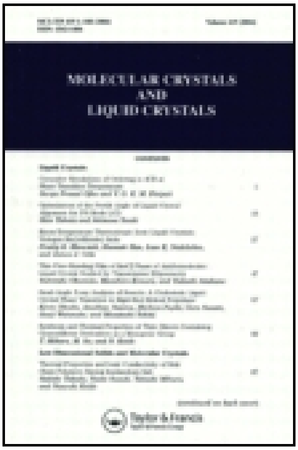


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# Electric and Magnetic Field Effects on Director Pattern and Disclinations in Nematics

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# Electric and Magnetic Field Effects on Director Pattern and Disclinations in Nematics

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Nematic 8CB and MBBA slabs, with a homeotropic zone between two parallel -1/2 disclinations (and associated splay bend zones), are subject to an electric or magnetic field acting transversely to the disclinations. Optical microscopic study of the static and dynamic characteristics of the boundary zones is carried out for the first time. The growth rate of the zones is linear in field-strength. As the field is progressively elevated, the zones widen nonlinearly, and merge to form a splay-bend wall in the mid-region. At a high enough field, the homeotropic region is squeezed out of the wall and a pair of wedge disclinations forms in its place. One of these combines with a -1/2 line originally present in the field off state, forming a loop that progressively collapses.

*Keywords:* Nematic; electric and magnetic fields; boundary zones; disclinations; splay bend wall; pincement



## INTRODUCTION

In a rectangular nematic slab, when the director is normal to all the limiting surfaces, a -1/2 disclination loop forms in the vicinity of lateral boundaries and around the central pseudo-isotropic zone. For a high conductivity, negative dielectric anisotropy ($\Delta\varepsilon$) compound (MBBA) studied in this 'boundary normal' configuration, we have earlier reported several non-linear electro-convective phenomena [1, 2]. In this paper, we deal mainly with reorientational effects in 8CB and MBBA, aligned initially in the boundary normal configuration, and subject to an electric or magnetic field. In particular, we discuss the static and dynamic features of the transition zone, under varying conditions of field strength, a.c. frequency and temperature. While the dynamical properties of -1/2 line defects in 5CB have previously been studied by Cladis *et al.* [3], characterisation of boundary zones in the field on state has not been carried out so far.

## EXPERIMENTAL

The 8CB sample was a BDH chemical (K24) showing the nematic phase in the range 33.5 – 40 °C, between the $S_A$ and isotropic phases

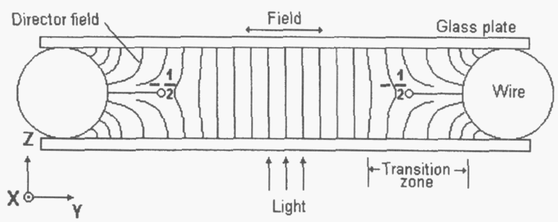


FIGURE 1. Experimental geometry. For electric field studies, both wire and flat strip spacer-electrodes were used. For magnetic field studies, only strip spacers were used.

The MBBA sample was an old Eastman Kodak chemical of high conductivity (~0.01μS/cm). The samples were held between glass plates and a pair of wires or flat metal strips separating the plates, and subject to electric or magnetic field acting transversely to the line of observation, as illustrated in Figure 1. The sample dimensions were: length *ca.* 15 mm, width 650 –2000 μm and thickness 70 μm for strip spacers and 150 μm for wire spacers. The observations were made under a Leica polarization microscope equipped with a hot stage and a colour video camera (Sony CCD IRIS). The images were analysed using the Leica Q500MC software.

## RESULTS AND DISCUSSION

### Field Variation of Growth Rate of Transition Zone

Upon a sudden application of electric or magnetic field above threshold, the transition zone begins to expand, while the central part remains pseudo-isotropic. The rate of this expansion at different field strengths was determined by timing the movement of the first maximum over a distance of 100μm. The growth rate was found to vary linearly with field strength, both in electric and magnetic field experiments (Figures 2a, b). A similar velocity-field variation found for the -1/2 lines in 5CB

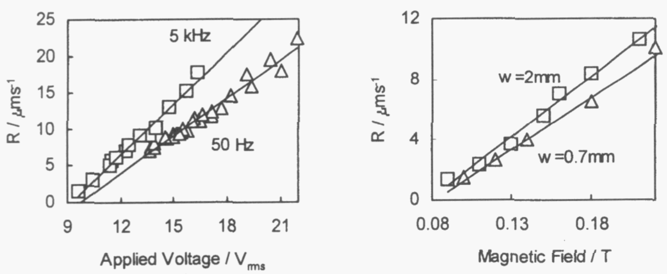


FIGURE 2. Growth rate R of transition zone as a function of (a) applied voltage and (b) magnetic field strength.

has been explained [3] by showing the gradient of excess free energy of the distorted zone over the homeotropic zone to be independent of defect location and proportional to electric field strength. This explanation could also be extended to the present case.

At lower fields upto twice the threshold, the disclinations remain practically static while the boundary zones grow. A possible director field corresponding to this situation is given in Figure 3.

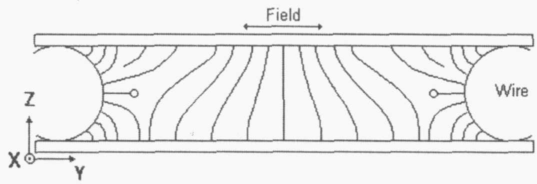


FIGURE 3. Director pattern corresponding to the growth of the boundary zone without the disclination displacement.

## Field Variation of Transition Zone Thickness

With the increase in field strength, the transition zones widen and eventually form a wall at the centre, as shown in Figure 4.

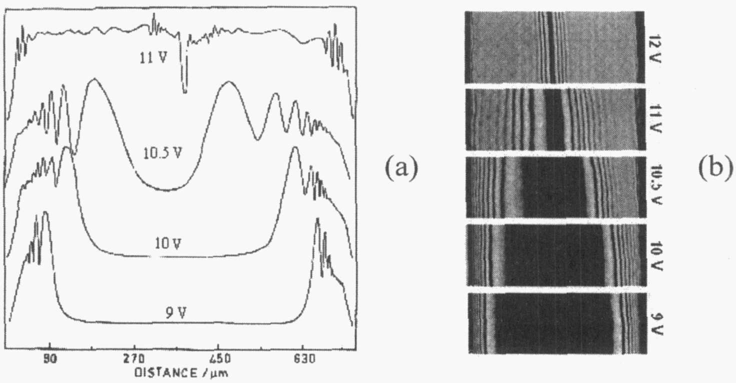


FIGURE 4. (a) Intensity profile across the width of the sample placed diagonally between crossed polarizers. (b) Birefringence fringes at various voltages.

The variation in transition layer thickness, which is nonlinear and nearly exponential with respect to the field strength, is presented in Figure 5. The low frequency behaviour is similar to that of magnetic field.

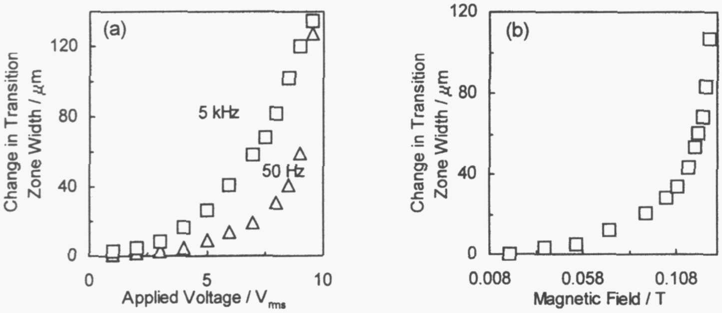


FIGURE 5. Field dependence of transition zone width. 70 μm thick, 650 μm wide sample.(a) 8CB, 37 °C and (b) MBBA, 22 °C.

But the high frequency behaviour shows a less rapid variation of the transition layer thickness. This may be attributed to the nature of electric field lines which differs for the two frequency regimes.

Frequency Dependence of Transition Zone Thickness

Figure 6a shows the variation in the transition zone width (as given by the first fringe position), with frequency. As will be seen later, the field configuration changes with frequency so that, for a given voltage, the field in the vicinity of the electrodes is higher at higher frequencies. This explains the initial rise of the thickness with frequency. The high frequency behaviour seems to involve the possible variation of $\Delta\varepsilon$ with frequency.

Temperature Variation of Transition Zone Thickness

Figure 6b shows the temperature dependence of the transition zone

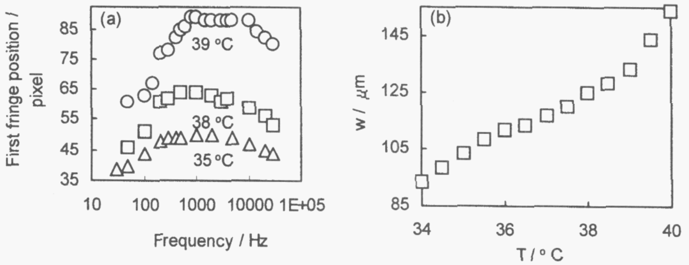


FIGURE 6. Transition zone width as a function of (a) frequency and (b) temperature. 1 pixel = 1.67 μm.

thickness for 8CB subject to a 50 Hz electric field. The significant increase in thickness with rise in temperature is only to be expected from the temperature dependence of elastic coefficients.

Divergence of Wall Thickness

As indicated by the intensity profile for 11 V in Figure 4, when the field is high, the two transition layers merge so as to form a splay bend wall in the mid region. At the centre of the wall, where alignment remains vertical, the zero order dark fringe appears. The distance, *d*, between the two first order maxima on either side of the principal minimum is a measure of the wall thickness [4,6]. For the magnetic case, $d^{-2}$ scales linearly as $B^2$ as expected [5]. A similar behaviour is also seen for the electric field case at low frequencies. However, for high frequencies, $d^{-1}$ is observed to vary as $(V^2 - V_c^2)$ rather than $(V^2 - V_c^2)^{1/2}$, $V_c$ being the threshold voltage. This behaviour has also been found previously for a phenyl benzoate [6]. The high frequency anomaly may be attributed to the nature of the field lines. For frequencies higher than the charge relaxation frequency, given by the ratio of electrical conductivity $\sigma$ to permittivity $\varepsilon$, the field lines may be expected to bulge out so that the actual field in the mid zone is lower than that given by the applied voltage treated as static. For 8CB, the relaxation frequency is of the order of 10 Hz.

## Line Disclinations

As the wall formed in the mid region is subject to an increasing field, its width progressively narrows. Eventually, above a critical field, it undergoes a discontinuous transformation into a pair of disclinations of strength +1/2 and –1/2 (Figures 7a, 8). The rate of this 'pincement' is found to vary linearly with field strength. A similar behaviour has been reported previously [7] for the Leger-Brochard walls formed in a mixture of phenyl benzoates.

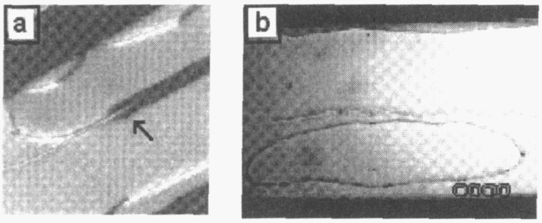


FIGURE 7. (a) Pincement of the wall indicated by the arrow. (b) Loop formed by two of the disclinations.

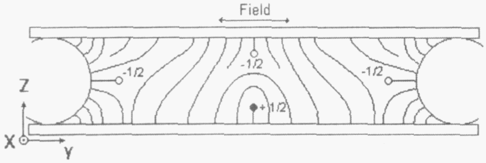


FIGURE 8. Director field after pincement showing four disclinations.

When the field is sufficiently high (above 80 kV/m), interestingly, the two –1/2 disclinations anchored at the long edges detach themselves and move inward. One of them combines with a defect line formed due to pincement, resulting in a loop which spontaneously collapses (Figure 7b). The remaining two line singularities, one from the pincement and the other due to boundary conditions, endure for long. They can be brought closer by increasing the field. On switching the field off, they recede to reach the long edges rather slowly, in a few minutes. Another characteristic of the disclination lines concerns their geometry. Whereas they are straight at lower frequencies of the ac field, they appear zig-zag without any definite periodicity at higher frequencies.

Acknowledgments
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