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Scaling of Defect Domain by Reverse Twist in Chiral Hybrid In-Plane Switching LC Mode

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We proposed a new Liquid Crystal (LC) mode named as chiral hybrid in-plane switching (CH-IPS) LC mode for LCD application. However, when LC is injected into a CH-IPS sample, the domains by reverse twist are induced usually. In order to remove such a defect, we investigate what the major factors which have influence on the creation of defects by the reverse twist domain are. By experiment, we define the major factors which have large influence on the formation of domains. By controlling these major factors properly, we can remove defect domains perfectly.

Keywords: chiral hybrid in-plane switching mode; domains by reverse twist

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1. INTRODUCTION

Recently, the liquid crystal displays (LCDs) have been occupied the largest area of flat panel display market. For wide viewing angle

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and vivid color image in LCD TV, several LC modes such as in-plane switching (IPS) [1], fringe-field switching (FFS) [2], patterned vertical alignment (PVA) [3], and multi-domain vertical alignment (MVA) [4] mode have been developed and successfully commercialized. Among them, the IPS mode shows the wide viewing angle characteristics and uniform gray level and colors because the effective birefringence is nearly same even in off-axis. However, since the LC directors on the electrode area are aligned vertically by external field direction, the optical state on the electrode becomes almost dark even in bright state [5] and it reduces the transmittance of LCD. In case of the latest mass produced IPS mode with 4:6 electrode ratio which means the ratio of electrode width and gap, the transmittance is about $60 \sim 65\%$ comparing to twisted nematic (TN) mode. Moreover, the IPS mode is suffering from the excellent dark state because of the difference between the rubbing direction and the easy axis of LCs and a misalignment between the easy axes of top and bottom LC alignment layers [6]. To overcome these problems and improve the contrast ratio of IPS mode, we have proposed a new LC mode named as chiral hybrid in-plane switching (CH-IPS) LC mode [7,8]. Figure 1 shows the schematic diagram of the CH-IPS mode in bright and dark state. In CH-IPS mode, the bright state is obtained by the wave-guiding of polarized light due to the twist of LC alignment as same as TN mode as shown in Fig. 1(a). Therefore, there is no loss of transmittance on the electrode and the transmittance is dramatically increased. When we applied external field, the LCs are aligned easily to the direction of field which is the same as the optic axis of top polarizer because the bulk elastic strength is much lower than surface anchoring strength. Furthermore, the CH-IPS mode can get better dark state

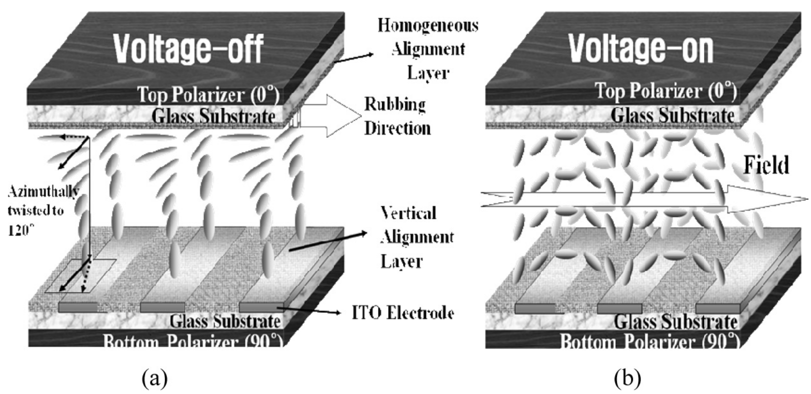


FIGURE 1 Schematic diagrams of CH-IPS mode in bright and dark state.

than conventional IPS mode because the rubbing direction of top substrate is parallel to the optic axis of top polarizer (0°). As a result, the CH-IPS mode has much higher contrast ratio (up to 1000:1) than that of conventional IPS mode even with relatively low voltage. However, the twisting power in CH-IPS mode would be weaker than it of the TN structure and the possibility of reverse twist could be increased. The reverse twist structure will degrade the performance of CH-IPS mode since the twisted structure is produced by added chiral dopant in CH-IPS mode different from TN structure in which it is promoted by the rubbing on top and bottom substrates.

In this article, we reported the optimization of cell parameters in CH-IPS mode to reduce the reverse twist structure.

2. EXPERIMENT

We used a homeotropic LC alignment layer (AL60702, JSR) on a bottom substrate and a homogeneous LC alignment layer (JALS1085, JSR) on a top substrate. And interdigitated electrode for in-plane switching is formed on bottom substrate. We placed two crossed polarizers with the optics axes of 0° and 90° at bottom and top substrate, respectively. Top and bottom substrates are rubbed parallel to the optical axis (0°) of polarizer coincident with horizontal direction of the field supplied from interdigitated electrode. The LC and chiral dopant used in this experiment were ZKC-5085 (Chisso) with birefringence $\Delta n = 0.15$ and S-811 (Merck), respectively. The T_{ni}, isotropic-nematic transition temperature of the LC, is 108°C.

3. RESULTS AND DISCUSSION

Figure 2 shows the change of alignment textures in CH-IPS mode depending on the applied voltages. Without the external voltage, you can see that the discilination lines are formed between reverse twisted domains as shown in Fig. 2(a). When we applied voltage, the LC directors are reorientated in the direction of field from the domains boundary. As shown in Fig. 2(b), the disclination lines are spread gradually from domain boundary with increasing voltage. Because of these spread of disclination line, the dark state is realized gradually from domain boundary as shown. in Fig. 2(c). Due to the behavior of discilination, it is difficult to maintain the gray level and get the dark state immediately. As most essential issue of CH-IPS mode for LCD application, therefore, it will be most important to remove clearly the domains by reverse twist in CH-IPS.

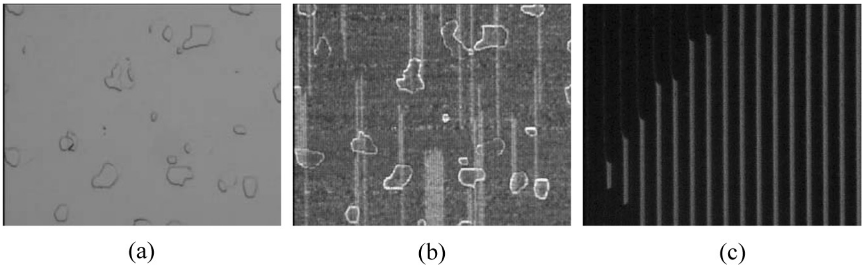


FIGURE 2 The microscopic images of CH-IPS sample; (a) without field, (b) with intermediate, and (c) with high field.

Experimentally, we found that three dominant factors such as LC injection temperature, LC injection direction with respect to the rubbing direction, and rubbing strength were greatly affected on the formation of disclination lines. Figure 3 shows the microscopic images of the sample with LC injection temperature. Since T_{ni} is 108°C for used nematic LC, we selected the injection temperatures, T_i, as below, comparable, and over to T_{ni}. As shown in Fig. 3(a), when we inject LC at $T_i = 50°C$ lower than T_{ni}, large domains with reverse twisted structure are created. On the other hand, small domains are generated with $T_i = 130°C$ as shown in Fig. 3(c). However, if we inject the LC near T_{ni} (103°C ~ 113°C), the formation of reverse twisted domains can be minimized as shown in Fig. 3(b). It is well known that the direction of LC injection has influence on the surface alignment of LC. Therefore, we optimized the LC injection direction with respect to the rubbing direction. Figure 4 shows the textures of the sample under crossed polarizers with different direction of LC injection. From the results, we found that the best alignment state can be obtained when

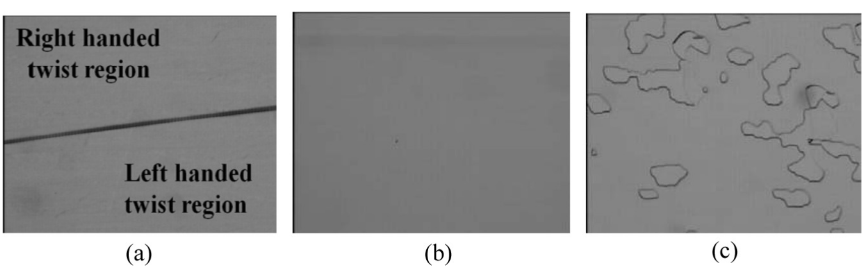
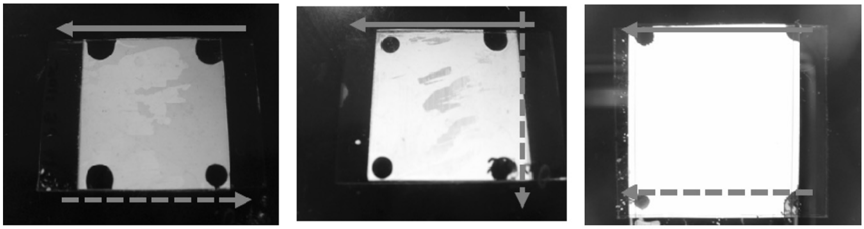


FIGURE 3 The alignment textures of the sample with different injection temperature at (a) 50°C, (b) 103°C ~ 113°C, and (c) 130°C.

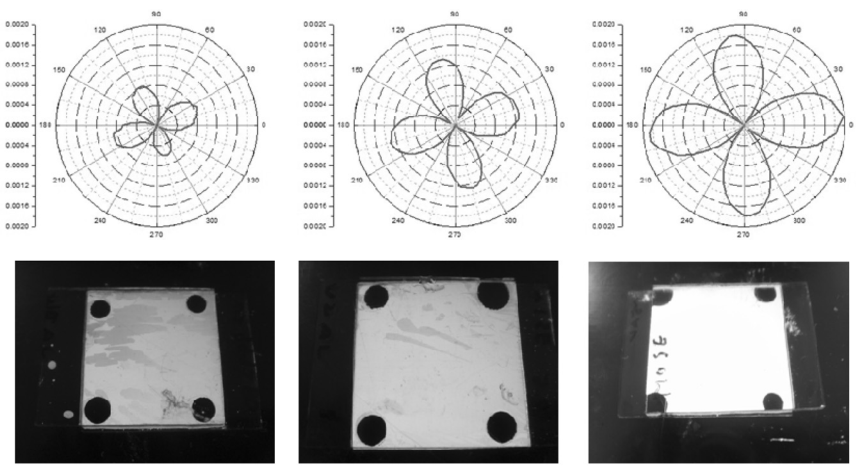


(a) (b) (c)

FIGURE 4 The textures of samples under crossed polarizers with different direction of LC injection with respect to the rubbing direction. The solid and dotted lines indicate LC injection and rubbing direction, respectively.

the LC injection direction is parallel to the rubbing direction. It may due to the flow of LC molecules during injection.

Another major factor which has influence on the formation of domains is anchoring strength which depends on rubbing strength. In order to control anchoring strength, we changed the number of rubbing with fixing all other parameters such as rubbing speed and pressure. It is known that the anchoring strength is directly related to the ordering of polymer chains in used polyimide which can be determined by measuring birefringence [9]. The birefringence of



(a) (b) (c)

FIGURE 5 The birefringence of polyimide layer and the alignment textures with different number of rubbing; (a) 1 time, (b) 5 times, and (c) 10 times.

rubbed polyimide is measured by using the PEM-100 (HINDS instrument) and Lock-in amplifier (Stanford Research Systems).

Figure 5 shows the measured birefringence of the rubbed polyimide and the alignment textures of the samples with different number of rubbing. From this result, we found that the formation of reverse twisted domains was suppressed with increasing anchoring energy.

4. CONCLUSION

We experimentally optimized the cell parameters to remove the reverse twisted domain in CH-IPS mode. We found that the major factors to influence on the creation of defects are LC injection temperature, LC injection direction with respect to the rubbing direction, and rubbing strength. The defects can be suppressed when the LC is injected at the temperature of near isotropic-nematic phase transition in the direction parallel to rubbing direction. Moreover, the mono domain can be obtained with increasing anchoring strength of homogeneous alignment layer.

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