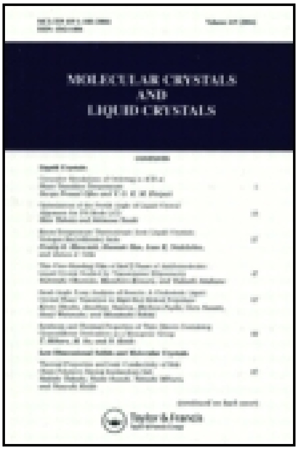

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Numerical Simulation on a Novel Cell Structure: Chevron HAN-FFS Mode LCD Cell Structure by TechWiz LCD

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In this paper, a novel cell structure, named as chevron hybrid alignment nematic by fringing field switching (HAN-FFS), is proposed for realizing higher transmittance and wide-viewing angle. The proposed structure comprises a modified pixel electrode with grooves at an angle of 45° in upper part and −45° in lower part of the one cell. Moreover, it has vertical surface in the middle of the cell. Transmittance of the chevron HAN-FFS had about 1.2 times than that of wedge-shaped HAN-FFS. And the saturation time is shorter for the chevron HAN-FFS than for the wedge-shaped HAN-FFS.

Keywords: chevron HAN-FFS; finite difference method; simulation; wedge-shaped HAN-FFS

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I. INTRODUCTION

A variety of cell structures for liquid crystal displays have been proposed to improve the light transmission efficiency and viewing angle, for instance, in-plane switching (IPS) [1,2], fringing field switching (FFS) [3,4], and vertical alignment (VA) [5,6]. HAN-FFS(Hybrid Alignment Nematic by Fringing Field Switching) [7], which has rectangular electrodes, exhibits excellent transmittance with reduced number of manufacturing process. However, the traditional HAN-FFS mode has a technical limit in the viewing angle because a single domain is formed by the directors. In order to overcome the shortcoming of the conventional HAN-FFS structure, a multiple number of domain, for instance two or four domain, has been proposed such as wedge-shaped HAN-FFS [8]. However, the wedge-shaped HAN-FFS device still has a shortcoming due to the presence of a dark region in the middle of the cell wherein the transmittance is even lower than that of the conventional HAN-FFS structures.

In this paper, a novel multi-domain cell structure, named as chevron HAN-FFS, is proposed which eliminates the dark region in the middle of the cell. The proposed cell structure comprises a modified pixel electrode with vertical surface at the corner. The electro-optical characteristic was calculated with commercial simulator, TechWiz LCD [11], and the simulation results were compared with those of the conventional structures.

II. SIMULATION AND RESULTS

In this work, we employed TechWiz LCD for the simulation of various types of HAN-FSS structures including the wedge-shaped HAN-FFS as well as chevron HAN-FFS in order to investigate the dynamic behavior, transmittance, and optimization. To simulate the liquid crystals cell, Ericksen–Leslie and Laplace equation is formulated in the bulk and also the surface region by finite difference method (FDM) [11]. The central, forward and backward difference method is applied in order to formulate the governing equations. Non-uniform grid generation scheme was used for fast simulation and adaptability to the structure. Optical characteristics are then calculated by the extended Jones method [10]. Periodic boundary condition is applied at the borders of the cell. Table 1 shows a set of parameters employed for the simulation of the HAN-FFS structure by TechWiz LCD. For instance, the simulation size along x axis is 19 μm while that along the y axis is 25 μm for each mode. The thickness of common, pixel and counter

TABLE 1 Simulation Parameters of the HAN-FFS

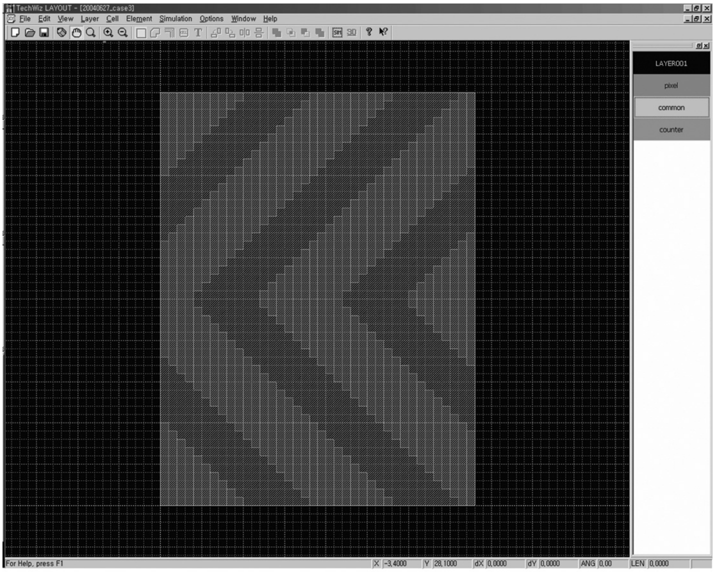
Parameter	Value
Parallel dielectric	3.6
Perpendicular dielectric	8.3
Ordinary refractive index	1.44
Extraordinary refractive index	1.55
Pre-tilt angle (bottom)	2°
Pre-tilt angle (top)	90°
Pre-twist angle	0°
K_{11}	10.8
K_{22}	8
K_{33}	14.9
Rotational viscosity	Infinite
Ne (real value of polarizer)	1.5
No (real value of polarizer)	1.5
Ne (image value of polarizer)	0.001929
No (image value of polarizer)	4.535e-5

electrode is 0.04 μm. The cell gap is 4 μm. Pixel and common electrode is transparent material.

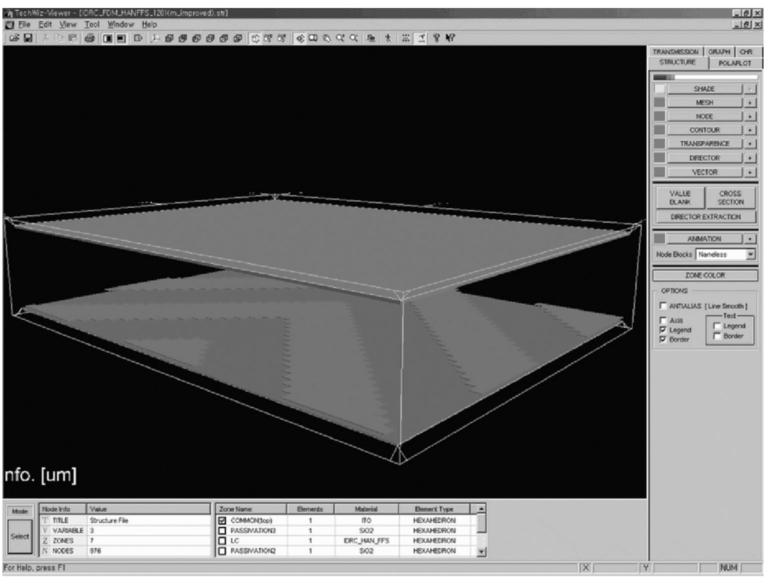
Figure 1 shows the mask layout and 3-D structure of the wedge-shaped HAN-FFS. As shown in Figure 1(b), common and pixel electrode is stacked on the bottom substrate and counter electrode is stacked to depress directors above the pixel electrode when voltage is applied. To investigate only the effect between common and pixel electrodes, gate and data electrode is not included.

Figure 2 shows the structure of the HAN-FFS with designating the configuration of directors when the pixel voltage is 5 V and the common electrode is grounded. A vertical electric field is generated in the 'B' region due to the pixel electrode at the bottom and counter electrode on the top, which rotates the molecule with negative dielectric anisotropy above the pixel electrode. The molecules 'A' near the corner of the pixel electrode try to align the vertical electric field due to the fringing field as depicted in Figure 2(b).

Figure 3 is a top-view illustrating the configuration of directors when voltage is applied to the pixel and common electrodes for the wedge-shaped HAN-FFS. The squared region designated with white color in Figure 3(a) is magnified in Figure 3(b) with director distribution. As shown in Figure 3(b), we can observe that the direction of electric field in the half cell is different from that of the other half. Consequently, the directors in a single unit cell are rotated in two-fold directions. This means that two-fold domain is formed within a cell.



(a)



(b)

FIGURE 1 Schematic diagrams illustrating (a) mask layout and (b) 3D-structure of the chevron HAN-FFS.

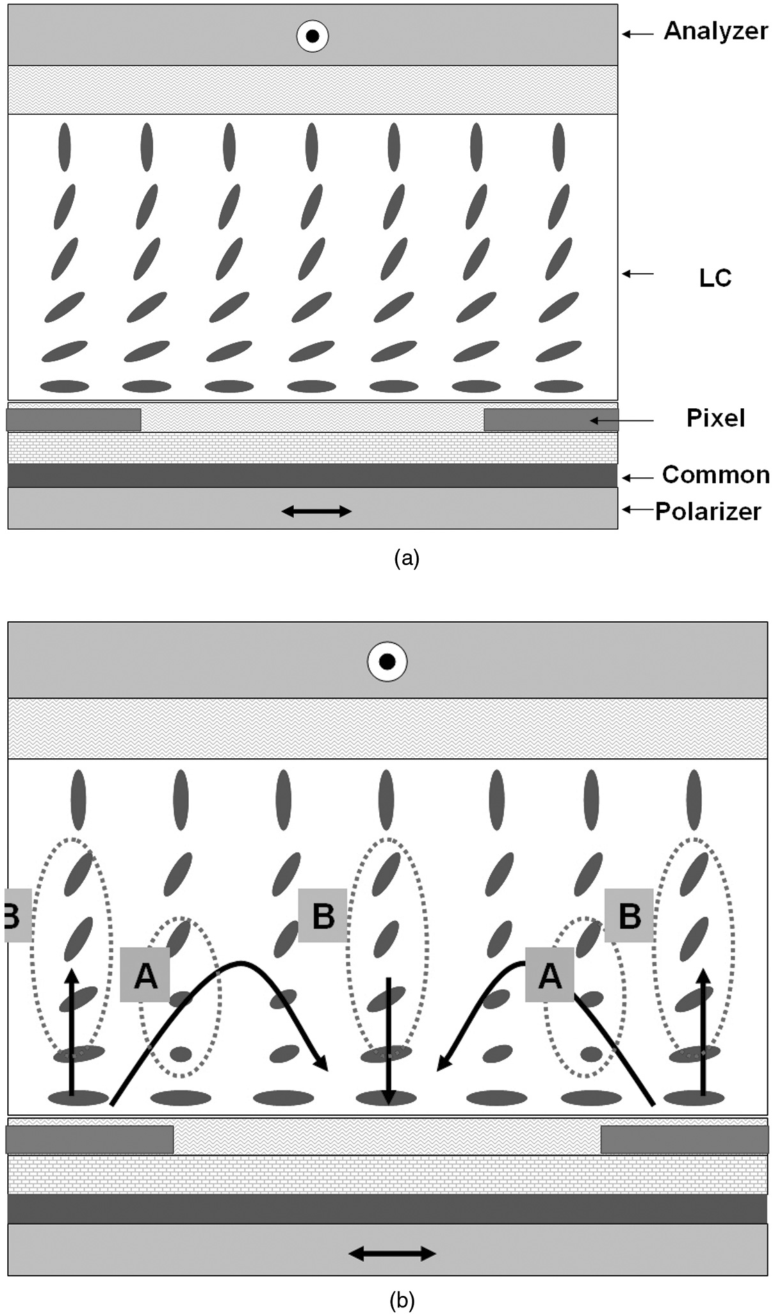


FIGURE 2 Schematic diagrams illustrating the directors with the structure of conventional HAN-FFS (a) at off state and (b) at on state.

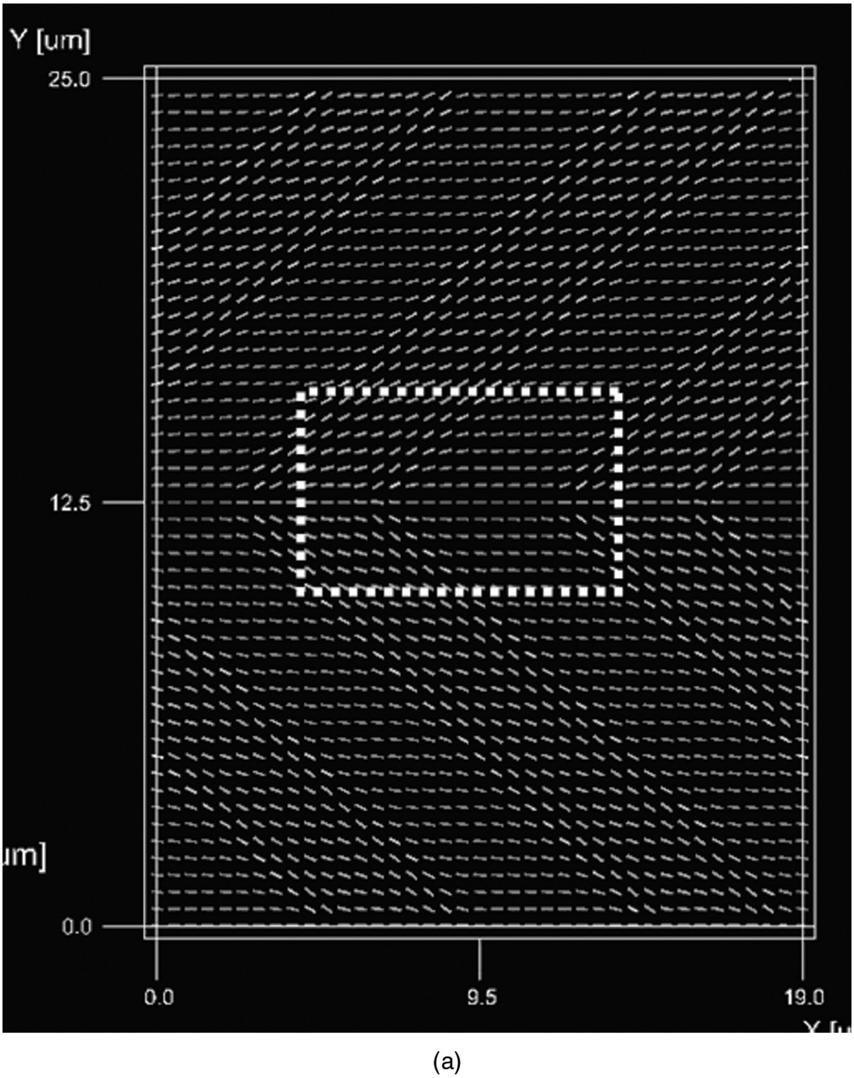
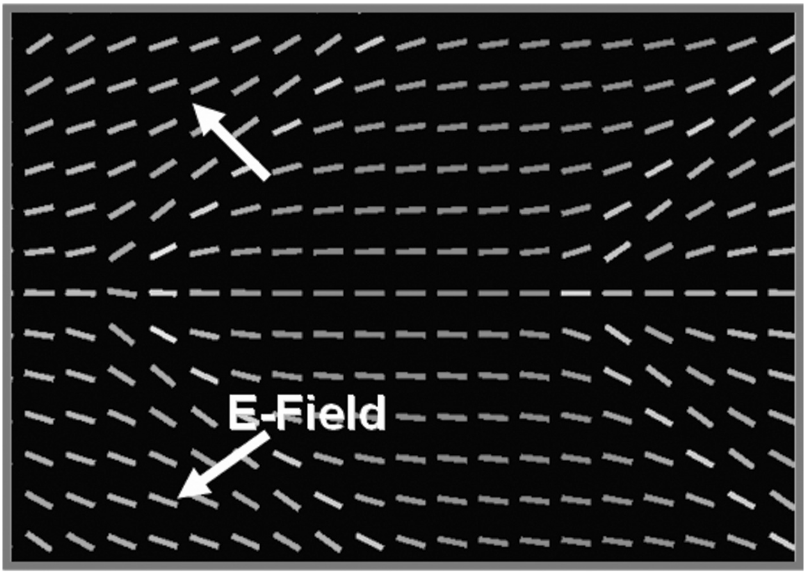


FIGURE 3 Calculated director distribution of the chevron HAN-FFS with electric field at 200 ms.

However, it should be noted that the directors in the middle of the cell are kept unchanged. This is because the elastic strain energy generated by neighboring directors is larger than the electric potential energy in the middle of the cell. In other words, the directors in the middle of the cell are not rotated in any particular direction due to



(b)

FIGURE 3 Continued.

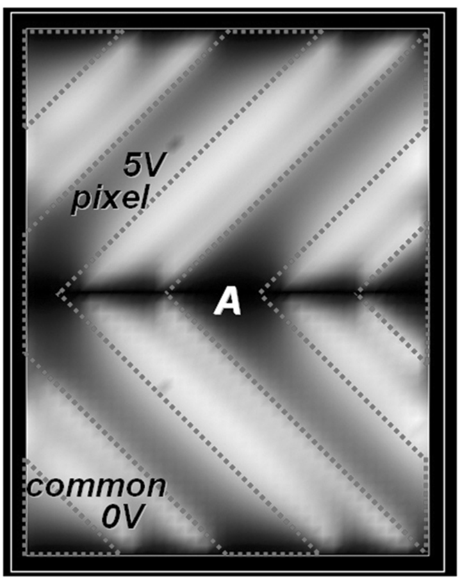
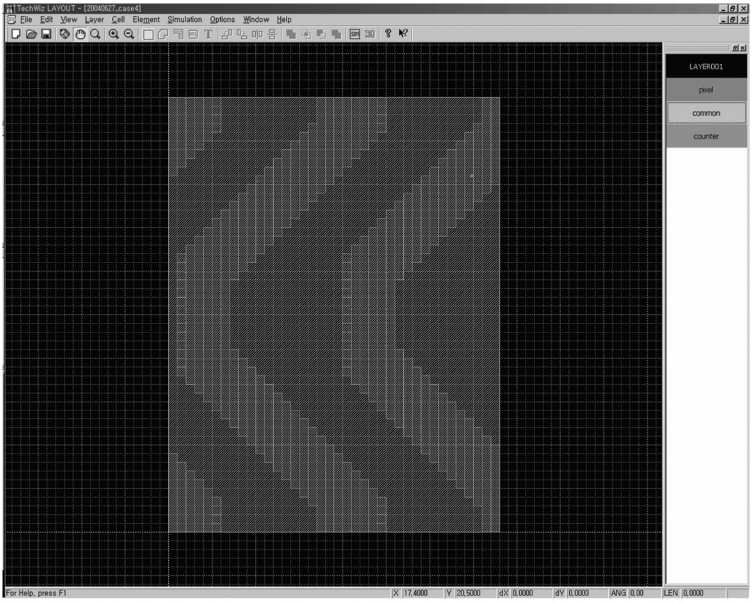
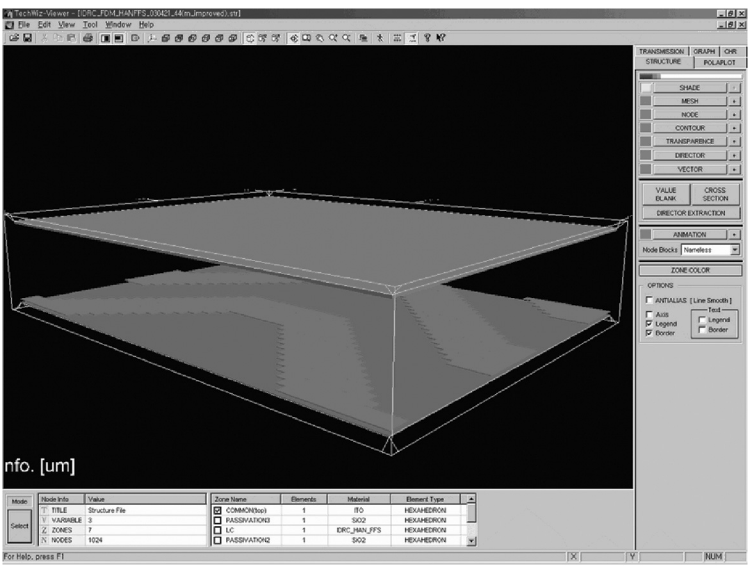


FIGURE 4 Transmittance of the wedge-shaped HAN-FFS at 200 ms.



(a)



(b)

FIGURE 5 Schematic diagrams illustrating (a) mask layout and (b) 3D-structure of the chevron HAN-FFS.

the presence of directors both in the upper part and the lower part of the cell.

Figure 4(a) shows transmittance characteristics of the wedge-shaped HAN-FFS at 200 ms. Dotted line means boundary of the pixel electrode. Light is transmitted in most of the regions. However, a dark region is formed because some molecules in the middle region do not respond even if voltage is applied. As a prior art, the wedge-shaped HAN-FFS has a strong feature in terms of viewing characteristics due to two-fold domain in a single cell. However, the transmittance of the wedge-shaped HAN-FFS is deteriorated because the directors in the middle of the cell are kept unchanged.

In order to eliminate the dark region in the middle of the wedge-shaped HAN-FFS, we proposed chevron HAN-FFS which has a modified pixel electrode. Figure 5 shows a mask layout and 3D-structure of the chevron HAN-FFS. As shown in Figure 5(b), the pixel electrode of chevron HAN-FFS is different from that of wedge-shape HAN-FFS. In case of the chevron HAN-FFS, the sharp corner is formed in the

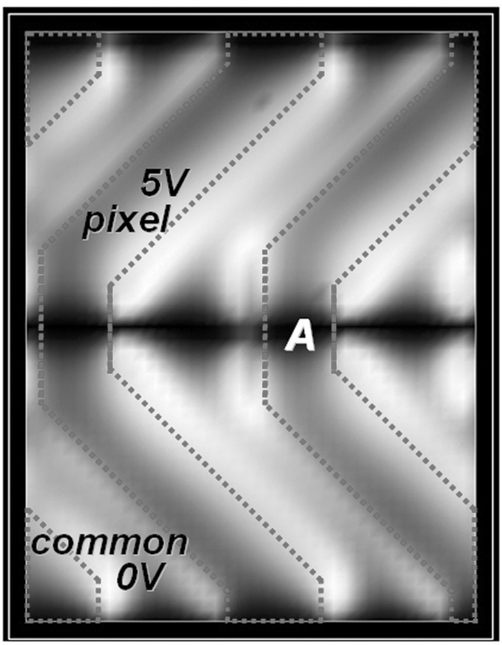
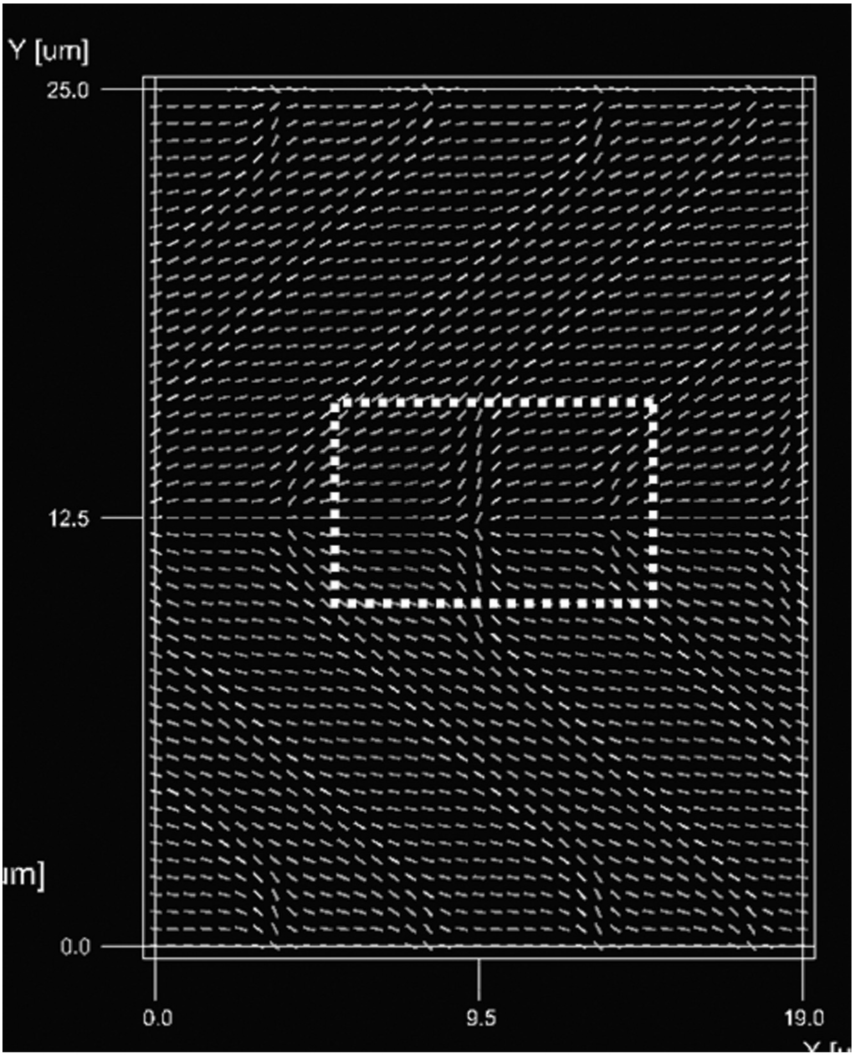


FIGURE 6 Transmittance of the chevron HAN-FFS at 200 ms.

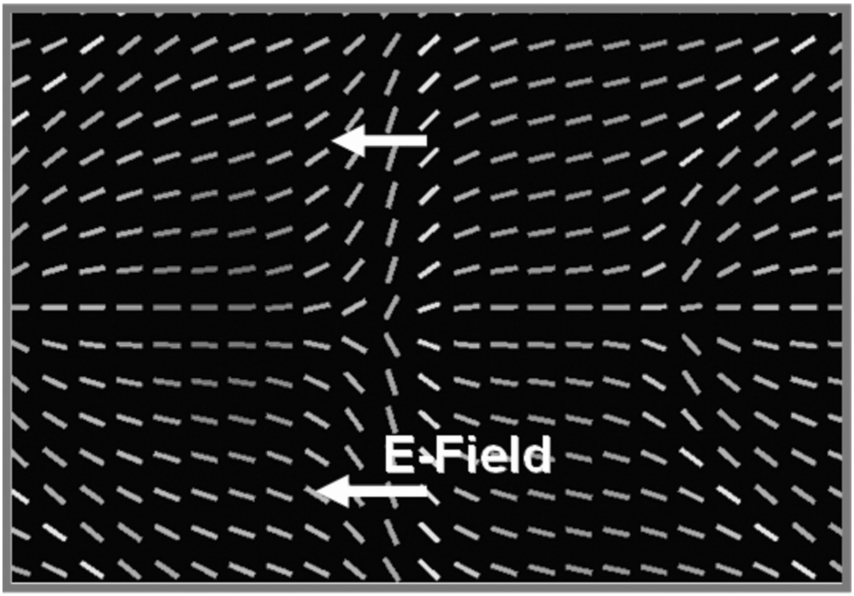
middle of the pixel electrode. It should be noted that pixel electrode has a vertical surface at the corner.

Figure 6 shows the transmittance of the chevron HAN-FFS. When the pixel voltage is 5 V and the common electrode is grounded, the cell



(a)

FIGURE 7 Calculated director distribution of the chevron HAN-FFS with electric field at 200 ms.



(b)

FIGURE 7 Continued.

became bright. Light is transmitted in most of the cell region. It is observed that the transmittance is not high in the middle region of the cell at time 200 ms. The area of the dark region of the chevron HAN-FFS is smaller than that of the prior art due to configuration of the liquid crystal molecules near the vertical surface of the pixel electrode.

Figure 7 shows the calculated director distribution of the chevron HAN-FFS. The white square region in Figure 7(a) is magnified and its director distribution is shown in Figure 7(b). Referring Figure 7(a), twist angle of the directors in the upper half of the cell is 45° while -45° in the lower half of the cell when voltage is applied. The directors in one cell are rotated in two-fold directions. Namely, two-fold domain is formed in a single cell. The director distribution of the proposed structure is quite similar to that of the conventional wedge-shaped HAN-FFS. However, it is observed that horizontal electric field is generated and the directors with negative dielectric anisotropy are rotated from horizontal to vertical near the vertical surface of pixel electrode. Director distribution near the vertical surface of pixel is very different from that of wedge-shaped HAN-FFS.

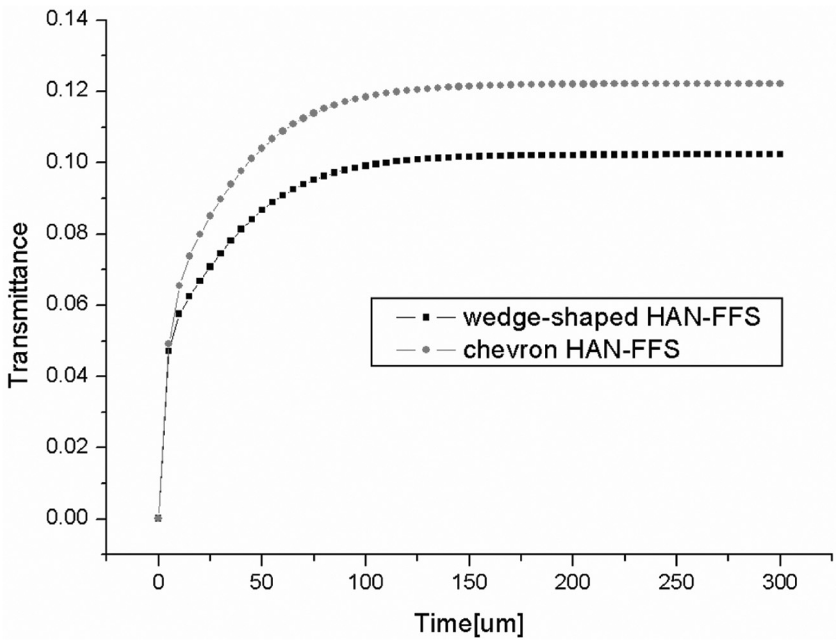


FIGURE 8 Transmittance as a function of time of the wedge-shaped HAN-FFS and chevron HAN-FFS.

Figure 8 shows the transmittance of the wedge-shaped HAN-FFS and chevron HAN-FFS at 300 ms. The X-axis means the simulation time and Y-axis means the transmittance of the cell. It turned out that transmittance of the chevron HAN-FFS has about 1.2 times than that of wedge-shaped HAN-FFS. Further, the saturation time is a little shorter for the chevron HAN-FFS than that of the wedge-shaped HAN-FFS because of rotated directors near the vertical surface of pixel electrode.

III. CONCLUSION

Our simulation reveals that the wedge-shaped HAN-FFS is superior to the conventional HAN-FFS structures in terms of viewing angle, as evidenced by the previous literatures. However, the transmittance is not satisfactory because of the presence of dark region in the middle of the cell. In this work, we propose a novel structure, named as chevron HAN-FFS, which has a modified pixel electrode in the cell. Since horizontal electric fields are generated near the vertical surface of pixel electrode, the proposed structure allows the directors to be rotated from the horizontal to the vertical directions. Consequently, transmittance of the proposed chevron HAN-FFS has about 1.2 times than that of the conventional wedge-shaped HAN-FFS. Furthermore, the saturation time is also improved for the chevron HAN-FFS for the wedge-shaped HAN-FFS. To achieve a better performance of the proposed chevron HAN-FFS, it is necessary to optimize the width of the pixel and distance between electrodes.

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