# Surface Effects on the Optical Performance of Liquid Crystal Displays

Hyung-Jin Youn*, Cheol-Soo Lee*, Moo-Sung Jung**, Dae-Woo Kim*,
Suk-In Yoon*, Sang-Ho Yoon*, and Taeyoung Won**
*Sanayi System Co., Ltd., Korea
**Department of Electrical Engineering, School of Engineering, Inha University, Korea

**Abstract**

In this paper, we report on our theoretical study on the effect of surface anchoring. Molecular dynamics as well as optical characteristics of PVA cell are computer-simulated with 3D-FEM numerical solver, *TechWiz LCD*®. Although simulation parameters are the same except for the consideration of surface anchoring, the simulation reveals that optical transmittance is improved by more than 8% for the weak anchoring case with comparison to the strong anchoring case. Moreover, capacitance between pixel and common electrode is 7% lower for the strong anchoring than that for the weak anchoring. This implies that there exists an appreciable difference between the strong anchoring case and the weak anchoring case. It is very important to take the effect of surface anchoring into account in order to figure out the optical characteristics of an LCD cell more accurately.

## 1. Introduction

Recently, numerous structure have been developed to improve the electro-optical characteristics for PVA(Patterned Vertical Alignment), MVA(Multi-domain Vertical Alignment), IPS(In-Plane Switching) and FFS(Fringe Field Switching) modes. Structure of these modes is very complex and various. The behavior of directors for these modes is determined not only by visco-elastic characteristics, but also by the anchoring between surface and directors. In other words, the director distribution of them is determined by the following major features: First, the elastic potential energy [1] in the liquid crystal; second, the influence of an external applied voltage; and last, the anchoring strength [2, 3] between surface and directors on the boundary layers. Therefore, surface anchoring between liquid crystal and substrate is very important for both device application and understanding of physical phenomenon.

In this paper, effect of surface anchoring was evaluated by a commercial tool (i.e. TechWiz LCD). TechWiz LCD [4] has surface anchoring module which has formulated Rapini-Papoular[5] equation for the anchoring energy per unit area.

## 2. Simulation results and discussion

In order to evaluate the effect of surface anchoring, we have chosen PVA cell with MLC-6608 of which the parallel and perpendicular dielectric anisotropy is 3.6 and 8.3, respectively. The elastic constant of liquid crystals is $K_{11}$=16.7[pN], $K_{22}$=7.3[pN], $K_{33}$=18.1[pN]. Strong and weak anchoring is applied to PVA cell to compare surface effect.

Figure 1 shows 3D-structure of PVA cell which has pixel electrode, gate line, and data electrode on the bottom substrate. Common electrode is located on the top substrate. Width and height of the PVA cell 90um and 270um, respectively. Pre-tilt angle is 90° on the bottom and top substrate. Polarizer is crossed each other and angle of polarizer is 0° on the bottom substrate. Periodic boundary condition is selected at the boundary of the cell.

Figure 2 shows the transmittance of the PVA cell on state (i. e. at 100[msec]). Voltage of pixel electrode and data line is 7[V]. Voltage of the others is 0[V]. Figure 2(a) and 2(b) shows the transmittance of the PVA cell with strong and weak anchoring, respectively. The transmittance with strong anchoring and weak anchoring is different each other. Above all, it is distinct at the pattern.

Tilt angle of directors is extracted at the point of 'A' which is shown in figure 1(b). Figure 3 shows tilt angle as a function of depth (i. e. z axis). The square, circle and triangle symbol means 0[msec], 10[msec] and 100[msec], respectively. There is considerable difference between the behaviors of director with weak and strong anchoring at the surface substrate.

When a voltage is applied to the electrode, as shown in figure 3(a), the directors in the bulk are rotated from 90° to 0°. However, the directors at the top and bottom substrate (i. e. 'A', 'B') are not rotated, because they are always fixed due to the strong anchoring. Figure 3(b) shows tilt angle of the directors with weak anchoring. When a voltage is applied to the electrode, all directors which is existed at the bottom, top substrate and bulk are rotated from 90° to 0°.

Figure 4 shows the transmittance as a function of time. X axis means time and y axis means transmittance of the PVA cell. Solid and dash line means transmittance in the case of weak and strong anchoring, respectively. The transmittance of the PVA cell is 5% higher for the weak anchoring than for the strong anchoring. Referring to the figure 3(b), because of weak anchoring, the directors at the top and bottom substrate are rotated to purposed direction. On the other hand, Strong anchoring interferes with the behavior of directors in the bulk region.

Figure 5 shows the parasitic capacitances as a function of time. X and y axis means time and capacitance, respectively. Value of capacitance is about XX% higher for the weak anchoring than for the strong anchoring.

## 3. Conclusion

In this paper, we report on our theoretical study on the effect of surface anchoring. Transmittance for the strong and weak anchoring is about 0.25[a. u.] and 0.23[a. u.] at 30[msec]. In other words, optical transmittance is improved by more than 8% for the weak anchoring case with comparison to the strong anchoring case. Moreover, capacitance for the strong and weak anchoring is 18[pF] and 17[pF]. Capacitance between pixel and common electrode is about 7% lower for the strong anchoring than for the weak anchoring. This implies that there exists an appreciable difference between the strong anchoring case and the weak anchoring case. It is very important to take the effect of surface anchoring into account in order to figure out the optical characteristics of an LCD cell more accurately.

## 4. Reference

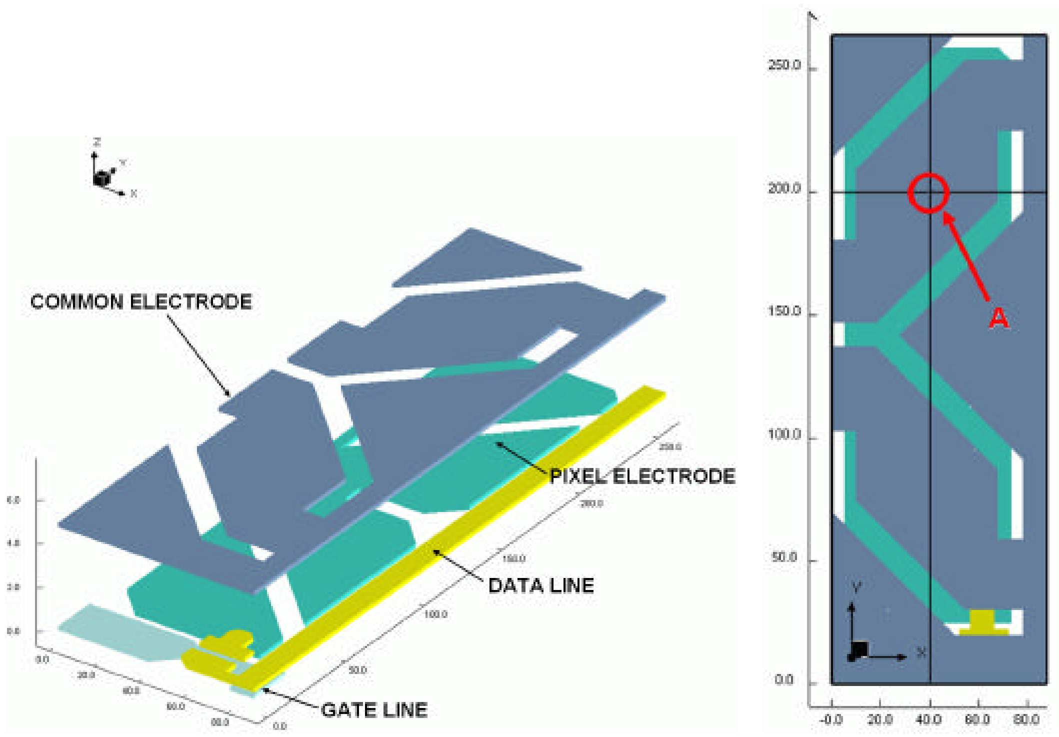

[1] Frank, F. C., Discuss. Faraday Soc. 25, 19 (1958)

[2] De Gennes, P. G., and Prost, J., The physics of Liquid Crystals (1993)

[3] Stelzer, J., Trebin, H.-R., and Longa, L., J. chem. Phys., 107, 1295, Erratum (1997)

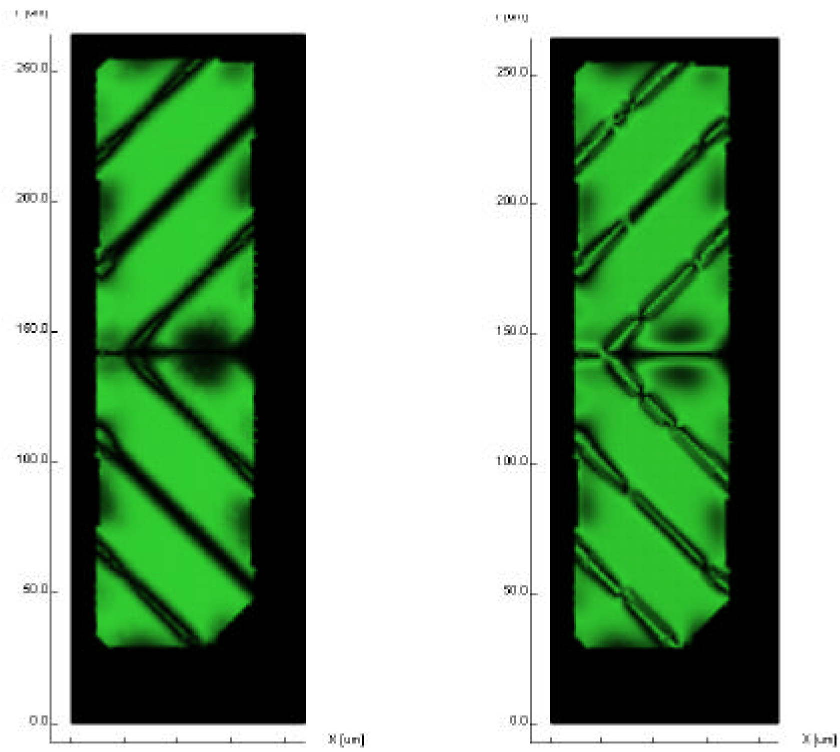
[4] User's Guide of TechWiz LCD 2005, www.sanayisytem.com, Sanyi System Co., Ltd (2005)

[5] A. Rapini and M. Papoular, J. Phys. (Paris) Colloq., 30, C4-54(1969)



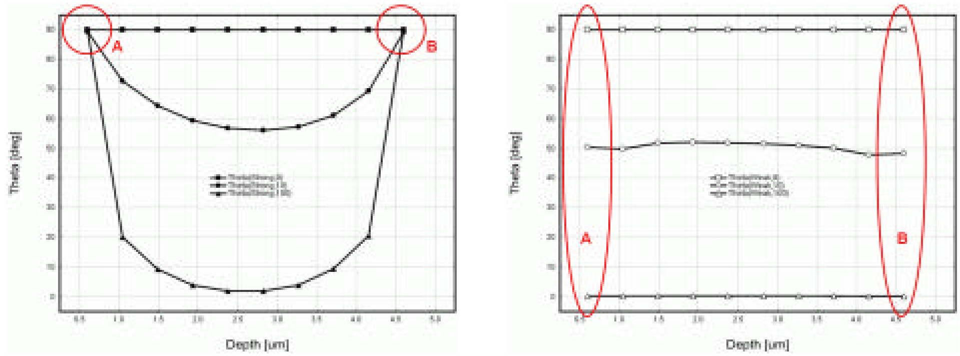

(a) (b)

Figure 1. Electrode structure: (a) 3D-structure, (b) top view of the PVA cell.




(a) (b)

Figure 2. Transmittance of the PVA cell: (a) strong anchoring, (b) weak anchoring.




(a) (b)

Figure 3. Director distribution as a function of depth at point ' A' :

(a) conventional FFS cell, (b) improved FFS cell

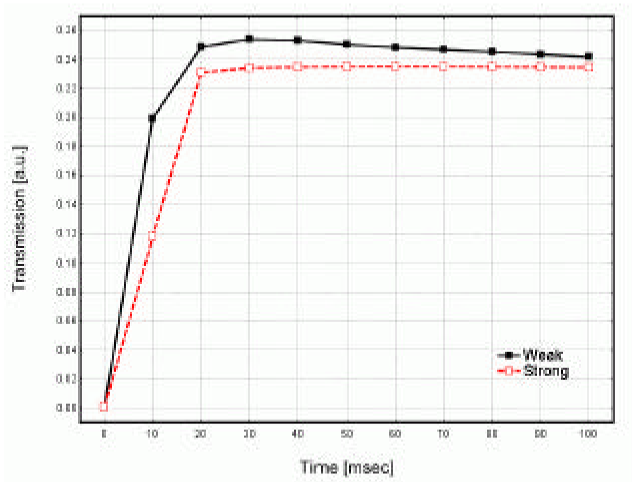



Figure 4. Transmittance graph for the strong and weak anchoring

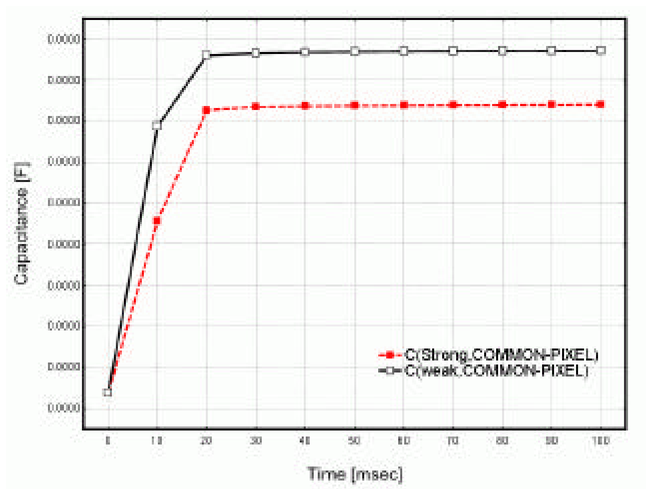



Figure 5. Capacitance graph as a function of time for the strong a nd weak anchoring