Optimization of Chiral Dopant and Rubbing Direction in Liquid Crystal Display

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Keywords : Chiral pitch, Liquid crystal, Twist effect, Rubbing direction

Abstract

In order to improve the performance of LCD, chiral dopant is added to liquid crystal mixture. When we decide the rubbing direction, we must consider the rotation direction of liquid crystal molecules by chiral dopant. When the rotation direction of liquid crystal molecules caused by dielectric torque decided by rubbing direction and that decided by chiral dopant are coincided, the performance of LCD would be improved along to our initial cell design intentions.

1. Introduction

Nowadays, to improve image quality, response time, transmittance and wide viewing angle , various LC modes were invented and are investigated like in-plane switching (IPS)[1] mode, fringe-field switching (FFS)[2] mode, multi-domain vertical alignment mode (MVA)[3] mode, patterned vertical alignment mode (PVA)[4], and so on. Among them, to improve the efficiency of transmittance of liquid crystal layer, many analyses have been done using in-plane field or fringe-field. In IPS mode, the electric field lines parallel to the substrate in the area between electrodes mainly exist so that only twist deformation of liquid crystal director. But, in FFS mode with closer electrode width than IPS mode between pixel electrode and common electrode causing strong electric field in order to twist the liquid crystal molecules, transmittance efficiency is better than in IPS mode[5]. And the effects of rubbing direction on the voltage-dependent transmission curve have been studied in FFS mode[6]. We found that it is strongly dependent on the rubbing direction when the liquid crystal with positive dielectric anisotropy is used in FFS mode. But, when we decide the rubbing direction, the optimized direction must be defined at fixed standard direction (for example, counter clock-wise (CCW) 7° direction from ITO slit).

And in TN mode, similarly like FFS mode, there is also the twist effect of liquid crystal decided by rubbing direction to generate transmittance. When the LC mode using twist effect like TN or FFS mode, chiral dopant could be added to overtwist liquid crystal molecules. Chiral dopant makes liquid crystal mixture to overtwist toward its originate rotation direction. So it could be more effective in getting better performance through the optimization between the rubbing direction and the rotation direction by chiral pitch in our study.

2. Calculation Condition

In normally white TN mode, liquid crystal molecules are twisted between lower substrate and upper substrate in off-state with generating 90° twist angle by rubbing process. In FFS mode, there is some transmittance differences generated at the edge of electrode and at the center of electrode, but it is also used the twist effect of liquid crystal for generating transmittance at both area in FFS mode.[7] To analyze the twist effect by various chiral pitches, we designed the simulation model for TN mode and FFS mode like following.

In this study, the commercially available software “2dimMOS” is used. Figure 1 shows the definition of rubbing direction in TN and FFS mode. In the TN cell structure for simulation, we decided the fixed rubbing direction of upper substrate is 45° with respect to the horizontal direction, and rubbing directions of lower substrate are defined -45° and 135° respectively. (In

each case, twist angles of liquid crystal is generated to 90° and -90°.)

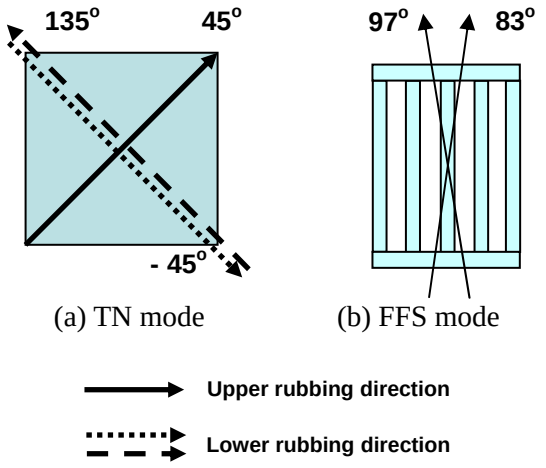
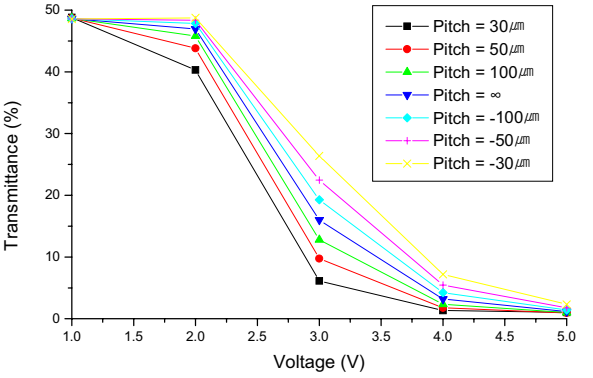


Fig. 1. Rubbing direction definition of the cell structure for simulation in TN mode and FFS mode.

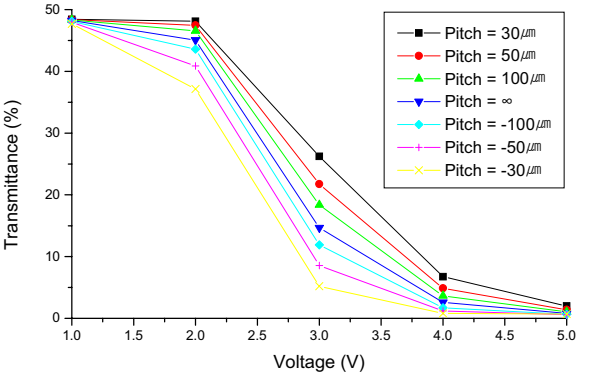
In the FFS cell structure for simulation, twist angle of liquid crystal in on-state is decided by between rubbing direction and ITO slit direction. So two case could be thought that if ITO slit direction is fixed to vertical direction, the first case is rubbed to the direction which is inclined to the clock-wise (CW) direction about ITO slit, and another is rubbed to the direction which is inclined to the counter clock-wise (CCW) direction about ITO slit. For simulation about these two cases, we decided the rubbing directions are 83° and 97° with respect to the horizontal component of the fringe electric field. The width of pixel electrodes and the distance between them are 3 ㎛ and 5 ㎛. The pitches of chiral dopant are varied as following : +100 ㎛, +50 ㎛, +30 ㎛, -100, -50 ㎛ and -30 ㎛ (in both LC mode).

3. Results and Discussion

Figure 2 shows the calculated transmittance for various chiral pitches of normally white TN mode when rubbing angle of upper substrate is fixed to 45° , the rubbing angle of lower substrate is -45° (in Figure 2 (a)) and 135° (in Figure 2 (b)).



(a) Rubbing angle of lower substrate : - 45°



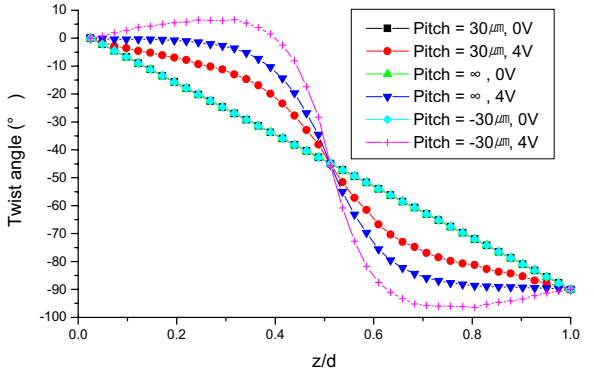
(b) Rubbing angle of lower substrate : 135°

Fig. 2. Calculated Voltage - Transmittance curve for various chiral pitches with rubbing angle of lower substrate -45° and 135° respectively in TN mode. (Rubbing angle of upper substrate : 45°)

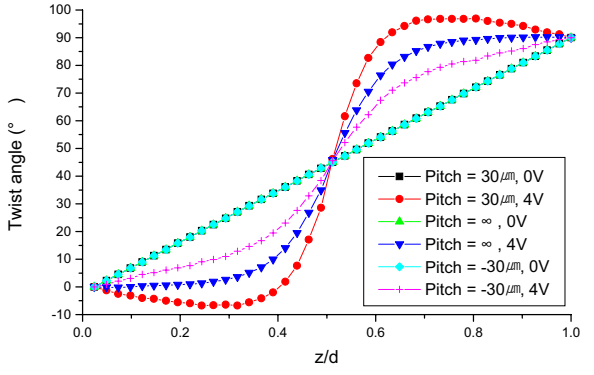
At rubbing angle of lower substrate -45°, liquid crystal molecules are rotated CW direction, and are overtwisted by chiral pitch with minus sign. So like in figure 1. (a), Vop is more increased than with no chiral pitch or with plus sign's pitch in on-state. (If the pitch of plus sign would be added, liquid crystal molecules are undertwisted, so the dark state would be occurred more quickly as the operating voltage increases.) And if rubbing angle of lower substrate is 135°, the reverse trend with regard to the result at -45° is occurred, so the Vop is decreased at the chiral pitch with minus sign.

Figure 3 shows the distribution of twist angles when rubbing angle of lower substrate is -45° and 135° respectively with varying operating voltage and

chiral pitch. In off-state, there is few difference in twist angle distribution, but in on-state there are noticeable difference by adding chiral pitch. If rubbing angle of lower substrate is -45°, the rotation direction of twist angle is CW, so twist angle with minus pitch gets larger than original LC or with plus pitch, and this causes Vop increase due to the increased phase retardation value by enlarged twist angle. The sign of twist angle at with rubbing angle of lower substrate -45° is reverse with regard to that of lower substrate 135°. This is due to the different rotation direction of liquid crystal molecules



(a) Rubbing angle of lower substrate : - 45°

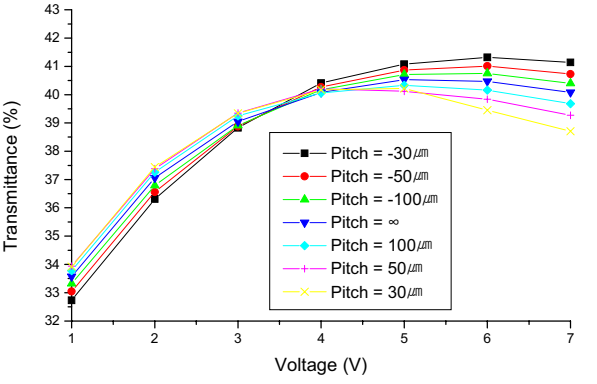


(b) Rubbing angle of lower substrate : 135°

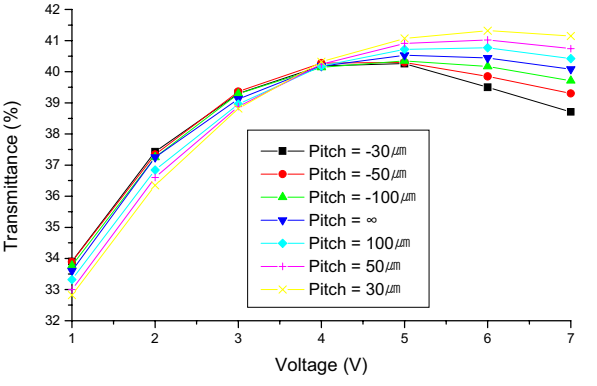
Fig. 3. Calculated twist angle for various chiral pitches with rubbing angle of lower substrate (a) -45° and (b) 135° in TN mode.

It was investigated that at the electro-optical characteristics of the FFS mode using a positive LC with an added chiral dopant.[8] In our study, the effect by chiral dopant in FFS mode is investigated with dividing into two cases like following.

Figure 4 shows the calculated transmittance for various chiral pitches when rubbing angle is 83° and 97° in FFS mode. The rubbing angle difference between 83° and 97° decides the rotation direction of liquid crystal molecules by the dielectric torque N. When rubbing angle is 83°, as chiral pitch is increased from minus sign to plus sign, Vop and transmittance are decreased. And when the rubbing angle is 97°, as chiral pitch is increased from minus sign value to plus sign value, Vop and transmittance are increased. Similarly in TN mode, when liquid crystal molecules are twisted toward CW direction, as chiral pitch increases from the minus value to the plus value, transmittance and Vop decrease. And when twisted toward left, as chiral pitch increases from the minus value to the plus value, transmittance and Vop also increase.



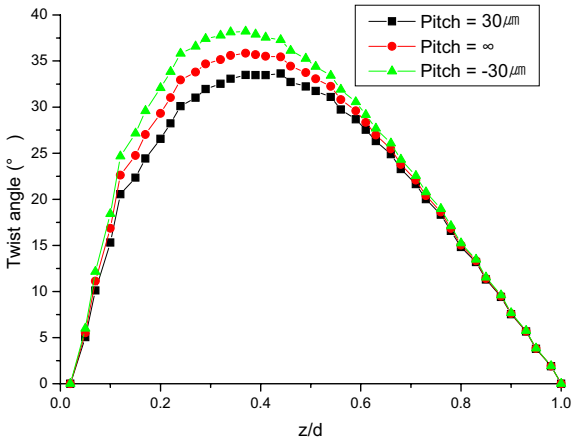
(a) Rubbing angle : 83°



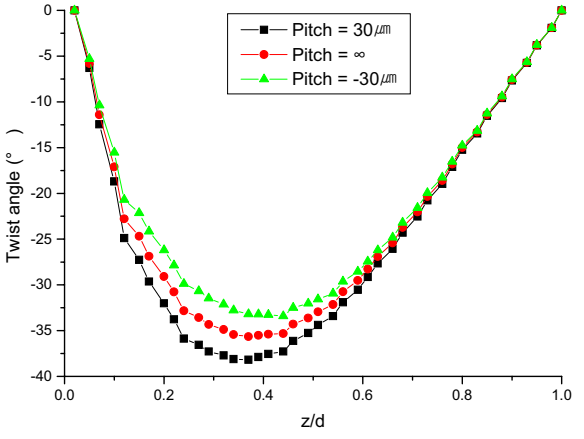
(b) Rubbing angle : 97°

Fig. 4. Calculated Voltage - Transmittance curve for various chiral pitches with rubbing angle (a) 83° and (b) 97° in FFS mode.

Figure 5 shows the calculated twist angle for various chiral pitches with (a) 83° rubbing and (b) 97° rubbing at ITO electrode center.



(a) Rubbing angle : 83°



(b) Rubbing angle : 97°

Fig. 5. Calculated twist angle for various chiral pitches with rubbing angle (a) 83° and (b) 97° in FFS mode.

Our results in FFS mode are similar to those in TN mode. When the rotation direction of liquid crystal molecules by rubbing angle and that by chiral pitch is coincided, liquid crystal molecules are overtwisted, and Vop is increased in TN mode. Similarly, when the rotation direction of liquid crystal molecules by dielectic torque and that by chiral pitch is coincided, liquid crystal molecules are also overtwisted, and both Vop and transmittance is increased in FFS mode. So from these results, we must design the cell process condition, especially rubbing direction (with regard to layout of panel), and additive chiral dopant of liquid crystal with considering the relation between the rubbing angle and the rotation direction by chiral dopant.

4. Summary

We investigated the relation between the rubbing direction and the chiral dopant of liquid crystal in LC mode using twist effect. When the rotation direction by chiral dopant is fixed, the rubbing direction has to be considered as our study's result. When rubbing angle of one substrate is changed, the rotation direction of liquid crystal molecules also be changed, and it needs the change of chiral dopant. Therefore, it must be careful when we mix special chiral dopant to the conventional liquid crystal mixture or change the rubbing direction. If the rubbing direction and the chiral dopant would be optimized, the performance of liquid crystal display could be improved as we designed.

5. References

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