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Are short-pitch bistable ferroelectric liquid crystal cells surface stabilized?

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Recent papers have described the short-pitch bistable ferroelectric liquid crystal effect (SBF) attributing its bistability to its stripe layer texture [1]. We have studied the bistability of this SBF effect for the short-pitch ferroelectric liquid crystal (FLC) mixture ZhKS-76 using thin planar aligned cells. Both the SBF texture (the stripe texture) and a uniform texture (uniform tilt layer structure with the extinction direction along the layer normal) were observed in different regions of a given cell when the cell was cooled down slowly from the isotropic phase to the chiral smectic C phase. Upon applying external fields, both regions are characterized by the formation of helix unwinding lines. The stripe area showed zig-zag unwinding lines and the uniform area exhibited straight unwinding lines, both running parallel to the layers. The bistability study shows a similar hysteresis curve and threshold behaviour on switching for both the SBF texture area and the uniform area, although the uniform area gcve better contrast. These facts strongly indicate that as in the long pitch FLCs, the surfaces rather than the layer stripe texture hinder the formation of the helix in the cell, and this produces dynamic bistable switching.

1. Introduction

Recently, bistable electro-optical effects have been reported by Funfschilling and Schadt [1] for short-pitch FLC materials in cells much thicker than the helix pitch. Based on the stripe texture observed in these short-pitch bistable ferroelectric (SBF) liquid crystal cells, they concluded that the bistability is caused by hindrance of helix unwinding line formation due to the stripe modulated layer structure, without the need for surface interactions. In this paper we present results obtained from bistability studies of the SBF effect, specifically on the influence of the layer structure on the bistable switching characteristics in SBF cells.

2. Experimental

2.1. *Sample preparation and appearance*

In our studies, the cells investigated were constructed in the surface stabilized geometry [2], with the FLC being sandwiched in a 1·7 μm gap between two ITO and Nylon-coated glass plates. Only one glass plate was brushed as was reported by Funfschilling *et al.* The short-pitch FLC material used was ZhKS-76 (helix pitch $p = 0{\cdot}3\,\mu$m at 20°C) with a measured phase sequence

$$\mathrm{X} \xleftrightarrow{<0^{\circ}\mathrm{C}} \mathrm{S}_{\mathrm{C}}^{*} \xleftrightarrow{59{\cdot}9^{\circ}\mathrm{C}} \mathrm{S}_{\mathrm{A}} \xleftrightarrow{70{\cdot}1^{\circ}\mathrm{C}} \mathrm{N}^{*} \xleftrightarrow{73{\cdot}7^{\circ}\mathrm{C}} \mathrm{I},$$

which was kindly provided to us by researchers at NIOPIK, Moscow.

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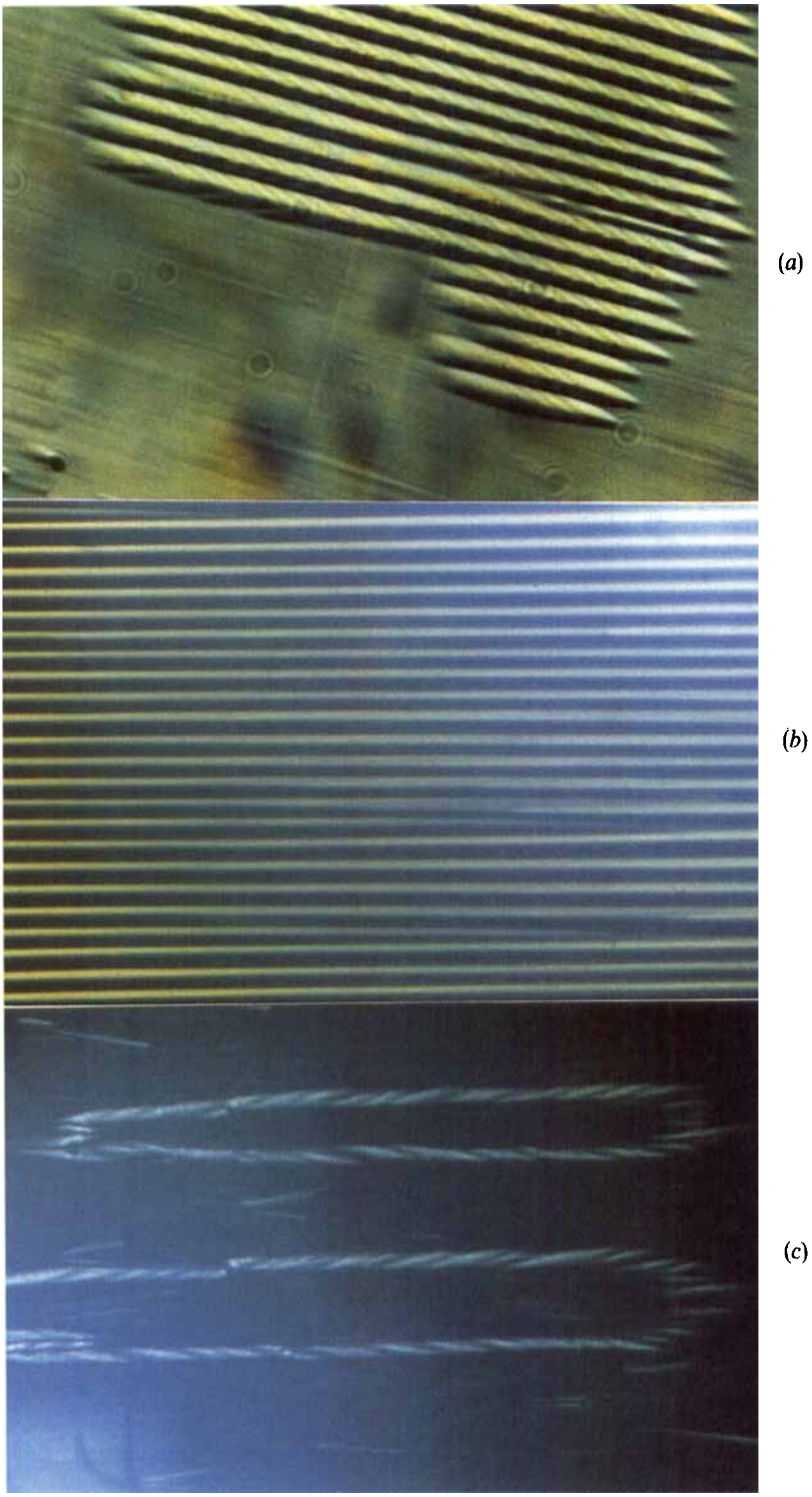


Figure 1. Microphotographs of our sample: (*a*) coexistence of the stripe (SBF) texture and the uniform texture: (*b*) close-up view of the stripe region; (*c*) close-up view of the uniform region.

Upon slowly cooling down from the isotropic phase to the chiral smectic C (S_C^*) phase, and before any field was applied, two different texture regions were formed in the cell, as shown in figure 1 (*a*). One was a stripe texture region (or SBF texture as it was called in reference [1]), and the other was a uniform-texture region with its extinction orientation having the axes of the crossed polarizer along the rubbing direction (we will call this layer normal orientation). The presence of zig-zag walls in the uniform region showed that the uniform region has the chevron layer structure [3, 4]. The lines in the stripe texture region are a special case of the zig-zag walls, in which they run along the layer normal direction [5, 6]. Application of an electric field large enough to unwind the helix irreversibly alters the layer structure, so our switching experiments were carried out following an AC field treatment (± 15 V, 30 Hz), after which the layer structure was field independent. The uniform and stripe regions, after field treatment, are shown in figures 1 (*b*) and 1 (*c*), respectively. The electric field treatment converts the parallel zig-zag layer structure into the folded bookshelf layer structure, in which the layers are locally normal to the plates [5–7]. Following the geometry relations developed by Rieker *et al.* [8, 9] for the zig-zag defect, as illustrated in figure 2, we have

$$\frac{\cos(\alpha-\gamma)}{\cos(\gamma)}=\cos(\delta), \tag{1}$$

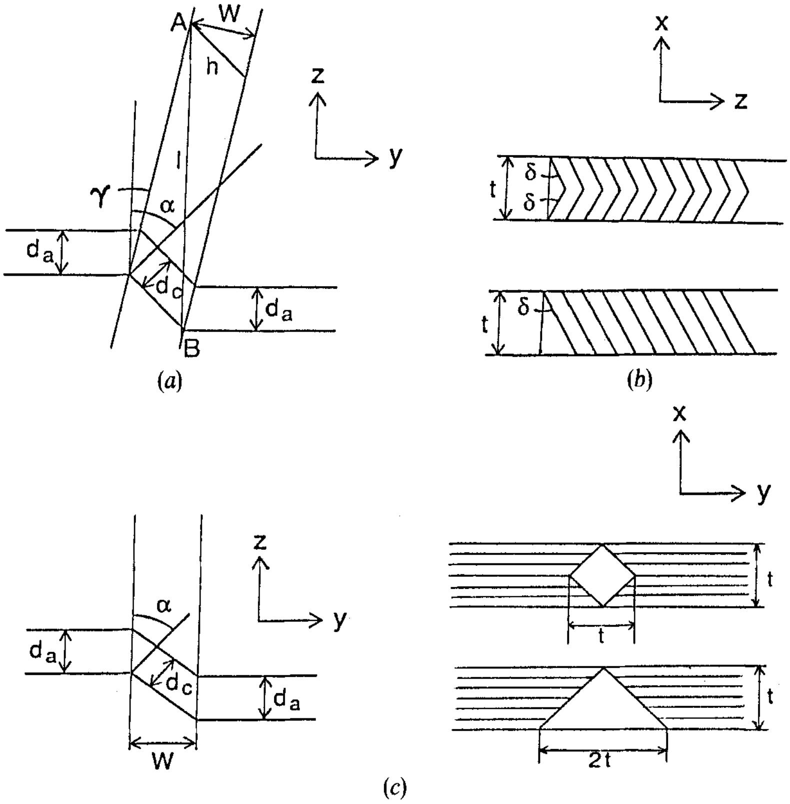


Figure 2. Schematic diagram of the layer structure of the zig-zag wall defect separating opposite, uniformly tilted layer domains: (*a*) top view: (*b*) side view for both symmetric chevron and uniform tilt local layer structures; the cut is made along line $\overline{AB}$; and (*c*) special case for both symmetric chevron and uniform tilt; $\gamma=0°$. The side view on the right is made perpendicular to the zig-zag wall direction.

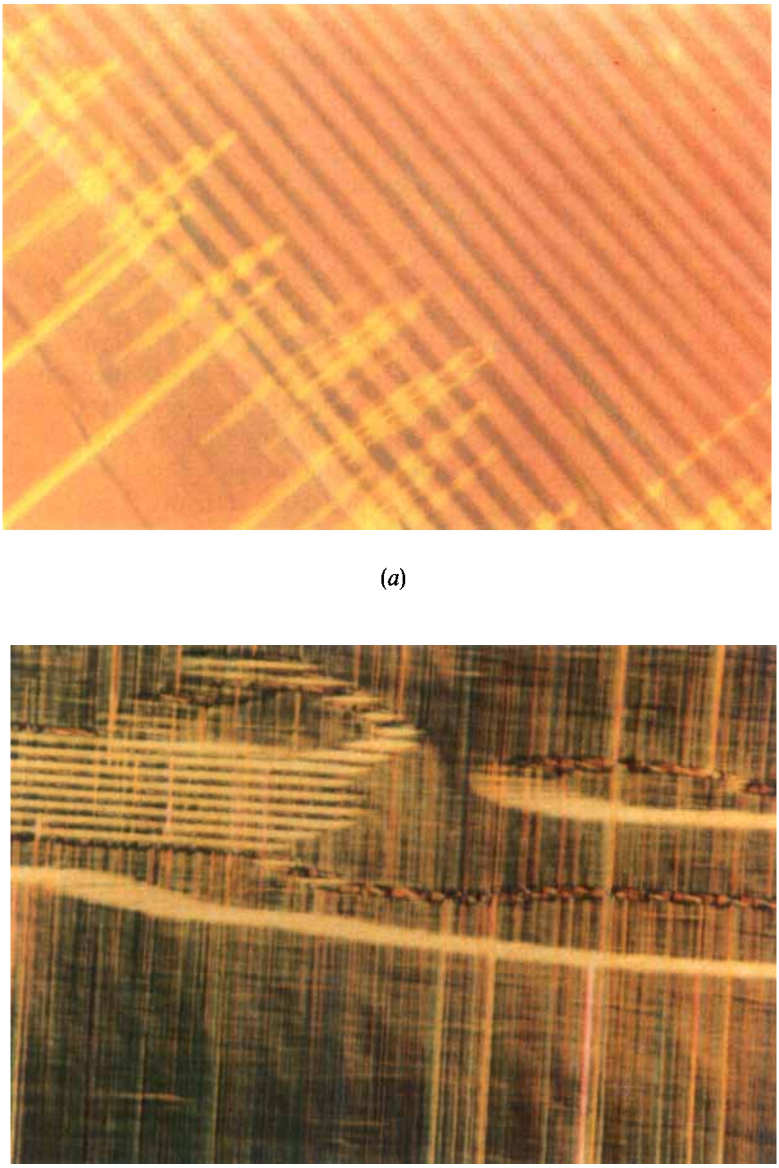


Figure 3. Microphotographs showing the local layer structure: (*a*) formation of the unwinding (dechiralization) lines; (*b*) width relation between the zig-zag walls and the stripes.

$$h\sin(\alpha)=t\tan(\delta), \tag{2}$$

$$w=h\cos(\alpha-\gamma), \tag{3}$$

where γ is the angle the zig-zag lines make with the projection of the smectic layer normal on to the substrate plane (z axis), α is the angle between the projections of the normal of the layers in the interior of the zig-zag line and the normal of undistorted layers on the substrate plane (z axis), δ is the layer tilt angle, t is the cell thickness, and w is the width of the zig-zag line. Using the above relations one can easily determine that the width of each stripe, which has an angle $\gamma = 0°$, should equal the cell thickness, $w = t$ [6]. This result was confirmed in our sample and also seems to agree well with the relation between stripe period and cell gap in the thin SBF cells observed by Funfschilling *et al.* [1]. The electric field treatment converted the initially chevron-uniform texture (see figure 2) to a tilted layer structure, also shown in figure 2(*b*). Evidence for this structure of uniformly tilted layers is given in figure 3(*b*). We found that the part of the zig-zag wall running perpendicular to the unwinding (dechiralization) lines (thus parallel to the local layer normal) has a width equal to twice that of each stripe. This would be a natural result if the regions separated by this zig-zag wall had uniform, but opposite tilt angles as shown in figure 2(*c*). In this case, equation (2) can be rewritten as (see figure 2)

$$h \sin(\alpha) = 2t \tan(\delta). \tag{4}$$

Thus for a wall running parallel to the layer normal direction, $\gamma = 0°$, we can easily get

$$\alpha = \delta, \tag{5}$$

$$w = 2t. \tag{6}$$

Hence, the zig-zag wall should have a width twice the cell thickness, and this is what we observe.

When an external field was applied, the helix could be analysed through the formation of helix unwinding lines [10], or the distorted helix ferroelectric (DHF) effect [11], as shown in figure 3(*a*). The local layer orientations in these two regions were also indicated very well by these unwinding lines, which ran parallel to the local layer orientation.

2.2. *Results and discussion*

Several bistability measurements were made using this cell at room temperature. The first ones were the hysteresis curves for both texture regions at different frequencies, as shown in figure 4. The driving wave-function was a triangular wave with a p–p amplitude at 12 V. The overshoot in these curves was caused by the large switching angle of the material ($\sim 64° > 45°$). It is obvious that the stripe region showed a slightly fatter hysteresis loop, while the uniform region gave slightly better contrast. The second measurement was the transmittance when the cell was switched by bipolar pulses. A typical result is shown in figure 5. The stripe area showed a flatter transmittance when the pulse was removed, but the uniform area gave better contrast.

All these differences in hysteresis loops and transmittance measurements can be qualitatively explained by surface pretilt effects [7, 8, 11, 12] due to differences in the local layer structure between the two regions. As was pointed out previously by several research groups [1, 6], the stripe area has the bookshelf layer geometry (with the smectic layers perpendicular to the bounding glass plates), and as we mentioned above, the uniform area had the tilted layer geometry. Therefore, there is no pretilt of the spontaneous polarization P at the surfaces in the stripe region, using the fact that the rubbed nylon alignment film made the LC molecules prefer to be parallel to the surface [13], which has been confirmed in SSFLC cells [14]. Thus the stripe region should show better bistability and therefore a fatter hysteresis loop, as demonstrated in figure 4, because even when the field was reversed, the molecules at the surfaces were still in a metastable state ferroelectrically. For the same reason, the existence of surface pretilt

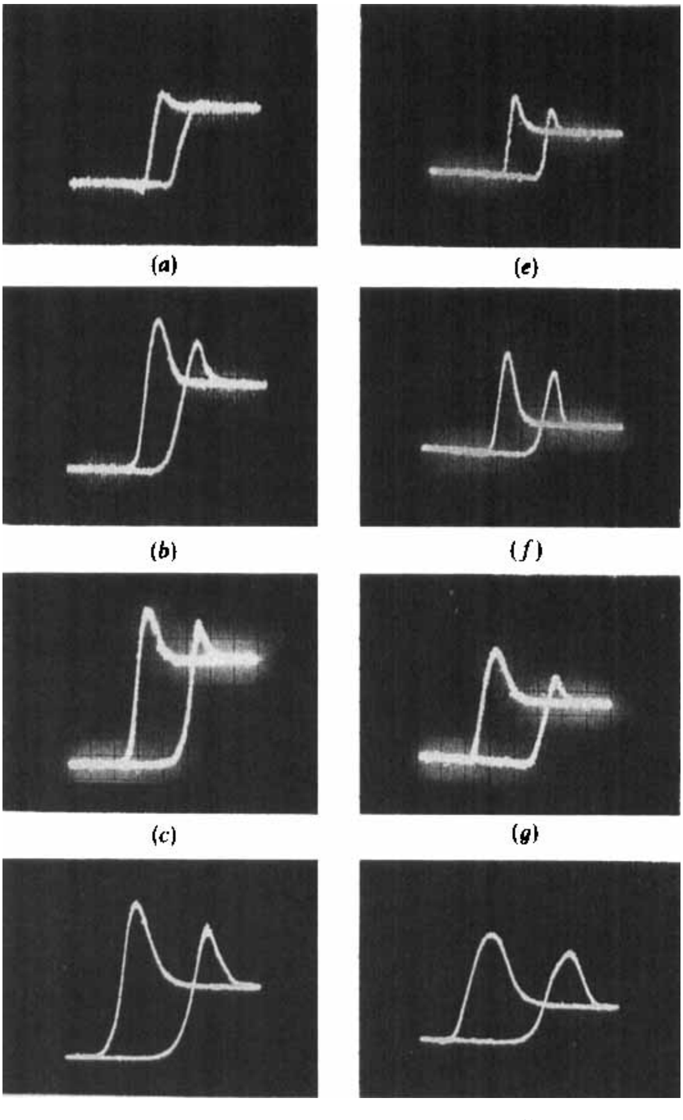
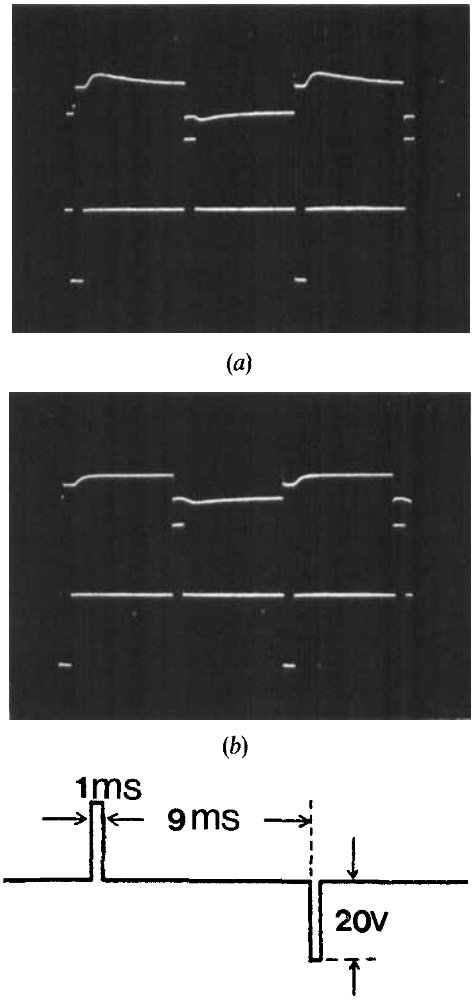


Figure 4. Hysteresis curves. The left column is for the uniform texture region and the right column is for the stripe texture region. The frequencies of the driving triangular wave are 1 Hz, 3 Hz, 10 Hz and 40 Hz, respectively from the top row to the bottom. The triangular wave has a p–p amplitude of 12 V.

forced the director profile to relax to an equilibrium with the elastic interaction in the uniform region after the pulse was removed [15], which was why its transmittance showed the relaxing behaviour in figure 5.

The threshold switching pulse width and amplitude behaviours are summed up in figure 6. We can see clearly in this figure that both the stripe (SBF) texture region (o) and the uniform region (*) showed similar threshold behaviour. The dashed line and the solid line in the figure give a guide to the eye. From point a to b it has the form $\tau \sim V^{-2}$, and from point c to d it has the form $\tau \sim V^{-1}$, where τ is the threshold pulse width and V is the pulse amplitude typical for SSFLC cells [16–18].



(*a*)

(*b*)

(*c*)

Figure 5. Electro-optic response of the ZhkS-76 cell: (*a*) the uniform texture region; (*b*) the stripe texture region; (*c*) parameters of the driving voltate pulses.

In conclusion, we have studied a short-pitch bistable FLC cell in the surface stabilized geometry which had both stripe (SBF) and uniform textures. First, the SBF texture itself is a result of surface stabilized geometry. Secondly, both texture regions showed a very similar bistable electro-optical effect, and the difference in remnant polarization between them can be qualitatively explained using known surface pretilt effects. These results indicate that the SBF bistability is due to the presence of the FLC–solid interfaces, as in SSFLC cells where the helix pitch and thickness are closer. In other words, it is the FLC–solid surface stabilization, which produces the dynamic bistable switching, even though the helix may be present under static field-free conditions.

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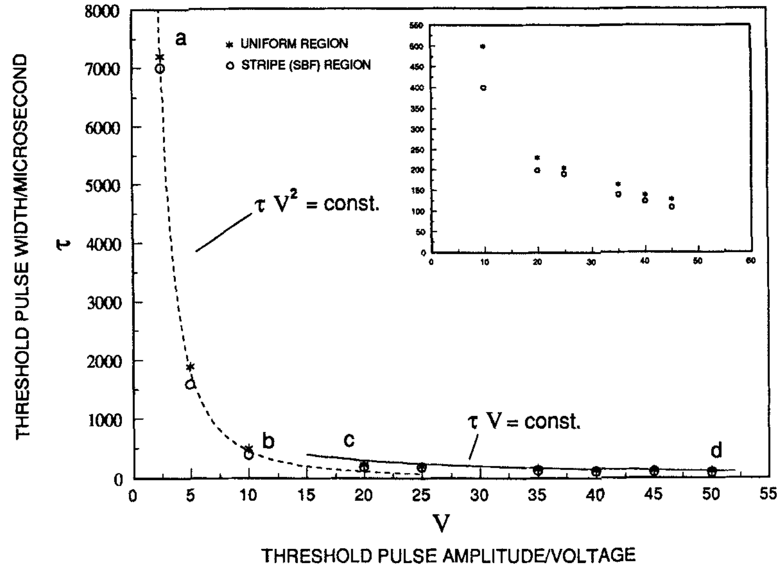

Figure 6. Threshold switching pulse width and amplitude. The insert is a zoom-in view of the high field regime.

References

[1] Funfschilling, J., and Schadt, M., 1991, *J. appl. Phys.*, **30**, 741.
[2] Clark, N. A., and Lagerwall, S. T., 1980, *Appl. Phys. Lett.*, **36**, 899.
[3] Rieker, T. P., Clark, N. A., Smith, G. S., Parmer, D. S., Sirota, E. B., and Safinya, C. R., 1987, *Phys. Rev. Lett.*, **59**, 2658.
[4] Clark, N. A., and Rieker, T. P., 1988, *Phys. Rev.* A, **37**, 1053.
[5] Verhulst, A. G. H., and Stommels, F. J., 1991, *Ferroelectrics*, **121**, 79.
[6] Shao, R. F., Willis, P. C., and Clark, N. A., 1991, *Ferroelectrics*, **121**, 127.
[7] Hartmann, W. J. A. M., and Luyckx-Smolders, A. M. M., 1990, *J. appl. Phys.*, **67**, 1253.
[8] Rieker, T. P., 1988, Ph.D. Dissertation, University of Colorado.
[9] Rieker, T. P., Clark, N. A., Smith, G. S., and Safinya, C. R., 1989, *Liq. Crystals*, **6**, 565.
[10] Brunet, M., and Williams, C., 1978, *Ann. Phys.*, **3**, 237. Brunet, M., and Isaert, N., 1988, *Ferroelectrics*, **84**, 25.
[11] Funfschilling, J., and Schadt, M., 1989, *J. appl. Phys.*, **65**, 3877.
[12] Clark, N. A., Rieker, T. P., and Maclennan, J. E., 1988, *Ferroelectrics*, **85**, 79.
[13] Handschy, M. A., and Clark, N. A., 1984, *Ferroelectrics*, **59**, 25.
[14] Zhuang, Z., Clark, N. A., and Meadows, M. R., 1992, *Phys. Rev.* A, **45**, 6981.
[15] Maclennan, J. E., Handschy, M. A., and Clark, N. A., 1990, *Liq. Crystals*, **7**, 787.
[16] Clark, N. A., and Lagerwall, S. T., 1981, *Recent Developments in Condensed Matter Physics*, Vol. 4, edited by J. T. Devreese, L. F. Lemmens, V. E. van Doren and J. van Doren (Plenum), p. 309.
[17] Clark, N. A., and Lagerwall, S. T., 1983, *Molec. Crystals liq. Crystals*, **94**, 213.
[18] Wahl, J., and Jain, S. C., 1984, *Ferroelectrics*, **59**, 161.