Generation of Disclination Line Dependent on Liquid Crystal's Rubbing Direction in Projection Displays

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Abstract

We have studied how rubbing direction affects generation of disclination line in transmissive microdisplay for 90° twisted nematic (TN) mode with pixel size of 22.2μm. The rubbing direction of bottom substrate is changed from 0° to -135° with a decrease step of 45°, and the results show that the generation regions of the disclination line are of a smallest size in -135° direction. The results were the same although the pixel size decreased. Consequently, the use of proper rubbing direction of liquid crystal can help overcome the problems of low aperture ratio and low contrast ratio in transmissive-type microdisplays. In addition, the pretilt angle of initial liquid crystal is found to make an important contribution to generation of the disclination line.

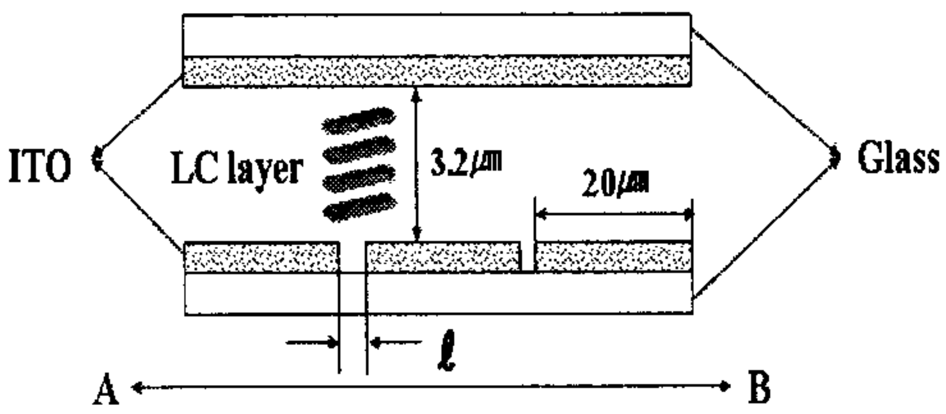
1. Introduction

Microdisplays can be classified into three categories depending on how the light is utilized: transmissive-type high temperature poly-silicon (HTPS), reflective-type liquid crystal on silicon (LCoS) and micro electro-mechanical system (MEMS).[1] In order to generate a picture of large-size projection display, the high resolution device is required. However, to realize a high resolution display, the distance between pixel and pixel becomes very short, giving rise to following problems such as decreased aperture, appearance of diffraction and increase of fringe-electric field instead of vertical field that is unwanted.[2] According to the previous report, there arises a reverse tilt domain at upper region of pixel electrode in vertical direction that due to a reversed application of voltage between adjacent pixel electrodes. So it deteriorates display image quality.[3] Further, in LC device, the fringe field causes generation of disclination line near the regions between pixels. To suppress the disclination line, some methods such as changing the shape of electrode near the edge and change of pretilt angle of the LC were proposed.[4-7]

In this paper, we have studied how the rubbing direction of the bottom substrate affects the generation of disclination line for the 90° TN while changing the distance between pixels and LC's pretilt angle.

2. Results and Discussion

Figure 1 shows cross-sectional and top view of the LC cell structure. Here, the cell gap (d)was 3.2μm with a pixel size of 20μm. The simulation was performed using the LCD Master (Shintech, Japan). The physical properties of the LC are given in table 1 and optical calculation was made based on 2 x 2 Jones matrix.[8]



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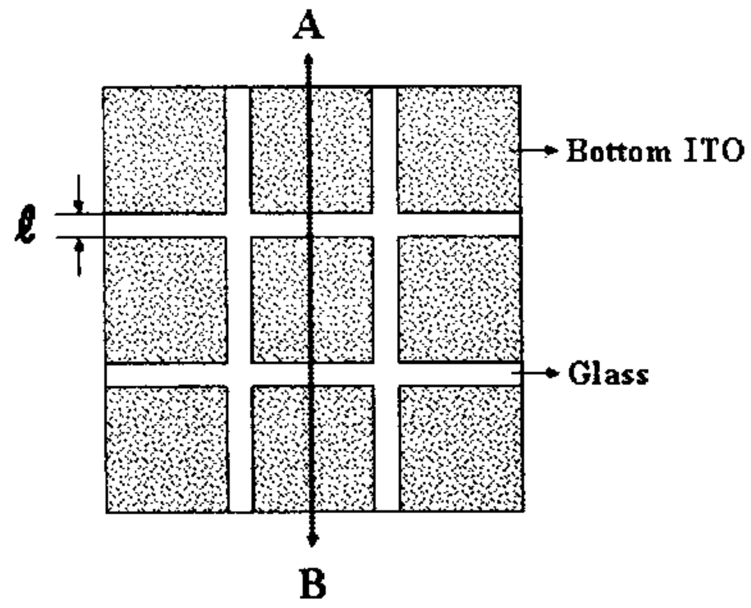


(b)

Figure 1 (a) Cross-sectional and (b) top view of LC cell structure used for simulation.

The generation of disclination lines along the line AB was studied and the rubbing direction is defined along horizontal axis of the bottom substrate.

Table 1 Parameters of liquid crystal that were used in the simulation.

	90°-TN
K_{11}(pN)	12.2
K_{22}(pN)	3.4
K_{33}(pN)	14.0
$\varepsilon_{\parallel}$	9.7
$\varepsilon_{\perp}$	5.7
$\Delta n(\lambda$=550nm)	0.15

First, in order to decide applied voltage we have calculated voltage-dependent transmission curve for an incident light of 550 nm, as shown in Figure 2. Here, the $d\Delta n$ of the cell is 0.48㎛ and the pretilt angle is 5°. For off- and on-voltage, 0V and 5V are applied, respectively.

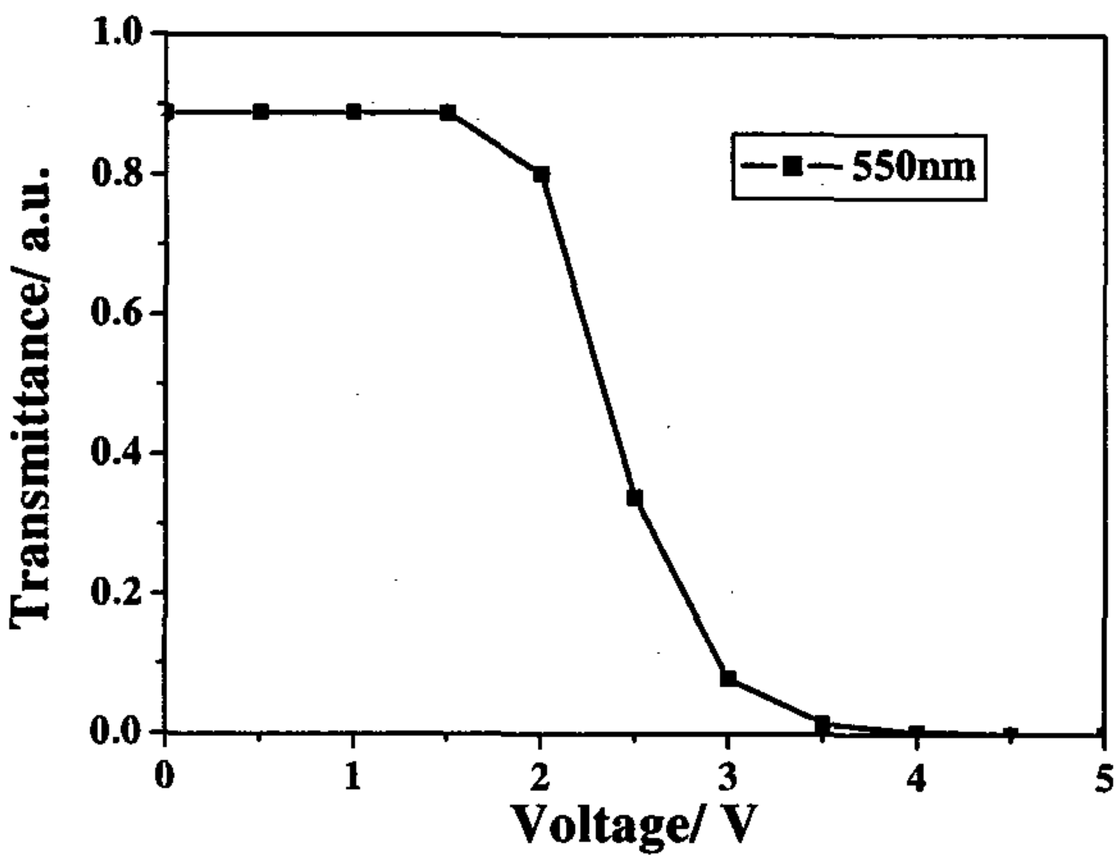
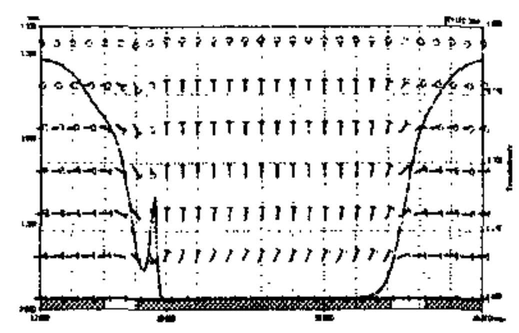


Figure 2 Voltage-dependent transmittance for an incident light 550nm.

Figure 3 shows how disclination lines occurs when the pixel at center is on and the two pixels surrounding center are off for different rubbing directions. Here, the solid line indicates the transmittance. As indicated, the relatively strong light leakage occurs near left side of the pixel at center, except for the cell with rubbing direction of -135°.

Figure 4 shows how disclination lines occurs when the pixel at center is off and the two pixels surrounding center are on for different rubbing directions. As indicated, the strong light leakage occurs at the right side of pixel at center, except for the cell with rubbing direction of -135°.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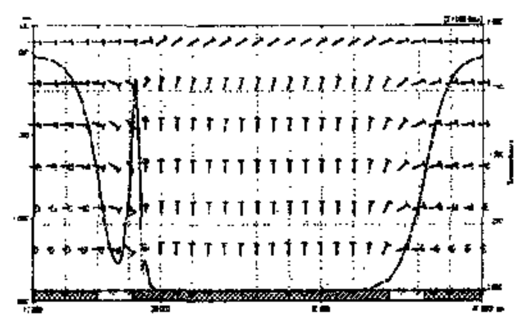
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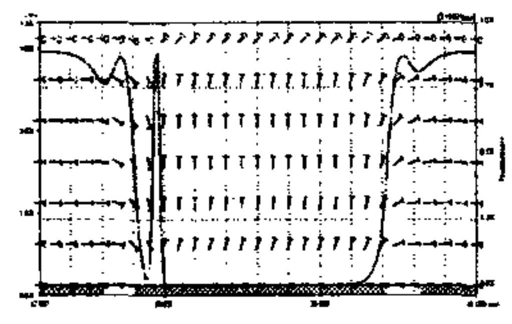
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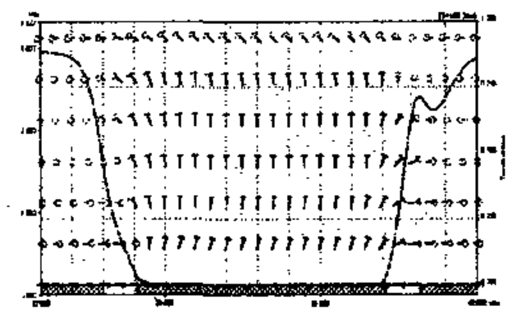
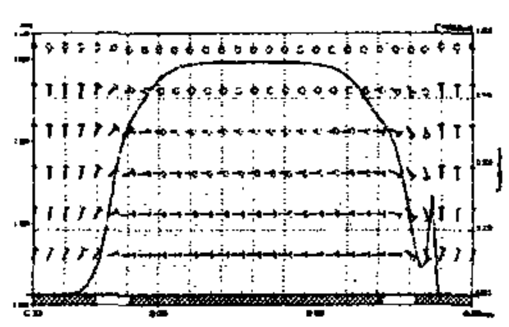

(d)

Figure 3 Transmittance of 90°-TN cell with a distance of 2.2㎛ between pixels as a function of rubbing direction of bottom substrate when one pixel is on and the adjacent pixels are off: (a) -90°, (b) 0°, (c) -45°, and (d) -135°.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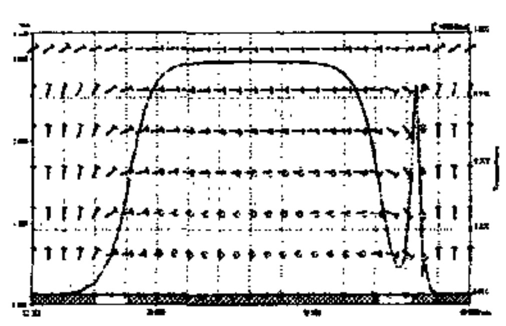
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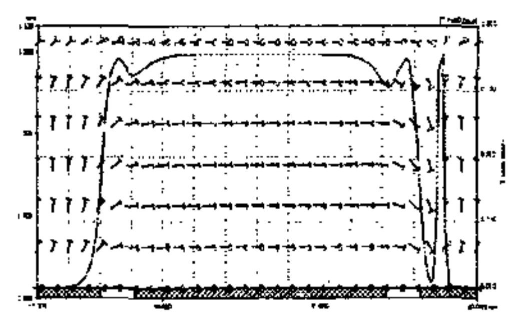
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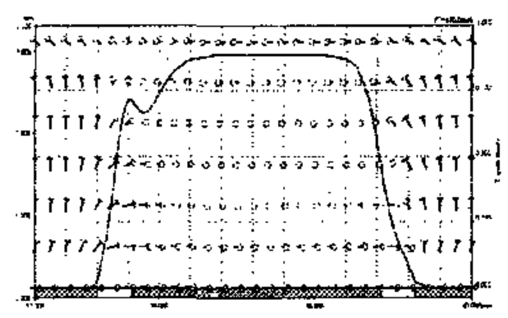
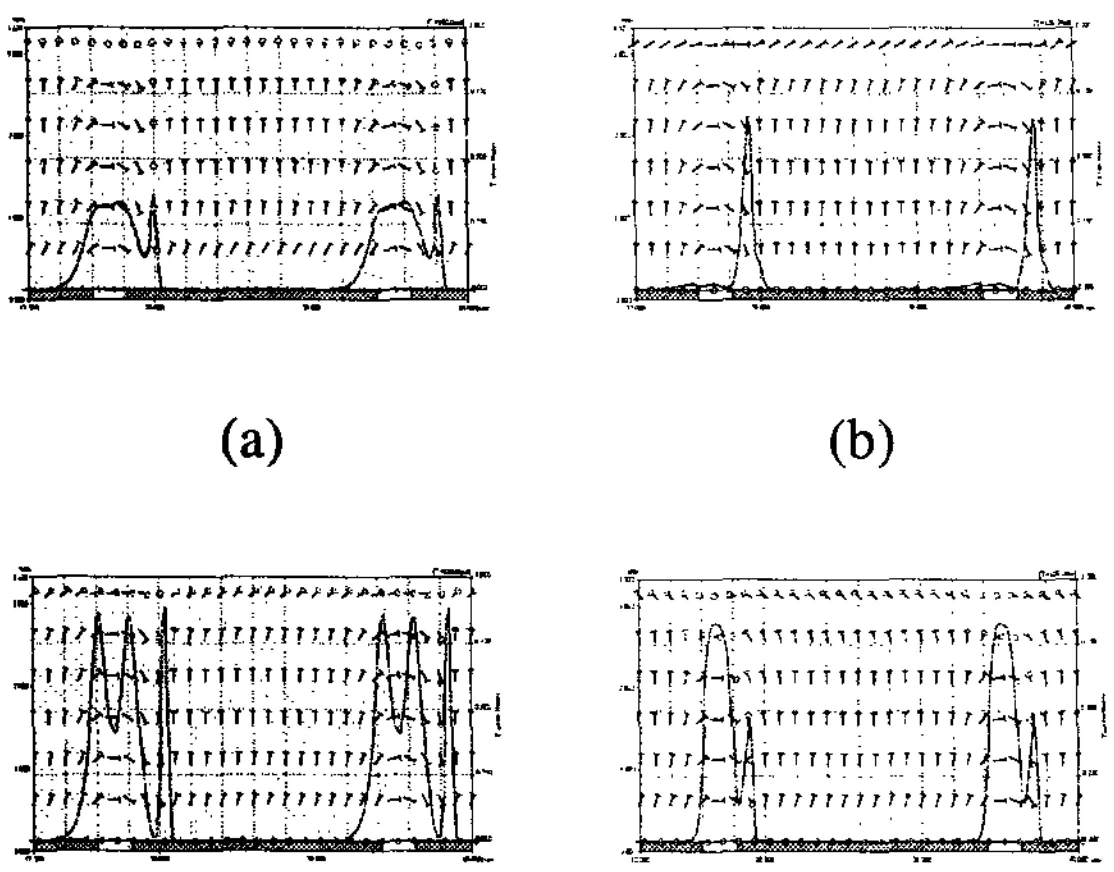

(d)

Figure 4 Transmittance of 90°-TN cell with a distance of 2.2㎛ between pixels as a function of rubbing direction of bottom substrate when one pixel is off and the adjacent pixels are on: (a) -90°, (b) 0°, (c) -45°, and (d) -135°.

Figure 5 shows the transmittance when all three pixels are on. All cells show some degree of light leakage, which needs to be blocked to achieve a high contrast ratio. However, the light leakage occurs in the narrow regions with peak intensity inside distance between pixels, meaning that the size of black matrix (BM) is the smallest, which can allow high brightness and high contrast ratio. Consequently, we can see that the generation of disclination line is strongly dependent on rubbing directions although the degree of twist from top to bottom is the same and when the rubbing angle is –135°, the interference between pixels is the least.



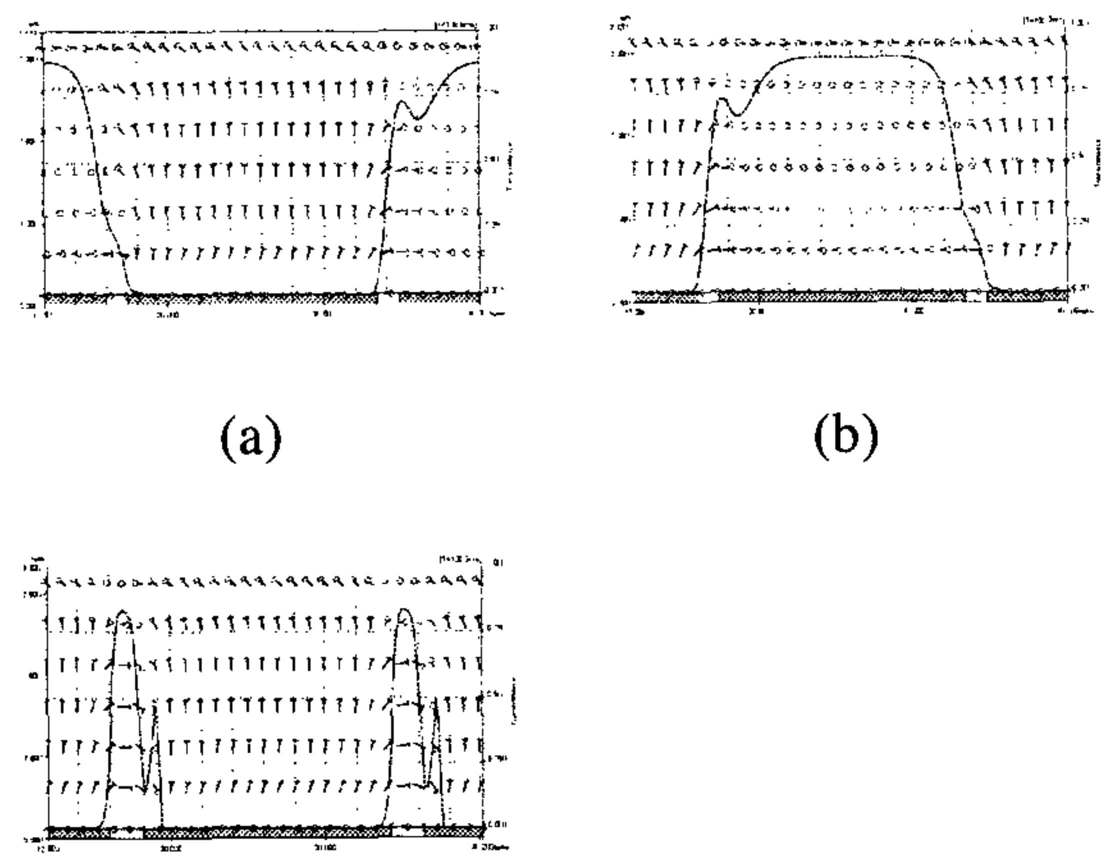
(a) (b) (c) (d)

Figure 5 Transmittance of 90°-TN cell with 22.2㎛ pixel as a function of rubbing direction of bottom substrate when all pixels are on: (a) -90°, (b) 0°, (c) -45°, and (d) -135°.

Figure 6 and Figure 7 show the transmittance when the distance between pixels becomes narrow to 1.4㎛ and 0.8㎛ for the cell with rubbing direction of –135°. In each case, the degree of disturbance is about the same, indicating that the size of BM can be kept the same while maintaining the image quality although the distance between pixels is shrunken.

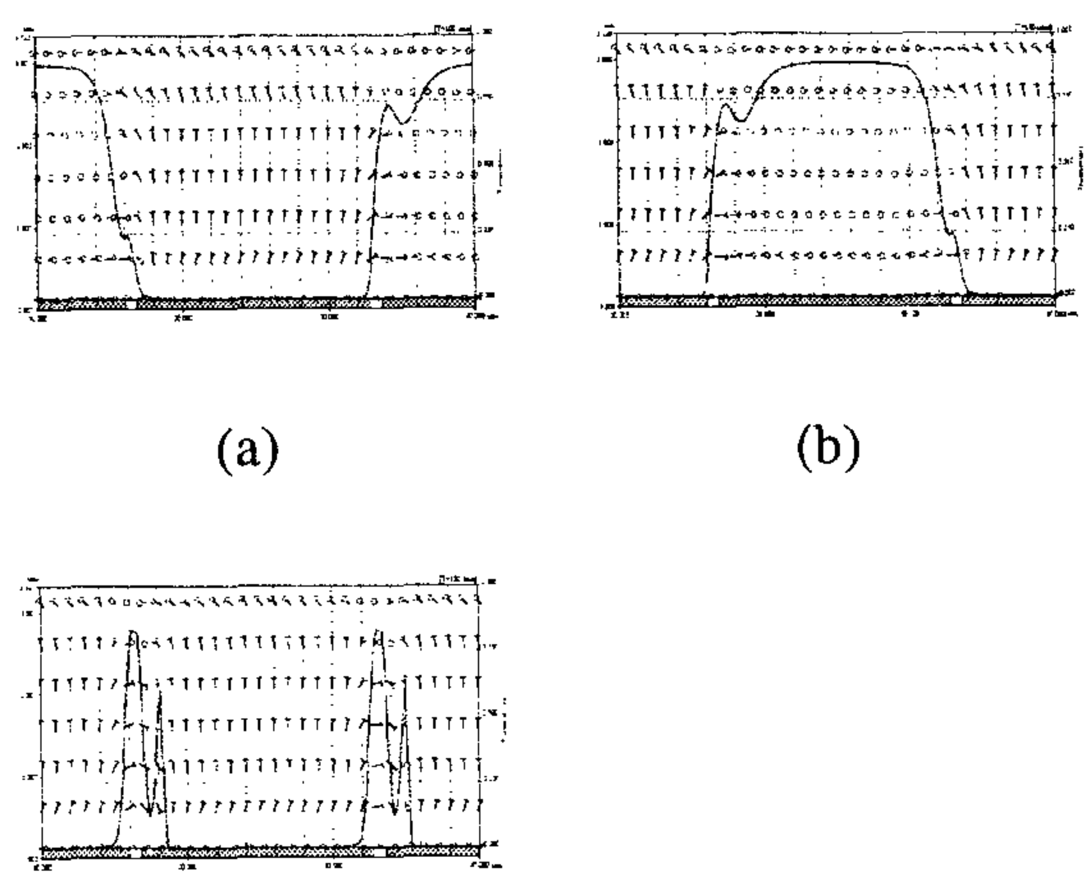
Finally, we have examined the pretilt angle-dependent disclination line when the distance between pixels are 2.2 ㎛with a pixel size of 22.2 ㎛, as shown in Figures 8-10.

As indicated clearly, when the pretilt angle is increased from 1° to 3°, the disclination line is well suppressed and with further increasing of pretilt angle up to 7° does not affect it much.



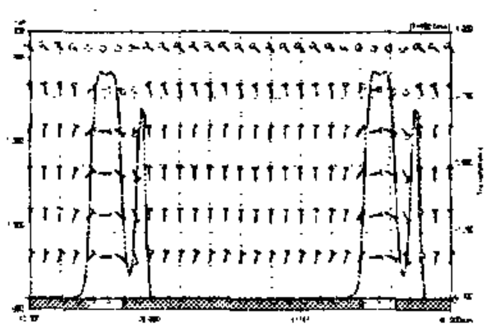
(a) (b) (c)

Figure 6 Transmittance of 90°-TN cell with a distance of 1.4 ㎛ between pixels when rubbing angle of bottom substrate is -135° and when applied voltage to the pixels are: (a) off-on-off pixels, (b) on-off-on pixels, and (d) on-on-on pixels.



(a) (b) (c)

Figure 7 Transmittance of 90°-TN cell with a distance of 0.8 ㎛ between pixels when rubbing angle of bottom substrate is -135° and when applied voltage to the pixels are: (a) off-on-off pixels, (b) on-off-on pixels, and (d) on-on-on pixels.



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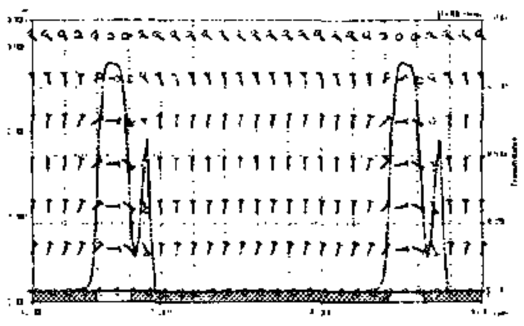

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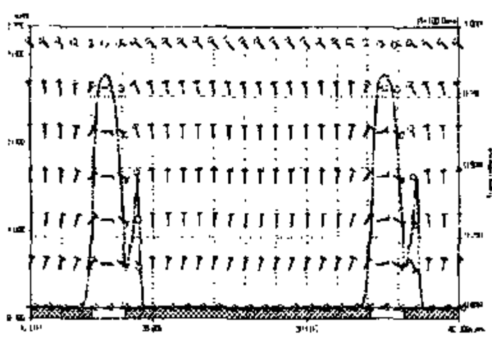
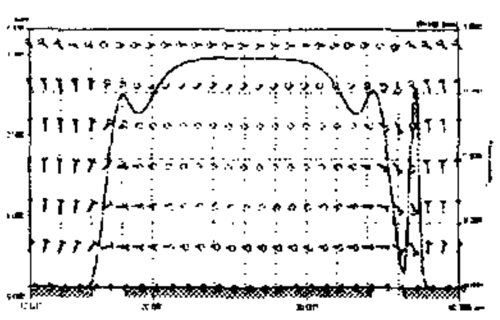


(c)

Figure 8 Transmittance of 90°-TN cell with a distance of 0.8 ㎛ between pixels as a function of pretilt angle of bottom substrate when all pixels are on: (a) 1°, (b) 3°, (c) 7°.



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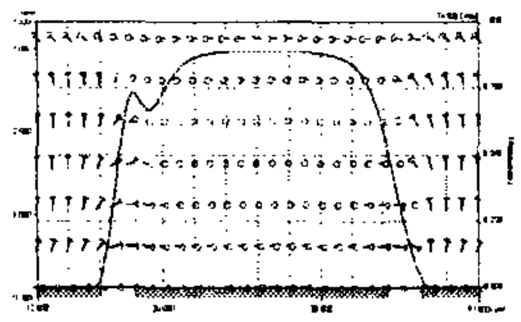

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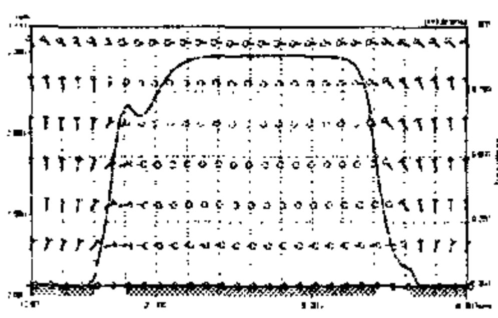

(c)

Figure 9 Transmittance of 90°-TN cell with a distance of 0.8 ㎛ between pixels as a function of pretilt angle of bottom substrate when one pixel is off and the adjacent pixels are on: (a) 1°, (b) 3°, (c) 7°.

5. References

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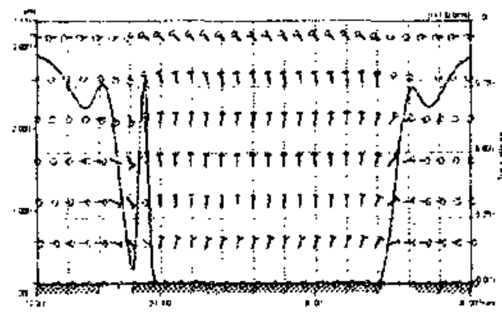

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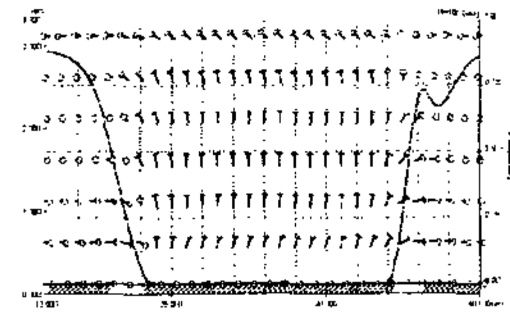

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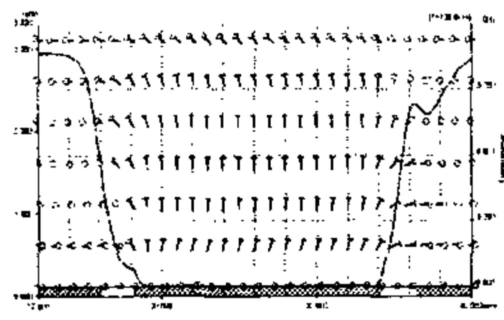

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Figure 10 Transmittance of 90°-TN cell with 22.2 ㎛ pixel as a function of pretilt angle of bottom substrate when one pixel is on and the adjacent pixels are off: (a) 1°, (b) 3°, (c) 7°.

3. Impact

We have studied generation of disclination line as a function of rubbing direction in transmissive microdisplay. For the 90°-TN cell, the formation of unwanted disclination line is the least when the rubbing direction of the bottom substrate is –135° and surface pretilt angle larger than 3° was required. A high contrast ratio and high brightness of the device can be achieved by optimizing rubbing direction and pretilt angle.

4. Acknowledgements

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