Photo Spacer Induced Bistable Mode Plastic PSFLCDs for High Mechanical Stability

Yu-Jin Kim, **Seo-Kyu Park, Soon-Bum Kwon**
School of Display Engineering, Hoseo University, Baebang-myun, Asan-shi, Chungnam, 336-795 Korea
Ji-Hoon Lee, Ock-Soo Son, Tong-Kun Lim
Department of Physics, Korea University, Anam-dong, Seongbuk-Gu, Seoul, 136-701 Korea

Abstract

We report new polymer stabilized ferroelectric liquid crystal (PSFLC) cells with mechanical stability which is achievable by introducing photospacers in the cells. It was found that the mechanical stability of the PSFLC cell was effected by introduction of photo spacers. We analyzed the dependence of mechanical stability and memory property on the density of photospacers in the PSFLC cell. The stability and memory properties of PSFLC Cells depending on photospacer density are discussed.

1. Introduction

Recently, flexible displays have attracted much attention because they have remarkable advantages: thinner, lighter, non-breakable and conformable features. Flexible displays have various potential applications such as e-book and e-paper displays utilizing the distinct features.

E-book and E-paper displays demand very low power consumption, so that bistable memory liquid crystal modes are required in case of flexible plastic LCDs for those application. Three kinds of memory LC modes have been developed; bistable nematic, bistable cholesteric and bistable FLC. Among them SSFLC as one of bistable FLC has big advantages such as low driving voltage, wide view angle and fast response time, SSFLC cells are, however, very weak against mechanical shock.

Polymer stabilized FLC (PSFLC) has been developed to overcome the poor mechanical stability of SSFLC. PSFLC was known to have network structure that FLCs are oriented with smectic layer ordering in polymer network. The polymer network stabilizes the FLC orientation, which leads to improvement of mechanical stability of PSFLCD. A lot of studies have been done for the application of PSFLC to flexible LCDs.[1~12] However, it should be noted that PSFLC does not have sufficient mechanical stability for the particular applications such as smart card LCD, where LCD is highly bendable.

Bead spacer was mainly used to maintain cell gap of conventional PSFLCDs. But the spacer density of it is not locally uniform in the cell, so that it is generally difficult that the PSFLCDs with bead spacers show sufficient mechanical stability.

In order to more improve the mechanical stability of PSFLCDs, we introduced photospacers into PSFLCDs. In this paper, we describe the improvement of mechanical stability by introducing photospacers into PSFLCDs.

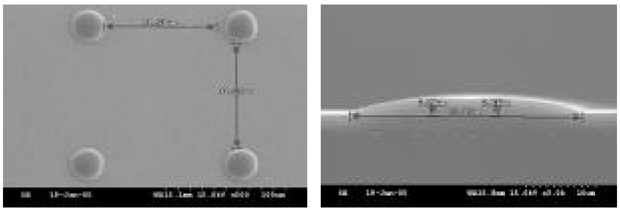
2. Results

We fabricated the PSFLC cells to investigate mechanical stability. We used polycarbonate film as a plastic substrate and a commercially available FLC, FELIX-018/100(Clarient). The FLC was injected into the cells at isotropic phase temperature, 110℃ in vacuum chamber. A PI(Chisso) suitable for FLC alignment was used. We rubbed the alignment layer anti-parallel and set cell gap 2.0 um. In order to form polymer networks we used reactive monomers, 1,9-nonane dithiol and triallyl-1,3,5-triazine-2,4,6(1h, 3h, 5h)-trione (Sigma-Aldrich). High pressure mercury lamp with intensity of 40mW was used for polymerization. The exposure time was 10 min. Negative type photoresist was used to make photospacers, the density of which was varied.

Figure 1 shows one type of photospacer formation structure, which was mainly used in this experiment. The uniform profile of photospacers was achieved as we designed; spacer distance = 100μm, spacer diameter = 33.1 μm, spacer height = 2.04 μm.

In order to evaluate the mechanical stability, we measured electrooptical properties of PSFLC cells with change of bending radius.

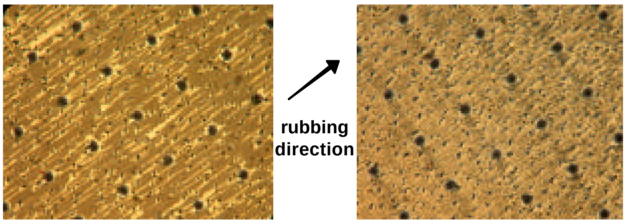
Figure.2. shows the Polarizing Optical Microscope (POM) texture of the FLC cell at both initial unbent state and highly bent state. The cell was bent in the rubbing direction and the bending radius of bent cell was 24mm.



(a) (b)

Figure 1 Scanning electron microscope photograph of the photospacer. (a) Top view (b) cross-sectional view

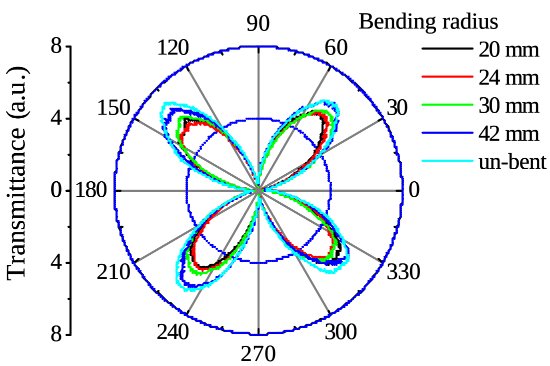
After the PSFLC cell was bent, the liquid crystal orientation state changed, particularly along the line perpendicular to bending direction.



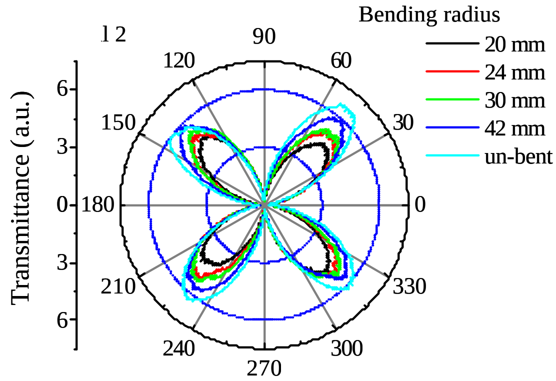
(a) (b)

Figure.2. POM textures of the cell at unbent state (a) and bent state with the bending radius of 24mm (b).

In order to analyze the influence of LC orientation change on optical properties of PSFLC cells, we measured transmittance change of the cells before and after bending. Figure 3 shows transmittance of PSFLC cells of different photospacer density with rotation of crossed polarizers for various bending condition. The numbers wrote around circle mean the angles between rubbing direction and polarizer direction. The distance between the measured point and center is proportional to transmittance.



(a)



(b)

Figure 3 Transmittance of PSFLC cells of different photospacer density with change of bending condition: (a) photospacer formed as shown in Figure 2, (b) photospacer density is 1/3 of that in case (a).

As the PSFLC cells were bent, the maximum transmittance decreased. The change of maximum transmittance is high for strong bending and it decreases photospacer density increases as shown in Figure 3 (a) and (b). It should be noted that minimum transmittance did not change.

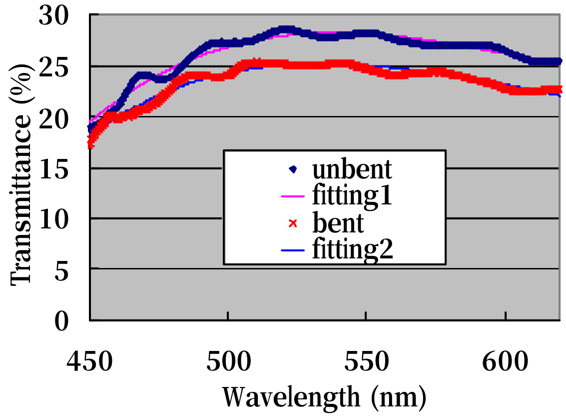
In order to analyze the above experimental results, we assumed that the transmittance of PSFLC cell is the same as that of typical ECB cell as follows;

$$T = \langle 1/2 \sin^2(2\theta) \sin^2(\pi \Delta nd/\lambda) \rangle \quad (1)$$

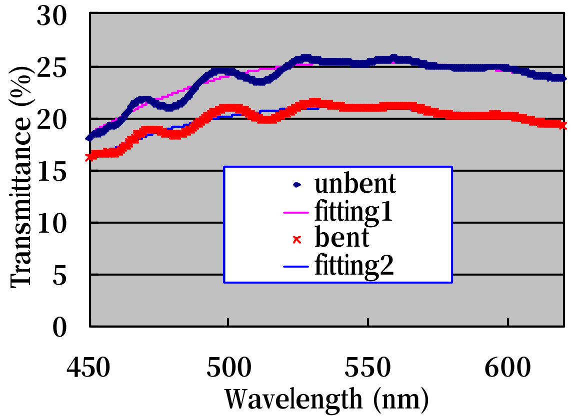
, where θ is the angle between LC director and polarizer angle and Δnd is the effective retardation of liquid crystal layer. The bracket means the spatial average.

No change of minimum transmittance implies no change of azimuthal orientation of liquid crystals after bent, namely $\langle \sin^2(2\theta) \rangle$ does not change after bent. Then, the change of maximum transmittance means the change of retardation of liquid crystal cells. It is considered that the retardation change is caused by the change of tilt orientation of liquid crystals if there is no change of azimuthal orientation of liquid crystals.

To estimate the change of the retardation of PSFLC cells after bent, we measured transmittance spectrum of the cells and that was fitted by the theoretical transmittance, equation (1). The Figure 4 shows the curve fitting of theoretical and measured transmittance spectrum of the PSFLC cells with two kinds of photo spacer density, which is described in Figure 3, before and after bent.



(a)



(b)

Figure 4 The curve fitting of theoretical and measured transmittance spectrum of the PSFLC cells with two kinds of photo spacer density before and after bent. The photo spacer densities of sample (a) and (b) are the same as those of Figure 3 (a) and (b).

The effective retardation of the samples (a) and (b) were calculated from the wavelength where fitted theoretical transmittance spectrum shows the maximum transmittance. The effective retardation of samples (a) and (b) before and after bent were calculated; 538nm and 534nm for unbent and bent sample (a), 552nm and 541nm for unbent and bent sample (b). Thus, the retardation change rate before and after bent in the samples (a) and (b) were calculated as 0.9% and 1.9%.

These results imply the retardation change, namely orientational deformation of liquid crystals, after bent is decreased as photospacer density increase. The change rate is rather small in photo spacer induced PSFLC cells. It is much smaller than that of bead spacer used PSFLC cells.

We measured the memory property of PSFLC cells with photo spacer. The multi-stability property was achieved in the photo spacer induced PSFLC cells as shown in Figure 5. It is concluded that photo spacer does not disturb the multi-stable memory property even for the high spacer density.

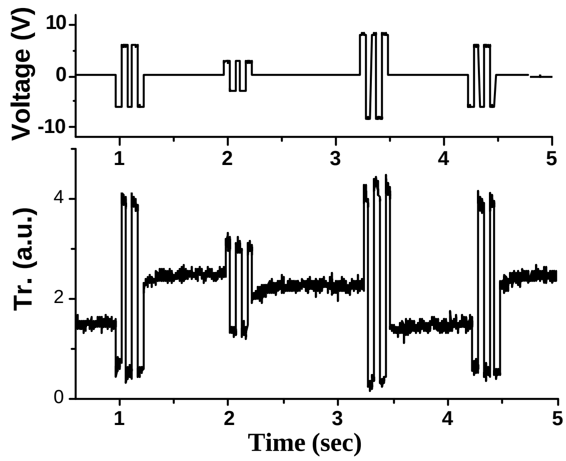


Figure.5. Multi-stable memory property of the photo spacer induced PSFLC cell.

3. Conclusion

We found that the mechanical stability of the PSFLC cell was enhanced by the introduction of photospacers. It is more improved as the photo spacer density increase. The optimum photospacer density can be decided by investigating the memory effect and LC filling processibility in detail. This investigation is in process.

4. References

[1]Y. Miyazaki, H. Furue, T. Takahashi, M. Shikada, and S. Kobayashi, Mol. Cryst. Liq. Cryst. 364, 491 (2001).

[2]J. Xu and S. Kobayashi, Jpn. J. Appl. Phys., Part 2 **41**, L651(2002).

[3]H. Furue, T. Miyama, Y. Iimura, H. Hasebe, H. Takatsu, and S. Kobayashi, Jpn. J. Appl. Phys., Part 1 **36**, 1517 (1997).

[4]H. Fujikake, K. Takizawa, H. Kikuchi, T. Fujii, M. Kawakita, and T. Aida, Jpn. J. Appl. Phys., Part 1 **36**, 6449 (1997).
[5]H. Sato, H. Fujikake, Y. Iino, M. Kawakita, and H. Kikuchi, Jpn. J. Appl. Phys., Part 1 **41**, 5302(2002).
[6]C. A. Guymon, L. A. Dougan, P. J. Martens, N. A. Clark, D. M. Walba, and C. N. Bowman, Chem. Mater. **10**, 2378 (1998).
[7]D. T. McCormick, R. Chavers, and C. A. Guymon, Macromolecules **34**, 6929 (2001).
[8]C. A. Guymon, E. N. Hoggan, N. A. Clark, T. P. Rieker, D. M. Walba, and C. N. Bowman, Science **275**, 57(1997).
[9]J. Lub, D. J. Broer, M. E. M. Antonio, and G. N. Mol, Liq. Cryst. **24**, 375 (1998).
[10]R. A. M. Hikmet and J. Lub, Prog. Polym. Sci. **21**, 1165(1996).
[11]H. Sato, H. Fujikake, H. Kikuchi and T. Kurita, Jpn. J. Appl. Phys., Part 2 **42**, 476(2003).
[12]Ji-Hoon Lee and Tong-Kun Lim, J. Appl. Phys., **97**, 1 (2005).