5.7 KG T=32°C and sample thickness=250μm H⊥E.

The calcuted theshold voltages as a function of frequency at various values of dielectric anisotropy and magnetic field strengths are in qualitative agreement with the experimental values reported (3).

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