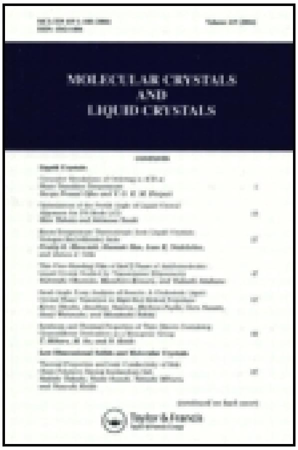

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The Influence of the Data Signal on Transmission Characteristics of LCD Cells

Suk-In Yoon [a b], Hyung-Jin Youn [a], Moo-Sung Jung [a], Dae-Woo Kim [a], Taeyoung Won [a], Sang-Ho Yoon [b] & Cheol-Soo Lee [b]

[a] School of Electronics and Electrical Engineering, Inha University, Yonghyun-Dong, Incheon, Korea

[b] Sanayi System Co., Ltd., Dohwa-Dong, Incheon, Korea

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The Influence of the Data Signal on Transmission Characteristics of LCD Cells

Suk-In Yoon
School of Electronics and Electrical Engineering, Inha University, Yonghyun-Dong, Incheon, Korea and Sanayi System Co., Ltd., Dohwa-Dong, Incheon, Korea

Hyung-Jin Youn
Moo-Sung Jung
Dae-Woo Kim
Taeyoung Won
School of Electronics and Electrical Engineering, Inha University, Yonghyun-Dong, Incheon, Korea

Sang-Ho Yoon
Cheol-Soo Lee
Sanayi System Co., Ltd., Dohwa-Dong, Incheon, Korea

In this paper, we report our preliminary study about the influence of data signal on the optical properties of LCD cell which is operated at vertical alignment (VA) mode. The VA cell employed in this study has a size of $88 \times 264\,\mu m^2$ with a cell gap of $4\,\mu m$. In order to analyze the optical crosstalk between the data signals, we employed finite element method (FEM) for calculating the LC director distributions and 2×2 extended Jones method for optical transmission. Our simulation revealed that the voltage discrepancy between data signal and pixel electrode voltage is the main cause for the reduction of brightness as well as the generation of flickers.

Keywords: finite element method; liquid crystal display; optical analysis; simulation

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Address correspondence to Taeyoung Won, School of Electronics and Electrical Engineering, Inha University, 253 Yonghyun-Dong, Nam-Gu, Incheon 402-751, Korea. E-mail: twon@hsel.inha.ac.kr

I. INTRODUCTION

The electro-optic performance of a modern liquid crystal display (LCD) keeps being improved. Several liquid crystal modes such as in-plane field switching (IPS) [1], fringe field switching (FFS) [2] and vertical alignment (VA) [3] have shown to provide wider viewing angle and faster response time in their own ways. The above-mentioned VA is one of the most powerful LCD driving modes due to high contrast ratio and fast response time. Figure 1 is a schematic view of the operation of VA mode. Generally, VA has an upper common electrode and a lower pixel electrode while a negative LC material is used with pre-tilt angle of 90° as shown in Figure 1(a). Figure 1(b) illustrates the operation of ON state. In the case of ON state, LC director rotates vertically with response to the electric-field generated between the pixel and common electrode.

The sub-pixel, however, has four types of electrode, comprising a pixel electrode, a common electrode, a data line and a gate line. Figure 2 is a schematic view of the (mth, nth) sub-pixel and the driving voltage of signal for each gate and data line. Each gate line is connected to V_g(on) during the period of selection (T_S), while being connected to V_g(off) otherwise, wherein the data lines are applied to various signal voltage as an inversion scheme. When the gate is turned on by V_g(on), the pixel electrode is charged by the signal voltage. Thereafter, when the gate is turned off, other signal voltages should propagate through the data lines. As a consequence, a horizontal electric field is generated near the fringe due to the crosstalk from the signals on the data line. This influences the electro-optic properties which causes erroneous inversion on gray levels.

II. SIMULATION AND RESULTS

In order to figure out the influence of the data signal on the electro-optical property of an LCD cell, we chose a simple VA mode cell with a couple of

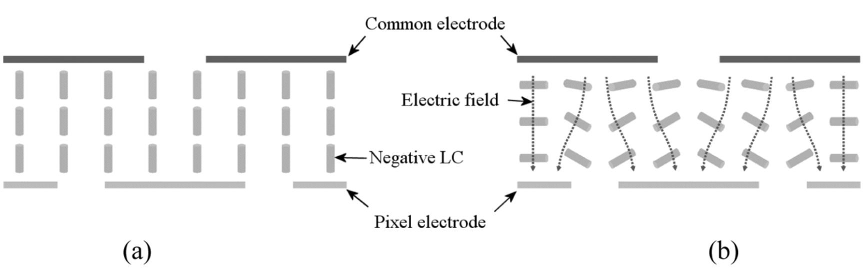

FIGURE 1 The operation of vertical alignment mode: (a) OFF state and (b) ON state.

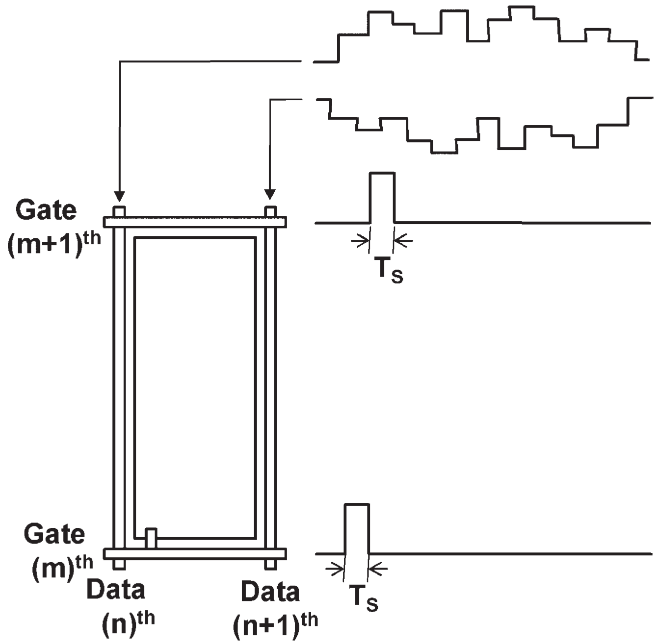

FIGURE 2 A schematic view of the (mth, nth) sub-pixel and the driving voltage of signal for each gate and data line.

domains for our simulation. Figure 3 shows the schematic view of our test VA structure while Table 1 shows the simulation parameter for the LC material. Referring to Figure 3 and Table 1, our test structure has a data line, common and pixel electrode. The cell gap of structure is 4 μm and common electrode patterns of 10 μm width along the x-axis. Regarding the voltage condition, we fixed the common electrodes at 4 V while varying the pixel electrode from 4 to 8 V with a step of 2 V. The data line was tied to the one of 4 different signal voltages (4, 6, 8, 10 V).

For the calculation of dynamic behavior of LC directors, we applied finite element method to the governing equations, which are the Ericksen–Leslie equation and the Laplace equation. The Ericksen–Leslie equation is the Euler–Lagrange form of the Frank-Oseen free energy density [4]. Optical calculation was performed at a single wavelength of 550 nm by using 2×2 extended Jones matrix method [5].

Figures 4 through 6 show the optical transmission on XY-plane under various data signal voltages at the fixed common and pixel voltage.

Figures 4(c) and 4(d) illustrates that light becomes leaky with increasing signal voltage of the data line. This is due to the fact that

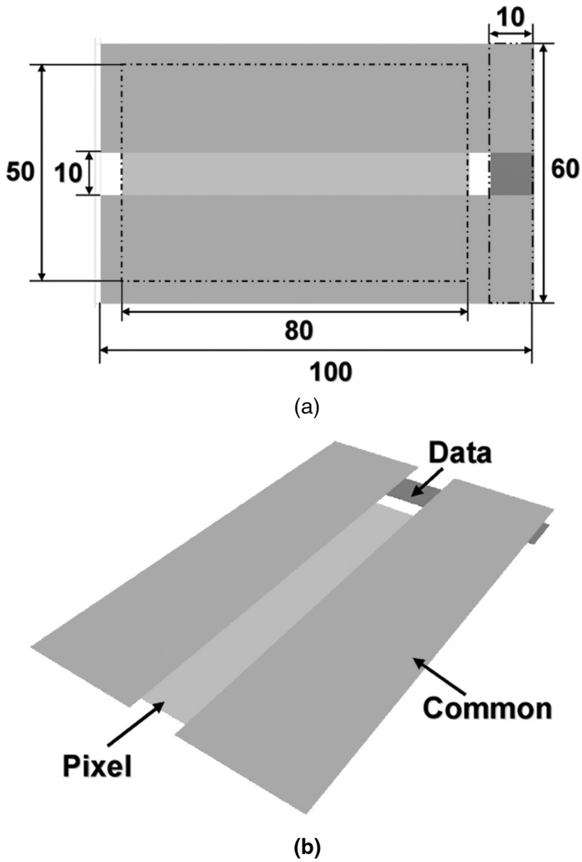

FIGURE 3 (a) Schematic view and (b) 3D structure of test structure (unit: μm).

the higher signal voltage, the stronger electric field between the data line and the pixel electrode. Moreover, the electric field between the data line and the pixel electrode generates a domain wall, as shown in Figure 5(a) and 5(b). It seems obvious that the transmittance of the cell enhances with the voltage of pixel electrode. However, the

TABLE 1 Simulation Parameter for the LC Material

Cell gap (μm)	4	K1 (pN/m)	16.7
Pretilt (°)	90	K2 (pN/m)	7.3
Δn at 550 nm	0.079	K3 (pN/m)	18.1
Δε	−4.2	γ (mPa · sec)	186

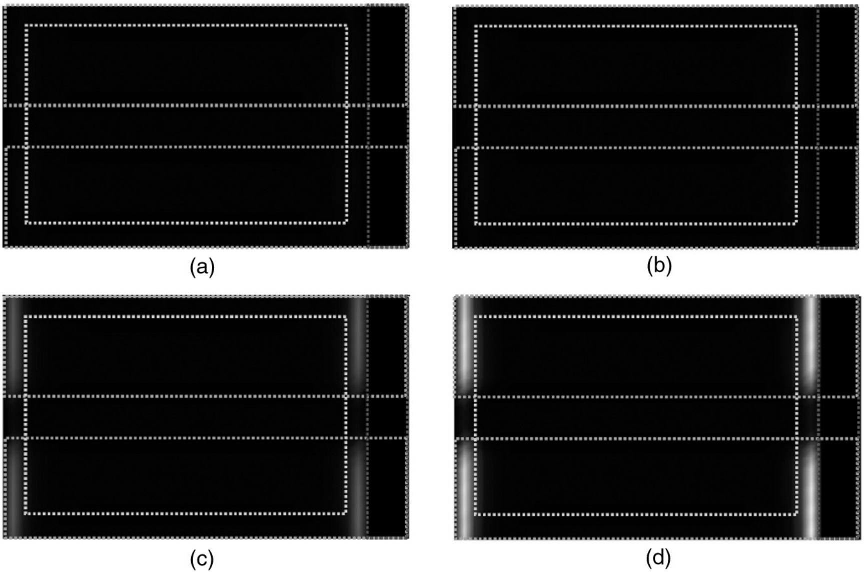

FIGURE 4 Optical transmission at data signal of (a) 4 V, (b) 6 V, (c) 8 V, (d) 10 V (common voltage: 4 V, pixel voltage: 6 V).

higher pixel voltage leads to the fringe electric field that makes domain walls. The magnitude of the fringe electric field is reduced when the signal voltage at peripheral data line increases. Consequently, if the voltage of the data line has the same value to the pixel voltage, domain walls seem to be disappeared as shown in Figure 5(c). Furthermore, as shown in Figure 5(d), as the voltage of the data line increased more than the pixel voltage, the domain walls appeared again because directors are turning reversely when the voltage of the data line increases.

Figure 6 shows the optical transmission when the voltage of common electrode and pixel electrode tied to 4 V and 10 V, respectively. As shown in Figure 6, it is very similar to that shown in Figure 5. Figure 7 shows the transmission curve as a function of the voltage of the data line. Referring to the Figure 7, in the case of lower gray level (the pixel electrode: 6 V, the common electrode: 4 V), the transmission increases continuously when the voltage of data line increases. It is due to the light leakage around the data line. However, in the case of a middle or higher gray level, the optical transmission increases suddenly, when the voltage of the data line has the same value to the pixel voltage.

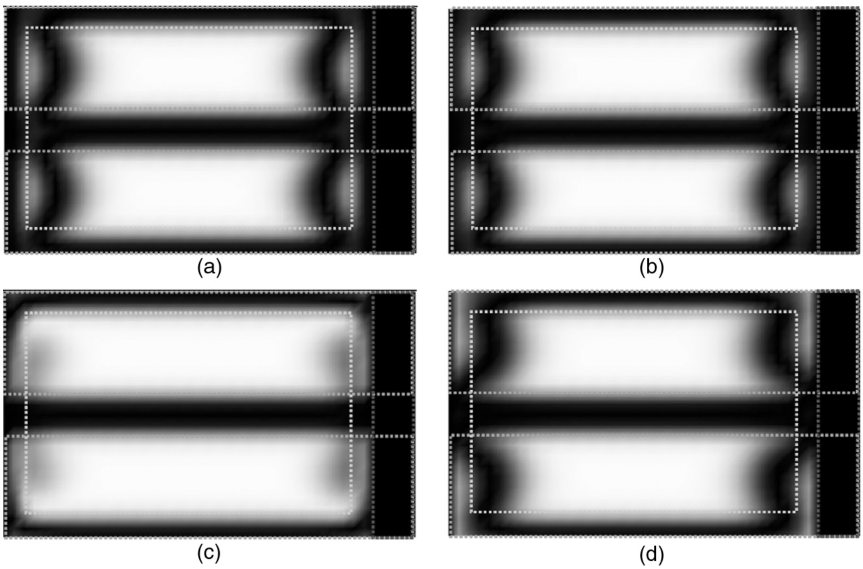

FIGURE 5 Optical transmission at data signal of (a) 4 V, (b) 6 V, (c) 8 V, (d) 10 V (common voltage: 4 V, pixel voltage: 8 V).

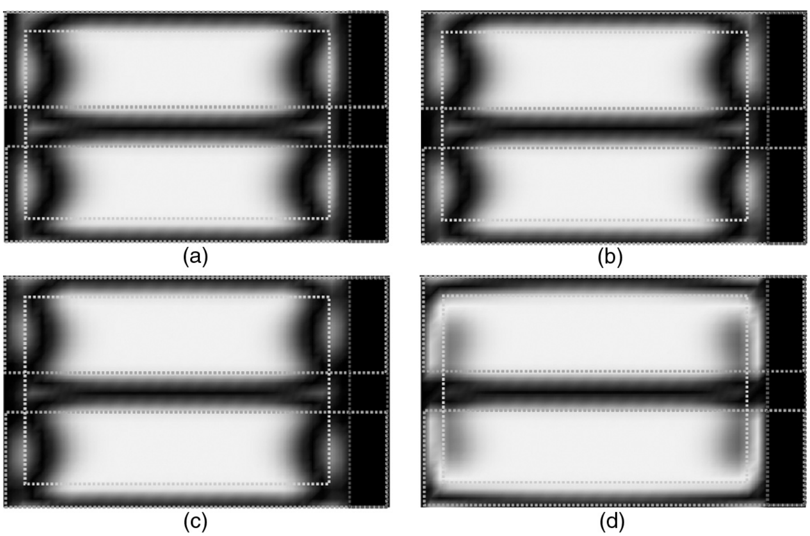

FIGURE 6 Optical transmission at data signal of (a) 4 V, (b) 6 V, (c) 8 V, (d) 10 V (common voltage: 4 V, pixel voltage: 10 V).

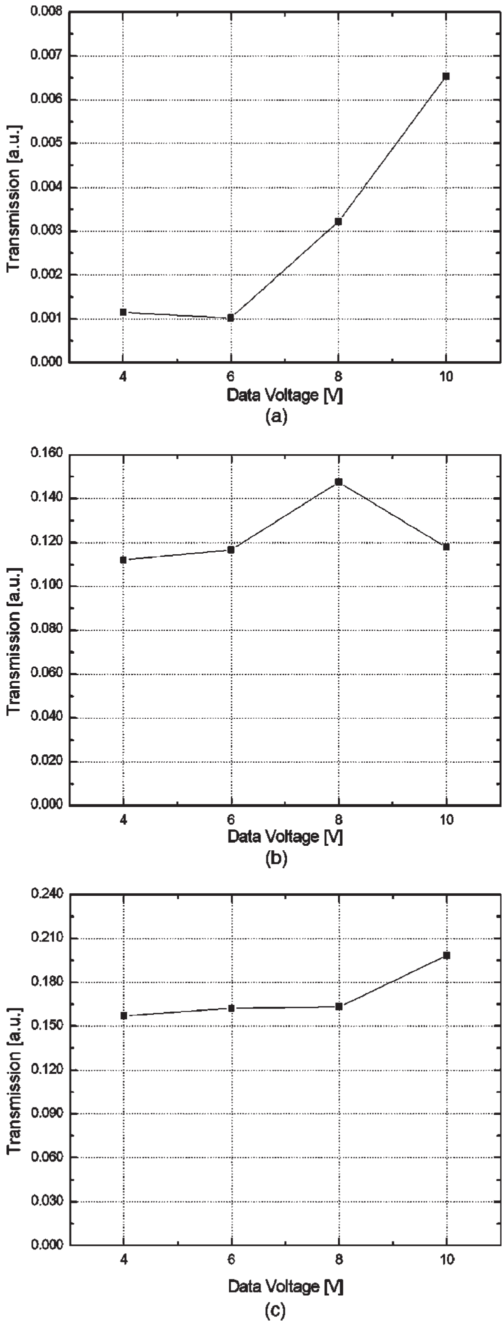

FIGURE 7 Calculated voltage-dependent transmittance curve at the fixed common voltage of 4 V with the pixel voltage of (a) 6 V, (b) 8 V, (c) 10 V.

As shown above simulation result, this result indicates that the fringe electric field between the data line and pixel electrode makes light leakage or domain walls and the test cell structure has the maximum optical transmittance when the voltage of peripheral data line is equal to the pixel voltage. The crosstalk effect of adjacent data line is crueler to the lower gray level than the middle or higher gray levels. However, this can be neglected because of the BM (Black Matrix). In the case of middle or high gray level, since the direction of the electric field between the data line and pixel electrode is different to that of the electric field between pixel and common electrode, the domain walls appear around the data line, even if the direction of the electric field between the adjacent data line and pixel electrode is reversed. The domain wall is only disappeared when the voltage of data line becomes equal to the pixel voltage.

Secondly, we simulate the conventional PVA cell having the common electrode with wing pattern. Figure 8 shows the layout of the simulated PVA cell and its 3D structure. The PVA cell has a size of $88 \times 264\,\mu m^2$ with a cell gap of $4\,\mu m$ and the simulation parameter of LC material has the same value of Table 1. In order to calculate optical transmittance of PVA cell, we assume that the gate line is tied to $-18\,V$ (V_g(off)) and pixel and common electrodes is tied to $12\,V$ and $6\,V$, respectively.

Figure 9(a) and 9(b) shows the optical transmission on XY-plane under the signal voltage of 6 V and 12 V at the fixed common and

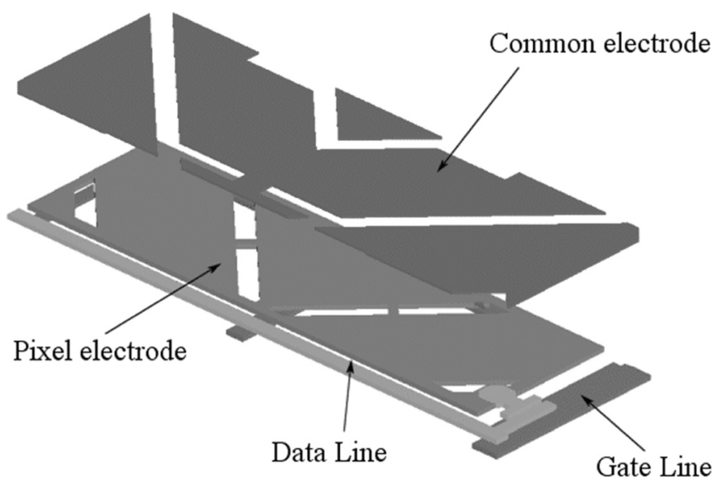

FIGURE 8 3D structure of the simulated PVA cell.

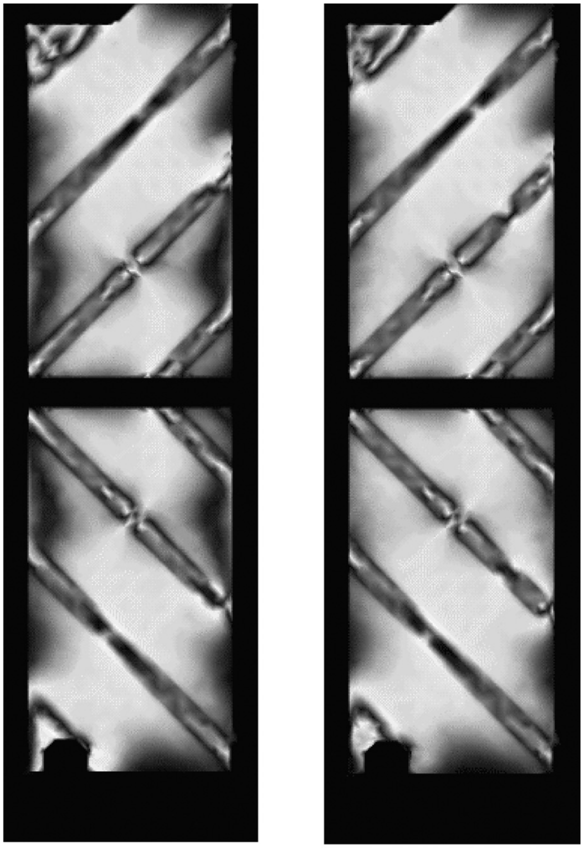

FIGURE 9 Optical transmission of the simulated PVA cell under data signal of (a) 6 V, (b) 12 V at the common voltage of 6 V and the pixel voltage of 12 V.

pixel voltage, respectively. Referring to Figure 9, as we mentioned before, the signal voltage different to pixel voltage generates another domain walls in the aperture. Moreover, if the signal voltage reaches the value of the pixel voltage, domain walls are disappeared. Figure 10 shows the transmission curves as a function of time. Referring to the Figure 10, there is 8% difference in max transmission. Therefore, in order to prevent the variation of transmission caused by the adjacent data line, technique to control the fringe electric field occurred between the adjacent data line and pixel electrode is needed.

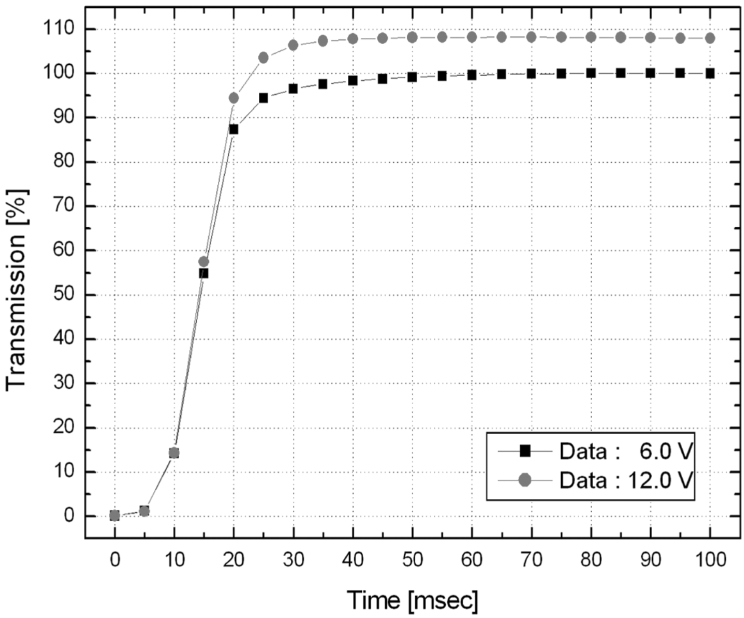

FIGURE 10 The transmission curves as a function of time under the various data voltage.

III. CONCLUSION

In this paper, we have reported the influence of the signal voltage on optical properties of LCD cells. As our simulation results, in the VA mode cell, the fringe electric field between the data line and pixel electrode makes light leakage or domain walls and the VA mode cell has the maximum optical transmittance when the voltage of peripheral data line is equal to the pixel voltage. Therefore, in order to prevent the increase of transmission caused by the adjacent data line, technique to control the reversed electric field occurred between the adjacent data line and pixel electrode is needed.

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