Optimization of H-IPS Structure for High Aperture Ratio.

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Abstract

We designed the H-IPS that has similar aperture ratio to the AS-IPS with organic insulator. To improve the aperture ratio without organic insulator, we positioned the pixel electrode over the preceding gate on the base of the H-IPS structure, and minimized the width of pixel and common electrodes. Without the additional process, we could obtain the similar brightness with that of AS-IPS in 15inch SXGA+ Panel.

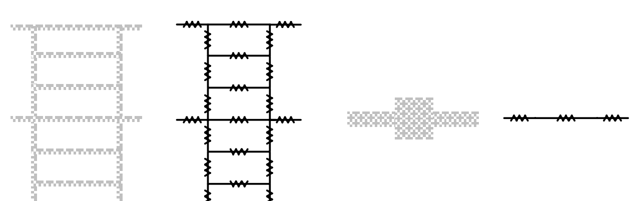
1. Objectives and Background

As application of TFT-LCD is getting various, needs for the performance such as high resolution, luminance, wide viewing angle and fast response have also been grown up [1-2]. The several modes such as IPS and VA (Vertical Alignment), and new process technologies have been proposed to satisfy various needs. Although high aperture ratio should be achieved for high luminance, VA and IPS have a disadvantage of low aperture ratio [1]. Therefore, the increase of aperture ratio is one of the important factors for IPS and VA mode. In order to improve luminance of conventional IPS, some researchers have attempted to increase aperture ratio by using organic insulator layer (so called "AS-IPS" by Y.nakayoshi in Hitachi Display, Ltd) [3-4]. But the adoption of organic insulator layer resulted in complicated process, cost increase and low yield [5-6]. We already proposed the new design of IPS panel (H-IPS), which has high aperture ratio without process modification in the other paper [7]. But, It still seems that brightness of H-IPS structure is lower than that of AS-IPS. In this paper, we achieved similar brightness of H-IPS compared with that of AS-IPS in 15inch SXGA+ Panel by reducing the electrode finger width.

In the light of RC delay, high resistance of narrow finger width may cause dc signal delay in H-IPS. However, horizontal common electrode in H-IPS can reduce the total resistance and the parallel resistance circuit in one dot pixel is shown in Figure 1. The 3 common electrodes with minimum width connected two dots. Since the overlapped area between data line and common electrode was not changed, it is evident that capacitance between the common electrode and data line also was not changed. Based on the reduced resistance and constant capacitance, it can be said that the total common RC delay was reduced in H-IPS.

2. Results

The H-IPS showed similar brightness to that of the AS-IPS for 15inch SXGA+ Panel. The results are summarized in Table 1 and it is clear that other properties are also similar to the AS-IPS as well as the brightness. Also, this H-IPS panels have no defects such as horizontal / vertical cross-talk, VAC (viewing angle cross-talk), Greenish, etc. And the Table 2 shows that viewing angle characteristics on rubbing in horizontal direction has no large difference with that in vertical direction.



a) H-IPS B) AS-IPS

H-IPS / AS-IPS total Resistance ratio = 0.89

Figure 1. Equivalent circuits for the common resistance of a) H-IPS and B) AS-IPS, respectively.

(1) The pixel design of AH-IPS

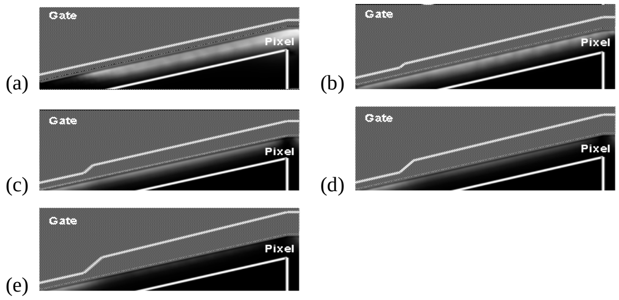


Figure 2. The simulation shows the light-leakage phenomenon for the overlap distance (a) 2 μm, (b) 3 μm, (c) 4 μm, (d) 5 μm, and (e) 6 μm, respectively. The white borderline shows the pixel electrode and gray-dotted area shows the gate electrode, respectively.

(a)

	AS-IPS	AH-IPS
Gate RC delay per dot (relative values)	1	0.94
Gate Resistance per dot	0.77 Ω	0.60 Ω
Capacitance on the gate per dot	72.1 fF	86.7 fF

(b)

Δnd	320nm	K_{11}	12.2 pN
$\Delta\varepsilon$	8.5	K_{22}	6.1 pN
Rotational viscosity	87 mPa·s	K_{33}	14.5 pN
Storage capacitance per dot		142 fF	170 fF
Voltage between the pixel and gate electrode		18.5V	

Table 1. (a) shows the gate RC delay and storage capacitance per dot of AS-IPS and AH-IPS. (b) shows the parameters for this simulation.

Since organic insulator has low dielectric constant compared with Silicon Nitride (SiN_x), common electrode (TCO) can cover the data line without significant data signal delay. The common electrode over the data line results in blocking electric field that causes rotation of LC molecule molecules. It is evident that AS-IPS can have much more narrow width of side common (metal) electrode compared with conventional IPS. Therefore, the aperture area is increased in vertical (perpendicular to gate line) and horizontal (perpendicular to data line) direction without significant gate signal delay and data signal delay, respectively.

In addition to increase of aperture area in horizontal direction for H-IPS [7], we gained additional aperture area increase in the vertical direction by overlapping the pixel electrode over the preceding gate line (which is called “pixel on the gate line structure”). However, some aspects such as gate signal delay due to parasitic capacitance, storage capacitance increase and light-leakage due to electric field between the preceding gate line and pixel electrode should be considered. Specifically, the light-leakage can be critical factor to design AH-IPS panel. Since the preceding gate line voltage is lower than that of the pixel electrode during the most time of operation, the LC molecules are rotated at the edge of pixel electrode on the preceding gate line.

Therefore, we need to consider restoring distance (the distance needed to restore LC orientation) to increase luminance without light-leakage problem. The correlation between light-leakage and restoring distance was simulated by the “Techwiz-LCD simulator” and shown in Figure 2. The Figure 1 shows that light-leakage phenomenon for the overlap distance (a) 2 μm, (b) 3 μm, (c) 4 μm, (d) 5 μm, and (e) 6 μm, respectively. Based on Figure 1, it can be concluded that the optimum overlapping distance is 6 μm in the terms of light-leakage problem. Also, we confirm that overlapped area between the pixel electrode and the gate line does not seriously affect the gate line delay and storage capacitance. These results are summarized in Table 1 (a) and the parameters for this simulation are listed in Table 1 (b). These values in Table 1 (a) were calculated by Techwiz-LCD.

To obtain the additional luminance, the TCO fingers were used for the common electrode instead of the metals. In IPS mode, transmittance efficiency of the pixel or common electrode area is about 30 ~ 40% compared with aperture area (without electrode). In this research, about 3.7 % increase of total aperture ratio was achieved by using TCO as the common electrode. Although application of TCO layer as electrode needs additional deposition process, it can be said that application of TCO still has advantages in terms of process simplicity and cost reduction comparing to IPS with organic insulator.

(2) The design flexibility of AH-IPS

We achieved the additional aperture area by minimizing the width of pixel and common electrodes in this paper. The electrode width can be minimized for the AH-IPS design, while not for the conventional IPS and AS-IPS. Because the control of the electrode width and the distance between pixel and common electrode for AH-IPS is flexible compared with conventional IPS and AS-IPS in case of the panel with dual domains.

The design for vertical direction is an important factor for AH-IPS while the distribution of electrodes in horizontal direction is a critical factor for conventional IPS as shown in Figure 2. When we design for vertical direction (for AH-IPS) as figure 2 (b), design for the center region is only considered (the electrodes with a different angle meet in the center region). However, a lot of factors are simultaneously controlled for horizontal direction (for conventional IPS) such as the distance from data to side common electrode, width of side common electrode, distance between pixel and common electrode, width of the electrodes and so on.

In Figure 2 (b), the triangle designated by arrow in the center presents unavailable aperture area. In the shaded area, the luminance decreases gradually as electric field between the electrodes increases, because electric field in this area already passed the maximum transmittance point in the Transmittance-Voltage curve (It is known that transmittance increases as voltage increases up to certain point, and transmittance starts to decrease as voltage increases in high voltage region). When the finger width of AH-IPS is reduced in Figure 2 (b), the triangle size can be increased and the shaded area can be decreased. As a result, a new available block could be made.

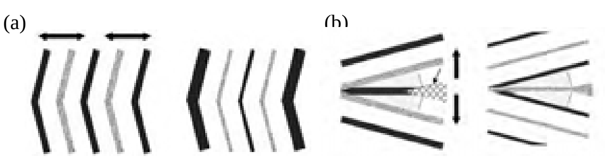


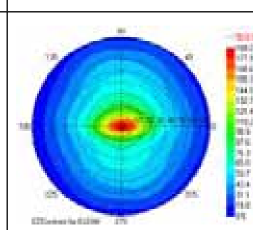
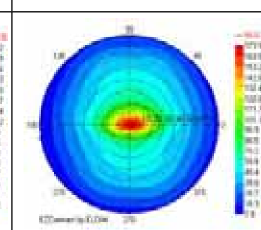
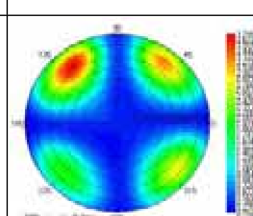
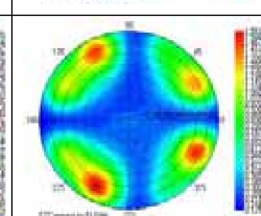
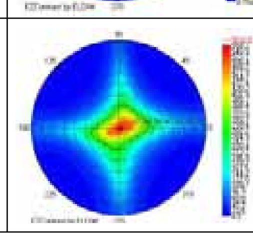
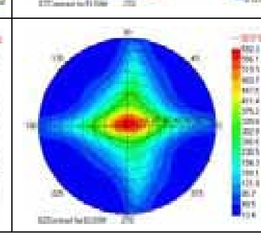
Figure 3. The schematic layout of (a) AS-IPS and (b) AH-IPS

Figure 3 (a) presents the pixel design of conventional IPS or AS-IPS pixel consisted of 4 blocks with dual domains. If horizontal width of the pixel is 60 μm and the distance between the electrodes is 10 μm and electrode width is 4 μm, 8 μm in horizontal direction is unavailable in terms of aperture area according to this pixel design. To optimize the aperture ratio, we should simultaneously consider the factors as follows; the electrode width, the distance between pixel and common electrode, driving voltage, the type of LC, response time and so forth, because these factors are dependent reciprocally. In terms of design flexibility, the electrode width can be minimized for AH-IPS, while not for conventional IPS as referred above.

Finally, we have designed the new design of AH-IPS, which is similar to the aperture ratio of IPS with organic insulator by the calculating values. From these values, we can easily confirm that the luminance of AH-IPS is similar to that of AS-IPS. The results and other properties are shown in Table 2

		AS-IPS	H-IPS
Luminance		204.7nit	202.4nit
CR		677.8	709.6
Response Time	Rising	16.9ms	16.3ms
	Falling	15.7ms	15.1ms
	Total	33ms	31ms
Half Luminance	Up/Down	-18°~13°	-17°~14°
	Right/Left	-25°~27°	-25°~27°
Half CR	Up/Down	-20°~19°	-27°~15°
	Right/Left	-22°~27°	-30°~35°
Cross Talk Level	Vertical	0.34	0.50
	Horizontal	0.33	0.2

Table 1. results of AS-IPS and H-IPS panel, respectively.

	AS –IPS	H –IPS
Lum.		
Blac k		
Half CR		

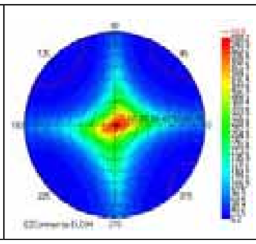
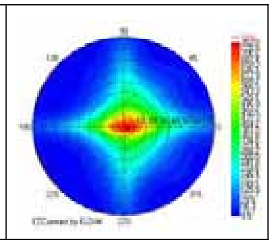
CR> 10		

Table 2. the viewing angle characteristics of AS-IPS (vertical) and H-IPS (horizontal direction rubbing), respectively

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3. Impact

We have designed H-IPS that has similar brightness to that of AS-IPS. The increase of aperture ratio in vertical direction was achieved by (1) putting the pixel electrode over the gate and (2) minimizing electrode width. In conclusion, H-IPS structure designed in this paper has the significant advantages of high aperture ratio without any additional process modification. It is evident that this new design is one of the best ways to design LCD panel with high luminance as well as a simple process.

4. Acknowledgements

Our thanks to LG Philips LCD Development center members and Process Engineers for developing the H-IPS technology.

5. References

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