Simulation of Domain Growth in Antiferroelctric Liquid Crystal Display

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Abstract

Most modeling about dynamic behavior of Antiferroelectric Liquid Crystal (AFLC) is limited to the hysteric characteristics of AFLC cells or thresholdless switching of frustrated AFLC cells. In this paper, domain growth of AFLC cells is modeled with extended bilayer model. When driving pulses that consist of a selection voltage, a bias voltage, and a reset voltage are applied to the AFLC cell, its dynamic behavior is simulated.

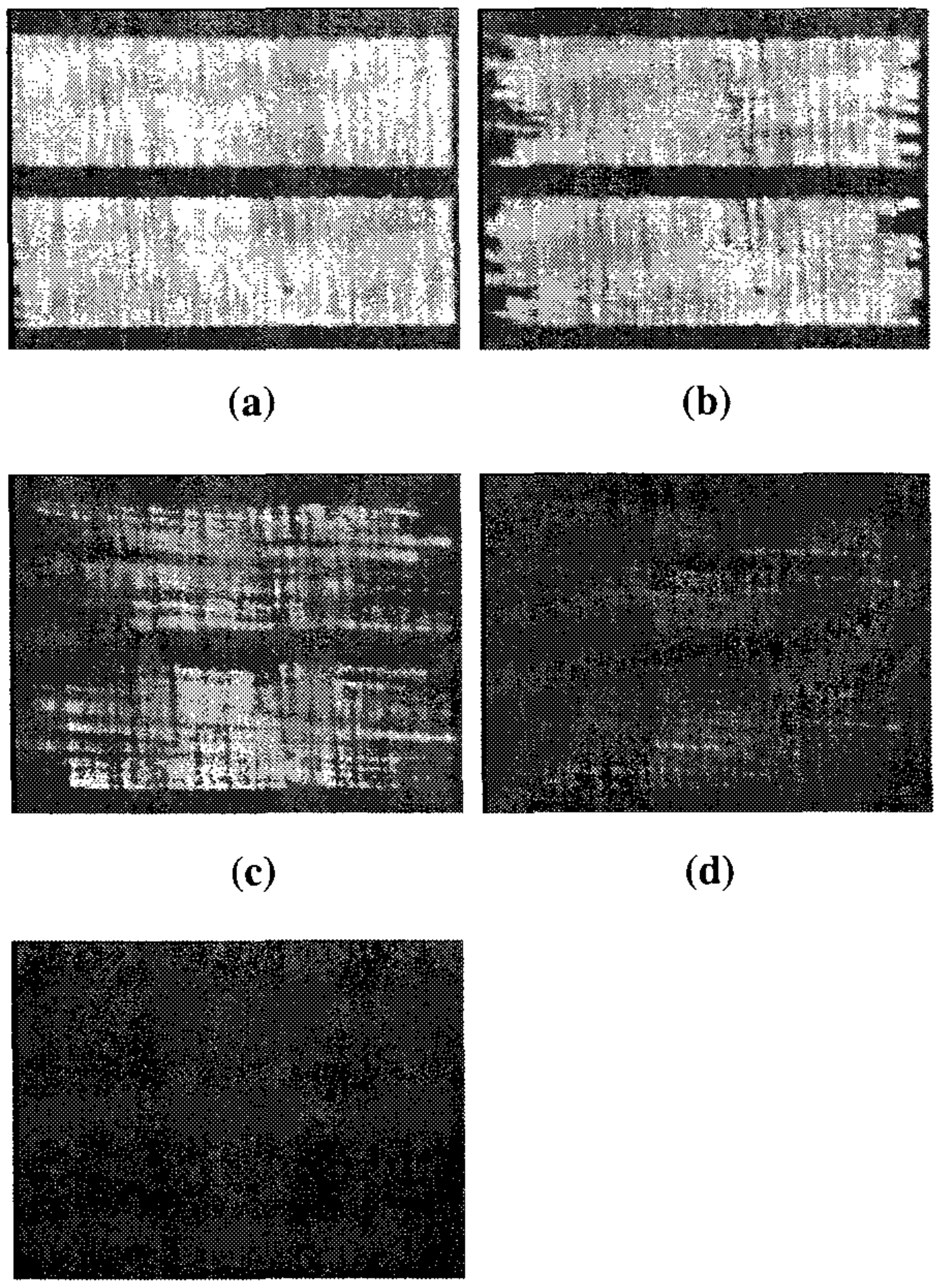
1. Introduction

The discovery of Antiferroelectric Liquid Crystals (AFLCs) [1] has attracted researchers' attention from both fundamental and practical viewpoints, and intensive research has been carried out to understand their characteristics [1-13]. Also there have been many efforts to simulate dynamic behavior of AFLC cell [8-10]. This modeling is focused on hysteric characteristics of AFLC cells or thresholdless switching of frustrated AFLC cells, but is not focused on domain growth in AFLC cells.

In this work, the domain growth of AFLC cells [11, 12] is modeled with extended bilayer model. When driving pulses that consist of a selection voltage, a bias voltage, and a reset voltage [13] are applied to the AFLCD, its dynamic behavior is simulated.

2. Domain growth in AFLCD

In the AFLC cell, the domain growth which appears by reset or bias voltage in order to make antiferro state or gray from ferro state is observed growing from the edge of the cell to the center as shown in Fig. 1 [11, 12].

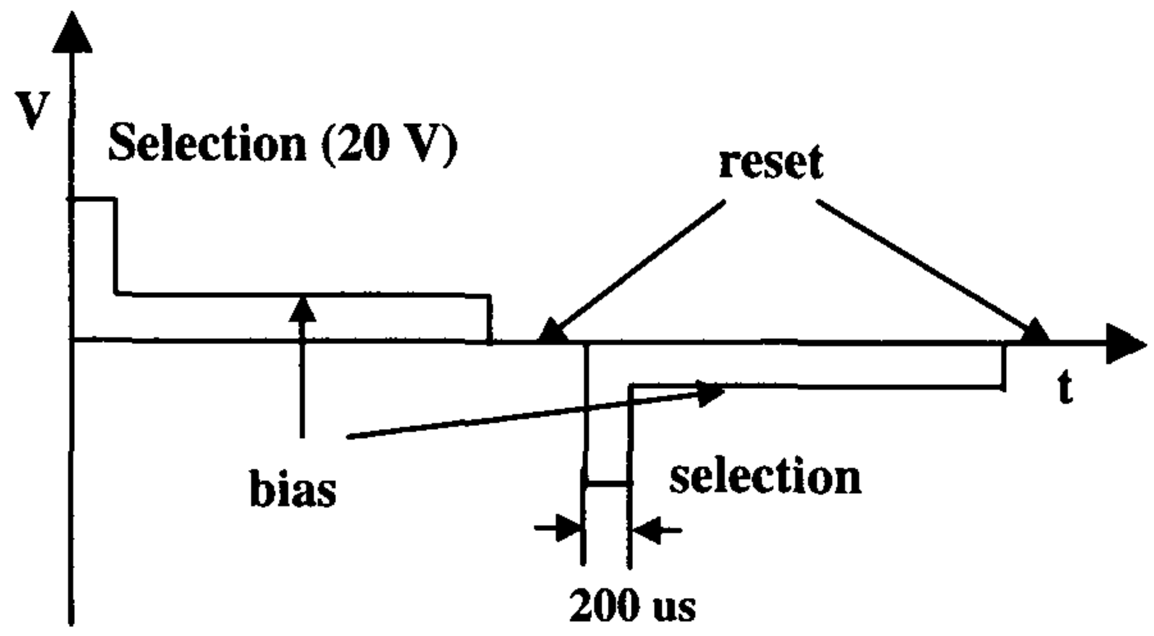


(a) (b) (c) (d) (e)

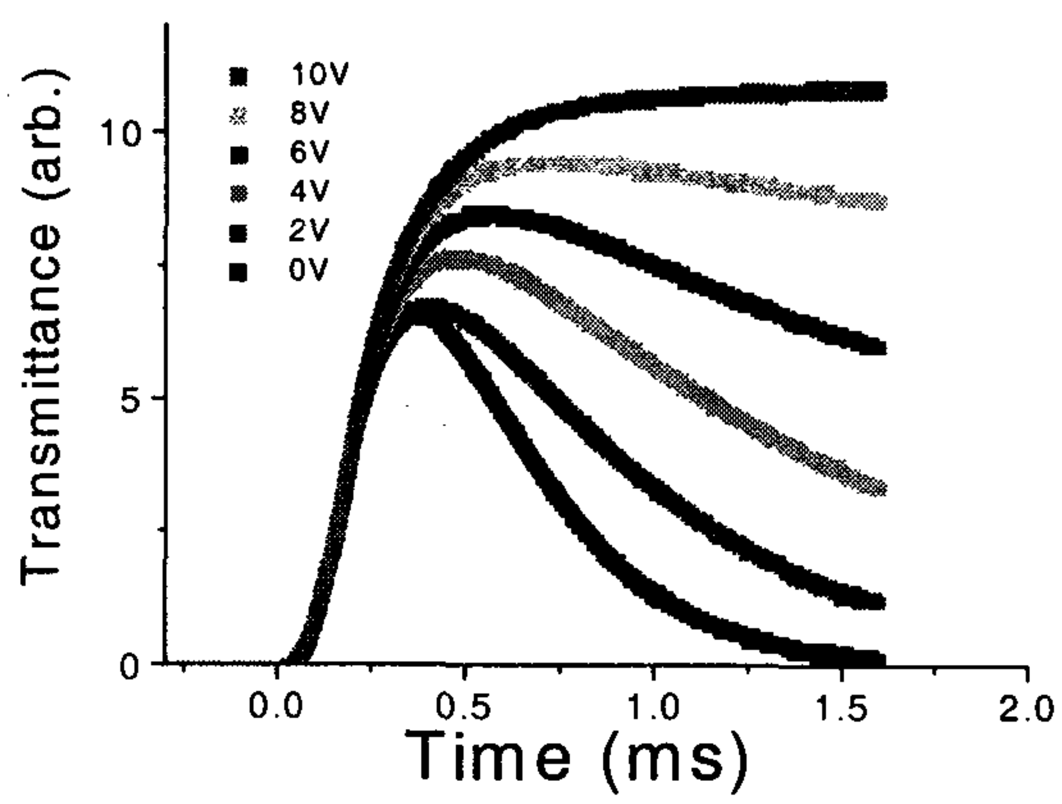
Figure 1. CCD images of domain growth, when AFLC cell is switched from ferro state to antiferro state: (a) Ferro state, (b)-(d) intermediate state, and (e) antiferro state.

Particularly in the passive driving device, this domain growth property can make optical transmittance or reflectance of AFLCD higher because domain growth effect sustains optical transmission even after the selection voltage turns off [14].

Figure 2 shows a delayed optical response with the variation of bias voltages, when driving pulses of SBR are applied to the AFLC cell. SBR pulses consist of a selection voltage, a bias voltage and a reset voltage. Pulse width and peak in the selection voltage are 20V and 200 μs us, respectively.



(a)



(b)

Figure 2. (a) Employed waveform (SBR) in the experiments and (b) optical response of AFLC cell with different bias voltages.

Experiment was carried out with different bias voltages at intervals of 2V between 0V and 10 V. Bias voltage value has influence on delay time of maximum peak and steepness of optical response, because propagating velocity of domain growth is affected by bias voltage [14]. Maximum brightness appears during the holding period. This effect might be more useful in the case of high-resolution.

2. Theory

Our model is based on the bilayer model in which we assume that there is no variation in P_o and P_e within each layer which is polarization vector in the odd-layer and even-layer, respectively [9]. In order to simulate the domain growth in AFLCD, we assumed that each molecular in the same layer can separately rotate and considered the dipole interaction of each molecule in the same layer, because domain growth propagates parallel to the smectic layer [11, 12]. Figure 3 shows extended bilayer model of AFLC, whose directors are in antiferro state. In the smectic layer, director can rotate on the cone separately.

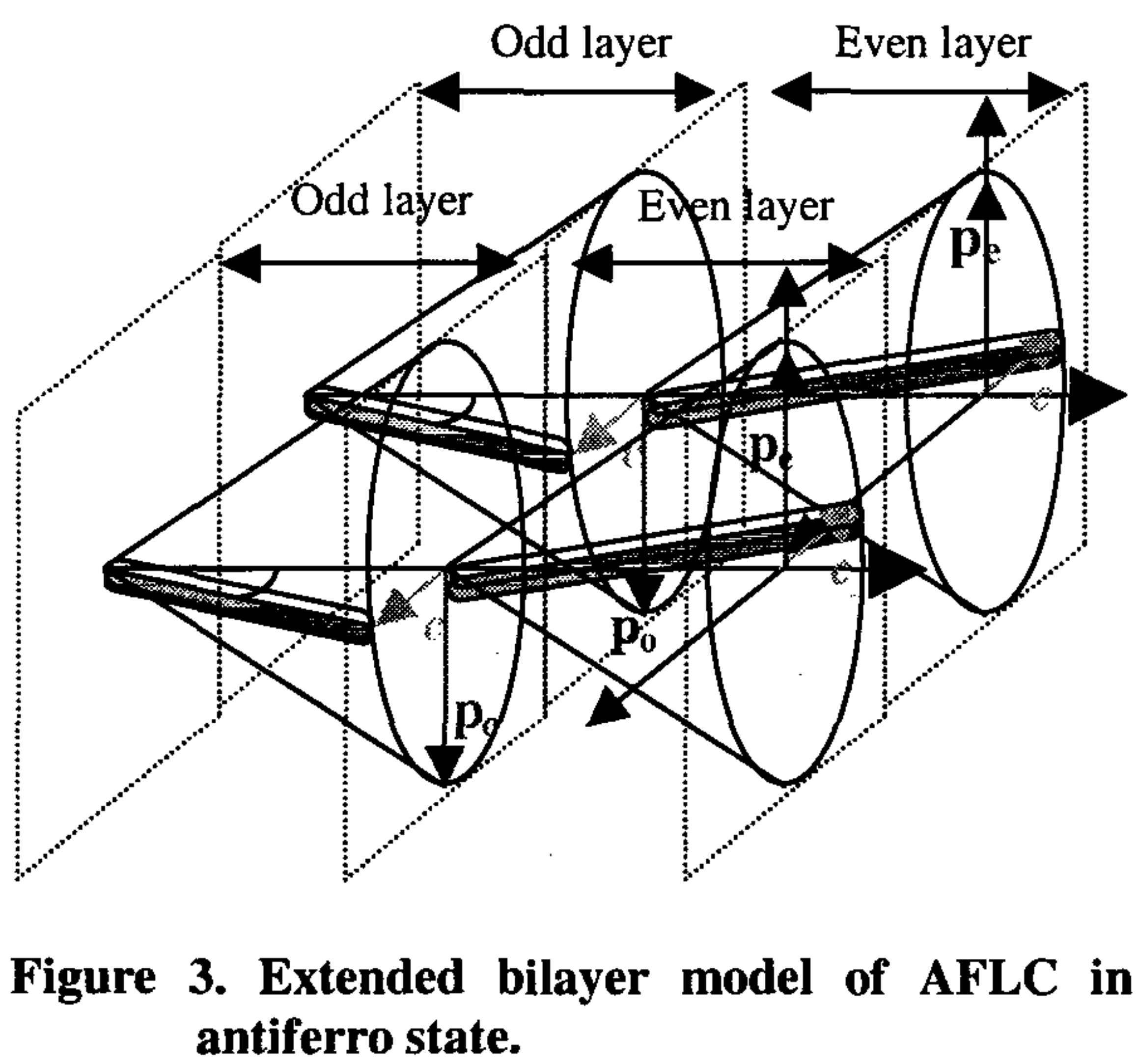


Figure 3. Extended bilayer model of AFLC in antiferro state.

Free energy will be represented by the following equation.

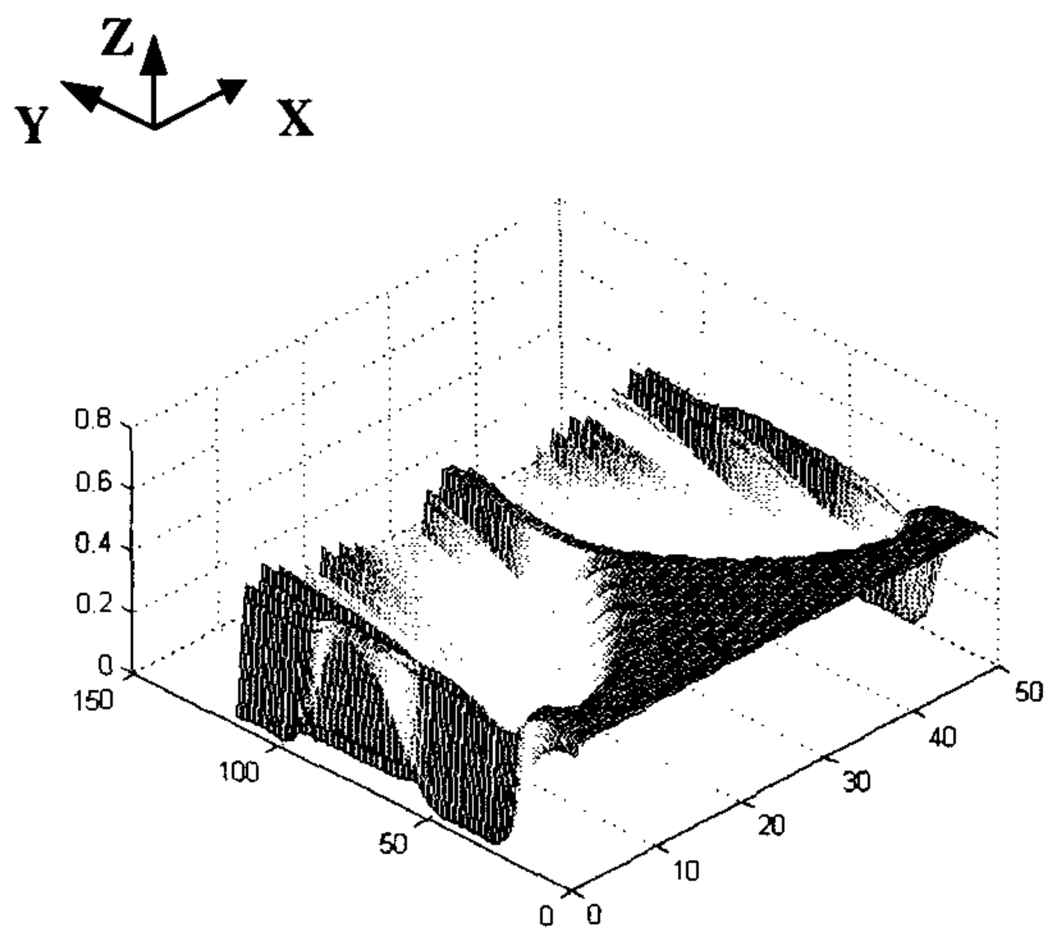
$$F = -\mu e_o \bullet P_{o_i} - \mu e_e \bullet P_{e_i} - K(e_o \bullet P_{o_i})^2 - K(e_e \bullet P_{e_i})^2 - (P_{o_i}+P_{e_i}) \bullet E + \gamma P_{o_i} \bullet P_{e_i} - \gamma' P_{o_i} \bullet P_{o(i\pm1)} - \gamma' P_{e_i} \bullet P_{e(i\pm1)} \quad \text{---(1)}$$

where e_o and e_e are the fixed vectors of cell boundaries [8, 9]. μ and **K** are a polar and a nonpolar molecular field which is related to the surface anchoring effect [8, 15, 16]. **E** is the applied field. γ is the coupling coefficient between adjacent molecules in the adjacent layer. We supplement γ' term in free energy of AFLC, which is the coupling coefficient between adjacent molecules in the same layer because each molecule in the same layer can rotate separately.

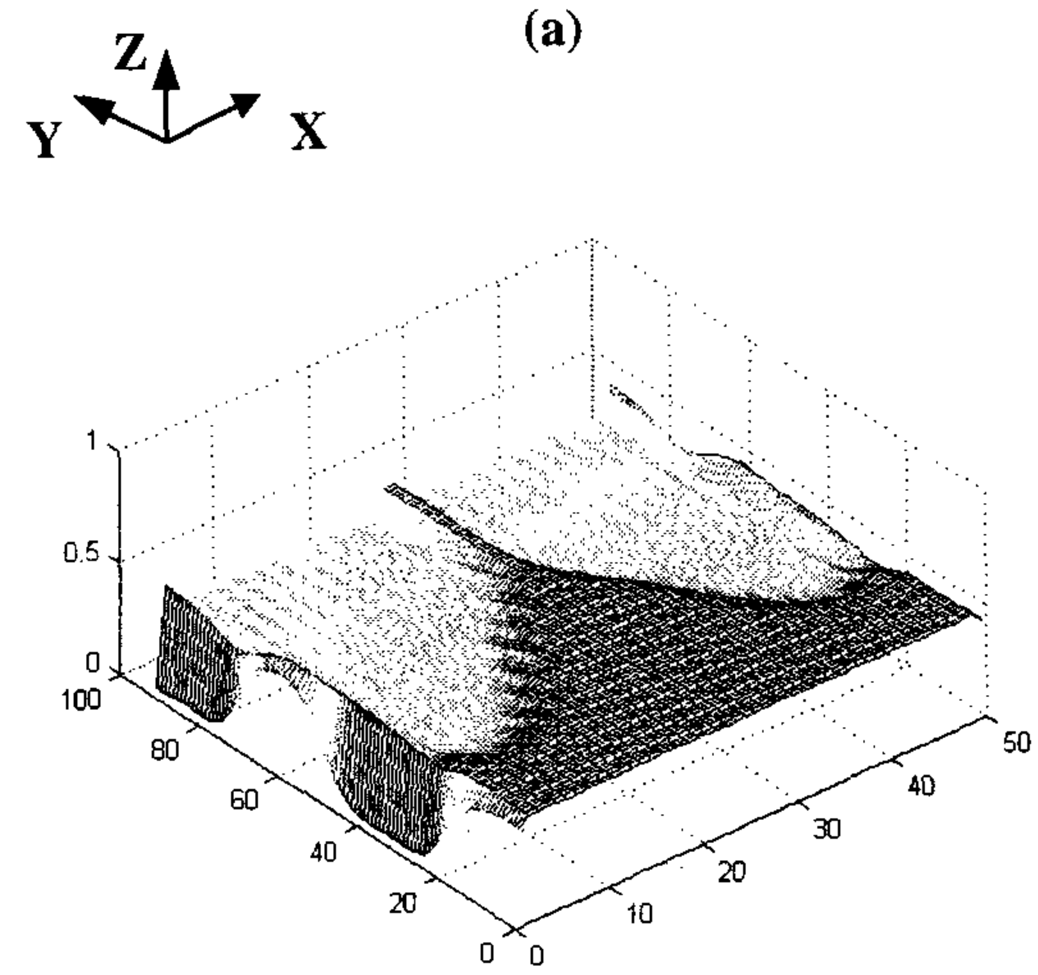
3. Results and discussion

Simulation is carried out when AFLCD is switched from ferro state to antiferro state like CCD images in Fig. 2. Figure 4 shows the simulation results of 1-dimensional domain growth in AFLC cell. The smectic layer of the cell is parallel to x-axis. X-axis represents the location of each molecule in the same layer, y-axis and z-axis represent time and transmittance, respectively. From the simulation results, domain growth propagates from the edge to the middle of the cell as time goes. When a higher bias voltage is applied to the AFLC cell, optical response has more delay time, because high bias voltage disturbs domain growth from ferro state to antiferro state when selection voltage is off [14].

The extended bilayer model is useful to describe the domain growth in AFLC cell and its dynamic behavior.



(a)



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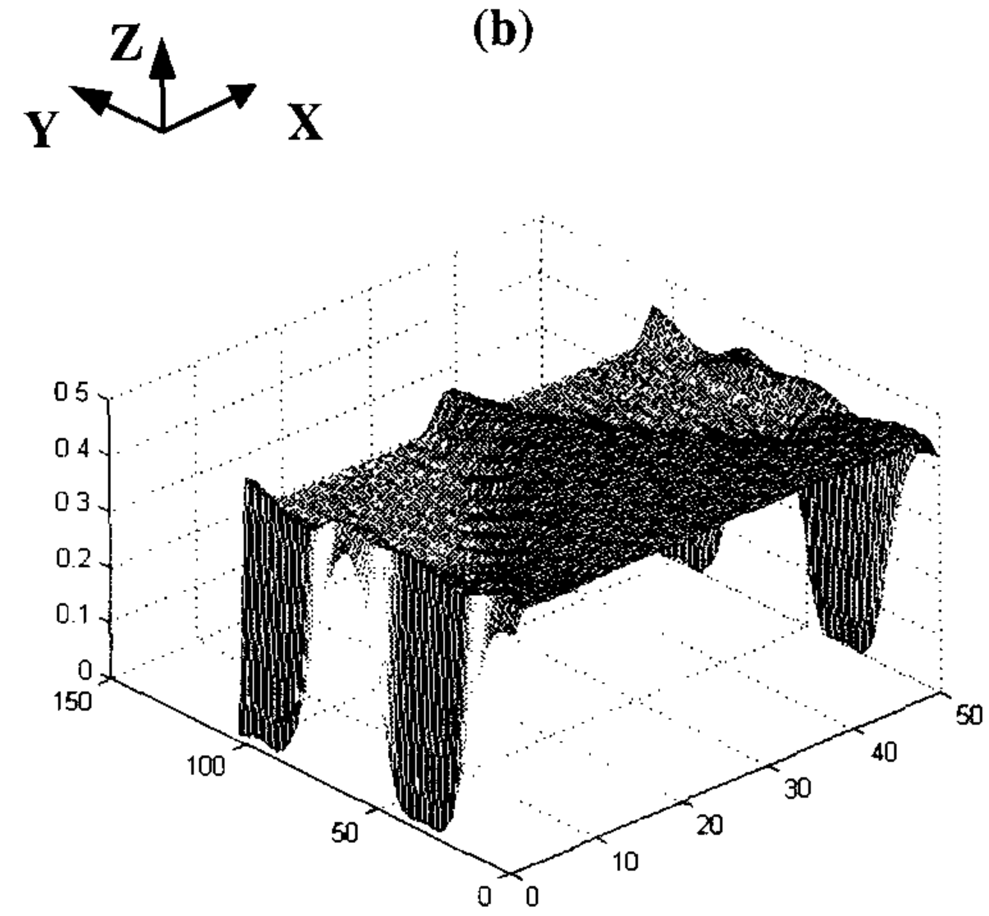

(c)

Figure 4. Simulation results of domain growth in AFLC cell according to bias voltages of (a) 0V, (b) 2V, and (c) 4V.

4. Conclusion

Domain growth of antiferroelectric LC cell was modeled with extended bilayer model, when driving pulses of SBR were applied to the AFLC cell. Its dynamic behavior was simulated. In the extended bilayer model, we supplement free energy of AFLC with γ' which is the coupling coefficient between adjacent molecules in the same layer, because domain growth propagates parallel to the smectic layer. The extended bilayer model is useful to describe the domain growth in AFLC cell and its dynamic behavior.

5. References

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