Modeling of the defect on the slit in Patterned Vertical Aligned (PVA) LC Cell using the fast Q-tensor method

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Abstract

In this paper we model the liquid crystal director field in the Patterned Vertical Alignment (PVA) LC using the fast Q-tensor method, which can model multidimensional director configurations with defects in the liquid crystal director field. We observed the dynamic behaviors of the defect experimentally by applying the voltage and modeled the LC director field with defect in the active area of the PVA cell. As a result, we could also calculate the optical transmittance.

1. Introduction

Demand on Large-area FPD-TVs has been sharply increased by expansion of the digital TV market. Liquid Crystal Displays (LCDs) is considered as a leading candidate for next generation display devices. LCD TVs have the advantages of high resolution, light weight, slim thickness, etc., while it have the disadvantages of slow response time of black to white. A PVA LC cell [1] is one of the most common modes using a multi-domain effect for high optical performance LC cell with wide viewing angle and high contrast ratio. In general, however, LC cells using multi-domain effect for wide viewing characteristic show relatively low transmittance because non-uniform voltage for the multi-domain effect can make the active area of the PVA cell have reverse tilt domain, so that defects can occur in the active area. Therefore, the defect on the slit decrease the optical transmittance and on/off response time.

In the typical PVA LC cell, we have found 3 positions where defects occurred in the active area by applying the voltage and we modeled each cases of the defect by using the fast Q-tensor method [2]. We can show the benefit of the 'defect trap' using the 3dimensional modeling. Finally, we could calculate optical transmittance of the PVA cell. In this paper, we also compare the result of the 2dimensional modeling for LC configuration with that by using vector method.

2. Electro-Optic Characteristic of Typical PVA cell

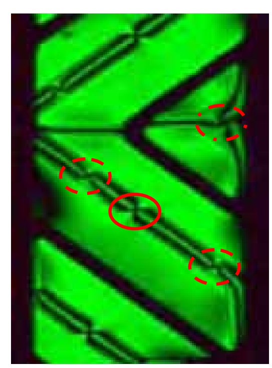


Figure 1. **Microscopic photograph of the PVA cell**

Figure 1 shows the generated defect cores on the slit of the PVA LC cell. In the figure, we can find 2 positions of the defect cores on the slit. In our experimental structure, the structure of the slit includes “defect trap” which prevent defect moving by applying the voltage. In the Fig. 1, solid circle represent defect generated by defect trap and dotted circle represent the defect area which are induced by non-uniform potential distribution around electrode edge and defect trap.

3. Simulation Results

3.1. 2 dimensional simulation results

The fast Q-tensor method was used because it can calculate both the normal behavior of the LC director and the defect. The ideal of 2 dimensional PVA modeling condition, which is no disturbance of the structure on the edge, we can observe the difference of calculation results between the vector method and the fast Q-tensor method. As an example, Figure 3 shows the difference calculation results of two methods. Using the geometry shown in Figure 2.

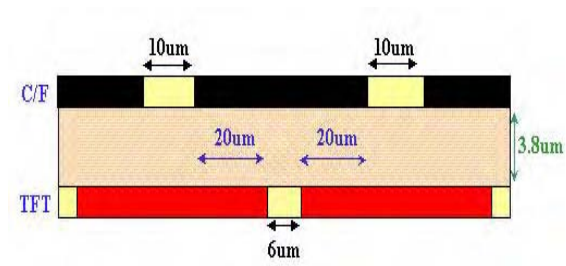


Figure 2. **The cell geometry used for the calculation**

Figure 2, shows that in this geometry. In the Cartesian vector representation, the discretized free energy expression gives different free energies for ***n*** and –***n*** [3, 4]. In real nematics, however, ***n*** and –***n*** are equivalent and should give the same torque and the same free energy. The Q-tensor representation always incorporates the multiplication of two ***n***’s [5]. This means that the sign of ***n*** is always cancelled out even when finite differences for the spatial derivatives are considered.

Figure 3. (a), (b) shows that the cross sectional view and top view of 8^{th} layer each calculation method. The applied voltage is 8V. We can observe the difference of director configuration in the middle of the slit area. Figure 3. (a), the reverse tilt wall make the directors configuration splay state. However, Figure 3. (b), the phase transition occurred in the middle of the slit area.

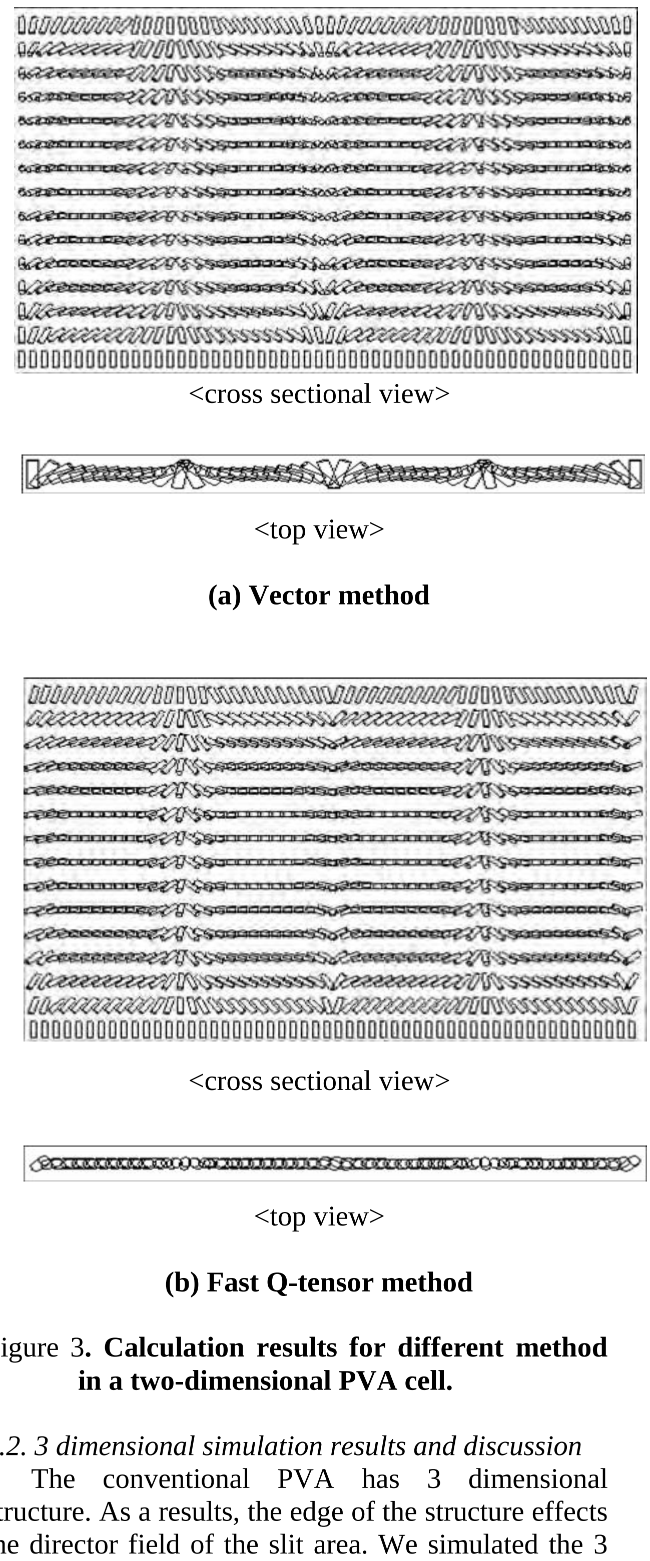


Figure 3**. Calculation results for different method in a two-dimensional PVA cell.**

3.2. 3 dimensional simulation results and discussion

The conventional PVA has 3 dimensional structure. As a results, the edge of the structure effects the director field of the slit area. We simulated the 3 dimensional LC modeling of conventional PVA's structure. And we observe that the edge effect distrurb the phase transition on the middle of slit area and generate another defect line moving to the active area.

Figure 4. shows the conventional structure of the slit in the PVA cell which includes defect trap in the center of the slit. In general, the conventional PVA cell without defect trap in the center shows very unstable dynamic behavior because the generated from slit edge move along the slit by applying the voltage.Therefore, defect trap as shown in Fig. 3 can prevent the defect from moving along the slit by applying the voltage.

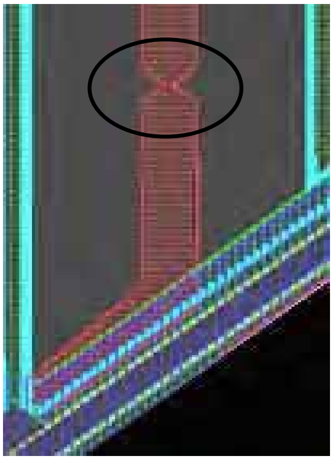
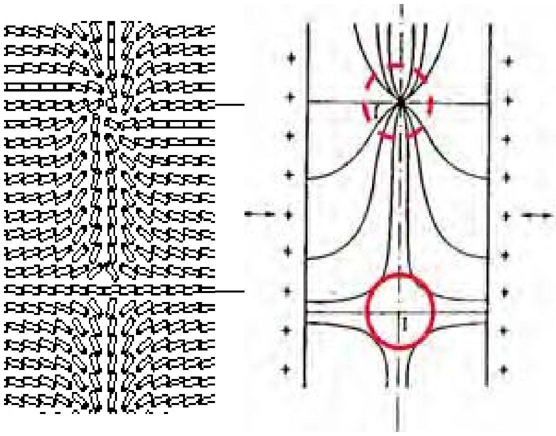


Figure 4**. the conventional structure of the PVA cell. Solid circle represents the defect trap in the center of the slit**

Figure 5 (a) shows the 3-dimensional modeling of the LC director field on the slit. The director configuration in the solid circle represents the generated defect by defect trap in the center of the slit and that in the dotted circle represents the defect core due to the competition of the strain energy by the edge of the slit and the defect trap of the center. In the Figure, we can assume that the LC director orientation due to the edge and the orientation due to the defect trap in the center are opponent along the slit as shown in Fig. 5 (a), so that another can be generated. Figure 5 (b) shows the cartoon of the modeling of the singular point for the Fig. 5 (a) [6]. The line in the Fig. 5 (b) represents the LC orientations. In the figure, we assume that the defect has Frank index (±1/2) with strength (±1).



(a) (b)

Figure 5**. 3-dimensional LC director modeling of the PVA LC cell and cartoon of the orientation of the LC director.**

Figure 6 (a). shows the 3dimensional calculated optical transmittance with applying 8V. We used a 2 x 2 Jones matrix for optical transmittance calculation. The normalized transmission of the liquid crystal layer between the polarizer and analyzer was given by

$$T/T_0 = \sin^2(2\alpha)\sin^2(\frac{\delta}{2}) = \sin^2(2\alpha)\sin^2(\frac{\pi_d \Delta_n}{\lambda})$$

where α is the angle between the effective optical axis of the LC director. We can calculate the optical transmittance using the above given equation , the figure 5 (a) and figure 6 (b),(c). The white transmittance state of LC director has α = 45,-45. The edge structure effect makes the white transmittance condition of LC director in the middle of slit. Also we can easily predict the black and white stripe at the slit area considering the orientation of the LC director in figure 5 (b).

We can figure out the difference LC director configuration of 2D and 3D simulation results in the slit area. The edge structure disturbs phase transition at the middle of the slit.

The solid circle in figure 5 (a) incicated the generating the defect core due to the edge structure and defect trap shape. Finally, we can calculate optical transmittance of defect in conventional PVA cell with 3 dimensional fast Q-tensor modeling.

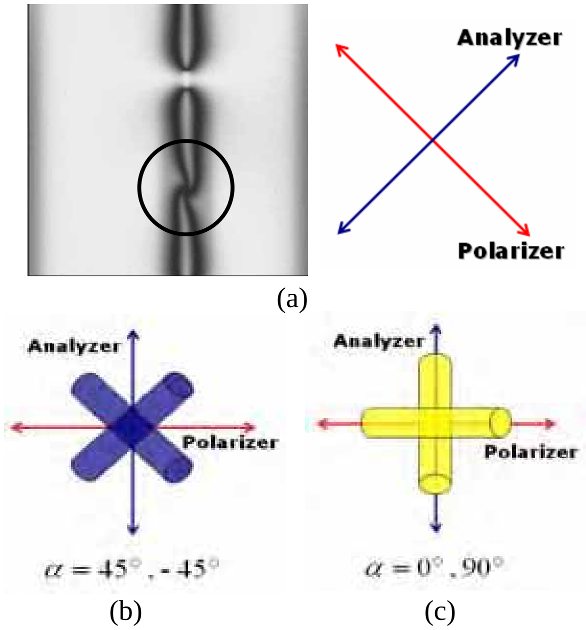


Figure 6**. Calculated optical transmittance using the results of the fast Q-tensor method.**

3. Conclusion

In this paper we modeled defect nucleation in the active area of the PVA cell. In order to model the defect as well as LC director configuration, we applied fast Q-tensor method, which can calculate scalar order parameter *S* in addition to director orientation *n*, to the modeling. Therefore, this paper will also show the comparison of the result of the fast Q-tensor method and that of the vector method. The exact modeling using the tensor method will successfully calculate optical transmittance of the PVA cell

4. Acknowledgements

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5. References

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