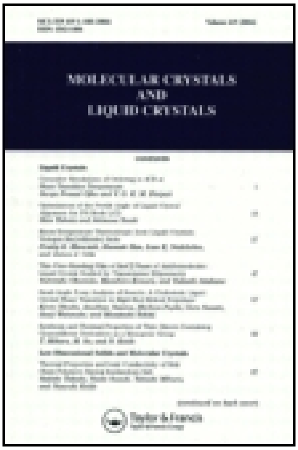

Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl19

ALIGNMENT INSTABILITY INDUCED BY IRRADIATION OF VISIBLE LIGHT IN FRUSTOELECTRIC LIQUID CRYSTALLINE CELLS SHOWING THE V-SHAPED SWITCHING

San-Seong Seomun [a] , Naoki Hayashi [b] , Tatsuhisa Kato [b] , Atsuo Fukuda [c] & Jagdish K. Vij [a]

[a] Department of Electronic and Electrical Engineering, Trinity College, University of Dublin, Dublin 2, Ireland

[b] Institute for Molecular Science, Myodaiji, Okazaki-shi, JAPAN

[c] Department of Kansei Engineering, Shinshu University Ueda-shi, Nagano, 386-8567, JAPAN

Version of record first published: 24 Sep 2006

To cite this article: San-Seong Seomun, Naoki Hayashi, Tatsuhisa Kato, Atsuo Fukuda & Jagdish K. Vij (2001): ALIGNMENT INSTABILITY INDUCED BY IRRADIATION OF VISIBLE LIGHT IN FRUSTOELECTRIC LIQUID CRYSTALLINE CELLS SHOWING THE V-SHAPED SWITCHING, Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals, 366:1, 785-795

Mol. Cryst. and Liq. Cryst., 2001, Vol. 366, pp. 785-795
Reprints available directly from the publisher
Photocopying permitted by license only

Alignment Instability Induced by Irradiation of Visible Light in Frustoelectric Liquid Crystalline Cells Showing the V-Shaped Switching

SAN-SEONG SEOMUN[a], NAOKI HAYASHI[b], TATSUHISA KATO[b], ATSUO FUKUDA[c] and JAGDISH K. VIJ[a]

[a]*Department of Electronic and Electrical Engineering, Trinity College, University of Dublin, Dublin 2, Ireland,* [b]*Institute for Molecular Science, Myodaiji, Okazaki-shi, JAPAN and* [c]*Department of Kansei Engineering, Shinshu University, Ueda-shi, Nagano 386–8567, JAPAN*

Irradiation of the powerful visible light from the laser expedites the deterioration of the frustoelectric liquid crystalline cells (Inui mixture) showing the V-shaped switching. This deterioration is caused by the light absorption in the aligning layer, which strongly influences the molecule-surface polar interaction; this cannot be observed in the cell with the transparent aligning material in the used visible light region. This is observed just in the tilted smectic X* phase, not in the SmA phase. Irradiation during the switching leads to hysteresis in the V-shaped pattern and changes even the surface molecular alignment. These results can be explained by the shielding of the surface charge due to the alignment of the spontaneous polarization and the disturbed polar anchoring.

Keywords: frustoelectric liquid crystal; surface charge; depolarization field; polar anchoring

INTRODUCTION

Recently chiral smectic liquid crystal displays have been extensively studied as an alternative to the nematic liquid crystal display. One such type of smectic liquid crystals is the frustoelectric liquid crystal (FR-LC) showing the V-shaped switching which is characterized by a novel thresholdless, hysteresis-free property.[1-8] This is expected to realize attractive displays with extremely wide viewing angle, very large contrast ratio and high-speed response.[9-10]

However, in addition to the switching mechanism that is being debated between the random process model[1-5] and the collective model,[6-8] there are some difficulties in its application. The most serious problem among them is the instability of the molecular alignment caused by some domains emerging in a rubbed cell.[11] These domains are observed only in the cell that has been used for a long time. The contrast ratio deteriorates with time and the switching instability also emerges with a prolonged use of these displays. Meanwhile, there is an attempt to improve this molecular aligning stability,[11] but the instability mechanism of the molecular alignment is not clear yet.

In order to study the deterioration of the cell accompanying the emergence of some domains, we have developed the system that expedites the deterioration in the cell. In this system, a polyimide with some absorption in the visible region of light is adopted as an aligning material. During the switching, an Ar ion laser beam (514 nm) was irradiated to expedite the cell deterioration to a one-side rubbed sandwich cell. The light absorption in the aligning layer strongly influences the switching pattern and even the surface interaction between the molecule and the aligning layer.

EXPERIMENTAL

Inui mixture composed of three chiral smectic liquid crystals was investigated. As an aligning material, two kinds of polyimide, RN1199 and RN1266 (Nissan Chemical Industries, Ltd.) were spin-coated on the glass substrate with ITO coating. The former absorbs light a little

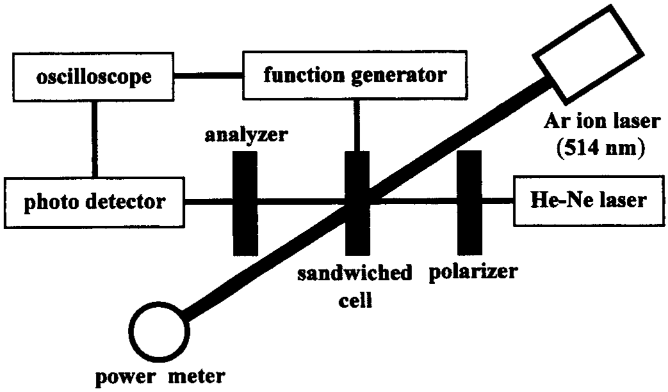

FIGURE 1 Schematic optical set-up.

in the visible region, while the latter is transparent. For a sandwich cell, one of the two spin-coated substrates was rubbed unidirectionally. The cell gap was controlled with a ball spacer of diameter 2 μm mixed with a UV curable adhesive. As described in the optical set-up (Figure 1), the switching behaviour was probed using monochromatic light from a He-Ne laser (632 nm) with a 2 mm aperture. Ar ion laser beam (514 nm) with a 3 mm aperture was irradiated to expedite the deterioration in the cell during the switching process. All the switching in this work was carried out in the SmX* phase (50 °C) showing the V-shaped pattern under an electric field of triangular waveform with the frequency of 1 Hz (the phase sequence: AF (20-43 °C:co-existence with SmX*) SmX* (64 °C) SmA (68.5 °C) Iso). Before and after the irradiation, the change of the switching pattern and the texture were observed.

RESULTS AND DISCUSSION

Figure 2 shows the laser-power dependence of the switching pattern during irradiation with the Ar ion laser beam into the cell with the aligning material of RN1199. Before irradiation, the initial switching shows the V-shaped pattern with no hysteresis. However, immediately after irradiation, hysteresis appears and its magnitude increases depending on the laser power irradiated. In each switching pattern, the level of the transmittance on the tip of the V is almost the same. So it is believed that the molecular motion itself during the switching hardly changed in spite of the emergence of the hysteresis. When the laser beam is shut out, the switching pattern turns back to the nearly initial shape but a little hysteresis remains.

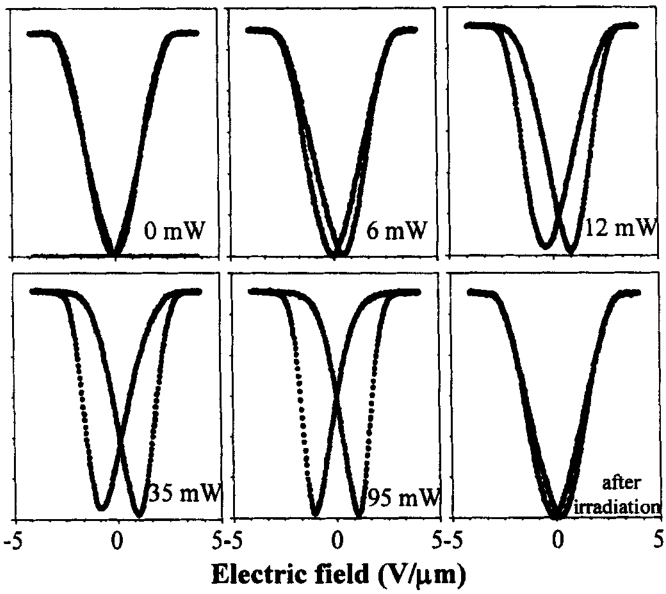

FIGURE 2 Laser-power dependence of the V-shaped switching during irradiation of the Ar ion laser beam. The dark level (arrow 1) remains almost the same after irradiation.

The magnitude of the hysteresis emerging during the switching was estimated by measuring the difference between the two tips of the V as indicated in Figure 3. By increasing the power of the laser beam, the magnitude of hysteresis abruptly increases and saturates at the laser-power of about 45 mW. Figure 4 shows the time dependence of the switching pattern during irradiation of the laser beam. The laser power was fixed at 95 mW. Under this condition, the early switching pattern immediately after irradiation is maintained independent of the irradiation time. However, when the laser beam is shut out after 2 hours, the switching pattern shows a larger hysteresis than the switching over a short term irradiation (Figure 2). Note the dark level (arrow 2 in Figure 4) rises when an applied electric field was turned off.

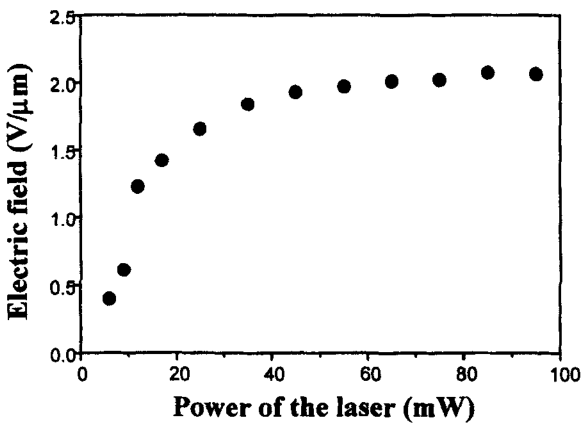

FIGURE 3 Laser-power dependence of the hysteresis of the V-shaped switching during irradiation with the Ar ion laser. Frequency of an applied triangular wave voltage is 1 Hz.

It is easily found that the different dark levels between before and after irradiation are due to the change of the director in the area irradiated by the Ar ion laser beam by microscopic observation.

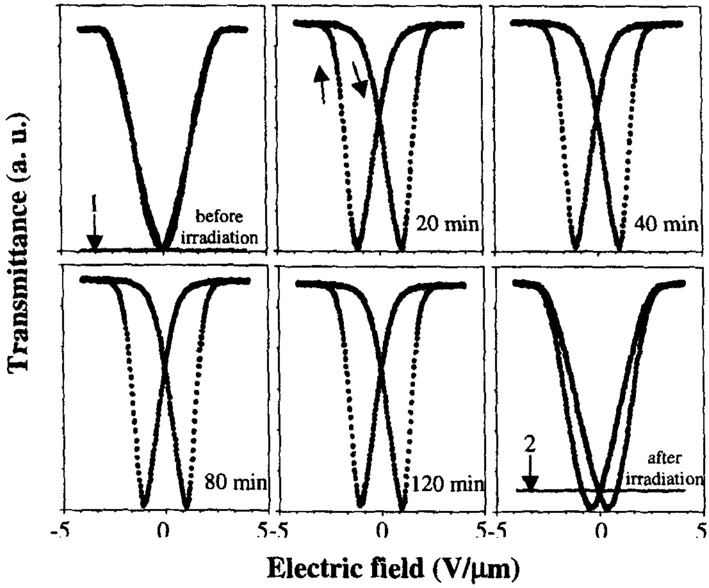

FIGURE 4 Time dependence of the V-shaped switching during irradiation of the Ar ion laser beam.

Figure 5 shows the polarizing micrograph of the cell taken after irradiation of the Ar ion laser beam at the SmX* phase (50 °C) for 2 hours. One of the crossed polarizers is set parallel to the rubbing direction. Arrow 1 and 2 direct the rubbing direction and the smectic layer normal, respectively. In this case, the difference between the smectic layer normal and the rubbing direction is ~12°, which was caused by the surface electroclinic effect when the Iso.-SmA transition occurs. The surprising change in the molecular orientation before and after irradiation was observed. Before irradiation of the Ar ion laser beam (the outside of the spot irradiated), the averaged optical axis is almost parallel to the smectic layer normal. After irradiation (the inside of the spot irradiated), however, the averaged optical axis parallel to the rubbing direction was obtained: that is, the molecules lie along the rubbing direction. Of course, the maximum transmittance in this region is obtained when the stage is rotated 45 $^{\circ}$ from the rubbing direction.

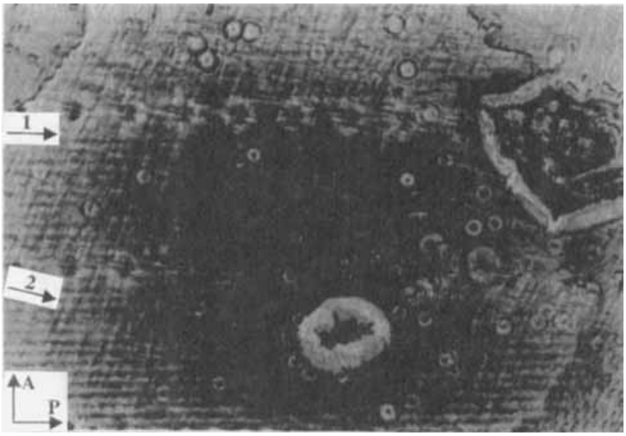

FIGURE 5 Optical micrograph of a one-side rubbed sandwich cell taken after irradiation of the Ar ion laser beam. The laser power is 95 mW and the beam diameter is 3 mm. Arrow 1 and 2 direct the rubbing direction and the smectic layer normal, respectively. See Color Plate XXII at the back of this issue.

As shown above, irradiation induces the drastic changes not only in the switching pattern but also in the molecular orientation in the SmX* phase. However, in the SmA phase, we hardly observe the same phenomenon under the same condition. In addition, the irradiated light directly interacts with the aligning layer, not the liquid crystalline molecules. This can be confirmed in the cell with the aligning material, RN1266 that is transparent in the visible light region. As indicated in Figure 6, the V-shaped switching in such a cell is maintained before and during irradiation of the Ar ion laser beam. The texture observed after irradiation remains the same as before irradiation, too. So that abnormal switching behaviour during irradiation is believed to be closely related to the interaction between the excited aligning layer and the spontaneous polarization emerging in the SmX* phase. No chemical damage of the aligning material was also checked by repeating the heating and cooling of the cell after irradiation. That is, the deteriorated cell returns to the original condition by cooling after reheating over the Iso-SmA transition.

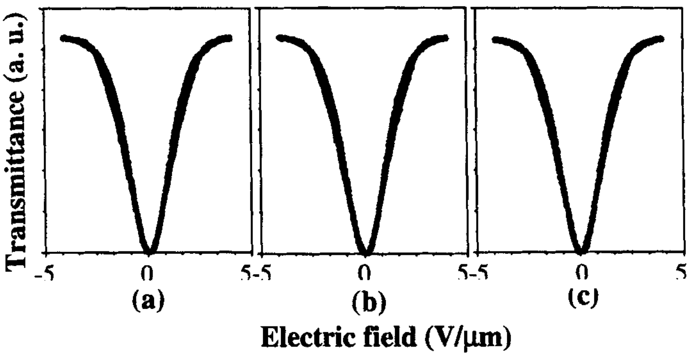

FIGURE 6 Observation of the V-shaped switching during irradiation of the Ar ion laser beam in the cell with an aligning material, RN1266. The laser power is 95 mW. (a) before irradiation (b) immediately after irradiation (c) after 2 hours.

Firstly, the emergence of hysteresis from the V-shaped switching is due to the increase of the internal field applied to the liquid crystal layer. Before irradiation of the Ar ion laser beam, in the bulk of the field-induced uniform state at a higher field all charge is compensated, but residual charge near the surfaces exists. This is the surface charge due to the alignment of the spontaneous polarization and generates the depolarization field in the cell.[12-14] This depolarization field is strongly shielded by irradiation of the Ar ion laser beam in this measurement. Therefore the internal field increases and consequently hysteresis emerges. As a possible shielding mechanism of the depolarisation field, the neutralization of the surface charge by the expedition of the charge injection from the aligning layer or the disturbance of the arrangement of the molecular dipoles at the interface between the aligning layer and the liquid crystalline molecules by the local heating is able to be considered.

Secondly, the new domain (Figure 5) with the extinction position parallel to the rubbing direction is caused by the decrease of the polar interaction between the molecules and the *unrubbed* surface. At the SmX* phase in this cell, the molecules near the rubbed surface are rotated to the rubbing direction due to the surface-molecule polar interaction in the early phase transition, SmA-SmX*. However, the strong in-plane anchoring by the rubbing treatment restrains all the molecules in the rubbing direction below 2 ~ 3 °C from the phase transiton.[15] On the other hand, the molecules near the unrubbed surface tend to align against the rubbing direction by the same polar anchoring as the opposite surface. So the original molecular orientation along the cell thickness is twisted between such the two asymmetric surface alignments.[15] The neutralization or the disturbance of the surface polarization by irradiation extremely weakens the molecule-surface polar interaction. In this case, the molecular alignment near the rubbed surface is not affected because the nonpolar anchoring restraints the molecules. Meanwhile, the molecules near the unrubbed surface that are set free from the polar anchoring are affected by the rubbed surface through the in-layer molecular interaction. Consequently all the molecules along the cell thickness are uniformly aligned parallel to the rubbing direction.

SUMMARY

Irradiation of the Ar ion laser beam expedites the deterioration of the FR-LC cell showing the V-shaped switching and leads to the emergence of hysteresis during the switching. This deterioration is suggested as the result that the disturbance/neutralization of the surface polarization cause the shielding of the depolarization field generated by the surface charge due to the alignment of the spontaneous polarization. In this paper, although ionic charge effects can exist, all the results was analysed only by the surface charge effect. The detailed mechanism of the cell deterioration including the ionic charge effect will be reported elsewhere.

Acknowledgements

We acknowledge Nissan Chemical Industries, Ltd. for supplying polyimide RN1199 and RN1266. The fellowship of S. S. Seomun was funded by the Higher Education Authority in Ireland under the initiative of Advanced Materials.

References

[1] A. Fukuda, *Proc. Asia Display 95(Hamamatsu)*, 61 (1995).

[2] S. Inui, N. Iimura, T. Suzuki, H. Iwane, K. Miyachi, Y. Takanishi and A. Fukuda, *J. Mater. Chem.* **6**, 671 (1996).

[3] S.S. Seomun, B.C. Park, A.D.L. Chandani, D.S. Hermann, Y. Takanishi, K. Ishikawa, H. Takezoe and A. Fukuda, *Jpn. J. Appl. Phys. Lett.* **37**, 691 (1998).

[4] T. Matsumoto and A. Fukuda, *Liq. Cryst. Today* **8**, 4 (1998).

[5] T. Matsumoto, A. Fukuda, M. Johno, Y. Motoyama, T. Yui, S.S. Seomun and M. Yamashita, *J. Mater. Chem.* **9**, 2015 (1999).

[6] B.C. Park, S.S. Seomun, M. Nakata, Y. Takanishi, K. Ishikawa, H. Takezoe and A. Fukuda, *Jpn. J. Appl. Phys.* **38**, 1474 (1999).

[7] P. Rudquist, J.P.F. Lagerwall, M. Buivydas, F. Gouda, S.T. Lagerwall, N.A. Clark, J.E. Maclennan, R. Shao, D.A. Coleman, S. Bardon, T. Bellini, D.R. Link, G. Natale, M.A. Glaser, D.M. Walba, M.D. Wand and X.-H. Chen, *J. Mater. Chem.* **9**, 1257 (1999).

[8] N.A. Clark, D. Coleman and J.E. Maclennan, *Liq. Cryst.* **27**, 985 (2000).
[9] T. Saishu, K. Takatoh, R. Iida, H. Nagata and Y. Mori, *SID 96 Digest*, 703 (1996).
[10] T. Yoshida, T. Tanaka, J. Ogura, H. Wakai and H. Aoki, *SID 97 Digest*, 841 (1997).
[11] M. Johno, T. Matsumoto, T. Yui and Y. Motoyama, *Jpn. Pat. Gaz.*H10–25478 (1998).
[12] Y. Inaba, K. Katagiri, H. Inoue, J. Kanbe, S. Yoshihara and S. Iijima, *Ferroelectrics* **85**, 255 (1988).
[13] J. Dijon, C. Ebel, C. Vauchier, F. Baume, J.-F. Clerc, M. Estor, T. Leroux, P. Maltese and L. Mulatier, *SID 99 DIGEST*, 246 (1988).
[14] K.H. Yang, T.C. Chieu and S. Osofsky, *Appl. Phys. Lett.* **55**, 125 (1989).
[15] This surface molecular alignment was confirmed in the open cell with the air-molecular boundary: S.S. Seomun, T. Fukuda, A. Fukuda, J.-G. Yoo, Yu. P. Panarin and J.K. Vij, to be published.