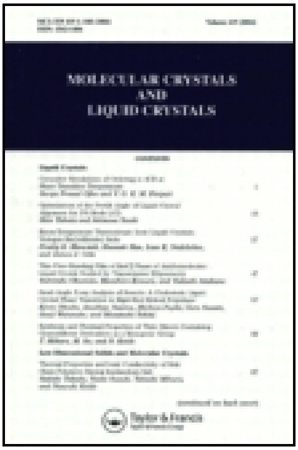

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Multi-domain PVA LCD Cell: Pros and Cons

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In this article, we report our comparative study on the electro-optical properties between the conventional patterned vertical alignment (PVA) cell and super-patterned vertical alignment (S-PVA) cell. Electro-optical properties of these cells are calculated with 3D FEM numerical solver, TechWiz LCD, which is commercially available in the market. Our simulation results implies that the color difference of S-PVA can be improved by more than 13% over the traditional PVA cell since S-PVA mode has twice as many domains as the conventional PVA mode.

Keywords: 8-domain; liquid crystal display(LCD); PVA; S-PVA

I. INTRODUCTION

LCD-TV market demands the emergence of a larger and larger size flat panel display. In addition to the size issue, the optical properties such as transmittance, viewing angle and color reproducing capability are considered to be more demanding. There has been a great deal of effort to devise a novel concept for LCD mode to improve the optical properties of the panel. Recently, S-PVA mode, which is proposed by Samsung Electronics Co., Ltd., exhibited a remarkable improvement

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in terms of viewing angle as well as color difference due to the use of 8 domains [1].

Since S-PVA is thought to have a great potential for wide applications, we undertook a theoretical investigation in an effort to optimize the optical properties of the mode through 3D finite element method (FEM) numerical simulator, TechWiz LCD [2].

In this article, we report our comparative study between the conventional PVA mode and the present S-PVA mode. We will also make some detailed description on the optimized cell structure as well as the layout design for highlighting the unique feature of the capacitively-coupled S-PVA (CC type S-PVA) mode [3].

II. CELL STRUCTURE

VA mode vertically aligns the LC molecules and they tilt when voltages applied. The transmittance of pixel controls by the voltage. The advantage of VA mode is superior to another in black state. So it has excellent contrast ratio. But the disadvantage of VA mode was viewing angle. But it has wide viewing angle according to separate domain. There are two types of VA mode, MVA and PVA mode. MVA mode has protrusions on the electrodes and PVA mode has the patterned ITO electrodes. As the patterned ITO electrodes form oblique electric fields. Which make the LC molecules tilt, PVA mode has multi-domain. Figure 1 illustrates PVA mode, when applied voltages, which has oblique LC molecules of right and left directions. The tilt angle of LC molecules in Figure 1(a) is larger than that of LC molecules in Figure 1(b) because of V_A voltage is bigger than V_B voltage.

To keep the symmetrical viewing angle characteristics, pixel of PVA is divided into four domains and LC molecules are inclined to four domains and LC molecules are inclined to four different azimuths when voltage is applied. PVA mode has 4-domain using patterned ITO to increase the number of domain from VA mode. Figure 2(a) shows the layout illustrating the conventional PVA mode. A, B, C and D molecules have same tilt angles but different azimuths when voltage is applied.

On the other hand, S-PVA mode divides a pixel of PVA mode into two sub-pixels (we will call “sub-pixel A” and “sub-pixel B”). Each pixel of S-PVA has its own tilt angle and is operated with independent voltages from each other. So the S-PVA mode has double domain (8-domain) than PVA mode. Figure 2(b) is a schematic diagram illustrating the basic structure of the present 8-domain S-PVA cell. It shows that a unit pixel of S-PVA mode is divided into two sub-pixels.

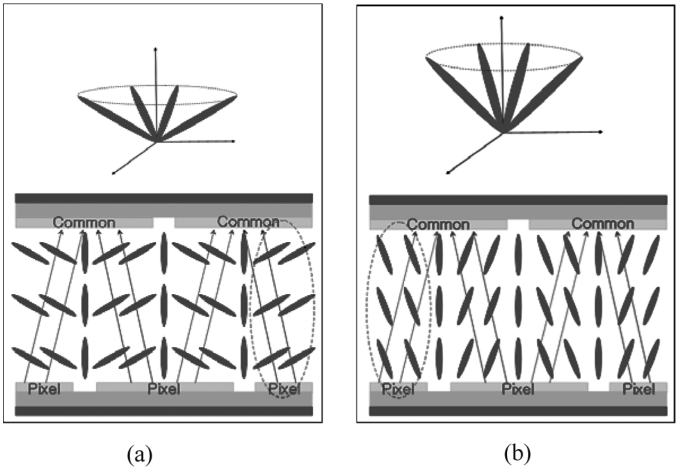

FIGURE 1 PVA mode with voltages: (a) has a V_A voltage and (b) has a V_B voltage. V_A voltage is bigger than V_B voltage.

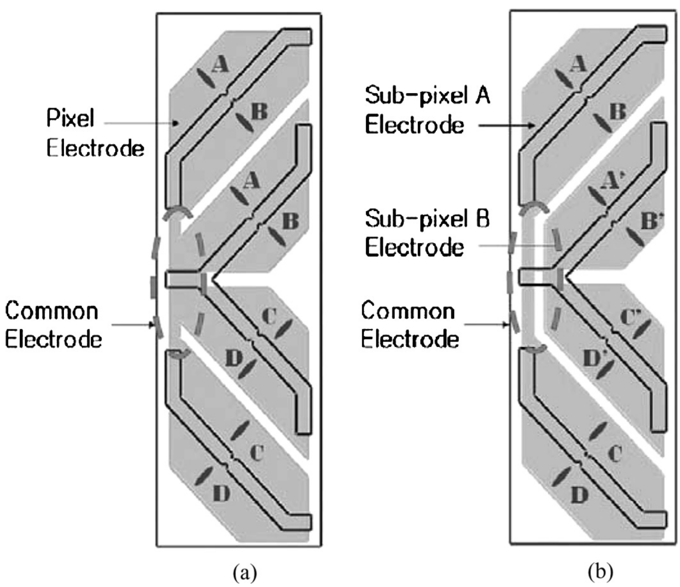

FIGURE 2 Structures illustrating the (a) conventional PVA and (b) S-PVA mode under investigation.

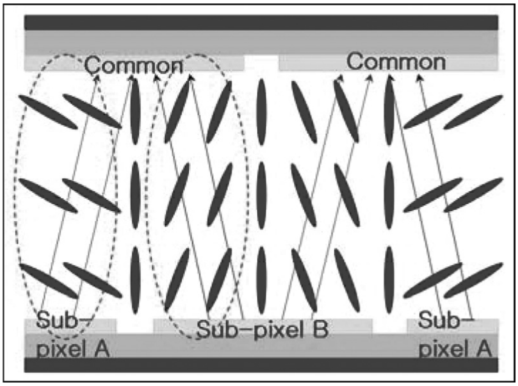

FIGURE 3 S-PVA mode with two voltages in two sub-pixels: The right and left sub-pixel : The right and left sub-pixel have V_A and the middle sub-pixel has V_B. V_A is same voltage on Figure 1(a) and V_B is same voltage in Figure 1(b).

Molecules A, B, C, and D share the same tilt angle but different azimuths when the voltage is applied. In addition, molecules A′, B′, C′, and D′ share the same tilt angle but different azimuths when voltage is applied. In the meanwhile, molecules A and A′ share the same azimuth but different tilt angles, which applies to molecules B and B′, C and C′, and D and D′ in a similar manner. There are two types of S-PVA mode. The first one has two transistors (TT type S-PVA). The electrodes of each sub-pixel applied different voltage directly by the two driving transistors. The other one has a transistor (CC type S-PVA). It should be noted that the CC type S-PVA mode has a single transistor. The electrodes of sub-pixel A are directly applied with the voltage driven by the driving transistor. However, the electrodes of sub-pixel B are set as floating and a floating voltage of the electrode of sub-pixel B is induced by the applied voltage in sub-pixel A. Our simulation uses the CC type S-PVA mode.

Figure 3 illustrates that sub-pixel A which has same voltage in Figure 1(a) and sub-pixel B which has same voltage in Figure 1 (b) are placed on a pixel. It shows the principle of operation of S-PVA mode. The electrodes of sub-pixel A are directly applied with the voltage driven by the driving transistor. However, the electrodes of sub-pixel B are set as floating and a floating voltage of the electrode of sub-pixel B is induced by the applied voltage in sub-pixel A. Thus the LC molecules above sub-pixel A have a larger tilt angle than sub-pixel B.

III. SIMULATION RESULTS AND DISCUSSION

Figure 4 is shown the equivalent circuit of CC type S-PVA mode. As shown in Figure 4, V_B is defined Eq. (1). The rate of induced voltage for sub-pixel B is changed under the control of C_{cp}. C_{cp} is a capacitor between electrode of sub-pixel A and sub-pixel B. And C_{lcb} is a capacitor between electrode of sub-pixel B and common. It is considered that the proper rate of induced voltage for sub-pixel B should lie between 60% and 80% [3].

Table 1 shows a list of voltages induced on the floating electrode in sub-pixel B for S-PVA mode. As shown in table 1, we note that approximately 73% of the applied voltage is induced at the floating electrode. It is calculated Eq. (2). V_A, V_B and V_C are voltages that are applied at the electrode of sub-pixel A, sub-pixel B and common, respectively. In this article, 5.5 V is applied to V_C.

$$V_B = V_A \times \frac{C_{cp}}{C_{cp} + C_{lcb}} \tag{1}$$

$$\text{The rate of induced voltage } = \frac{V_B - V_C}{V_A - V_C} \times 100 \tag{2}$$

Figure 5 are shown the light transmission characteristics for two cases when the applied voltage is varied from 5.5 V to 12.5 V. The light transmission images were calculated with TechWiz LCD [2] when the same voltage is assumed to be applied. The cell structure employed

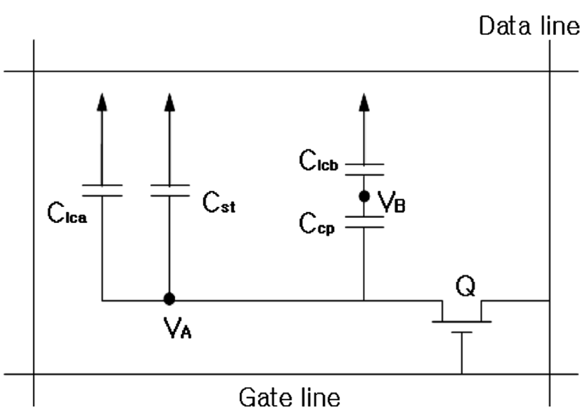

FIGURE 4 Equivalent circuit of CC type S-PVA: C_{cp} is a capacitor between sub-pixel A and sub-pixel B electrode. And C_{lcb} is a capacitor between sub-pixel B and common electrode.

TABLE 1 List of Voltages Induced at the Floating Electrodes in S-PVA Mode Wherein V_C is a Voltage that is Applied at the Common Electrode. In this article, 5.5 V is applied to V_C

Voltage of sub-pixel A	Voltage of sub-pixel B	The rate of induced voltage (%)
5.500000	5.485333	
6.000000	5.857330	71.47
6.500000	6.229327	72.93
7.000000	6.601324	73.42
7.500000	6.973321	73.67
8.000000	7.345319	73.81
8.500000	7.717316	73.91
9.000000	8.089314	73.98
9.500000	8.461312	74.03
10.000000	8.833310	74.07
10.500000	9.205308	74.11
11.000000	9.577307	74.13
11.500000	9.949305	74.16
12.000000	10.321304	74.17

in this study stems from the disclosure in the Korean Patent Publication No. 10-2006-0010118 [3]. Figure 5(a) and (b) demonstrate the switching process from the black to the white in the PVA and S-PVA mode, respectively. We can see that S-PVA mode has a different optical transmittance on the pixel due to its different voltage applied at those two sub-pixels. Referring to Figure 5 (b), we can observe that gray-scale images are produced with both darker and brighter gray-scales. Sub-pixel A and sub-pixel B have different tilt angle. It thus makes that S-PVA mode has eight-domain. Sub-pixel B, which has a floating electrode, exhibits reduced light transmission when compared to the sub-pixel A. But sub-pixel A, which has a same voltage in the pixel of PVA mode, exhibits same light transmission when compared to the pixel of PVA mode.

Figure 6 is a diagram illustrating V-T (voltage-transmission) curve for the traditional PVA and the present CC type S-PVA mode, respectively. The transmittance (black line) of S-PVA mode is found to be lower than that of PVA mode (dotted line). Further, the simulation revealed that S-PVA has a higher saturation voltage, which means S-PVA mode separates gray level more easily while having a higher driving voltage than that for the traditional PVA mode.

Figure 7 shows a plot calculated color difference as a function of viewing angle. Referring to Figure 7, we find that color difference can be improved by more than 13% for each viewing angle.

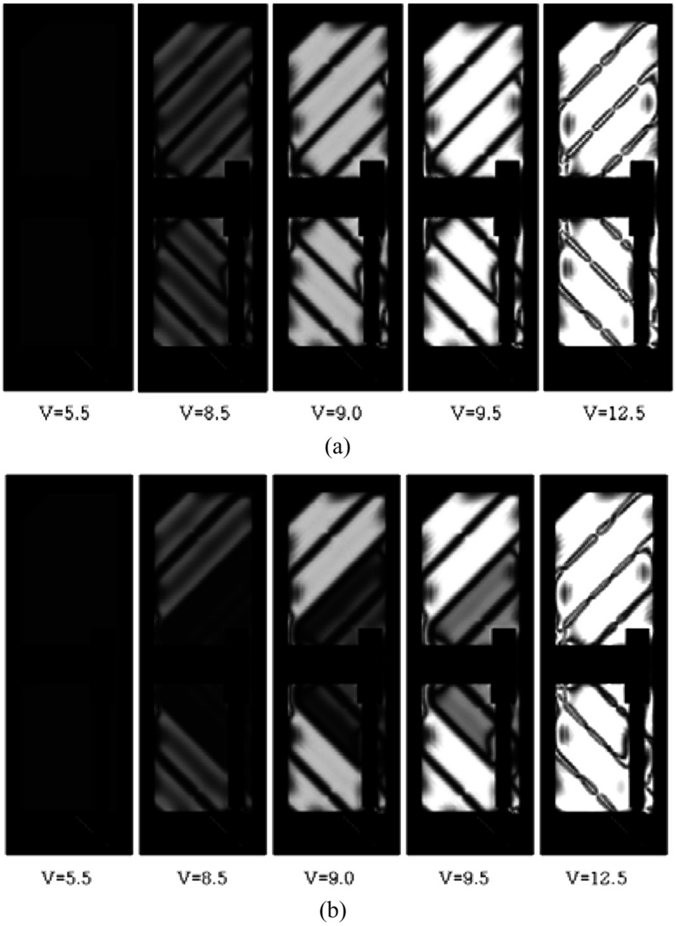

FIGURE 5 Simulation results of the switching process from the black to the white in the PVA and S-PVA mode, respectively.

IV. CONCLUSION

In this article, we report our preliminary study on the electro-optical properties of S-PVA cell through a numerical simulation. Our theoretical study revealed that the viewing angle property as well as the color difference can be tremendously improved when compared with the traditional PVA structure. Further, our simulation implied that the induced voltage at the floating electrodes in sub-pixel B of the present

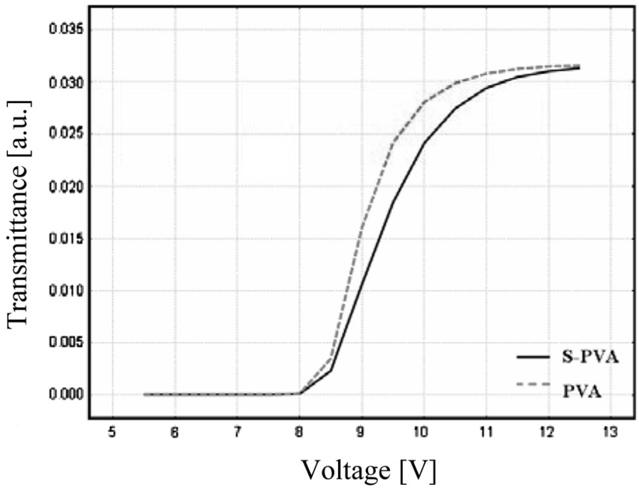

FIGURE 6 Voltage-dependent light transmittance curves for PVA(dotted line) and S-PVA mode(solid line), respectively.

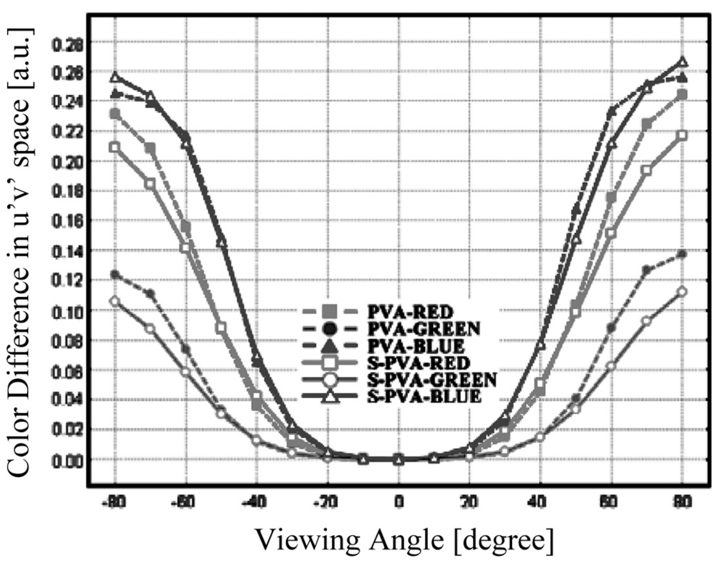

FIGURE 7 Color difference as a function of viewing angle along the diagonal for PVA and S-PVA mode, respectively.

S-PVA mode is approximately 73% of the applied voltage in sub-pixel A. In order to optimize the cell, the correlation between the rate of areas of sub-pixels A and B as well as the rate of voltage induced on the floating electrodes in sub-pixel B should be understood.

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