Liquid Crystal Alignment Control using Reactive Mesogen mixed with Alignment Layers

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ABSTRACT

We proposed a new method for controlling alignment and orientation of liquid crystal molecules through surface modification using UV curable reactive mesogen mixed with alignment layers for high display performances.

1. INTRODUCTION

High performance liquid crystal displays (LCDs) with high brightness, wide viewing angle, and fast response time characteristics are widely used in both large and small size LCD applications. Various approaches have been taken for controlling the alignment and orientation of LC molecules because they play an important role in electro-optic characteristics of LC displays. Many kind of LCD modes such as in-plane switching (IPS) [1], multi-domain vertical alignment (MVA) [2], and patterned vertical alignment (PVA) [3] have been developed for high display performances by controlling the alignment and orientation of LC molecules. Among them, PVA mode is very useful mode for large size LCD applications due to rubbing free fabrication process, high contrast ratio at normal direction, and wide viewing angle characteristics through multi-domain structures controlled by a fringe field effect from patterned electrodes. However, they have drawbacks such as low transmittance and slow response time, particularly for rising time due to the formation of disclination between the LC molecules in the presence of an electric field. In order to solve these problems, polymer stabilized PVA (PS-PVA) mode is suggested in which the mixture of LCs with reactive mesogen (RM) was used to generate pretilt angle [4]. In PS-PVA, the pretilt angle is determined by polymerization of RM monomer in the presence of electric field. Due to the pretilt angle, threshold voltage can be decreased and the response time is drastically improved in PS-PVA mode. However, since the remaining uncured monomer in LCs can be treated as impurities in LCs, it is possible to generate severe image degradation such as image sticking.

In this paper, we proposed a new method for controlling alignment and orientation of LC molecules through surface modification using UV curable RM mixed with alignment layers. The azimuthal and polar direction of LC molecules are determined and memorized on the alignment layer by polymerized RMs through UV exposure in the presence of electric field. The LC molecules fall directly down to the substrate when applied voltage without any alignment process and that make possible to improve the response time remarkably. Since our proposed the method of controlling alignment of LCs using RMs mixed with alignment layer is possible to be adopted into all kinds of LCDs, it is very useful to improve the display performance and design new LC modes. In this paper, we will focus to describe how to improve the display performance such as high transmittance using a patternless electrode structure and wide viewing angle using 8-domain structure as well as fast response time characteristics in PVA mode.

2. Experimental

Figure 1 show the schematic diagram of proposed PVA mode fabrication process base on the surface modification using RM mixed with alignment layer, so called surface controlled PVA (SC-PVA) mode [5]. The mixture of the vertical alignment material AL60101 (JSR) and RM257 (BASF) with proper weight ratio were coated on both ITO substrates with chevron type electrode pattern as conventional PVA does. The alignment layer was pre-baked at 80 ˚C

for 10 min followed by curing at 180 ˚C for 1 hour. The cell gap was maintained with 3.0 μm and filled with LC (MLC-6610, Δε = -3.1 and Δn = 0.0996, Merck). Without applying voltage, the LC molecules were aligned vertically due to vertical alignment material and the RM monomers were distributed randomly in the alignment layer.

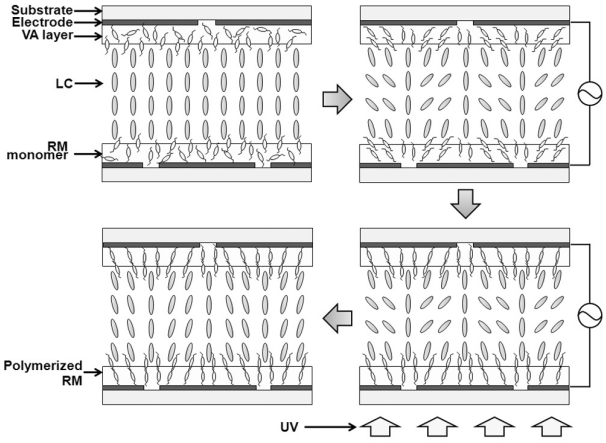

Fig. 1
The Schematic diagram of proposed VA mode and fabrication processes.

When we applied voltage is larger than threshold voltage, the LC molecules fell down in four different diagonal directions as same as that of a conventional PVA mode. At this stage, the RM monomers which have some fluidity and the alignment characteristics of LC phase are aligned along the LC molecules on the alignment layer to reduce the excluded volume and the cell was exposed to the UV light. In experiment, we applied 4 V to the cell during UV exposing process. Then the RM monomers are polymerized with certain direction which is controlled by the strength of electric field, and thus generated pretilt and azimuthal angles are memorized on the alignment layer. The memorized pretilt and azimuthal angles are maintained even after removing the voltage.

3. Result and Discussion

Figure 2 shows the microscopic textures under crossed polarizers for conventional PVA mode and proposed SC-PVA mode with 6 V after 10 ms to investigate the stability of LC reorientation under an applied voltage. In the conventional PVA cell, the texture shows defects on the overlapping regions of the pixel and common electrodes, which make slow response time during switching [Fig. 2(a)].The defects are produced by the uncontrolled tilting direction of LC molecules between patterned electrodes because the pretilt angle is 90˚ from the substrate parallel in this area.

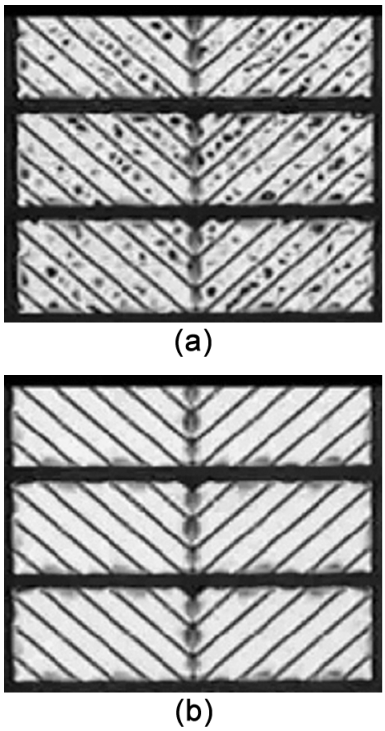

Fig. 2
Microscopic textures under crossed polarizers for (a) conventional VA mode and (b) a proposed SC-PVA mode after 10 ms with 6V.

	Conventional PVA mode	SC-PVA mode
Rising time	23.2 ms	5.6 ms
Falling time	4.8 ms	6.3 ms
Response time	28.0 ms	11.9 ms

Table 1
Response time between a conventional PVA mode and SC-PVA mode.

On the contrary, SC-PVA cell shows uniform texture during the switching as shown in Fig. 2(b) without any point defects and disclination lines due to the pre-defined pretilt angle by polymerized RM on the alignment layers. The result clearly indicates that the proposed SC-PVA mode minimizes the formation of defects and improves the rising time. The rising time to reach stabilized state of conventional PVA mode was 23.2 ms and that of the

SC-PVA one was 5.6 ms at 6 V, as shown in Table 1. As increasing the curing voltage, the response time would be faster but the contrast ratio would be decreased due to a light leakage which is introduced by the effective retardation as a result of surface induced pretilt angle at dark state.

Our proposed method is very useful to improve the display performances. For improve the viewing angle characteristic for specially off-axis directions, the super-PVA modes with dual capacitor or thin film transistor (TFT) were proposed [6-8]. However, because of dual capacitor or TFT system, many side effects are resultant such as complexity of driving scheme, lack of turn-on time, and low aperture ratio and complex manufacturing processes. For overcome this problem, we adopted our LC alignment controlling method to realize an 8-domain PVA mode as same as produced by dual capacitor or TFT systems. Figure 3 shows the schematic diagram of the fabrication processes. In this application, the UV curable RM monomers are exposed under certain applied voltage with triangular shape shadow mask covering the half of each pixel.

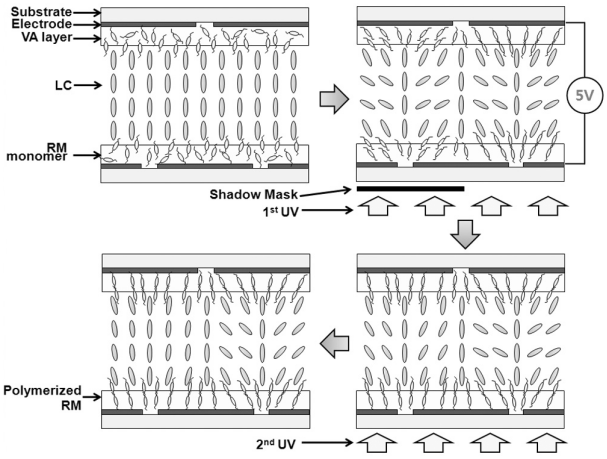

Fig. 3
The Schematic diagram of proposed 8-domain VA mode and fabrication processes.

The polymerized RM produces the pretilt angle of LC that is maintained even in field off state. As a result, the UV exposed area has the different pretilt angle to unexposed one. So, the each pixel was divided into two parts, and the each part in a pixel have different voltage induced tilt angle due to different pretilt angle produced by polymerized RM. The two divided domains effectively construct an 8-domain VA cell, which can compensate and minimize gamma distortion for images viewed off-axis.

As another application, we can improve the high aperture ratio for high brightness by removing the common electrode pattern of upper substrate in PVA mode. If we use only one patterned electrode in a conventional PVA structure, the response time due to reorientation time of LC director when electric field was applied is extremely slow that it is so hard to apply for the display device, as shown in Fig. 4(a). In our proposed method, LCs are reoriented to minimize the free energy with applied voltage and it takes long time to stabilize perfectly, as conventional PVA mode does. After the LC directors are stabilized, we exposed the UV light to the sample for polymerization of RM monomers along LC director. As a result, the polymerized RMs are memorized the pretilt angle over whole panel area, so the LCs fall directly down to the substrate with driving voltage (see Fig. 4(b)). From these results, we could realize the high transmittance as well as fast response time in PVA mode.

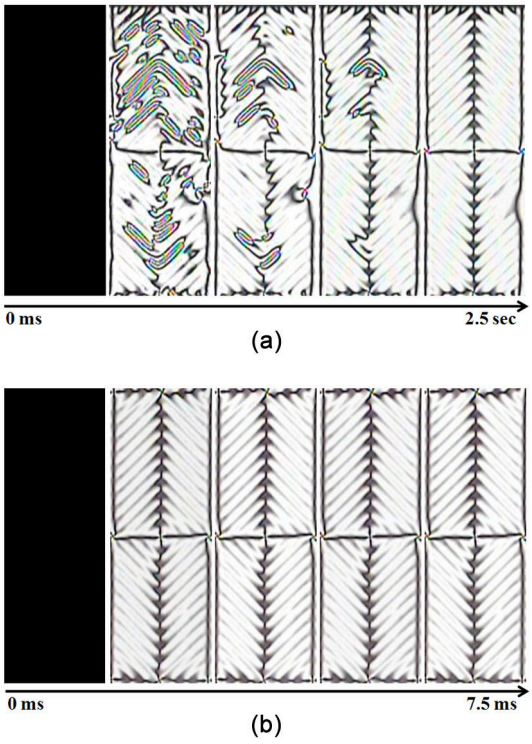

Fig. 4
The time resolved microscopic textures for (a) a conventional patternless PVA mode and (b) a proposed patternless SC-PVA mode.

4. Conclusion

In this paper, we proposed a new method for controlling alignment and orientation of LC molecules through surface modification using UV curable RM mixed with alignment layers. The RM monomers are polymerized along the LC molecular direction with applied electric field during UV curing process and produced pretilt and azimuthal angles are memorized on the alignment layer. Since our proposed the method of controlling alignment of LCs using RMs mixed with alignment layer is possible to be adopted into all kinds of LCDs, it is very useful to improve the display performance and design new LC modes. As results, we could realize the fast response time, high brightness, and wide viewing angle characteristics in LCD.

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