Fabrication of cholesteric LCD using the IPS switching

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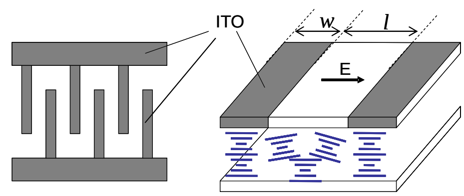
Abstract
In the paper we have proposed a fabrication method for color reflective cholesteric LCD by an in-plane switching. By applying an in plane electric field, the cholesteric helix could be partially unwound, which lead to shift of selective reflection and exhibition of color change.

1. Objectives and Background
Cholesteric liquid crystal (ChLC) displays have attracted a lot of interest from liquid crystal industry due to their many promising applications such as e-papers and PDAs [1,2]. Selective reflection and bistability are the key elements to achieve the above applications. Unlike the conventional nematic LCDs, the selective reflection allows one to fabricate ChLC displays without polarizers and color filters. It is also known that planar and focal-conic states are stable in ChLC cells in the absence of the electric field [3-6]. When the ChLC is in the planar state, the helical axis is normal to the substrates and the liquid crystal selectively reflects light incident on the ChLC cell. In focal-conic state, randomness of helix axes of ChLC scatters light, resulting in dark state using black background in reflective mode.

To improve the viewing angle in large-size LCDs, the in-plane switching (IPS) mode has been used [7-9]. The electric field applied in the plane of substrates switches liquid crystal directors to be in-plane Briefly describe the goals of your work, and give background information.
Earlier in 1960s, electric-field-induced color change in ChLC cell was reported [10-13]. Elongation of helical pitch by an application of electric field perpendicular to the helical axis was responsible for the apparent color change in the cell. Recently, the ChLCD incorporating IPS mode for visible and IR application has been studied [14].
In this paper we utilize an in-plane switching in the cholesteric liquid crystal displays, and investigate the electro-optical response of the IPS-ChLCD cell.

2. Experimentals
ChLC mixture used in this experiment was a mixture of ZLI-6000-100 (Merck, n_o=1.5082, n_e=1.6589) and chiral additive S-811 (Merck Co.). The resulting liquid crystal mixture with chiral additive (~28wt%) appeared greenish at ambient light. Reflection peak wavelength at zero field is about 530nm in the planar state.
To apply in-plane electric field, we devised a comb-shaped ITO (Indium Tin Oxide) pattern on glass substrates as shown in Fig. 1(a). The width of ITO electrode w is about 7 μm and the distance between electrodes l is about 43 μm.



(a) (b)

FIG.1. Schematic of (a) interdigital electrode and (b) IPS ChLCD cell. Alignment layers on both substrates are not shown in (b).

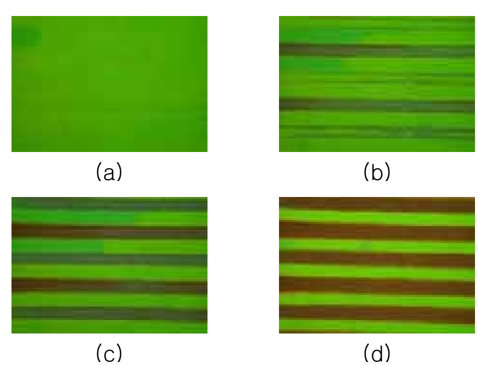


FIG.2. Microphotographs of IPS ChLCD cell at different applied voltages: (a) 0V, (b) 60V, (c) 120V, and (d) 200V respectively

Further, glass substrates coated with ITO were treated with PVA(poly vinyl alcohol) and rubbed using velvet cloth to induce homogeneous alignment. A pair of ITO-patterned glass and bare glass was assembled in a sandwich cell as illustrated in Fig. 1(b). The thickness of the cells was about 7 μm. The ChLC cell was capillary filled in the isotropic phase. After filling, the ChLC cell were slowly cooled to the room temperature, at which all the experiments were carried out.

We investigated the electro-optical effects of the cells in a microscope equipped with polarizers. The reflectance was measured by using an Ocean Optics

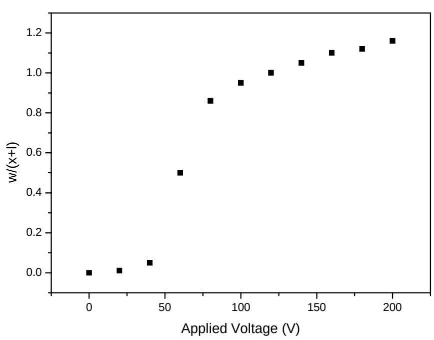


FIG.3. Width of dark stripe *x* as a function of applied voltage.

S2000 UV-Vis spectrometer connected to the microscope by a single mode optical fiber.

3. Results and Discussion

Figure 2 shows microphotographs of an IPS ChLCD cell at different in-plane voltages. Non-planar textures (either focal-conic or homeotropic) were observed in the ITO electrode areas, where the electric field is perpendicular to the cell substrates. In these regions, the vertical electric field on top of ITO electrodes drives cholesteric liquid crystal to switch planar to focal-conic (or homeotropic) states by reorienting the helical axis. Since neither focal-conic nor homeotropic textures are capable of selective reflection, rather dark stripes on the ITO electrode were observed in the cells by optical microscope with crossed polarizers, as shown in Fig. 2. In addition to the ITO area, a narrow region adjacent to ITO electrode switches to the non-planar texture as the voltage increases. As a result, the dark stripes grew wider with increasing voltage as shown in Fig. 3. Aside from the characteristics of textural change, the width of dark stripes was collected from microphotographs of IPS ChLCD cell at different voltages. The ratio of dark-stripe width (*x*) to ITO pattern width ($w + l \approx 50\ \mu\text{m}$) grew faster at lower voltages, because the vertical rather than in-plane field reorients the LC molecules, switching from planar to focal-conic state.

Figure 4 shows reflectance of the cell at different voltages. The peak wavelength of reflection shifted to higher wavelength as the in-plane voltage increases up to V=200 V. That is in consistent with the previously reported "redshift" effect [14] that features continuous color change as an applied voltage increases. If we estimate the electric field induced pitch elongation by using R.B. Meyer's formula [6] that relates peak wavelength and applied voltage:

$$\lambda = \lambda_o (1 + \alpha V^4) \qquad (1)$$

with

$$\alpha = \varepsilon_o^2 \Delta\varepsilon^2 P_o^4 / 32(2\pi)^4 K_{22}^2 l^4 \qquad (2)$$

where λ_o is peak wavelength at the zero voltage, P_o is helical pitch and K_{22} is the twist elastic constant of the cholesteric LC mixture. Using the parameters of our cholesteric mixture, we roughly obtain at *V*=200 V and *l*=43 μm [6]. As a result, we expect that the shift of peak wavelength should be in the range of 0~32 nm when we apply voltage 0~200V. However, in our experiment, peak wavelength shift was not conspicuous.

At *V*=0V, the reflectance at peak wavelength is slightly higher than 50% because of additional reflectance at glass-air interface at normal incidence. Figure 4 also shows that the reflectance of the cell decreases as an applied voltage increases. That is consistent to the fact that non-reflecting regions in the cell increase with increasing voltages, as seen in photos of Fig. 2.

4. Summary

In this work, we have proposed a fabrication method for color reflective cholesteric LCD by an in-plane switching. By applying an in plane electric field, the cholesteric helix could be partially unwound, which lead to shift of selective reflection and exhibition of color change.

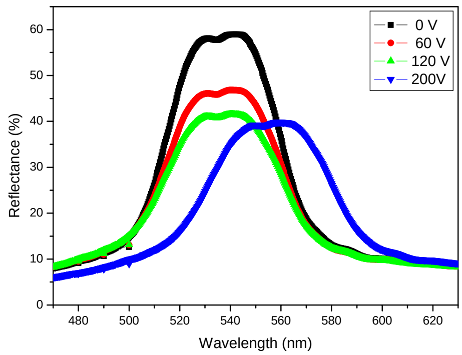


FIG. 4. Reflectance spectrum of IPS-ChLCD cell

5. Acknowledgements

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6. References

[1] S.-T. Wu and D.-K. Yang, Reflective Liquid Crystal Displays (John Wiley & Sons, New York 2001).

[2] P.S. Drazic, Liquid Crystal Dispersions, (World Scientific, Singapore, 1995).

[3] D.-K. Yang, J.L. West, L.-C. Chien, and J.W. Doane. J. Appl. Phys. 76, 1331 (1994).

[4] J.L. West, R.B. Akins, J. Francl, and J.W. Doane. Appl. Phys. Lett. 63, 1471 (1993).

[5] Y. Kim, J. Francl, B. Taheri, and J.L. West, Appl. Phys. Lett. 72, 2253 (1998).

[6] K.S. Kwon and D. Kang, Journal of Information Display, 6, 8 (2005).

[7] M. Oh-e and K. Kondo, Appl. Phys. Lett. 67, 3895 (1995).

[8] C.J. Yu, J.H. Kim, and S.D. Lee, Jpn. J. Appl. Phys. 41, 5298 (2002).

[9] R. Kiefer, B.Weber, F. Windscheid, and G. Baur, Pro. Jpn. Display 92, 547 (1992).

[10] W.J. Harper, Mol. Cryst. 1, 325 (1966).

[11] J.R. Hansen and R.J. Scheneeberger, IEEE Trans. Electron Devices 15, 896 (1968).

[12] F.J. Kahn, Phys. Rev. Lett. 24, 209 (1970).

[13] R.B. Meyer, App. Phys. Lett. 12, 281 (1968).

[14] H. Xianyu, S. Faris, G.P. Crawford, Applied Optics 43, 5006 (2004).