# Optimized electrode design to improve transmittance in the Patterned Vertical Alignment Liquid Crystal Display

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## Abstract

*Patterned vertical alignment (PVA) mode requires multi-domain to exhibit wide viewing angle whereas the transmittance is sacrificed. To overcome the demerit, a fine pattern was formed at folded region in PVA Z-shape electrode structure. In the present work fine patterns were formed near domain boundary regions where the unwanted field direction which causes the LC to tilt down in unwanted direction exists. Thereby transmittance is improved near those fine patterns. This method is very simple and more cost-effective process than the other methods. In this article, we show the method of fine pattern formation and its influence on LC molecule in PVA mode with Z-shape electrode structure.*

## 1. Introduction

Display market in the fields of mobile phone, note book, monitor, TV etc is keen on developing display devices which have more light, more slim and more clear images to meet the customers requirements. Fall into step with this tendency, demand for the flat panel display is increasing in recent years. TFT-LCD in comparison with the other FPDs, has the advantage of high resolution, ultra light, ultra slim, low power consumption. But TFT-LCD has chronic problems like low transmittance, lake of uniformity contrast ratio and color characteristics with respect to viewing angle. Though the use of back light unit or color filters may increase the transmittance, these techniques were found to be unfavorable on the basis of cost-effectiveness. Among variable modes of TFT-LCD, TN mode[1)] and FFS mode[2, 3)] are definitely superior to the others like VA mode[4-6)] which shows low transmittance compared with former. At Fig. 1, in case of PVA Z-shape, transmittance is lower than single domain VA mode because pattern on electrode for forming multi-domain generate a collision between LC molecules. So these patterns have bad influence on transmittance.

Since the increase of transmittance in TFT-LCD is cost dependent factor improving transmittance is so important in the current competitiveness in the field of display devices. In this paper, we suggest a new pixel structure which improves transmittance but keeps the same cost.

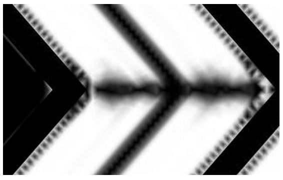


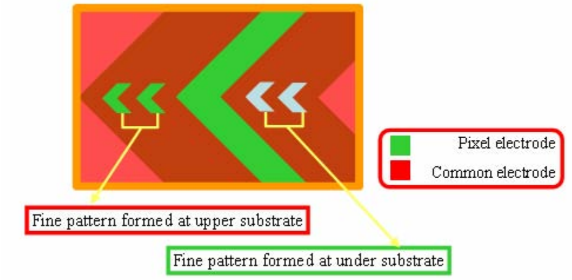
**Fig. 1. Disclination of PVA Z-shape structure caused due to transmittance decrease.**

## 2. Experimental

Simulation conditions followed in the present study uses liquid crystal ($\Delta\varepsilon$ = -4.2 and $\Delta n$ = 0.079). Cell gap is 4.0 $\mu m$.

Fig. 2 is a comparison of data between normal Z-shape electrode structure and fine patterned Z-shape electrode structure for increasing transmittance. Locations of fine patterns are different according to in-side or out side of common electrode slit at the boundary region. Fine patterns are formed in pixel electrode at in-side of common electrode slit at a boundary region and in common electrode at out-side of common electrode slit at a boundary. Shapes of all fine patterns are same as the folded electrode shape and the angle of these patterns is ±45° in horizontal direction. Detailed condition of fine patterns is discussed in our next article. Proposed electrode structure is very simple and needs no additional process for increasing transmittance.

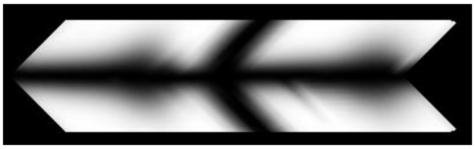
(a) conventional structure



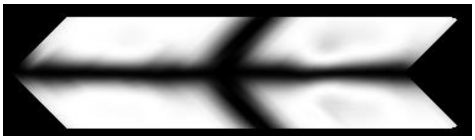

(b) new structures

**Fig. 2. Comparison of data between normal Z-shape electrode structure and fine patterned Z-shape electrode structure for increasing transmittance.**

Fig. 3 is the result of 3-dimension simulation. Fig. 3 (a) show maximum transmittance of PVA mode and Fig. 3 (b) show maximum transmittance of fine patterned PVA mode. It is show that region of transmittance is broaden than that of conventional structure.



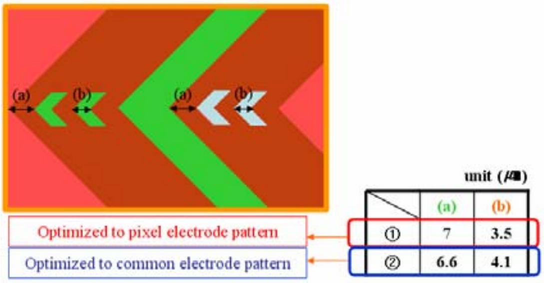
(a) conventional



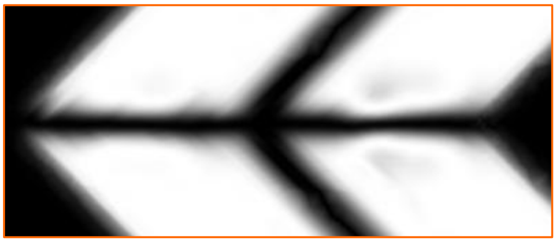
(b) new structure

**Fig. 3. Comparison of disclination width between two pixel. Above is conventional Z-shape and bottom is improved Z-shape.**

In Fig. 4, Fig. 4 (a) shows the numerical value of interval and width of optimized fine pattern. Fig. 4 (b) shows that maximum transmittance of fine patterned electrode structure with above condition. Fine pattern's width and interval formed at pixel electrode are 3.5 ㎛ and 7.5 ㎛, respectively. And width and interval of fine patterns formed at common electrode are 4.1 ㎛ and 6.6 ㎛, respectively. Also the height of all fine patterns are uniformly 10 ㎛ and the optimized fine pattern condition is the same for all the cells irrespective of pixel size. With these optimized fine patterns conditions are satisfied, collisions region of LC molecules are minimized and with maximized transmittance.




(a) Electrode structure



(b) Simulation result

**Fig. 4. Interval and width of fine pattern were optimized at common and pixel electrode**

Fig. 5 is the analysis data of LC molecule movement according to fine pattern's size. Fig. 5 (a) shows LC molecule's movement in case of no fine pattern. In this case, Collision region of LC molecular is broadening at domain boundary region. Fig. 5 (b) shows LC molecule's movement when optimized fine pattern was formed at domain boundary region. In case of latter, width of disclination is significantly decreasing and from this, we know that electro field direction generated by fine pattern has an effect on LC molecules. Also it explains that principle of increasing transmittance is influenced by fine patterns. In other words, when voltage is applied to pixel electrode and then electric field is occurred, the regions with domain to domain boundary do not have field direction as wanted due to the inevitable shape of electrodes. Fine pattern formed at pixel electrode hold the electric field generated from common electrode. So electric field near domain to domain boundary is stronger as expected in the desired direction. The fine pattern formed at common electrode helps to generate stronger electric field. Thus former is collecting the electric field and latter is emitting the electric field.

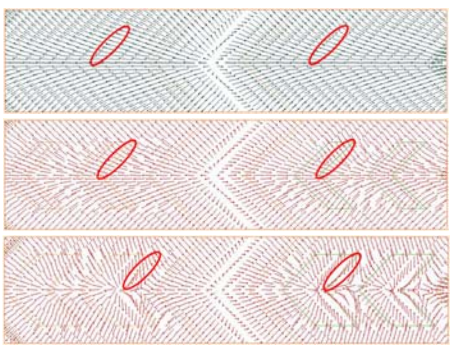



**Fig. 5. Comparison of LC director according to pattern width and interval.**

Fig. 6 is the Electro field formation by fine pattern. The above principle of working can be clearly understood from Fig. 6. Fine patterns on pixel electrode generate strong electro field which has the angle of 45° in horizontal direction. And Fine patterns on common electrode hold electro field which has the angle of 45° in horizontal direction.

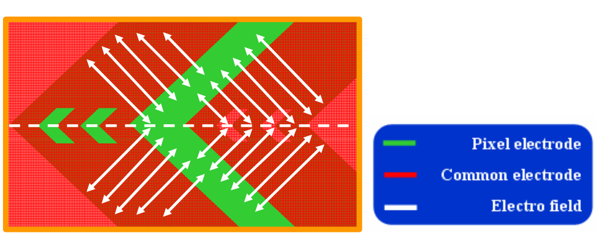
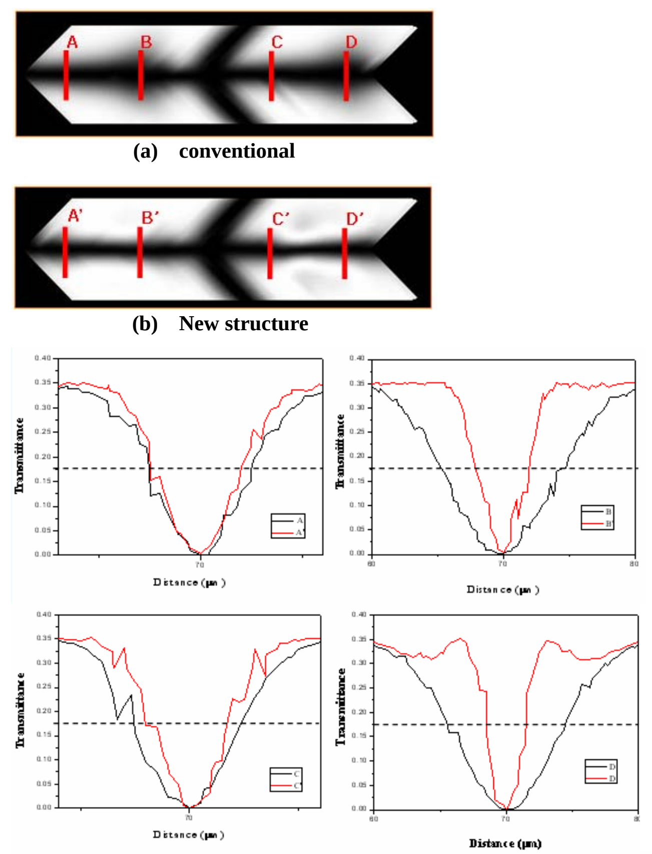



**Fig. 6. Electric field formation by fine pattern.**

## 3. Results and discussion

The result of our simulation showed that the collision region of LC molecule is decreased and hence transmittance is increased at pixel formed with optimized fine pattern. The effect of fine pattern on pixel structure is analyzed with more detailed numerical value as shown in Fig. 7 and Fig. 8.

Fig. 7 is the comparison of data between before and after the fine patterning. In this the thinnest region is compared with most thick region of domain to domain boundary region of disclination. As you see the graph, transmittance is increasing about 10~20% at most thin disclination region and increasing about 60~70% at most thick disclination region.




• graph width at Y = 0.175 (μm)

| | |
|---|---|
| A | 5.02 |
| A' | 4.46 |

| | |
|---|---|
| B | 9.13 |
| B' | 4.04 |

| | |
|---|---|
| C | 4.89 |
| C' | 3.73 |

| | |
|---|---|
| D | 8.88 |
| D' | 2.96 |

11% improved 55.8% improved 23.7% improved 66.6% improved

**Fig. 7. Comparison of disclination width between A, B, C, D and A', B', C', D'.**

Also Fig. 8 shows the comparision of data for conventional and new structures for β which is angle between polarization axis and LC directors in range of 7 μm with respect to mid-disclination region. Pixel with fine pattern has a high β value of 45˚ compared to conventional structure. Because of this pixel with fine pattern the new structure shows greater transmittance than that of conventional one.

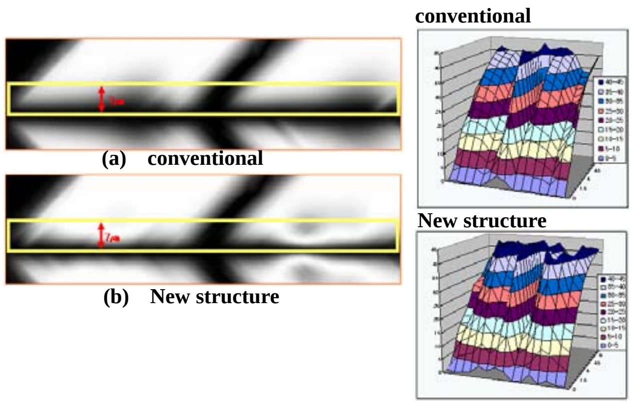



**Fig. 8. Angle (β) between polarization axis and LC directors were compared with each other within the 7 ㎛ range from mid-area**

Fig. 9 is the scheme about increasing transmittance. It shows that the transmittance is increased by 18% when the range from mid-disclination to up and down is 20 ㎛.

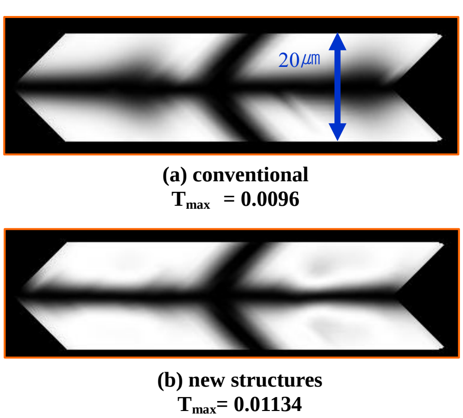



**Fig. 9. Calculated transmittance in (a) conventional and (b) new PVA structures.**

## 4. Conclusion

A new PVA structure with fine pattern was proposed and it showed improvement of transmittance by 18% near domain-collision regions by allowing the LC director to tilt down in more diagonal directions. This method could be completed without any additional process.

## Acknowledgments

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## 5. References

1 M. Schadt and W. Helfrich, *Appl. Phys. Lett.* Vol. 18, 127 (1971).
2 S. H. Lee, S. L. Lee, and H. Y. Kim, *proceeding of the Asia Display,* 1998, p. 371.
3 S. H. Lee, S. L. Lee, and H. Y. Kim, *Appl. Phys. Lett.* Vol. 73, 2881 (1998).
4 K. H. Kim, K. Lee, S. B. Park, J. K. Song, S. Kim and J. H. Souk, *proceeding of the Asia Display,* p. 383 (1998).
5 A. Takeda, S. Kataoka, T. Sasaki, H. Chida, H. Tsuda, K. Ohmuro, T. Sasabayshi, Y. Koike, and K. Okamoto, *Dig. Tech. Pap. Society for Informaion Display Int. Symp*, p. 1077 (1998).
6 Y. Yamada, K. Miyachi, M. Kubo, S. Mizusima, Y. Ishii, and M. Hijikigawa, *IDW '02,* p. 203 (2002).
7 S. S. Kim, B. H. Berkeley, K-H. Kim, J. K. Song, *Journal of the SID,* Vol. 12, No. 4, p353 (2004).