Two-dimensional LC analyses for increasing operation voltage in the FFS mode with fine slit pixel electrode

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Abstract

We studied for high transmittance panel technology in the FFS mode. We found that fine slit of pixel electrode makes increase of panel transmittance, and at the same time this structure has an issue which is increasing operation voltage (Vop). We analyzed the reason of high Vop in the FFS pixel with fine slit using two-dimensional LC analyses. Finally we suggest the solution which has high transmittance with suitable operating voltage.

1. Introduction

FFS mode has many advantages which are high transmittance, wide viewing angle, pooling free, fast response, sun light readability, low logic driving voltage and vivid color characteristic for portable application.[1-4] Because of these excellent characteristics, our products have been accepted many customers. Recently our customers have required very high transmittance with LED B/L which required very thin thickness and variable dimming voltage for power saving property. Therefore we became study for high transmittance panel technology with fine pattern design rule and fine slit of pixel electrode in the FFS mode. We found that fine slit of pixel electrode make increase of panel transmittance, and at the same time this structure has an issue which is increasing operation voltage (Vop).[5] In this study, we analyzed the reason of high Vop in the FFS pixel with fine slit using two-dimensional LC analyses. We calculated the transmittance at the different electrode positions of sub-pixel. And also we calculated twist angle and tilt angle properties of LC at the different cell gaps in the each electrode position. Finally we commented the solution which has high transmittance with suitable operating voltage.

2. Results and Discussion

Figure 1 shows the V-T curves with different w/ℓ’ at the real panel. In case of w/ℓ’=3 ㎛/5 ㎛, Vop is 5V with 3.05 Panel transmittance. But in case of fine slit with w/ℓ’=2 ㎛/3 ㎛, the Vop become increasing about 30% to 6.5V compared with normal structure with w/ℓ’=3 ㎛/5 ㎛. And Panel transmittance also increases 7% with 3.28.

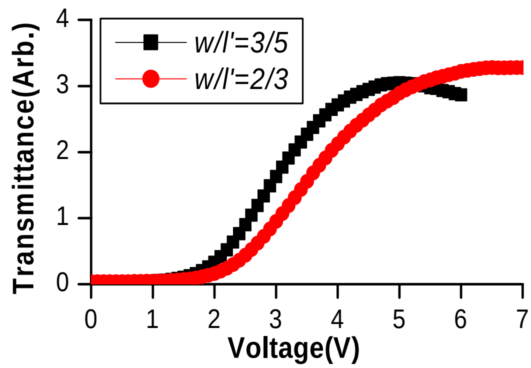

Figure 1. V-T Characteristic with different slit of pixel electrode at real panel

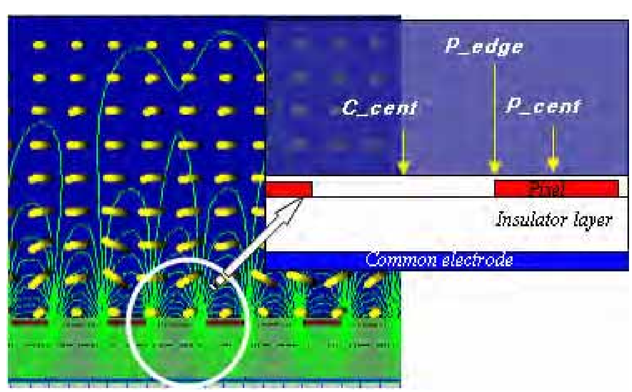

Figure 2. Calculating positions of V-T on the sub-pixel of FFS mode

We calculated the transmittance at the different electrode positions of sub-pixel. Figure 2 shows the calculating positions of V-T on the sub-pixel of FFS mode. We divided three positions which are common center (C_cent), pixel edge (P_edge), and pixel center (P_cent), respectively. Usually on the sub-pixel of FFS mode, the average transmittance decided by repetition of transmittance at these three positions. Therefore we considered these positions for electro-optic analysis. For simulation (2DIMOS; Autronics Co. of Germany), we used positive dielectric LC with $\Delta\varepsilon$ = 8.2, Δn = 0.0987, Y1 = 84mPa.s and 3.6 ㎛ cell gap. Figure 3 shows the calculated results of V-T with different electrode positions of sub-pixel at each slit pattern. In fine slit, these operating voltages more increase than those of normal slit pattern at all positions. Therefore average Vop is increased with increased transmittance.

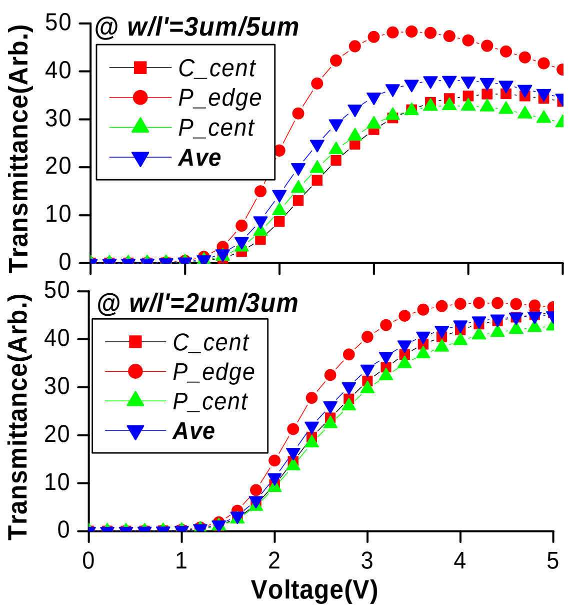

Figure 3. Calculated results of V-T with different electrode positions of sub-pixel at each slit pattern

Figure 4 and Figure 5 show the calculated results of voltage-twist angle with different cell gap of each electrode position at w/l'=3/5 and w/l'=2/3, respectively. We analyzed 1/4, 2/4, 3/4 cell gap positions which have a meaning of representation to explain the dynamic behavior of LC molecules. As compared with each slit for voltage-twist angle curves, fine slit has some characteristics. First, at the pixel edge position of fine slit, twist angle change ratio according to increased voltage from initial angle is slower than it of normal slit with w/l'=3/5. Second, at the electrodes center with d=0.9 ㎛ cell gap position of fine slit, twist angle from initial angle is larger than it of normal slit. Therefore we can guess that these properties make high transmittance due to same twist angle with same time according to increased voltage and increasing operating voltage due to slow twist ratio from initial angle at the pixel edge. And we also find that twist behaviors of LC molecules at fine slit have more similar shape than those of normal at each electrode position according to increasing voltage. This meaning is that uniform transmittance is occurred at the same time on whole area of pixel. Therefore transmittance is high at a fine slit pixel. Figure 6 and Figure 7 show the calculated results of voltage-tilt angle with different cell gap of each electrode position at w/l'=3/5 and w/l'=2/3, respectively. As compared with each slit for voltage-tilt angle curves, tilt property of fine slit showed different LC tilt characteristic. Generally LC dynamics of pixel edge position are unstable then other positions. And at the position of common center and pixel center, tilt up behavior of LC molecules is similar shape according to increasing voltage. Total behaviors of tilt angle change at the fine slit are smaller than those of normal slit. This result shows LC dynamics is more stable in fine slit pixel.

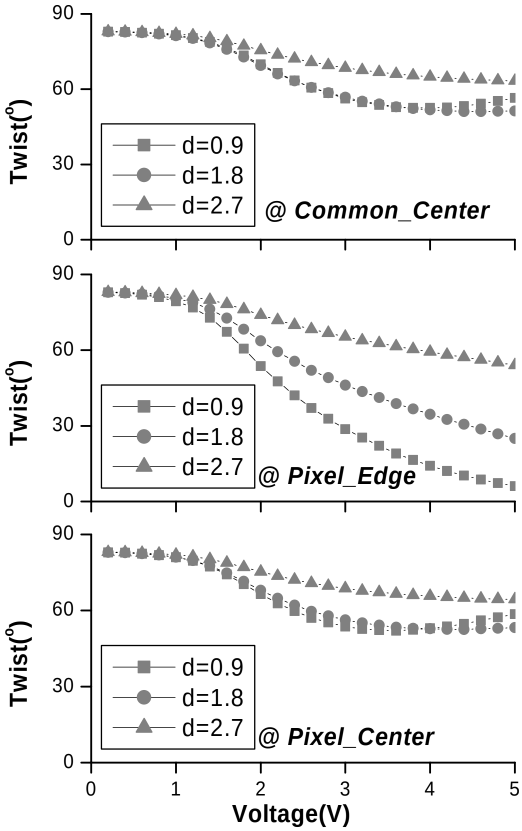

Figure 4. Calculated results of Voltage-Twist angle with different cell gap of each electrode position at w/l'=3/5

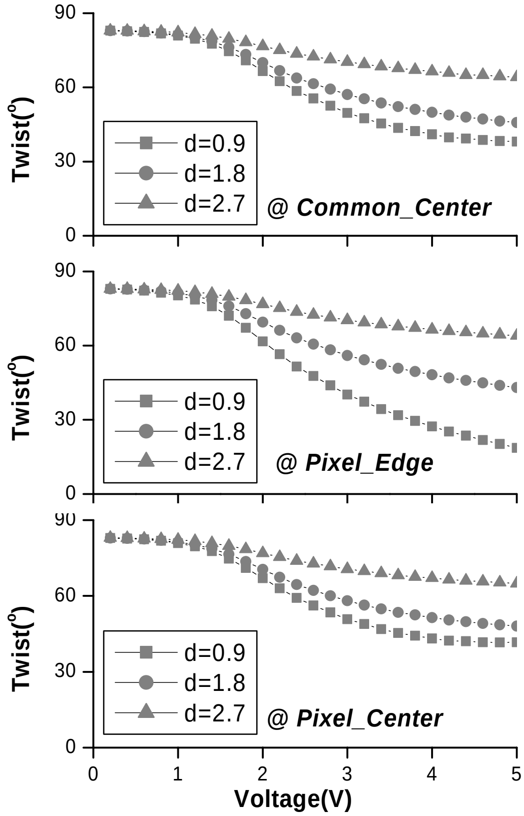

Figure 5. Calculated results of Voltage-Twist angle with different cell gap of each electrode position at w/l'=2/3

3. Conclusion

In this study, we found that fine slit of pixel electrode make increasing operation voltage at real panel. As result of analysis, in fine slit, first, twist ratio from initial angle at the pixel edge position is slower than it of normal slit. Second, twist angle at the middle cell gap of electrodes center is larger than it of normal slit. And we also find that twist behaviors of LC molecules have more similar shape than normal those at each electrode position according to increasing voltage. This meaning is that uniform transmittance is occurred at the same time on whole area of fine slit pixel. Therefore transmittance is high at a fine slit pixel.

In addition, total behaviors of tilt angle change at the fine slit are smaller than those of normal slit. This result shows LC dynamics is more stable in fine slit pixel. Therefore we can believe firmly that these properties make high transmittance due to same twist angle with same time at different voltage from initial rubbing direction and increasing operating voltage due to slow twist ratio from initial angle at the pixel edge. Finally for decreasing Vop, we applied high dielectric LC in a cell and made new pixel structure with reduced insulator layer after active etch process. Therefore we achieved excellent transmittance characteristic in FFS mode compare to other wide viewing technologies

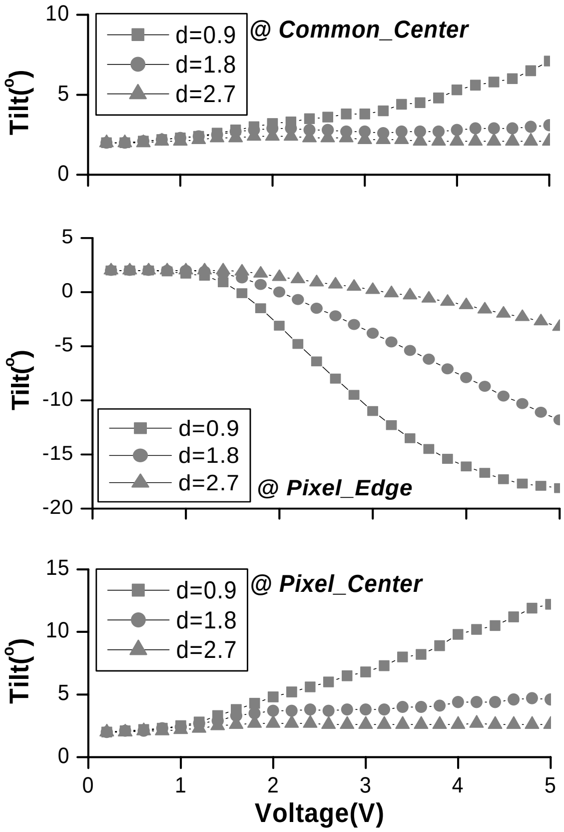

Figure 6. Calculated results of Voltage-Tilt angle with different cell gap of each electrode position at w/l'=3/5

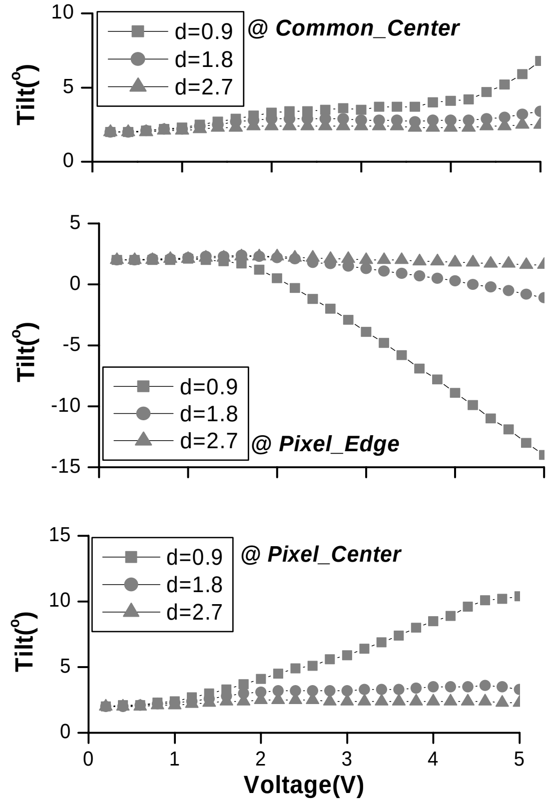

Figure 7. Calculated results of Voltage-Tilt angle with different cell gap of each electrode positions at w/l'=2/3

4. References

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