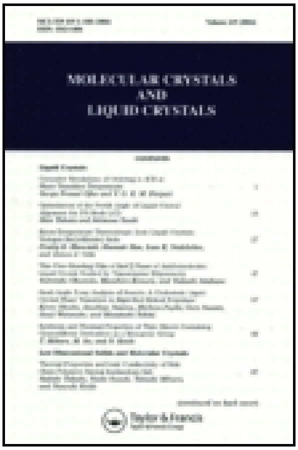
MOLECULAR CRYSTALS AND LIQUID CRYSTALS

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

A Bistable Twisted Nematic Mode for a Reflective Liquid Crystal Display with One Polarizer

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Version of record first published: 04 Oct 2006

Mol. Cryst. Liq. Cryst., 1999, Vol. 331, pp. 367-374
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A bistable twisted nematic (BTN) mode for a reflective liquid crystal display with one polarizer is proposed. In this configuration, an excellent bistable switching between the bright and the dark states can be achieved in a driving scheme with the data signal in addition to the reset and the selection voltages. Three types of BTN cells in a reflective configuration are studied to evaluate their electro-optic (EO) characteristics. The reflective BTN cell with a retardation film whose optic axis is perpendicular to the rubbing direction is found to be the best one among the three cells.

Keywords: bistable twisted nematic; reflective display; retardation film

INTRODUCTION

Since the main concept of the bistable twisted nematic (BTN) structure was proposed a decade ago[1], it has been recently demonstrated that an electro-optic (EO) device can be constructed in a BTN structure for practical applications[2]. In the BTN structure, an EO switching between two metastable states is achieved. The BTN structure can be produced using a proper ratio of the cell thickness d to the natural pitch p in a homogeneously aligned geometry. The degree of twist Φ is governed by d as well as the amount of a chiral dopant which dictates p. When a relatively high electric field is initially applied and then switched off, a field-driven state becomes relaxed into one of two possible states which has the twist angle

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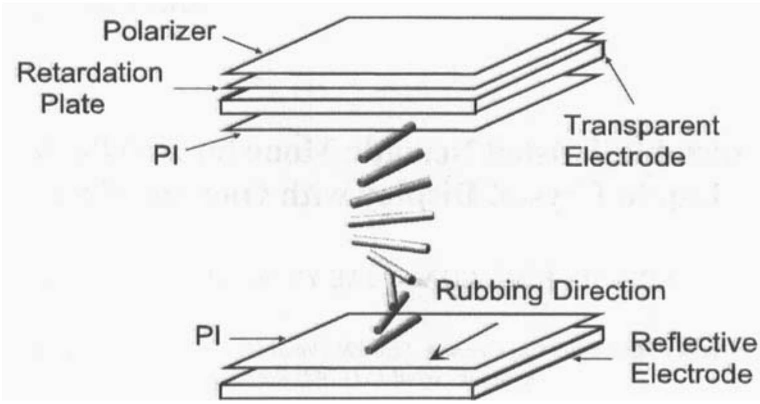

FIGURE 1 The structure of a bistable twisted nematic mode in a reflective configuration.

of either $\Phi - \pi$ or $\Phi + \pi$. The switching between the bright and the dark states is then obtained in a proper driving scheme. The EO properties of such BTN structure have been systematically studied as a function of the cell parameters[3] and temperature[4]. Most of BTN-based displays reported are operated in the transmissive mode.

We propose here a reflective type of a BTN display which comprises one polarizer and one optical retardation film. The BTN mode studied in a reflective configuration is shown in Fig. 1. A metal electrode was prepared on the inner side of the lower substrate to reduce parallax due to the thickness of the glass substrate[5–7]. An optically uniaxial retardation film attached on the upper substrate compensates the phase retardation experienced through the LC layer. The role of the retardation film is to transform a quarter-wave of the incident light into a half-wave for the reflected light from the mirror in the BTN cell. Thus, the retardation film enhances the contrast between the bright and the dark states of the BTN cell in the reflective configuration.

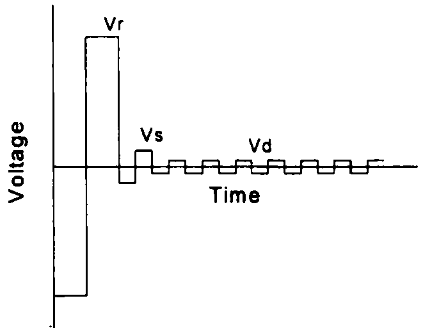

FIGURE 2 The driving voltage waveform for the BTN cell in the reflective configuration. V_r and V_s stand for the reset and selection voltages, respectively. The data voltage V_d is introduced for practical applications.

EXPERIMENTAL

Three different types of the BTN cells were studied in a reflective configuration. The BTN cells were made using indium-tin-oxide (ITO) and metal coated glass substrates. The polyimide (PI) of SE-3140 (Nissan Chemical Co.) was coated on both the ITO substrate and the metal electrode so as to promote planar alignment. The rubbing axes on the PI layers were antiparallel to produce stable 0-twisted and 2π-twisted states. The cell thickness was maintained by glass spacers of 2 μm. A chiral dopant was introduced into LC, and the doping concentration was adjusted to give d/p = 0.62. The LC and the chiral dopant used were ZLI-3700-100 (the birefringence Δn=0.098 and the dielectric anisotropy $\Delta\varepsilon$ = 5.4) and S-811 of E. Merck, respectively. A polarizer was oriented to make an angle of 45° with respect to the rubbing direction. One BTN cell has no retardation film, and the other two cells have a retardation film whose phase retardation is 140 nm. The optic axis of the retardation film attached to the cell is either parallel or perpendicular to the rubbing direction.

The three BTN cells were operated using the driving voltage waveform shown in Fig. 2. The driving waveform consists of the reset, the selection, and the data signals. The widths of the reset and the selection signals are 2 msec and 1 msec, respectively. A reset voltage V_r above the Fredericks threshold[8] was initially applied to orient the LC molecules along the direction perpendicular to the cell surface, and a selection voltage V_s was subsequently applied to the cell. With a proper combination of the two voltage signals, the initial π-twisted state can be transformed into the 0- or the 2π-twisted state. The magnitude of the selection voltage will determine which of the two states is favored. For example, the 0-twisted state will be produced under a relatively high selection voltage. A series of the data signals, V_d, that follow sequentially the reset and the selection voltages are introduced for practical applications. The magnitude of the reset voltage was fixed as 40 V, and the frame frequency of the driving waveform was 50 Hz. The amplitude of the data signal was varied from 0 V to 2 V in a step of 1 V. A He-Ne laser of 543.5 nm was used as a light source, and the reflected light intensity was measured through each BTN cell.

RESULTS AND DISCUSSION

In Fig. 3, the EO characteristics of a reflective BTN cell with no retardation film is shown as a function of the selection voltage. In this cell, the 2π-twisted and the 0-twisted states correspond to the bright and the dark states, respectively. Since the 2π-twisted state is optically isotropic, an excellent bright state can be achieved. However, in the 0-twisted state, there exists a leakage of light, resulting in low contrast, as shown in Fig. 3. The smallest reflection occurs at $V_d = 2$ V in the range we studied. Moreover, the reflected light intensity strongly depends on the amplitude of the data signal.

The critical value of the selection voltage at which one of two metastable states is favored decreases with increasing the data signal. For

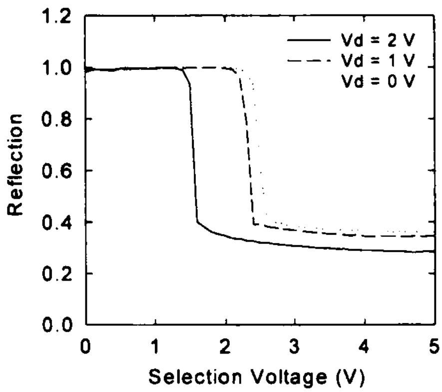

FIGURE 3 The reflected light intensities in the BTN cell with no retardation film as a function of the selection voltage. Solid, dashed, and dotted lines represent $V_d = 2$ V, 1 V, and 0 V, respectively.

practical applications, the data signal should be adjusted between the Fredericks threshold in the 0-twisted state and that in the 2π-twisted state. In our case, the calculated Fredericks threshold in the 0-twisted state is about 1.74 V. Above the Fredericks threshold, the LC molecules tend to orient along the direction perpendicular to the surface. In an optimized driving scheme, the minimum reflection will be achieved under the condition that the phase retardation through the cell corresponds to a quarter-wave of the incident light.

Figure 4 shows the EO characteristics of a reflective BTN cell with a retardation film whose optic axis is perpendicular to the rubbing axis. The case that the optic axis of the retardation film is parallel to the rubbing axis is shown in Fig. 5. In contrast to the BTN cell with no retardation film, the 0-twisted and the 2π-twisted states correspond to the bright and the dark states, respectively. Since the Fredericks threshold in the 2π-twisted state is higher than the data signal, the dark state becomes nearly independent of the data signal. The bright state, however, depends weakly

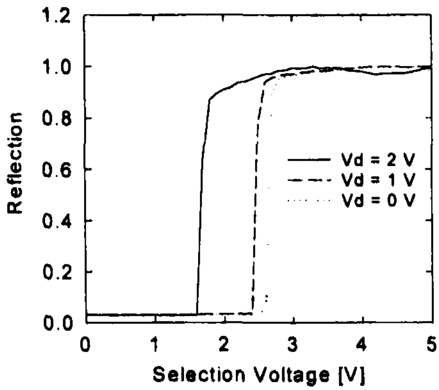

FIGURE 4 The reflected light intensities in the BTN cell with a retardation film of 140 nm whose optic axis is perpendicular to the rubbing axis. Solid, dashed, and dotted lines represent V_d = 2 V, 1 V, and 0 V, respectively.

on the data signal because of the Fredericks-like molecular reorientation caused by the data signal. In general, the reflected light intensity through the BTN cell with a retardation is almost independent of the data signal but the critical value of the selection voltage still depends on it.

In a reflective BTN cell with a retardation film whose optic axis is parallel to the rubbing direction, the EO characteristics exhibit rather strong dependence on the data signal. In this case, an extra phase retardation of 2π comes through the whole cell compared to the above case because the optic axes of both the LC and the retardation film coincide. Under the assumption that a perfect 0-twisted state involves no twist at all, the phase retardations of 0 and 2π will produce the same optical effect. In the presence of the chiral dopant giving $d/p = 0.62$, however, the molecular director becomes twisted throughout the cell. In the 0-twisted state of such BTN structure, the pitch is long enough to produce the waveguiding effect. This waveguiding effect produced in the 0-twisted state is mainly

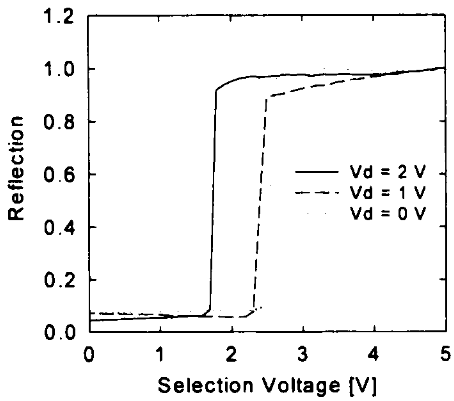

FIGURE 5 The reflected light intensities in the BTN cell with a retardation film of 140 nm whose optic axis is parallel to the rubbing axis. Solid, dashed, and dotted lines represent $V_d = 2$ V, 1 V, and 0 V, respectively.

responsible for the difference between the perpendicular and the parallel orientations of the retardation film.

It may be then concluded that the reflective BTN cell with a retardation film whose optic axis is perpendicular to the rubbing direction is the best one among the three cells we studied. Both the bright and the dark states were found to be quite insensitive to the data signal. In this case, a more flexible driving scheme will be adapted and a stable switching will be achieved.

CONCLUDING REMARKS

We have developed a reflective type LC display (LCD) in a BTN configuration with a mirror electrode and a single polarizer. In this configuration, an excellent EO switching between the bright and the dark states can be achieved in a driving scheme with the data signal in addition to the reset and the selection voltages. In an optimized reflective configuration with a retardation film, the BTN cell will give high contrast and brightness. Moreover, the BTN structure is expected to provide better viewing and response characteristics than a conventional twisted nematic structure. Further studies on the driving scheme for the BTN structure will lead to the development of high performance reflective LCDs.

Acknowledgements

This work was supported in part by Ministry of Education of Korea through BSRI-98-2415.

References

[1] D. W. Berreman and W. R. Heffner, *J. Appl. Phys.* **52,** 3032 (1981).
[2] T. Tanaka, Y. Sato, A. Inoue, Y. Momose, H. Nomura, and S. Iino, *Proc. Asia Display 95,* 259 (1995).
[3] H. S. Kwok, *J. Appl. Phys.* **80,** 3687 (1996).
[4] Y. J. Kim, S.-M. Park, S.-W. Suh, and S.-D. Lee, *Proc. Eurodisplay 96,* 337 (1996).
[5] S.-T. Wu and C.-S. Wu, *Appl. Phys. Lett.* **68,** 1455 (1996).
[6] C.-L. Kuo and C.-K. Wei, *Proc. Eurodisplay 96,* 387 (1996).
[7] T. Uchida, T. Nakayama, T. Miyashita, M. Suzuki, and T. Ishinabe, *Proc. Asia Display 95,* 599 (1995).
[8] P. G. de Gennes and J. Prost, *The Physics of Liquid Crystals* (Clarendon, Oxford, 1993).