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Fast Switching Liquid Crystal Modes using Reactive Mesogen Material

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We proposed the reactive mesogen (RM) coating method to improve response time in liquid crystal modes (LCDs). The polymerized RM network on the planar alignment layer enhances the surface anchoring energy through an interaction with liquid crystal (LC) molecules on the surface. As a result, we can obtain fast response time characteristics over whole gray levels.

1. Introduction

Nowadays liquid crystal displays (LCDs) are most commonly used in display market due to several advantages such as lightest weight, lowest power consumption and highest resolution and so on. However, it has a drawback such as relatively slow response time which is not fast enough to high quality moving picture and it is serious problem to expand LCDs into new display market such as three dimensional (3D) displays. The response time of LCDs is limited by the LC's slow behavior of themselves. For example, image blurring is one of the major problems. To overcome this problem, blinking backlight method [1] or low viscosity LC materials [2] were suggested. However, these methods have side effects with changing LCDs driving method or LC parameters.

Recently, new methods for surface control using ultra-violet (UV) curable reactive mesogen (RM) materials were suggested in the vertical align (VA) mode [3, 4]. RM monomers mixed in LC or alignment layer are polymerized according to the LC director by UV exposure process. As a result, response time characteristic was improved by polymerized RMs that decide switching direction of LC molecules. However, these methods do not acceptable to LCD mode using planar alignment layer like electrically controlled birefringence (ECB) mode or twisted nematic (TN) mode [5] due to polymerization problem of RMs on the planar alignment layer.

In this paper, we proposed an advanced method for improving LC response time through the surface modification using RMs without any complicated driving method and the changing of LC material parameters. The polymerized RM network on the planar alignment layer increases the surface anchoring energy through an interaction with LC molecules on the surface. As a result, response time characteristics improved dramatically, especially falling time.

2. Experiments

Figure 1 shows a schematic diagram of the proposed RM coated cell structure. The planar polyimide (PI) material (AL-22620, Japan Synthetic Rubber) was spin-coated on the indium-tin-oxide (ITO) coated glass. The coated planar PI material was soft-baked at 100 °C for 10 min to evaporate the solvent and hard-baked at 210 °C for 2 hr for perfect imidization. A surface of the hard-baked planar PI layer was rubbed unidirectionally for uniform alignment. The mixture of RM monomers and photo-initiator (Ciba Chemical, IRGACURE 651) dissolved in PGMEA was spin-coated on the rubbed planar PI layer and baked at 60 °C for 90 sec to eliminate the solvent. Lastly, the RM monomers on the planar alignment layer were exposed to the UV light (λ = 365 nm) for 30 min to composite cross-linked polymer network. The surface of RM coated layer was assembled anti-parallel, then the nematic LC (MLC-6012, Δn = 0.1016, $\Delta\varepsilon$ = 8.2, E. Merck Ltd.) was injected by capillary action at isotropic phase. The thickness of the ECB sample was maintained using glass spacers of 3.1μm. The microscopic textures were obtained by polarized optical microscope (Nikon Eclipse E600 POL). And electro-optic (EO) properties were measured by digitalized oscilloscope (Tektronix TDS754D) and a He-Ne laser (λ = 632.8 nm) as a light source. All the measurements were carried out at room temperature.

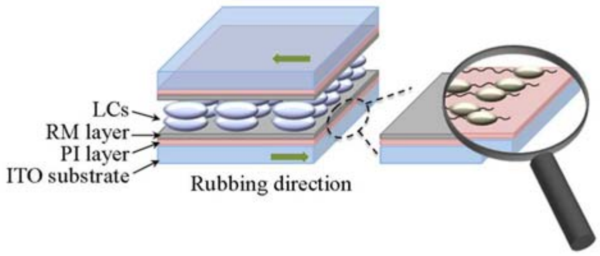

Figure 1. Schematic diagram of the stacked RM structure.

3. Results

We investigated the surface morphologies of RM coated planar PI layer with RM concentrations. As shown in Fig. 2 (a) and (b), we could obtain good coating uniformity below RM 0.7 wt%. However, RM aggregation phenomenon occurs over RM concentration 0.8 wt % as shown in Fig. 2 (c) and (d). Therefore, we fabricated the ECB cell coated with RM 0.7 wt% and compared the electro-optic characteristics with the conventional ECB cell.

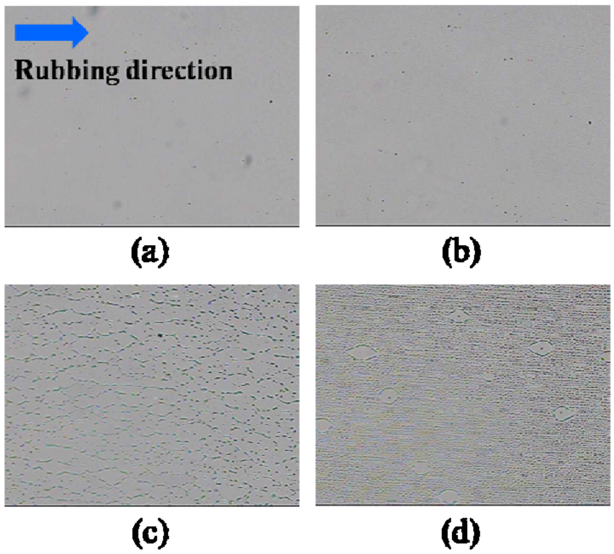

Figure 2. Microscopic images of RM coated layer with RM concentration (a) 0.5 wt%, (b) 0.7 wt%, (c) 1.0 wt% and (d) 2.0 wt %.

Figure 3 shows the voltage-transmittance characteristics of the conventional ECB cell and surface modified ECB cell. There is no difference in maximum transmittance and black state between conventional ECB cell and surface modified ECB cell. However, we can find that the threshold voltage (V_{th}) of the surface modified ECB cell is larger than that of the conventional ECB cell. This means that the anchoring energy of the RM coated cell is stronger than that of conventional ECB cell. Thus, we measured the polar anchoring energy by using LC-capacitance method [6]. The cell gap of the test cells is 20 μm and then the variation of the capacitance with applied voltage was measured using capacitance meter (HP-4284A). The measured polar anchoring energy of the conventional ECB cell is 6.59×10^{-5} J/m^2 and that of RM coated ECB cell is 9.05×10^{-5} J/m^2, respectively.

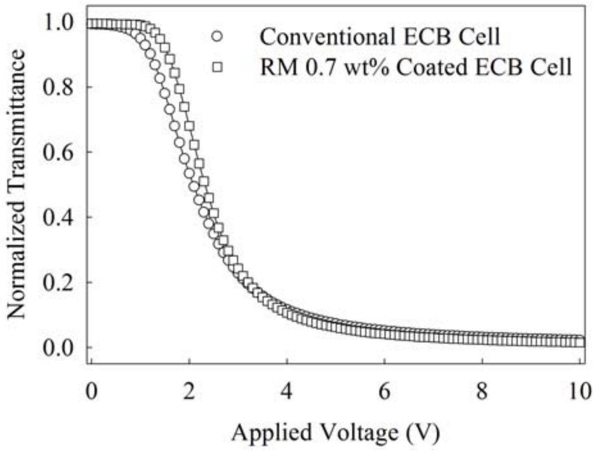

Figure 3. The voltage-transmittance characteristic of the conventional ECB cell and RM coated ECB cell.

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

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

Here, this mathematical relation is derived on the assumption that the surface anchoring energy strength is so strong. Namely, the surface anchoring energy (W) is infinite ($W \rightarrow \infty$). However, the surface anchoring energy is virtually finite and the larger anchoring energy has an important role in reducing the LC response time [8]. Fig. 4 shows falling time characteristics of the conventional ECB cell and RM coated ECB cell. In case of RM coated cell, the falling time improved 27.3% compare with conventional ECB cell, which comes from the enhanced surface anchoring energy due to the polymerized RM network on the surface. The falling time of the conventional ECB cell is 14.15 ms and that of surface modified ECB cell is 10.29 ms, respectively.

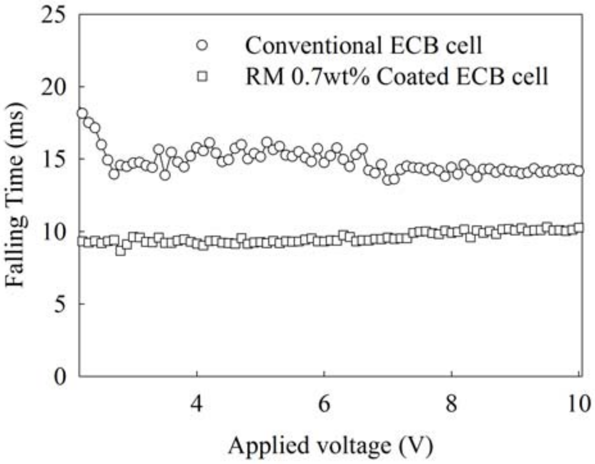

Figure 4. Response time characteristics of conventional ECB cell and RM coated ECB cell.

4. Conclusion

We proposed the method for improving LC response time using photo-curable RM stacked on the planar alignment layer. The polymerized RM network on the surface strengthens the surface anchoring energy and we improved response time of the ECB mode dramatically using the enhanced surface anchoring energy without changing driving method or LC parameters. We expect that this method is useful to other modes using planar alignment layer such as TN mode or IPS mode [9] or FFS mode [10] and so on.

References

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