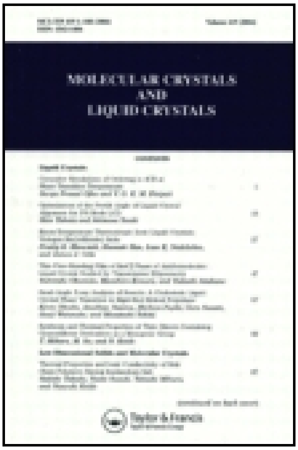

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J. Prakash [a] [b] , A. Choudhary [b] , D. S. Mehta [a] & A. M. Biradar [b]

[a] Instrument Design and Development Center, Indian Institute of Technology Delhi, New Delhi, India

[b] Polymeric and Soft Material Section, National Physical Laboratory, New Delhi, India

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Effect of Surface Anchoring on Optical Bistability in Deformed Helix Ferroelectric Liquid Crystal

J. Prakash[1,2], A. Choudhary[2], D. S. Mehta[1], and A. M. Biradar[2]
[1]Instrument Design and Development Center, Indian Institute of Technology Delhi, New Delhi, India
[2]Polymeric and Soft Material Section, National Physical Laboratory, New Delhi, India

The effect of surface anchoring on the optical bistability in deformed helix ferroelectric liquid crystal (DHFLC) has been investigated by electro-optical and textural methods. The threshold voltage studies have been carried out in strongly and weakly treated DHFLC cells. The long lasting memory effect has been observed in weakly treated DHFLC cells, which is due to minimization of depolarizing and ionic charges. Moreover, the response time has been shown to exhibit the dependence on the surface anchoring and the cell thickness. The informations obtained could be helpful for optimizing the parameters for memory devices based on DHFLC materials.

Keywords: deformed helix ferroelectric liquid crystal; memory effect; response time; surface anchoring

1. INTRODUCTION

The interest in surface anchoring effect in liquid crystal (LC) has been received a large boost for the last few decades because of the search of weak surface anchoring which is an important issue for a whole class of liquid crystal display devices. The surface alignment in LC displays

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Address correspondence to A. M. Biradar, Instrument Design and Development Center, Indian Institute of Technology Delhi, New Delhi-110016, India. E-mail: abiradar@mail.nplindia.ernet.in

has become much important as it controls the director of one of the two states of the display. The LC materials are anchored at the substrate along the preferred direction induced by the surface. Several alignment techniques have been reported in the literature [1–4]. The surface anchoring effect in nematic liquid crystals (NLCs) has been studied extensively from several decades to understand the precise interaction between the surface and LC materials [5,6]. But the surface anchoring effect studies in ferroelectric liquid crystals (FLCs) has been reported rarely in literature because of the complexity in surface interactions caused by the introduction of spontaneous polarization and layer structure. Nie *et al.* [7] have explained the effect of surface anchoring on the LC response time where the thickness of the cell was also taken into account. To achieve the switching of the surface director between the two states of the display device, the weak anchoring becomes much important. Moreover, the weak anchoring overcomes the disadvantages, e.g. the possibility of deposition of dust particles [8] and creation of zigzag defects [9], produced by the well known rubbed polymer alignment technique. Several methods for producing the weak anchoring [10–14] have been reported. The weak anchoring effect in NLCs has been studied well [8,10]. But such effects in FLCs have not been studied. Among all FLCs, deformed helix ferroelectric liquid crystals (DHFLCs) are very useful and have much application potentials in display devices because of their low deriving voltage, grey scale generation capability, easily achievable alignment even in thicker cells, and fast response time [15,16]. Apart from these attractive properties these materials have several advantages over surface stabilized FLCs like better contrast and memory effect. In this article, the effect of surface anchoring on the optical bistability has been studied in DHFLC material. It has been shown here that the weak anchoring lowers the threshold voltage. The prolonged memory effect has been shown in weakly treated DHFLC cells. The dependence of response time of DHFLC material on the surface anchoring has been demonstrated with respect to the cell thickness. The experimental results have been analyzed by electro-optical and textural methods in DHFLC cells.

2. EXPERIMENTAL

The DHFLC cells for the present study were prepared using indium tin oxide (ITO) coated glass plates. We prepared three types of samples. For the first type samples, two electrodes were treated with polymer (thick layer of Nylon 6/6) and strongly rubbed (the number of strokes were kept forty with maximum rubbing strength), we called them strongly treated (ST) cells. In second type samples, two electrodes were treated with polymer (thin layer of Nylon 6/6) and then smoothly rubbed (number of strokes were kept twenty with rubbing strength lower than that of the ST cells), they were called medium treated (MT) cells. In the case of the third type samples, both the electrodes were left untreated (neither polymer was coated nor rubbed) and they were called weakly treated (WT) cells. Moreover, we have not given any kind of surface treatment in the case of the WT cells. The coating of the polymer and then rubbing in the case of the first and second type samples were performed to obtain homogeneous alignment. The alignment in the case of the WT cells may be possible due to the concept given by Miyano [17]. The glass plates were assembled into cells maintaining a uniform gap of various thicknesses. In this study, a DHFLC material (FLC 6304, Rolic, Switzerland) having spontaneous polarization of 90 nC/cm^2 and a pitch value of 0.35 μm was used. The phase sequence of this material is as follows.

$$\text{Cryst.} \overset{-14^\circ\text{C}}{\longleftrightarrow} \text{Sm C}^* \overset{60.5^\circ\text{C}}{\longleftrightarrow} \text{Sm A} \overset{64^\circ\text{C}}{\longleftrightarrow} \text{Iso.}$$

The material was introduced into the cells by means of capillary action at elevated temperature to ensure that filling takes place in the isotropic phase. The smectic layers were arranged with layer planes perpendicular to the cell surfaces. The electro-optical measurements were carried out by applying an electric field parallel to the smectic layers. For threshold voltage studies, the tilt angle was measured by observing the texture under polarizing microscope (Ax-40, Carl Zeiss Germany) on the application of bias field. For optical response, the sample was mounted on a polarizing microscope and the transmission of normally incident polarized light through the sample and analyzer was monitored with a photodiode. The time delayed square pulse generated from the pulse generator was applied to the sample and studied by using a storage oscilloscope (HM 1507-3, HAMEG, Japan) interfaced with the computer via SP-107 software. The textural studies were carried out by mounting the sample under a polarizing microscope attached with a computer-controlled charge coupled device camera. The response time and the spontaneous polarization measurements were performed using automatic liquid crystal tester (ALCT, Instec, U.S.A.).

3. RESULTS AND DISCUSSIONS

It has been observed that the weak anchoring is responsible for lowering the threshold voltage in the LC materials [8,10]. The studies for comparing the threshold voltage (the voltage required to switch the most of the molecules completely before the saturation voltage region) in ST and WT sample cells were performed by taking the variation of tilt angle at different DC voltages, which is shown in Figure 1. As can be seen from the figure the tilt angle increases at lower voltage but it starts to saturate as the field is further increased. No change was observed in the tilt angle after certain voltage. The saturation in the tilt angle in WT samples has been found almost at the half DC voltage to that of the saturation for ST samples, which is clearly reflected in the Figure 1. The decrease in the threshold voltage in the case of the WT sample has been attributed to the weak anchoring because the threshold voltage is found anchoring energy dependent [18].

Figure 2 shows the optical response of the DHFLC material for ST (Fig. 2(a)) and WT (Fig. 2(b)) sample cells on the application of time delayed square wave pulse of frequency 10 Hz and amplitude 20 V. As can be seen clearly from the Figure 2(a) that there is no memory effect in ST cell. On the contrary, a complete memory effect was observed in WT sample as shown in Figure 2(b). The memory effect in these samples has been observed in a wide frequency range (100 mHz–100 Hz, but not shown in the figure). It has been found that the memory effect in DHFLC material could be seen at certain frequency and voltage [19]. The complete memory effect in WT sample was due to the fact that we did not use any alignment layer in these

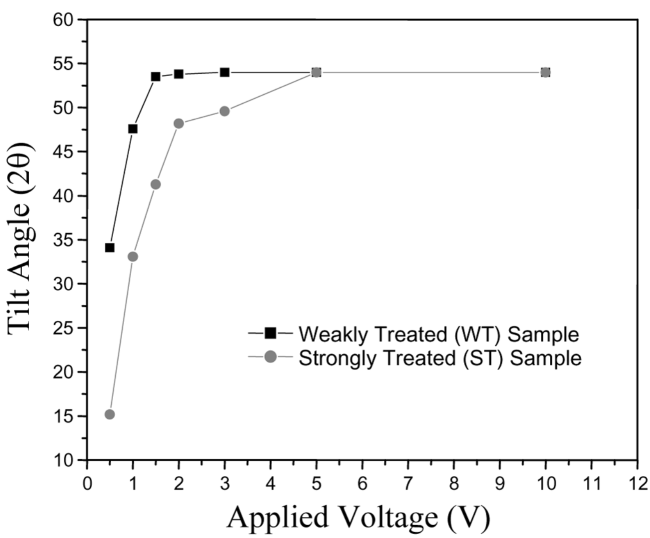

FIGURE 1 Behavior of optical tilt (2θ) as a function of bias voltage for ST and WT samples.

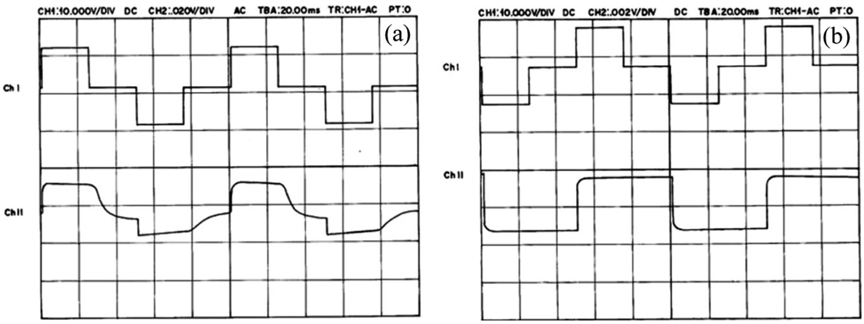

FIGURE 2 Optical response of DHFLC at room temperature in 4 μm cell at 20 V at 10 Hz for (a) ST, and (b) WT samples.

kind of samples and no surface treatment was given to the cell i.e., the conducting FLC medium was directly in contact with the conducting ITO coating. Because of this, there was an injection of free charges, which screen or neutralize the depolarization and ionic charges. The depolarization field is caused by the charges developed on the surface of bounding glass plates as a result of attaining stable states when electric field is applied to the sample. This develops free charges on the bounding glass plates, which in turn develops a depolarization field [20,21]. The origination of ionic charges may be due the fact [22] that if the pulse width of the external voltage is larger than approximately few hundred μs then accumulation of excess ions at the interface between FLC medium and the alignment layers takes place. These excess ions create the external field which combines with the depolarizing field and becomes responsible for having no memory effect in ST sample cells. It is worth mentioning here that minimum or weak anchoring leads to the better memory effect ever observed in DHFLC material.

Figures 3 and 4 show the textural observations in deep SmC* phase by the application of 15 V bias in ST and WT samples respectively. Figure 3(a) shows the texture of virgin cell i.e., without the application of any bias. A complete switched state was observed on the application of 15 V bias (Figure 3(b)). The sample switched back immediately to the original state as the bias is removed which is shown in Figure 3(c). In Figure 3(d), again scattering state has been shown. The last state did not retrain in the ST sample because of the presence strong depolarization and ionic charges. On the other hand, the last state has been retained for many hours in WT samples. Figure 4(a) shows the texture of virgin cell of the WT sample. A switched state was observed when 15 V bias was applied to the WT sample (Figure 4(b)). Figure 4(c)

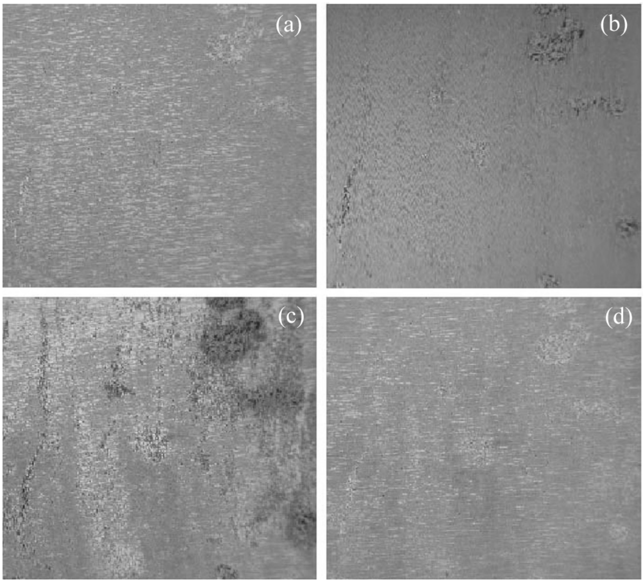

FIGURE 3 Optical micrographs of 4 μm ST cell at room temperature at (a) 0 V, (b) 15 V bias, (c) 10 min after removal of bias, and (d) again 0 V.

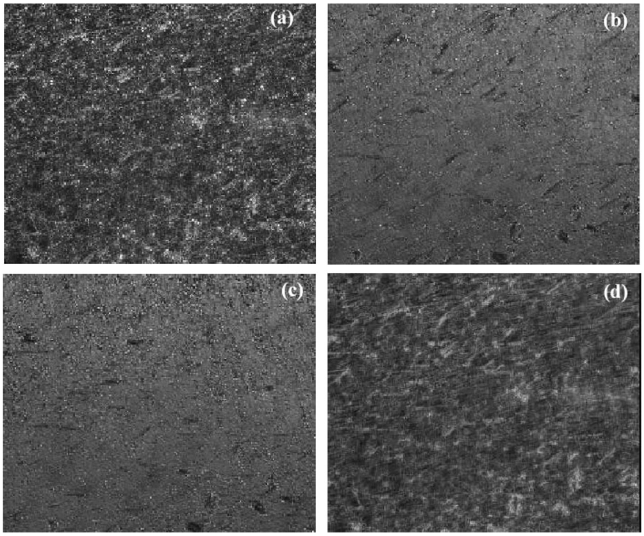

FIGURE 4 Optical micrographs of 4 μm WT cell at room temperature at (a) 0 V, (b) 15 V bias, (c) 30 min after removal of bias, and (d) again 0 V.

shows that the memory was retained even after removal of bias [the texture shown is after 30 minutes of removal of bias] unlike the ST samples. The last memory state was retained even after a prolonged period (e.g., for 90 hours) when bias was removed. The observation of long lasting memory ensures the absence of depolarization field as the last state retains for a long time. The memory state in WT samples was switched back forcibly to the original state on the application of sinusoidal field of low amplitude (1 V) and high frequency (30–50 Hz) which has been shown in Figure 4(d).

Figure 5 shows the response time [the sum of rise (switched on) time and decay (switched off) time] as a function of cell thickness where the effect of surface anchoring has been taken into account. Nie *et al*. [7] reported the effect of surface anchoring on response time where the dependence of cell thickness on the response was also taken into account. According to them the response time is directly proportional to cell thickness and indirectly proportional to the anchoring energy however they derived two different formulae for strong and weak anchoring. The dependence of cell thickness on different parameters e.g. dielectric constant [23,24], transition temperature [25], electrical property [26], response time [7,27] etc. have been studied well earlier. As the response time is inversely proportional to the anchoring energy, so for weakly treated cell, the response time will

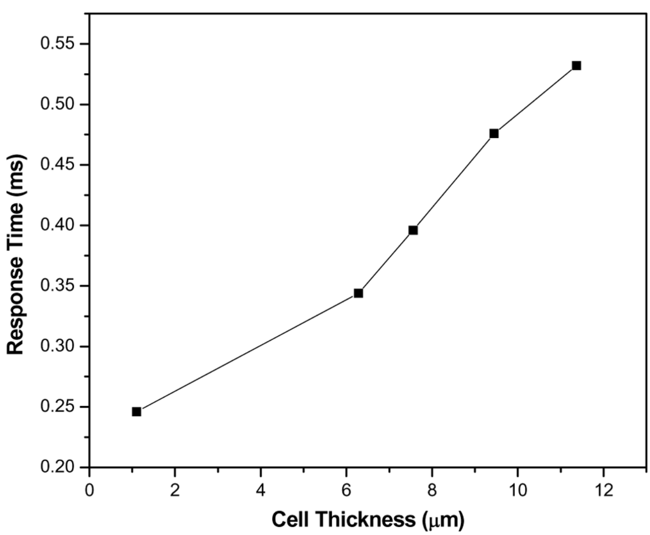

FIGURE 5 Behavior of DHFLC response time with cell thickness for medium treated sample cells at room temperature.

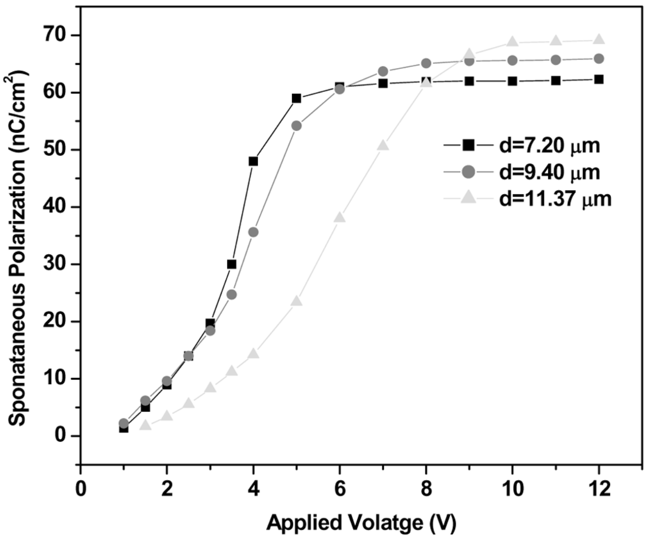

FIGURE 6 Behavior of spontaneous polarization (P_s) with applied voltage for medium treated cells of different thicknesses at room temperature.

be large which is not good for display purposes. On the other hand the response time will be small for strongly treated samples but the good alignment is not achievable in such cells of higher thickness. So we see the effect of response time with respect to the cell thickness for medium treated cells. As shown in the Figure 5 that for having the fast response, the cells of lower thickness and medium treatment are found to be appropriate.

The behavior of spontaneous polarization with applied voltage for medium treated cells of different thicknesses has also been observed which is shown in Figure 6. We did this to see the behavior of spontaneous polarization with cell thickness where sufficient field was applied for full switching. It has been found that spontaneous polarization increases with the cell thickness. However, the behavior of spontaneous polarization above the threshold voltage decreases with the cell thickness in the cells having thickness below 6 μm and this strange behavior would be carried out in detail, which will be reported separately elsewhere.

4. CONCLUSIONS

The effect of surface anchoring on the optical bistability has been demonstrated. It has been found that the threshold voltage is less in weakly treated cells than in the strongly treated cells. The long lasting memory has been observed in weakly treated cells which are attributed to the absence of depolarization and ionic charges. The effect of surface anchoring on the response has also been studied while thickness dependence was taken into account. These studies open new ways to understand the effect of surface anchoring on electro-optical properties of FLC material, the interaction of FLC molecules with surface of cell substrate, and optimizing the parameters for liquid crystal display devices.

REFERENCES

[1] Fukuro, H. & Kobayashi, S. (1988). *Mol. Cryst. Liq. Cryst.*, *163*, 157.
[2] Yokoyama, H. & van Sprang, H. A. (1985). *J. Appl. Phys.*, *57*, 4520.
[3] Seo, D. S., Muroi, K., Isogami, T., Matsuda, H., & Kobayashi, S. (1992). *Jpn. J. Appl. Phys.*, *31*, 2165.
[4] Bawa, S. S., Biradar, A. M., Saxena, K., & Chandra, S. (1990). *Appl. Phys. Lett.*, *57*, 1398.
[5] Yokoyama, H. (1988). *Mol. Cryst. Liq. Cryst.*, *165*, 265.
[6] Faetti, S. (1987). *Phys. Rev. A*, *36*, 408.
[7] Nie, X., Lu, R., Xianyu, H., Wu, T. X., & Wu, S. T. (2007). *J. Appl. Phys.*, *101*, 103110.
[8] Nespoulous, M., Blanc, C., & Nobili, M. (2007). *J. Appl. Phys.*, *102*, 073519.
[9] Haridas, E. P., Bawa, S. S., Biradar, A. M., & Chandra, S. (1995). *Jpn. J. Appl. Phys.*, *34*, 3602.
[10] Bryan-Brown, G. P., Wood, E. L., & Sage, I. C. (1999). *Nature*, *399*, 338.
[11] Sato, Y., Sato, K., & Uchida, T. (1992). *Jpn. J. Appl. Phys.*, *31*, L579.
[12] Vorflusev, V. P., Kitzerow, H. S., & Chigrinov, V. G. (1997). *Appl. Phys. A*, *64*, 615.
[13] Pozhidaev, E., Chigrinov, V., & Li, X. (2006). *Jpn. J. Appl. Phys.*, *45*, 875.
[14] Kang, W. S., Kim, H. W., & Kim, J. D. (2002). *Liq. Cryst.*, *29*, 583.
[15] Beresnev, L. A., Chigrinov, V. G., Dergachev, D. I., Poshidaev, E. P., Funfschilling J., & Schadt, M. (1989). *Liq. Cryst.*, *5*, 1171.
[16] Funfschilling, J. & Schadt, M. (1989). *J. Appl. Phys.*, *66*, 3877.
[17] Miyano, K. (1979). *Phys. Rev. Lett.*, *43*, 51.
[18] Nehring, J., Kmetz, A. R., & Scheffer, T. J. (1976). *J. Appl. Phys.*, *47*, 850.
[19] Kaur, S., Thakur, A. K., Chauhan, R., Bawa, S. S., & Biradar, A. M. (2004). *J. Appl. Phys.*, *96*, 2547.
[20] Bawa, S. S., Biradar, A. M., & Chandra, S. (1987). *Ferroelectrics*, *76*, 69.
[21] Bawa, S. S., Biradar, A. M., & Chandra, S. (1987). *Phys. Stat. Sol. (a)*, *102*, 829.
[22] Yang, K. H., Chiew, T. C., & Osofsky, S. (1989). *Appl. Phys. Lett.*, *55*, 125.
[23] Mukherjee, A., Rehman, M., Bhattacharyya, S. S., Chaudhuri, B. K., & Yoshizawa, A. (2007). *Chem. Phys. Lett.*, *443*, 71.
[24] Yoshino, K., Nakao, K., Taniguchi, H., & Ozaki, M. (1987). *Jpn. J. Appl. Phys.*, *26*, 97.
[25] Kundu, S. K., Suzuki, K., & Chaudhuri, B. K. (2004). *Jpn. J. Appl. Phys.*, *43*, 4286.
[26] Yoshino, K., Urabe, T., & Inuishi, Y. (1983). *Jpn. J. Appl. Phys.*, *22*, 115.
[27] Yoshino, K., Ozaki, M., Sakurai, T., & Honma, M. (1985). *Jpn. J. Appl. Phys.*, *24*, 59.