Surface Control with Reactive Mesogen for Fast Switching LCD Modes

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ABSTRACT

We propose an advanced method to improve response time characteristics of the liquid crystal displays (LCDs) through stacking reactive mesogen (RM) on the alignment layer. The RM polymers enhance the surface anchoring strength, and thus the response time of the LCDs was significantly improved, especially in relaxation time.

1. INTRODUCTION

The liquid crystal display (LCD) is most promising technology among the flat panel displays due to its superior image quality. However, response time of the LCDs is still insufficient in comparison to other information displays such as plasma display panel (PDP) and organic light emitting diodes (OLED) display. The slow response is mainly originated from the viscous rotation of the LC molecules and is one of barriers to expand new display market such as three dimensional (3D) displays. To overcome this problem, a blink backlight driving method [1] and/or low viscosity LC materials [2] were introduced. However, these methods inevitably involved a complicated driving scheme and/or an optimizing difficulty of the material parameters.

Recently, the advanced methods for improving response time using photo-curable reactive mesogen (RM) were suggested in vertical alignment (VA) mode [3,4]. The RMs blended with the LC or the alignment layer are polymerized along the direction of the LC directors by the ultra-violet (UV) exposure. By the polymerized RMs, as a result, the predetermination of the switching directions of the LC molecules improves the response time characteristics. Currently, however, these methods are not adoptable to the LCD modes using a planar alignment layer such as an electrically controlled birefringence (ECB) mode and a twisted nematic (TN) mode [5] due to the polymerization problem of the RMs on the planar alignment layer.

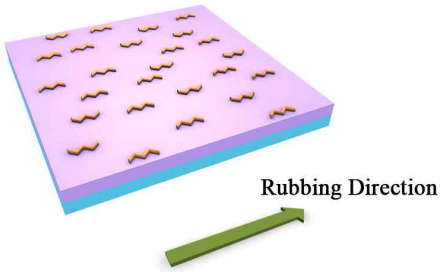
In this work, we suggest an advanced method for improving response time through the surface control by coating UV curable RMs on the rubbed planar alignment layer without any complicated driving method and/or any changing material parameters. The polymerized RMs on the surface of the planar alignment layer enhance the polar anchoring strength, and thus the response time improved, especially in relaxation time.

2. EXPERIMENTS

Figure 1 shows a schematic diagram of the proposed RM coated system. The planar alignment material of AL-22620 (Japan Synthetic Rubber) was spin-coated on the indium-tin-oxide (ITO) coated glass and pre-baked at 100 °C for 10 min to remove the solvent, followed by the post-baking at 210 °C for 2 hs for the complete imidization. The substrates were unidirectionally rubbed to promote uniform alignment. The RM mixture of monomers (BASF) and photo-initiator (Ciba Chemical, IRGACURE 651) dissolved in propylene glycol monomethyl ether acetate (PGMEA) solvent was spin-coated on the rubbed planar alignment layer and baked at 60 °C for 90 sec to evaporate the solvent. Finally, the UV exposure was carried out for 30 min to polymerize the RM monomers on the surface of the planar alignment layer.

The ECB sample was prepared by the sandwiched substrates coated with the RM. After assembling two substrates antiparallelly, the nematic LC of MLC-6012 (E. Merck, $\Delta\varepsilon$ = 8.2, Δn = 0.1016) was injected by the capillary action in an isotropic phase. The thickness was maintained by the glass spacers of 3.1 μm thick. Optical microscopic textures were obtained with the polarizing microscope (Nikon Eclipse E600 POL)

and the electrooptic properties were measured by a digitized oscilloscope (Tektronix TDS754D) and He-Ne laser system.



Top Layer : Reactive mesogen layer

Middle layer : Rubbed planar alignment layer

Bottom layer : ITO coated glass

Fig. 1 The schematic diagram of the proposed RM coated layer system.

3. RESULT AND DISCCUSION

We investigated the surface properties of the RM surface coated on the planar alignment layer depending on a RM concentration. Figures 2(a) and 2(b) show the microscopic images of the RM coated layers with the RM concentration of 0.7 wt% and 0.8 wt%, respectively. As shown in Fig. 2 (a), a uniformly coated surface was observed below 0.7 wt%. However, the RM aggregation occurred over 0.8 wt% as shown in Fig. 2(b). Therefore, we fabricated the ECB cell coated with 0.7 wt% RM and compared the electro-optic characteristics to the conventional ECB cell.

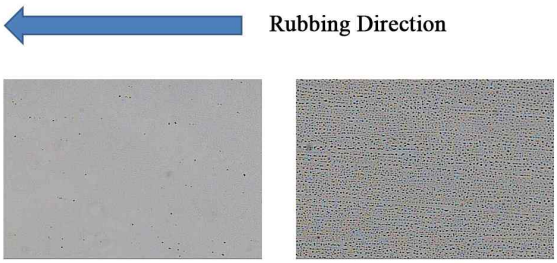


Fig. 2 Microscopic images of the RM coated layer of (a) 0.7 and (b) 0.8 wt%.

Figure 3 shows the electro-optic transmittance of the conventional and surface-controlled ECB cells. It should be noted that no difference in maximum transmittance and black state was observed between the conventional and surface-controlled ECB cells. However, the subtle difference in the threshold voltage was observed as shown in Fig. 3. The threshold voltage of the surface-controlled ECB cell is larger than that of the conventional ECB cell, which means that the anchoring energy of the RM coated surface is stronger than that of the rubbed surface in the conventional ECB cell. The strengthening of the polar anchoring energy was confirmed using LC-capacitance method [6]. The measured polar anchoring strengths of the conventional and the surface-controlled ECB cells are 6.59×10^{-5} and 9.05×10^{-5} J/m^2, respectively.

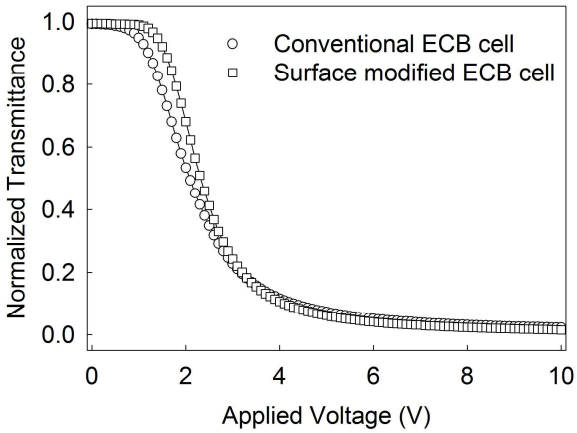


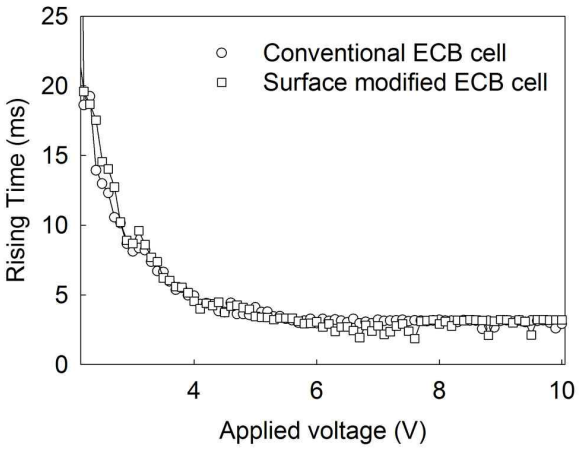
Fig. 3 The electro-optic transmittances of the conventional and surface-controlled ECB cells.

In general, the falling time of the LC (τ_0) is governed by the LC cell parameters such as rotational viscosity (γ_1), cell gap (d), and the elastic coefficient (K) as follows [7],

$$\tau_0 = \gamma_1 d^2 / \pi^2 K$$

Here, it is assumed that the surface anchoring strength (W) is infinite ($W \to \infty$). In fact, however, the surface anchoring energy is virtually finite and the larger anchoring energy has an important role in reducing the LC response time [8]. Figures 4(a) and 4(b) show the rising and falling times of the conventional and surface-controlled ECB cells as a function of the applied voltage. In the rising time, no remarkable difference was observed in all measured regions as shown in Fig. 4(a). On the other hand, as shown in Fig. 4 (b), the falling time

of the surface-controlled ECB cell was reduced by 27.3% comparing to that of the conventional ECB cell, which comes from the enhanced surface anchoring strength by the RM polymer networks on the surface. The falling times of the conventional and the surface-controlled ECB cells are measured to be 14.15 and 10.29 ms, respectively.



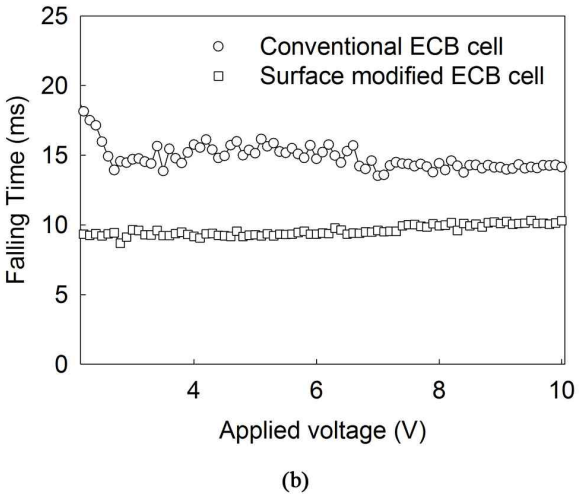


Fig. 4 The dynamic responses for (a) rising and (b) relaxing processes of the conventional and surface-controlled ECB cells.

We also investigated the stability of the RM coating layer against cleaning process because it is important factor to the mass production processes. After spin-coating the RM mixture on the planar alignment layer, the cleaning process was carried out with deionized (DI) water and air blowing gun. The surface morphologies of the RM layer before and after UV exposure were observed using an atomic force microscope (AFM). Figure 5 shows the AFM images for various substrate conditions. The RM coated surface without involving any cleaning processes is shown in Fig. 5(a). Here, the protrusions represent the aggregated RMs. Before UV exposure, involving the cleaning process, the RM coated layer was damaged as shown in Fig. 5(b) since the RM monomers did not polymerized and thus were easily washed away. After UV exposure, however, the polymerized RMs bore up against the cleaning process as shown in Fig. 5 (c).

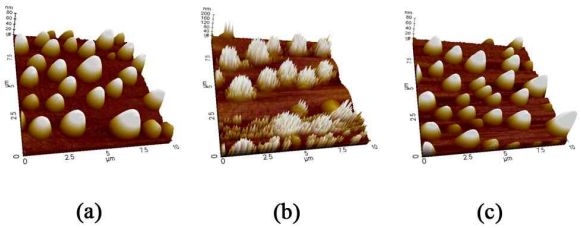


Fig. 5 AFM images of the substrate after (a) RM coating process, cleaning processes (b) before and (c) after UV exposure. Here, all images are not the same points.

4. CONCLUSION

We proposed the advanced method for improving response time using the photo-curable RM stacked on the rubbed planar alignment layer. The polymerized RM network on the surface remarkably strengthened the surface anchoring energy and thus dramatically improved the response time of the ECB mode without any complicated driving scheme and/or any changing material parameters. In addition, the polymerized RM layer on the surface is stable against the cleaning processes. We expect that this method is useful to other modes using planar alignment layer such as TN mode, in-plane switching mode [9], fringe-field switching mode [10], and so on.

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