Improvement of IPS Mode Structure using Fast Q-tensor Method

Hyunchul Choi*[a], Joun-Ho Lee[a], Seong-Wook Choi**[b], Jin-Seok Yang**[b], and Gi-Dong Lee[b]

Abstract

IPS and VA have evolved in various structures such as H-IPS, AS-IPS, and S-PVA gain more competitiveness. The new pixel structures inherently have more domains which cause disclination areas. The effect of disclination is no longer neglected in those structures. A new simulation tool based on FAST Q-tensor method enables one to predict the shape of disclinations and the resulting optical properties. It ensures more accurate results compared to vector-based simulation. We applied this simulation tool for the development of 26-inch wide monitor having H-IPS mode.

Keywords : H-IPS , disclination, fast Q-tensor

1. Introduction

LCD makers started with NBPC applications early in the 1980s. Monitor applications had kept LCD business attractive in the mid 90's. Recently LCD business are getting more and more focused in TV applications. However the challenge of PDP and competition between LCD technologies result in improving LCD performance. As a result, the pixel structure of LCD have been modified to achieve better performance. Fig. 1 shows the evolution of LCD modes .

In-plane-switching(IPS) has been changed into Horizontal (H) -IPS or Field Fringe Switching(FFS) for high aperture ratio whereas Vertical Alignment (VA) has been transformed to Super(S) -PVA which targets better viewing angle properties. Both changes have resulted in the introduction of more complicated pixel structures which consist of multi domains. For example, to compensate for the gamma distortion of off-axis images, S-PVA divides each pixel into two parts, constructing an 8-domain VA cell [2, 4].

Manuscript received January 10, 2007; accepted for publication June 15, 2007.
This work was supported by Dong-A University and Sanayi System Co., Ltd.
* Member, KIDS; ** Student Member, KIDS
Corresponding Author : Hyunchul Choi
[a] LG Philips LCD, 642-3 Jinpyung-dong, Gumi-city, Kyungbuk, 730-350, Korea
[b] Department of Electronics Engineering, Dong A University, Pusan 604-714, Korea
E-mail : chc4321@lgphilips-lcd.com

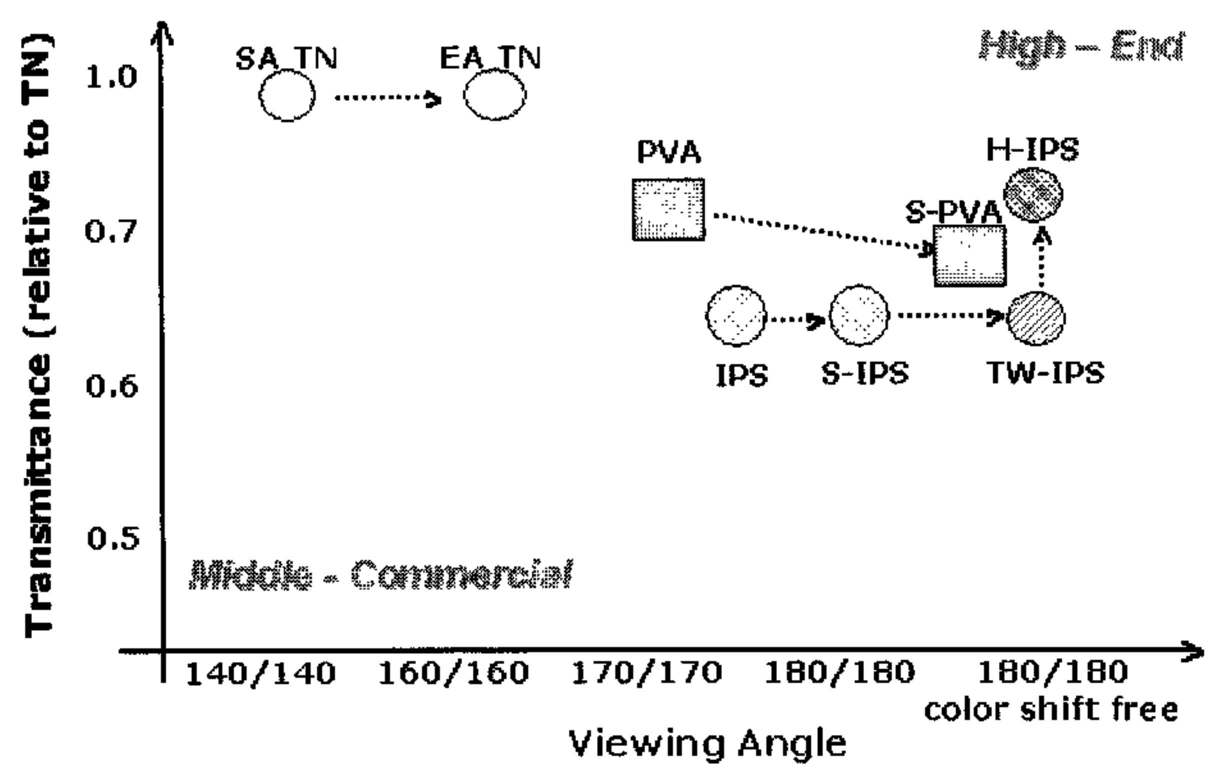


Fig. 1. History of LCD Mode.

True Wide (TW) -IPS was introduced enabling clear image for all directions including diagonal axis [3]. As the performance of LCD is improving the pixel structure has become more complicated, this may generate a lot of disclination areas. For example, wide viewing angle property is achieved by multi-domain structures, but the spatial LC director field generates disclinations because of high elastic distortion energy due to the multi-domain effect. Sometimes, disclinations cause the optical transmittance in a multi-domain LC cell to decrease. Therefore, it has become important to have a good understanding of the dynamic behavior of the LC director field for advanced LC modes such as H-IPS .

In this work, we investigated especially disclinations in the electrode's edge. Generally, LC dynamics are very unstable around the electrode edge so that unstable disclinations

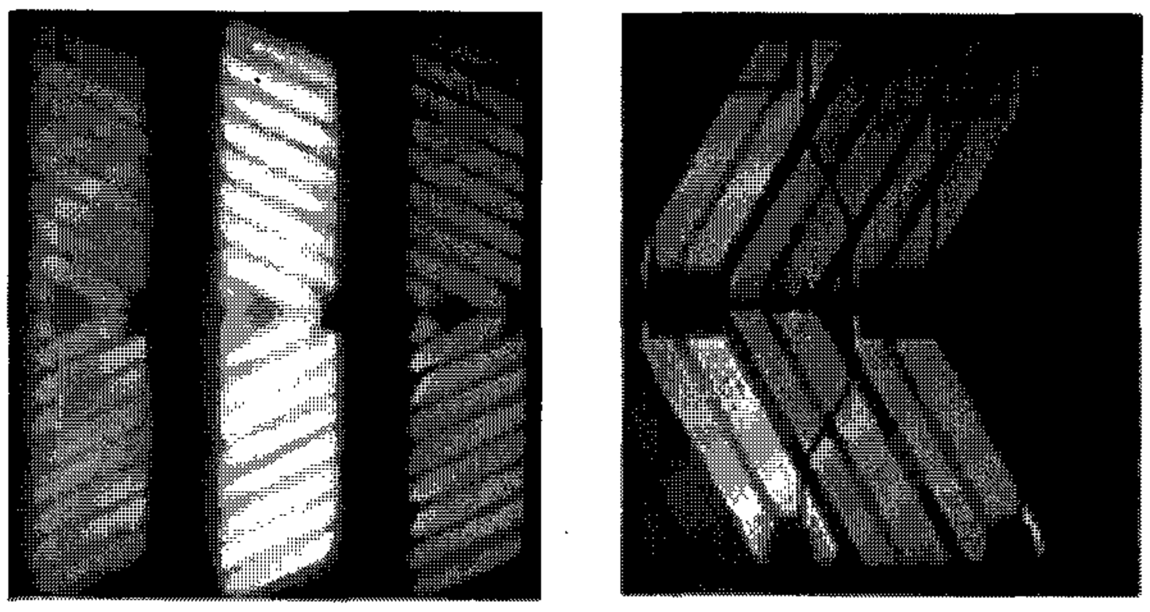


Fig. 2. H-IPS and S-PVA.

Fig. 3. Photographs of the generated defect cores around the edge of a H-IPS LC Cell; (a) the Vpp 8V. (b) the Vpp 10V

can be easily detected. To understand LC dynamics around the edge, we tested different electrode shapes. An advanced electrode shape which includes defect trap shows minimization of disclination resulting in transmittance increase.

2. Fast Q-tensor method

The fast Q-tensor method can model the defect dynamics in a liquid crystal director field as well as the electrical behavior of the LC director. Typically, the LC director's simulator is based on the Ossen-Frank vector representation. The Ossen-Frank vector representation has a limitation when it comes to defect explanation. Previous papers [5, 6] have discussed about the fast Q-tensor method. Dickman had reported that Ossen-Frank vector representation could go to the Q-tensor representation when we use only one 3rd order Q component [7].
The Gibbs free energy formulation is described as follows.

$$[f_g]_{Qjk} = \text{strain term}([f_g]_S) + \text{voltage term}([f_g]_V) + \text{temperature term}([f_g]_T) \quad (1)$$

In the fast Q-tensor method, the total energy density of the LC director consists of elastic energy term (fs), electric energy density (fe) and temperature energy density (ft). It is possible to simulate the LC director which includes temperature term by using the fast Q-tensor method.

The H-IPS pixel design can reduce the width of side common electrode with minimizing cross talk and light leakage which is caused by interference between data bus line and side common electrode. The H-IPS mode enables one to get the better efficiency of the luminance.

However, H-IPS mode has to cope with edge structure-induced problems. Conventional H-IPS cells do not have defect trap at the electrode edge, and so we can observe very unstable dynamic behavior because high strain energy can be stored in the very small area.

Fig. 3 shows the nucleated defect on the edge of the electrode. In general, the edge of the electrodes can easily make the nucleation of the defect, because the generated defect competes to the strain energy from the electrode edge. The defect moves to the upper right side core by applying voltage to the cell. Fig. 3(a) shows the panel which is applied by the peak to peak voltage (Vpp) 8V. Fig. 3(b) is in case of Vpp 10V.

Fig. 4 shows the 3-dimensional model of the LC director field around the edge using fast Q-tensor method. We found that the defect core moves to the upper right side by applying the voltage. As we previously mentioned, the same

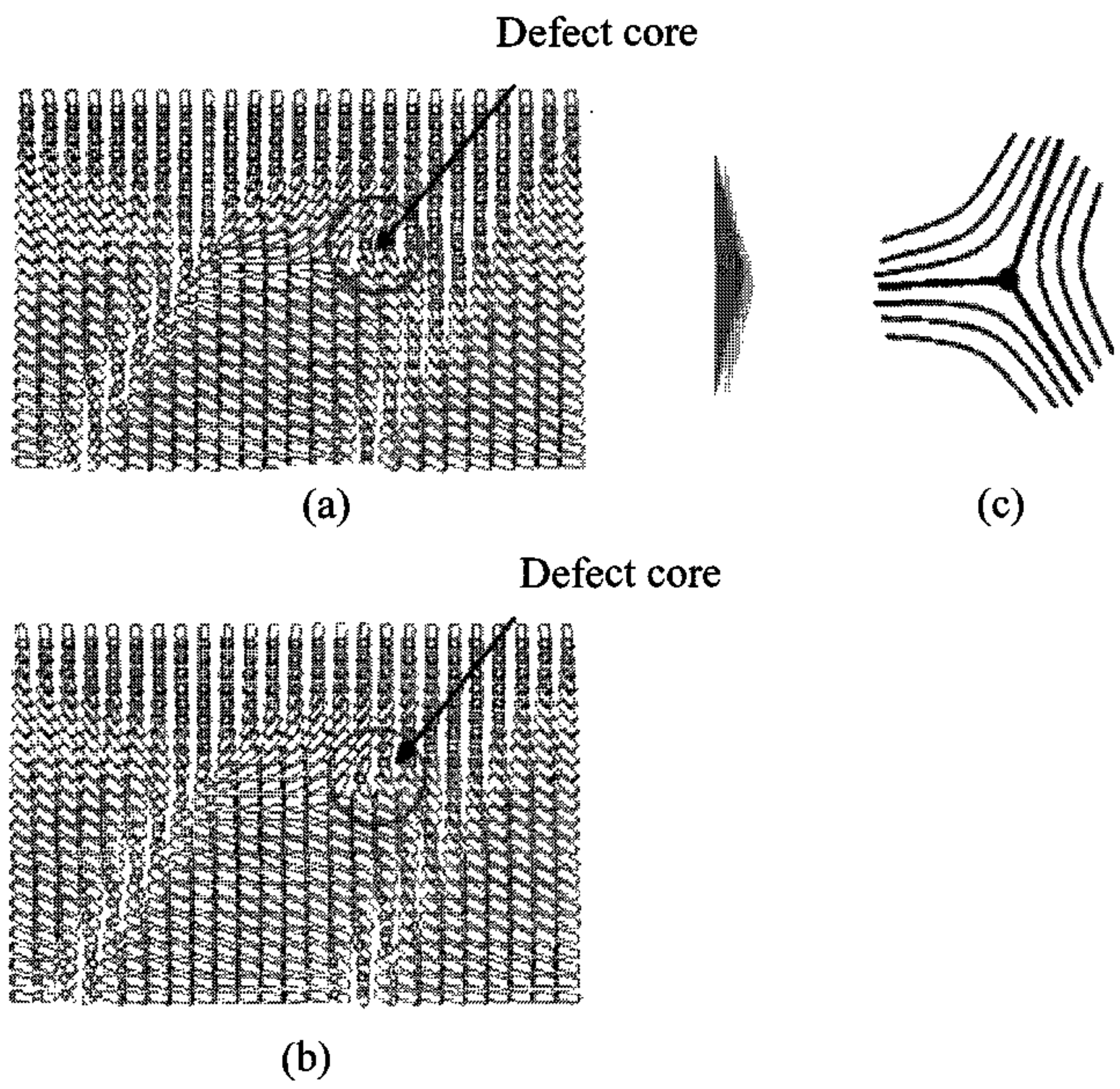


Fig. 4. Modeling of the LC configuration on the edge of the electrode in a H-IPS LC; (a) Vpp 8 V. (b) Vpp 10 V. (c) Cartoon of the orientation of the LC director.

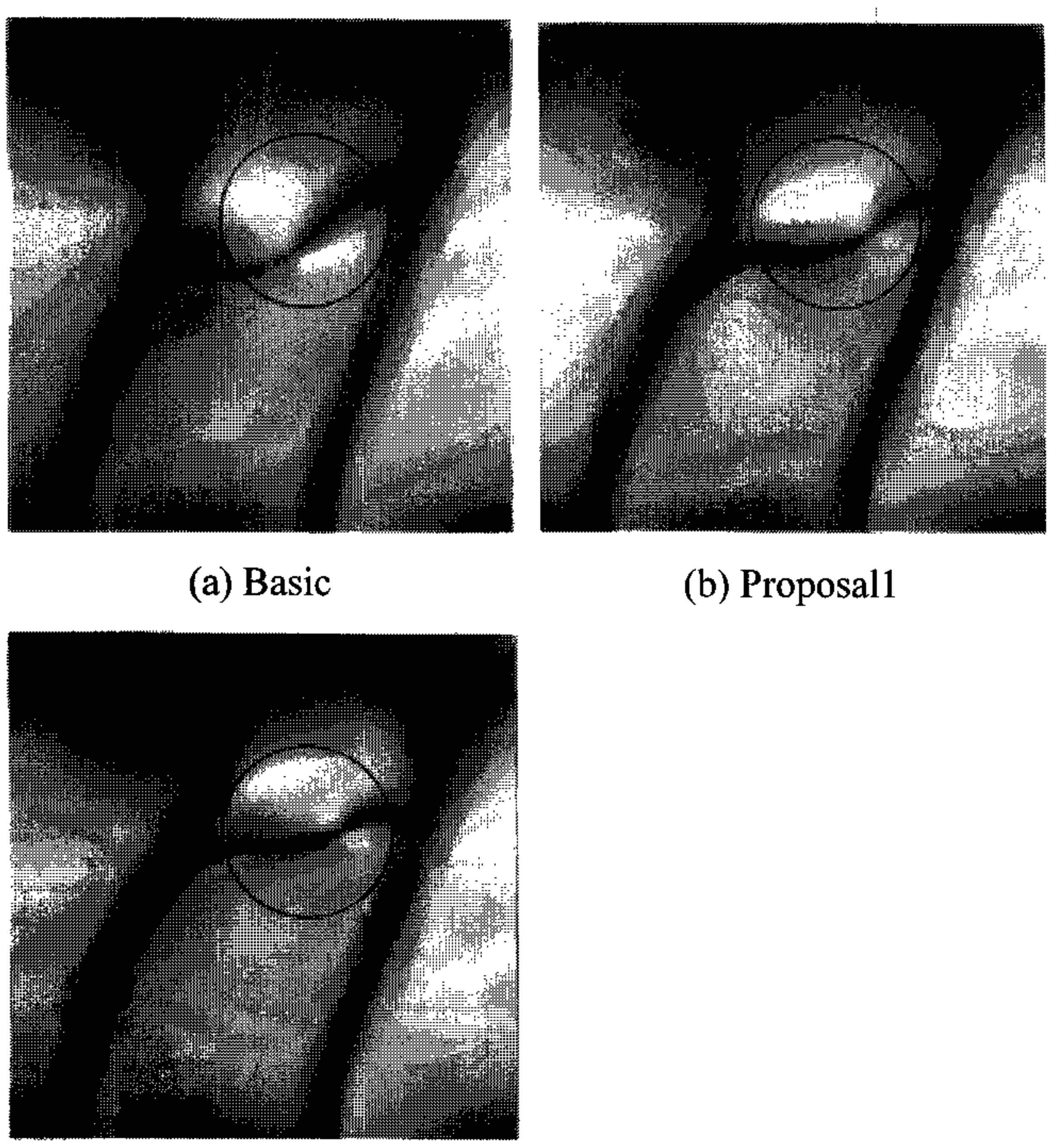
phenomena was observed in the real panel. Fig. 4(a) shows the simulation result for Vpp 8V. Fig. 4(b) shows the simulation result for Vpp 10V. Fig. 4(c) tells us that the LC director configuration can be modeled into a defect with Frank index n=-1 and strength s= -1/2 [8].

To minimize the defect in the edge, we applied an advanced shape of the electrode as shown in Fig. 5(b) and Fig. 5(c). Fig. 5 shows the structure of the electrode and the optical transmittance of the conventional and the proposal H-IPS cells. The optical transmittance was calculated by 2 x 2 Jones matrix. The normalized transmission of the liquid crystal layer placed between the polarizer and analyzer could be given by

$$T/T_0 = \sin^2(2\alpha)\sin^2(\frac{\delta}{2}) = \sin^2(2\alpha)\sin^2(\frac{\pi d\Delta n}{\lambda}) \quad (2)$$

Where α is the angle between the effective optical axis of the liquid crystals and the transmission axis of the polarizer. At α =45°, the equation was simplified to

$$T/T_0 = \sin^2(\frac{\delta}{2}) = \sin^2(\frac{\pi d\Delta n}{\lambda}) \quad (3)$$



(a) Basic (b) Proposal1

(c) Proposal2

Fig. 5. Comparison of the simulation results between conventional H-IPS cell and proposal H-IPS cells.

The simulation results of Proposals 1, 2 are 3.24 %, 4.97% increase of transmittance, respectively. But those of conventional vector methods shows -2.0%, 0.31% for each case. These results don't comply with the real panel data.

Various analysis tools for electro-optical characteristics of advanced LC modes have been developed so far. The Fast Q-tensor method is the most effective because it is the only tool that can deal with defects.

The fast Q-tensor method was used for 26.0" H-IPS development, enabling as to suggest and optimize the design of the H-IPS mode. Various types of defects could be predicted and those defects could be analyzed through optical calculation considering the order parameter.

3. Conclusion

For high performance, LCD modes have been evolved into multi-domain structures. As a result, we have to cope with disclination which is likely to happen due to multi-domain effect. When we design LCD application, it is necessary to consider disclination areas. We made a simulation tool which can suggest optimized electrode structures with minimum disclination areas. This tool is based on the fast Q-tensor method. Finally, we proposed the H-IPS cell which can increase the optical luminance by 16% compared to S-IPS .

Table 1. Specification of 26-inch H-IPS Monitor.

Items	Specification
Display size (diagonal)	26 inch
Resolution	WUXGA
Display pixel(Hor.xVer.)	1920 x 1200
Pixel Pitch	0.2865 mm x 0.2865 mm
Color Gamut	72%
Color coordinate(white)	0.313, 0.329
Contrast ratio	> 800:1
Brightness	500 cd/m^2
Response time	12 msec
Viewing angle(CR ≥0)	Viewing angle free

References

[1] Young Jin Lim , Min Oh Choi, and Youn Hak Jeong , *J.*

Inform. Dis. **6,** 7(2005)
[2] Sang Soo Kim, Brian H. Berkeley, Jin Hyeok Park, Taesung Kim, and Dong Gyu Kim, in *2005 IMID* (2005), p. 15.
[3] Joun-Ho Lee, Jin-Ho Kim, Chung-sun Lim, Sung O Mun, Chang-Ho Oh, Jae Chang Kim and Gi-Dong Lee, in *SID'05 Digest* (2005), p. 642.
[4] S. S. Kim and et al, in *SID Symposium Digest* (2004), p. 760.
[5] G.-D. Lee, J. Anderson, and P.J. Bos, *Appl. Phys. Lett.* **81,** 3951 (2002).
[6] G.-D. Lee, P. J. Bos, S. H. Ahn and K. H. Kim, *Phys. Rev. E* **67,** 041715 (2003).
[7] S. Dickman, J. Eschler, O. Cossalter and D. A. Mlynski, in *SID'93 Digest* (1993), p. 638.
[8] Iain W. Stewart, *The Static and Dynamic Continuum Theory of Liquid Crystals* (Taylor & Francis, London and New York, (2004).