Fast Response Time Patterned Vertical Alignment Mode Using Double Step UV Exposure

Dong-Ha Kim, Youngsik Kim, Jae Ho Lee*, You-Jin Lee*, Chang-Jae Yu*, and Jae-Hoon Kim***

*Department of Electronics and Computer Engineering, Hanyang University, Seoul 133-791, Korea
**Department of Information Display Engineering, Hanyang University, Seoul 133-791, Korea

ABSTRACT

We propose an advanced patterned vertical alignment (PVA) mode with a fast response time through double ultraviolet (UV) exposure to UV curable reactive mesogen (RM) mixed in alignment layer. The double step UV exposures using a photomask divide an active pixel region into two regions with a modified pretilt region and a high elastics deformation energy one.

1. INTRODUCTION

The liquid crystal displays (LCDs) have been developed to achieve the high performances using variety of LC modes such as in-plane switching (IPS), fringe-field switching (FFS), multi-domain vertical alignment (MVA), and patterned vertical alignment (PVA) [1-4]. Especially PVA mode is one of the most adopted liquid crystal (LC) modes because of the strong points such as high contrast ratio at a normal direction and rubbing-free fabrication process [5]. However, PVA mode has slow response time due to the reorientation of the LC molecules.

Recently, *Lee et al.* [6] proposed a surface-controlled PVA (SC-PVA) mode to overcome this problem by generating the pretilt angle using reactive mesogen. The pretilt directions are determined by the direction of the fringe field and fixed by UV exposure in the presence of the applied electric field [7]. The rotational preference of the LC molecules governed by the pretilt direction reduced a threshold voltage and the response time. However, the falling time was increased because the elastic deformation energy was decreased by the pretilt angles.

In this paper, we propose an advanced method to improve response time of the SC-PVA mode by using UV curable reactive mesogen (RM) mixed in alignment layer through double step UV exposure process. During the first UV exposure, the RM monomers in electrode-overlapping regions are polymerized along the LC directors with pretilt angle using the UV mask under an applied voltage and the RM monomers in electrode-slit regions are polymerized by second UV exposure without voltage and pretilt angle. As a result, the falling time can be improved due the increased elastic deformation energy in the zero pretilt region.

2. EXPERIMENTS

Figure 1 shows the fabrication process of proposed SC-PVA mode. To obtain the patterned electrode, indium-tin-oxide (ITO) coated glass was patterned using photo-lithography process. And then, the alignment layer was obtained by the spin coating method using the mixture of vertical alignment material AL60702 (from Japan Synthetic Rubber) and RM 257 (from BASF) with ratio of 2 wt%. The alignment layer was pre-baking at 100 ℃ for 10 minutes to evaporate the solvent in alignment material and the cured at 180 ℃ for 1 hour to complete imidization. The cell gap was maintained using glass spacers of 3.3 μm and filled with LC material (MLC-6608, $\Delta\varepsilon$ = -4.1 and Δn = 0.083, from Merck). At an initial state, the LC molecules were aligned vertically due to the anchoring force of the vertical alignment material and the RM monomers were distributed randomly in the alignment layer as shown in Fig. 1(a).

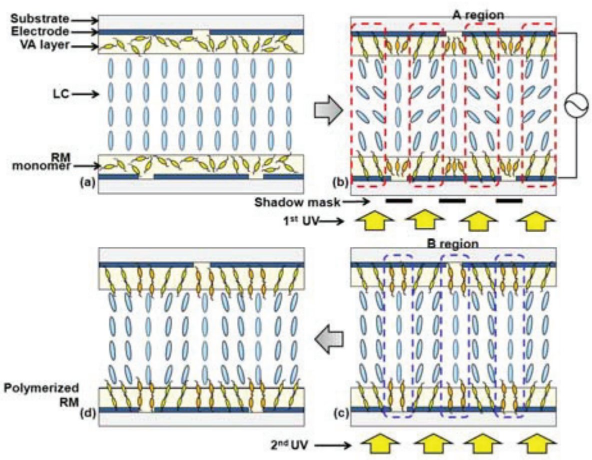

Fig. 1 schematic diagrams of proposed double step UV exposure method.

When the voltage larger than a certain threshold voltage (V_{th}) was applied to the sample, the LC molecules fell down to the substrate. And the RM monomers near the interface were re-aligned parallel to the LC molecules. The RM monomers are easily dissolved in the LCs and movable due to the liquid crystalline property. To make the different pretilt in one sub-pixel, we used the shadow mask to divide the sub-pixel. In the present of the electric field (4V) larger than threshold voltage, electrode-slit regions (B) were blocked by the shadow mask and the LC cell in electrode-overlapping regions (A) was exposed to the UV light. At this step, the RM monomers in the regions (A) were polymerized in the alignment layer and pretilt angle was generated (Fig. 1(b)). After that, whole panel was exposed to the UV light without shadow mask and electric field. And then the RM monomers in the regions (B) were polymerized in the alignment layer (Fig. 1(c)). By the double-step UV exposure process with shadow mask, two different pretilt angles can be obtained in one pixel.

3. RESULTS AND DISSCUSION

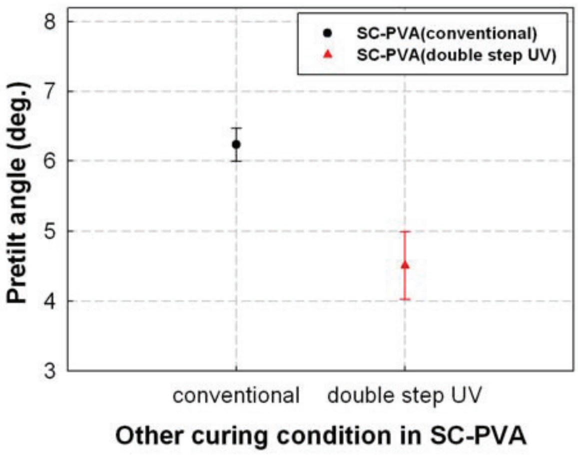

Fig. 2 The measured pretilt angle of conventional SC-PVA cell and the proposed SC-PVA cell with double step UV processes.

The low pretilt angle is important in VA mode to achieve the high transmittance and fast falling time characteristics. Figure 2 shows the measured pretilt angle for normal SC-PVA cell and proposed SC-PVA cell. The pretilt angle was measured polarizer rotation method [9]. By adding the zero pretilt angle regions (B), proposed cell shows the lower pretilt angle than conventional SC-PVA mode about 1.7°.

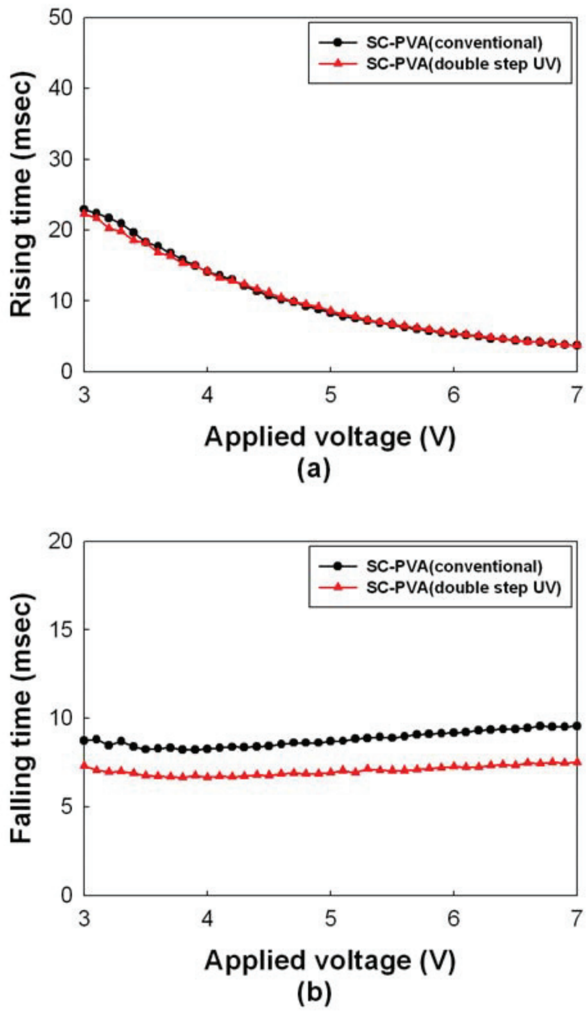

Fig. 3 The measured response time of conventional SC-PVA cell and the proposed SC-PVA cell with double step UV processes (a) the rising time, (b) the falling time.

Figure 3 shows response time characteristics as a function of applied voltage for normal SC-PVA cell and proposed SC-PVA cell. The rising time was similar to the SC-PVA cell with double step UV exposure at whole grey level as shown in Fig. 2(a) due to the generated pretilt angle by polymerized reactive mesogen. And the falling time was improved about 20% compare to the conventional SC-PVA mode. Because the polymerized RM in the electrode-slit regions maintains the zero pretilt angle and increases the elastic deformation energy.

As a result, the proposed SC-PVA mode with double step UV exposure of RM polymerization shows the considerable improvement of response time without any increase of falling time than the conventional SC-PVA mode.

4. CONCLUSION

In summary, we proposed advanced method with double step UV exposure of RM in SC-PVA mode. The rising time was similar to conventional SC-PVA due to pretilt in the electrode-overlapping regions and the falling time was faster due to increase the elastic deformation energy of the vertical LC orientation in the electrode slit regions.

As a result, the advanced PVA method was realized with double step UV exposure of RMs, which made possible to realize the fast falling time.

5. ACKNOWLEDGMENT

This research was supported by a grant (2011-10040035) from the Fundamental R&D Program for Core Technology of Materials funded by the Ministry of Knowledge Economy and by a grant from Samsung Display Co., LTD.

REFERENCES

[1] M. Oh-e and K. Kondo, "Electro-optical characteristics and switching behavior of the in-plane switching mode," *Appl. Phys. Lett*. **67**, 3895 (1995)

[2] S. H. Lee, S. L. Lee, and H. Y. Kim, "Electro-optic characteristics and switching principle of a liquid crystal cell controlled by fringe-field switching," *Appl. Phys. Lett.* **73**, 2881 (1998)

[3] H. L. Ong, N. Cheong, J. Lo, M. Metras, and O.Woodard, "New Multi-Domain Vertical Alignment LCD with High Contrast Ratio and Symmetrical Wide Viewing Angle Performance and Simplest Fabrication Design and Process," *SID' 03 Digest*, 680 (2003)

[4] I. H. Yu, I. S. Song, J. Y. Lee, and S. H. Lee, "Intensifying the density of a horizontal electric field to improve light efficiency in a fringe-field switching liquid crystal display," *Phys*. D **39**, 2367 (2006)

[5] S. G. Kim, S. M. Kim, Y. S. Kim, H. K. Lee, S. H. Lee, G.-D. Lee, J.-J. Lyu, and K. H. Kim, "Stabilization of the liquid crystal director in the patterned vertical alignment mode through formation of pretilt angle by reactive mesogen," *Appl. Phys. Lett.* **90**, 261910 (2007)

[6] Y.-J Lee, Y.-K. Kim, S. I. Jo, J. S. Gwag, C.-J. Yu, and J.-H. Kim, "Surface-controlled patterned vertical alignment mode with reactive mesogen," *Opt. Express* **17**, 10298 (2008)

[7] S. I. Jo, Y.-J. Lee, Y.-K. Kim, A. R. Yoon, S. W. Choi, and J.-H. Kim, "Surface Controlled 8-Domain Patterned Vertical Alignment Mode with Reactive Mesogens," Proceedings of the IDW'09, 604 (2009)

[8] I. Jánossy and T. I. Kósa, "Gliding of liquid crystals on soft polymer surface," *Phys. Rev. E* **70**, 052701 (2004).

[9] S. B. Kwon, K. Y. Han, and T. Uchida, "Polarizer Rotation Method for the Measurement of LC Pretilt Angle in the Full Range of 0 – 90 Degrees," J. Inst. Image Inf. Telev. Eng. **18**, 13 (1994)