Cell Gap Dependent Transmission Characteristic of the Fringe-Field Switching Mode in a LC with Negative Dielectric Anisotropy

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Abstract

We have studied cell gap-dependent electrode-optic characteristics of the FFS mode using the LC with negative dielectric anisotropy. In case of a small cell gap of 2 ㎛, the transmittance at the center of pixel and common electrodes is low due to stronger influence of surface anchoring that holds the LC to the initial state than twisting force induced by neighboring LCs. In case of a large cell gap of 4 ㎛, the influence of surface anchoring force becomes weak so that the LCs at the center of pixel and common electrode can be twisted enough by applied voltage, giving rise to high transmittance. Therefore, we conclude that the light efficiency in the device is dependent on the cell gap.

1. Objective and Background

In liquid crystal displays (LCDs), the electro-optic characteristics of the LCDs depend on LC mode.[1] Several LC modes are being commercialized now. Among them, the fringe-field switching (FFS) mode is known to exhibit high transmittance and wide viewing angle at the same time overcoming the problem of the rest LC modes.[2-5] In the device the homogeneously aligned LC is driven by fringe field that has both horizontal and vertical components of electric field, such that the electro-optic characteristics of the device is strongly dependent on dielectric anisotropy of the LC.[6,7]

In most of the LCDs, the light efficiency is function of cell retardation value not a cell gap (*d*). However, we found that in the FFS mode as the cell gap decreases, the transmittance decreases although the retardation value is the same. In this paper, we have investigated why this behavior occurs by simulation.

2. Results Discussion

To perform the simulation, the LC with physical properties such as $\Delta\varepsilon = -4$, $K_1 = 13.5$pN, $K_2 = 6.5$pN, and $K_3 = 15.1$pN is used. The surface pretilt angle is 2° and the rubbing angle is 12° with respect to horizontal field component. For optical calculations, 2x2 extended Jones matrix is applied for incident light 550nm.

First, we have calculated voltage-dependent transmission characteristics while changing cell gaps from 2㎛ to 4 ㎛. Here, the cell retardation value 0.36㎛was kept the same for each case to observe only the cell gap effect. Figure 1 shows calculate results, indicating that with decreasing cell gap, the driving voltage (V_{op}) increases and the transmittance decreases. To understand the origin of decreasing transmittance with decreasing the cell gap, we have calculated the transmittance along the electrode position at three different voltages, 0.5V below V_{op}, V_{op}, and 0.5V above V_{op}, as shown in Fig. 2.

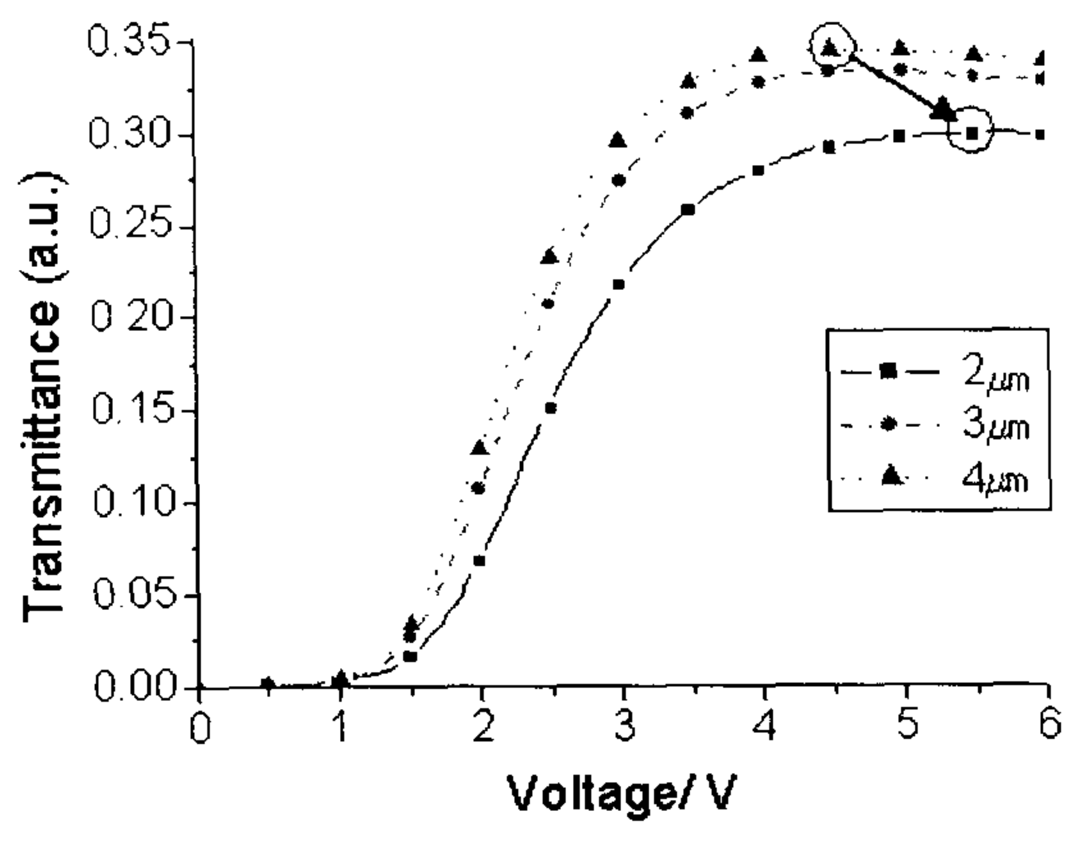

Figure 1 Voltage-dependent transmittance curve in the FFS mode as a function of cell gap.

Here, A, B, and C indicate the transmittance at three different voltages, respectively and the configuration of the LC molecules is obtained at V_{op}. In addition, since the transmittance inside one pixel and one electrode is periodic along horizontal axis in the FFS mode, the transmittance only in that distance is shown. When the cell gap is 4㎛, the transmittance is only slightly dependent on electrode position and with increasing voltage from below V_{op} to above V_{op}, it starts to decrease from maximal transmittance at the edge of pixel electrode. This indicates that the V_{op} is electrode positional dependent in the FFS mode unlike conventional TN mode but its dependence is not so severe (see Fig. 2(c)). One noticeable thing is that the configuration of the LCs is different depending electrode position. When the cell gap is 3㎛, its dependence becomes rather large, that is, the transmittance difference between the edge and the center of pixel electrode becomes bigger than that for the cell with 4㎛. Now, when the cell gap is 2㎛, the transmittance is strongly changing along horizontal axis. Especially, it is low at the edge of pixel electrode and the center of pixel and common electrode, indicating that the voltage that gives rise to maximum transmittance depends on electrode position. Further, the transmittance at the center of pixel and common electrode is relatively lower for the cell with 2㎛ than that for the cells larger than 3㎛, irrespective of applied voltage. This implies that the behavior of the LC at that position is rather different when the cell gap is very low like 2㎛.

If one knows well about the switching principle of the FFS mode, it is known that the LC deformation occurs by two interactions, first dielectric torque near the edge of electrode and then twisting elastic force between neighboring molecules above center of pixel and counter electrode.

To understand the positional-dependent transmittance, we have calculated the profile of the LCs at three positions, as shown in Figs. 3 and 4. As indicated, when the cell gap is 4㎛, the highest twist deformation at the edge of electrode near bottom surface occurs due to strong horizontal field intensity. At the center of pixel electrode, the maximum twist angle is about 45° just below the middle layer. This is quite similar even when the cell gap is 3㎛. However, when the cell gap is 2㎛, the maximum twist angle occurs around middle layer, which means that the transmittance will be maximum when it is about 45° in average.

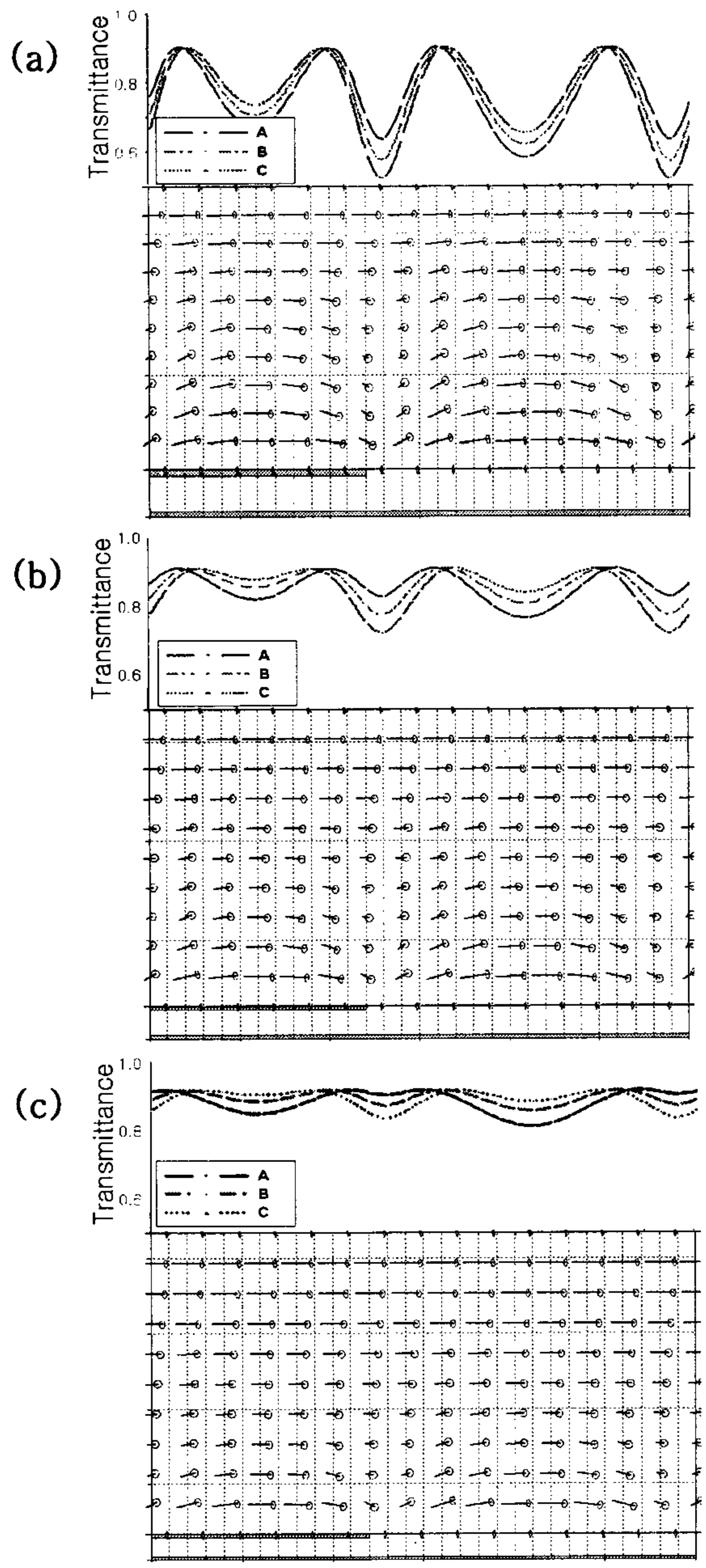

Figure 2 Transmittance distribution at different voltages and LC director distribution at maximum transmission for the FFS mode using a liquid crystal with negative dielectric anisotropy when the cell gap is (a) 2㎛, (b) 3㎛, and (c) 4㎛.

Near the edge, it is about 65° while it is 30° at the center of electrode, meaning that the transmittance is not maximal due to over- and less-twist respectively. Considering the tilt angle as appeared in Fig. 4, it is kept low below 18° at I and 12° at H, indicating that it

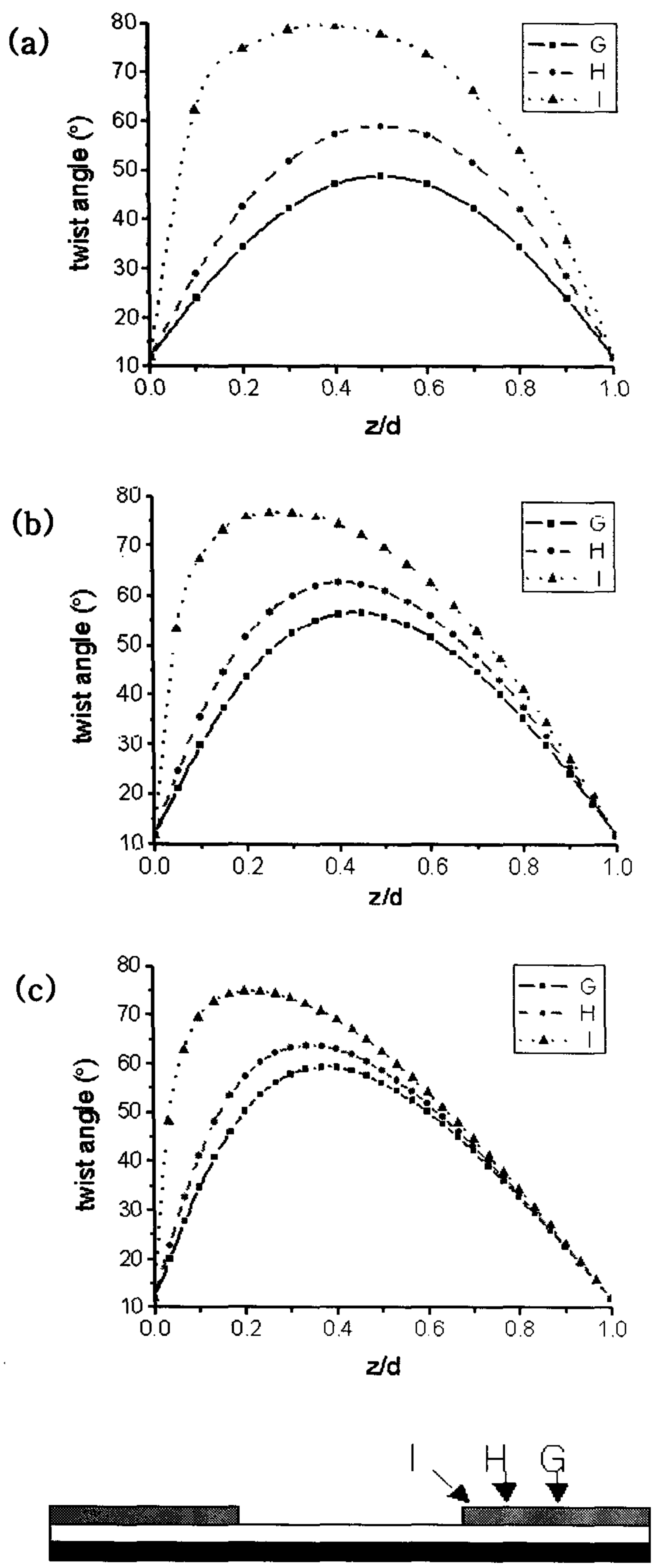

Figure 3 Calculated twisted angle at three different position, near the edge (I), between (H), and center (G) of pixel electrode.

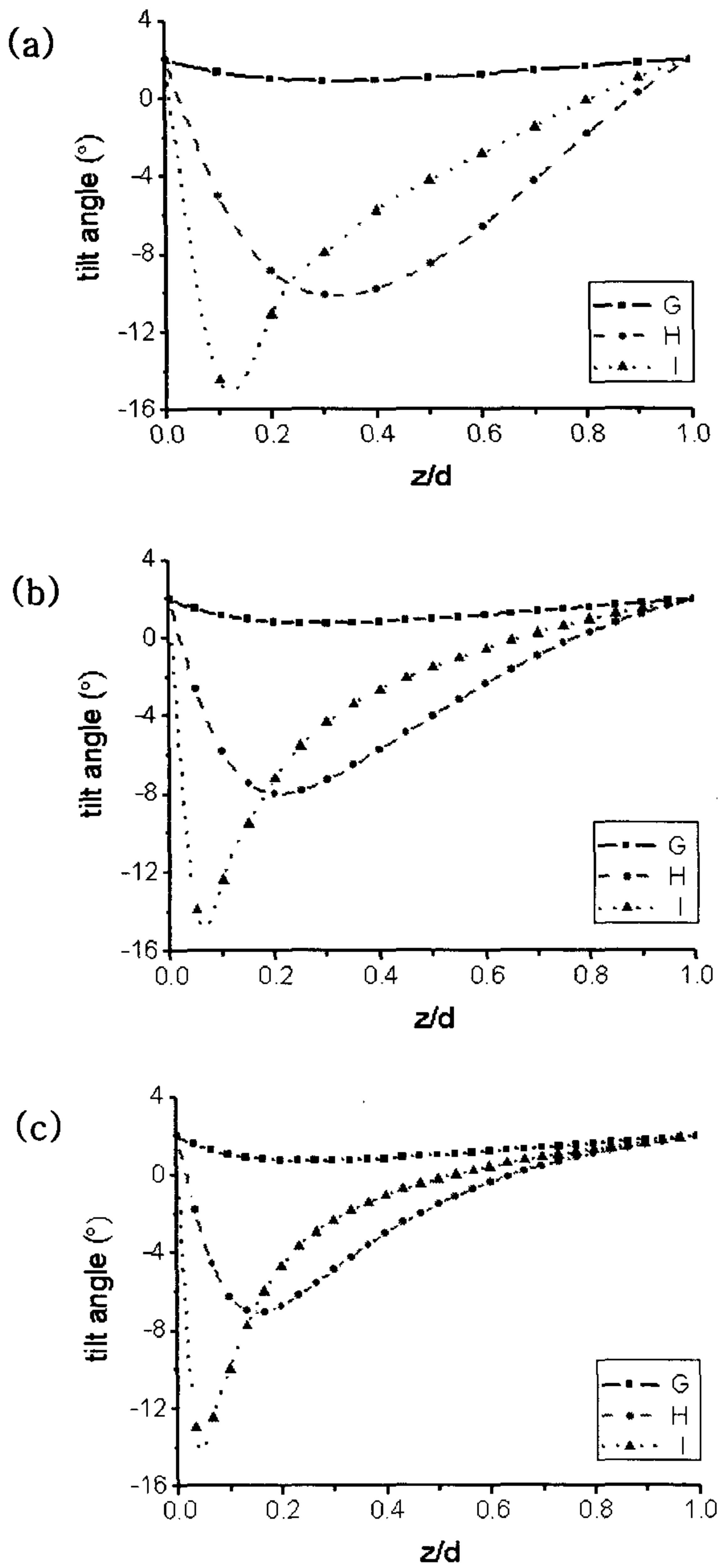

Figure 4 Calculated tilt angle at three different position, near the edge (I), between (H), and center (G) of pixel electrode.

affects on twisting elastic force very weakly.

From the analysis of the director distribution, we can conclude that when the cell gap becomes low, the influence of surface anchoring becomes larger than that in the cell with large cell gap. Therefore, the LCs at the center of electrodes, which are twisted by elastic force between neighboring molecules, cannot be rotated fully because the force cannot overcome enough the force that holds the LC to the initial state by surface anchoring force.

3. Summary

We have investigated the cell gap-dependent transmittance in the FFS mode. Unlike conventional other displays, the transmittance of the device is dependent on the cell gap although the cell retardation value is the same. Especially, the low transmittance occurs in the positions at the center of and near the electrodes. The first results from the competition between the elastic energies and the latter results from over twist of the LC director.

4. Acknowledgements

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5. References

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