Improvement of IPS mode structure using the fast Q-tensor method

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Abstract

LCD business has grown up changing its strategy and main focus by the order of NBPC, MNT and TV for decades. The presence of PDP drives TV market more demanding. The performance of LCD is required to be improved to struggle against PDP. To strengthen the competitiveness in the market, IPS and VA have evolved in various structures such as H-IPS, AS-IPS, and S-PVA. The introduction of new structures which have multi domains requires the interpretation of disclination area. We developed a new simulation tool based on fast Q-tensor method. It enables us to predict the shape of disclinations and the resulting optical properties. We applied this simulation tool to the development of 26-inch wide monitor having H-IPS mode.

1. Introduction

LCD makers started LCD business with NBPC applications early in the 1980s, in the mid-90's, monitor applications have kept LCD business attractive for next several years. Recently LCD makers are getting more and more involved in TV applications. However the existence of the big competitor, PDP is driving LCD makers struggling in TV market because LCD has to compete with PDP for customer's choice. As a result, LCD makers have been devoting themselves to new pixel structures which improve LCD performances. Figure 1 shows the evolution of LCD modes.

IPS structure has been changed into H-IPS for high aperture ratio which has been considered to a weak point, whereas VA has been transformed to S-PVA which targets better viewing angle properties. Both changes result in the introduction of more complicated structures which consists of muti domains. For example, to compensate gamma distortion for off-axis images, S-PVA divides each pixel into two parts, constructing an 8-domain VA cell [1, 3].

In case of IPS, to stress its strong point, TW-IPS was

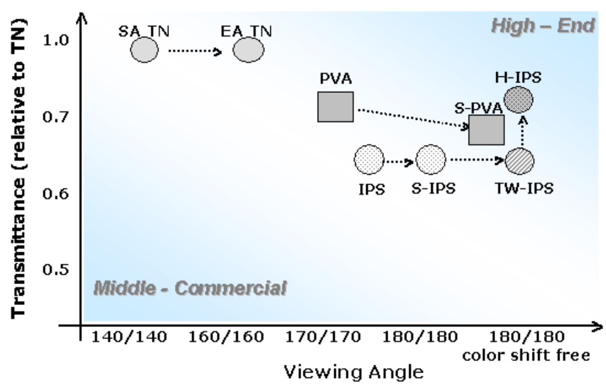


Figure 1) History of LCD Mode

introduced enabling clear image for all directions including diagonal axis [2]. Recently H-IPS was developed to increase the aperture ratio which has been one of challenging points for IPS. As the performance of LCD is getting better, the pixel structure is getting complicated which is apt to generate a lot of disclination area.

The wide viewing angle property is achieved by multi-domain structures, but the spatial LC director

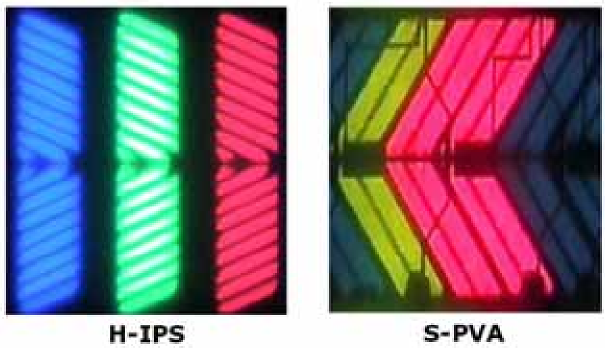


Figure 2) H-IPS and S-PVA

field generates disclinations because of high elastic distortion energy due to the multi-domain effect. Sometimes, disclinations cause a decrease of the optical transmittance of the multi-domain LC cell. Therefore, an understanding of the dynamic behavior of the LC director field has become important for advanced LC modes such as the H-IPS mode.

In this work, we investigate especially disclinations of the electrode's edge. Generally, LC dynamics are very unstable around the edge of the electrode, so that we can easily find the unstable disclination. To interpret LC dynamics around the edge, we tested on 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 in addition to electrical behavior of the LC director. Typically, the LC director's simulator typically uses the Ossen-Frank vector representation. The Ossen-Frank vector representation has a limitation when it comes to defect explanation. Previous papers [4, 5] explain fast Q-tensor method. Dickman had shown that Ossen-Frank vector representation could go to the Q-tensor representation when we use only one 3rd order Q component [6].

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

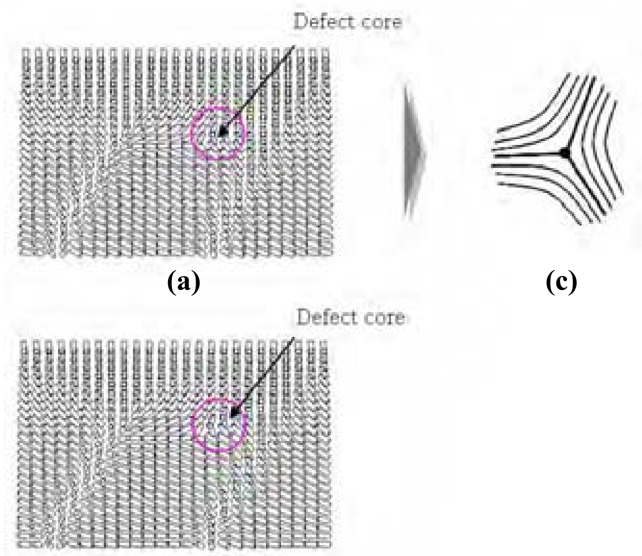
The H-IPS pixel layout design can reduces the width of side common electrode with minimizing the cross talk and light leakage which is caused by interference between data bus line and side common electrode of conventional IPS mode. The H-IPS mode enables to get the better efficiency of the luminance.

(a) (b)

Figure 3. Photographs of the generated defect cores around the edge of a H-IPS LC Cell

; (a) Vpp 8V. (b) Vpp 10V.

But, H-IPS mode has to cope with structure-induced problems because of a lot of edges. Conventional H-IPS cells do not have defect trap at the edge of the electrode, so we can observe very unstable dynamic behavior because high strain energy can be stored in the very small area. Figure 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 edge of the electrode. The defect moves to upper right side core by applying voltage to the cell. Figure 3(a) shows us when the panel is applied by the peak to peak voltage (Vpp) 8V. Figure 3(b) is in the case of Vpp 10V.



(a) (c)

(b)

Figure 4. Modeling of the LC configuration on the edge of the electrode in a H-IPS LC

; (a) Vpp 8V. (b) Vpp 10V. (c) Cartoon of the orientation of the LC director.

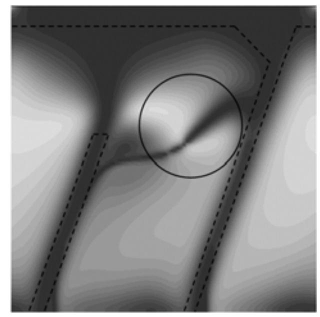
Figure.4 shows the 3-dimensional modeling of the LC director field around the edge using fast Q-tensor method. We found the defect core moves to upper right side by applying the voltage. As I previously mentioned, the same phenomena was observed in the real panel. Figure 4(a) shows the simulation result for Vpp 8V. Figure 4(b) shows the simulation result for Vpp 10V. Figure 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[7].

To minimize the defect in the edge, we applied the advanced shape of the electrode as shown in Figure 5(b) and Figure 5(c). Figure 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

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



(b) Proposal1

(c) Proposal2

(a) Basic

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

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

Fast Q-tensor method was used for 26.0'' H-IPS development, enabling to suggest and optimize the design of H-IPS mode. Various types of defects could be predicted and analysis of those defects was possible though optical calculation considering order parameter.

3. Conclusion

For high performance, LCD modes have been evolved into multi-domain structures. As a result, we have to cope with side effect of disclination which is likely 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 fast Q-tensor method. As a result, we proposed the H-IPS cell which can increase the optical luminance by 16% compared to the normal S-IPS mode.

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

Table 1 Specification of 26-inch H-IPS Monitor

4. Acknowledgements

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