# Theoretical Study of d/p Margin


Jun Sik Oh, Han Yong Lee

Technology Division, Samsung Display Devices Co., Ltd.,

575, Shin-Dong, Paldal-Gu, Suwon City, Kyungki-Do, Korea



**Abstract**

We have calculated the d/p boundary values in which the low twist defect and the stripe domain defect can occur with dielectric constants and elastic constants and compared them with experimental data using the compensation factors. We estimated d/p margin for 250° twist angle without experimental data and investigated qualitatively the reasonability of the behavior.


## Introduction

It is very important to know d/p margin beforehand for LCD mass production because too large d/p results in the stripe domain defect and too small d/p results in low twist defect. If we know upper and lower boundary that the defects can occur we will be able to obtain a larger process margin by setting the process condition in center. When we try to obtain the d/p boundary values by experiments a lot of efforts will be needed. We know that two engineers have made experiments for 6 months to obtain the d/p margins of 5 kinds of liquid crystals with 220 ° and 240 ° twist angle. We tried to obtain d/p margin through the theory and the computer simulation without making the experiments that need a lot of time and efforts.

## Theoretical Study

### 1)For the Low Twist

The low twist state is a 180° less twisted one than a normal one(eg. In a 240° twist STN, a 60° twist domain may appear). We can confirm it by matching the measured and the simulated transmission spectrum of low twist state. Why the low twist state occur is explained by the difference of free energy [1]. The free energy of 240° state is usually lower and more stable in a normal state. But if free energy of 60° state is lower than 240° state the low twist state may appear. Inversion of the free energy will provide the origin of low twist defect. Fig. 1 shows the difference of free energy and inversion pattern. The maximum and the minimum values of difference curve vary according to changes of d/p values where d is the cell thickness and p is the natural helical pitch. We could obtain from the experimental data that the low twist appeared when the minimum of negative value was about 1.5 times as much maximum of positive value in a difference curve of free energy..

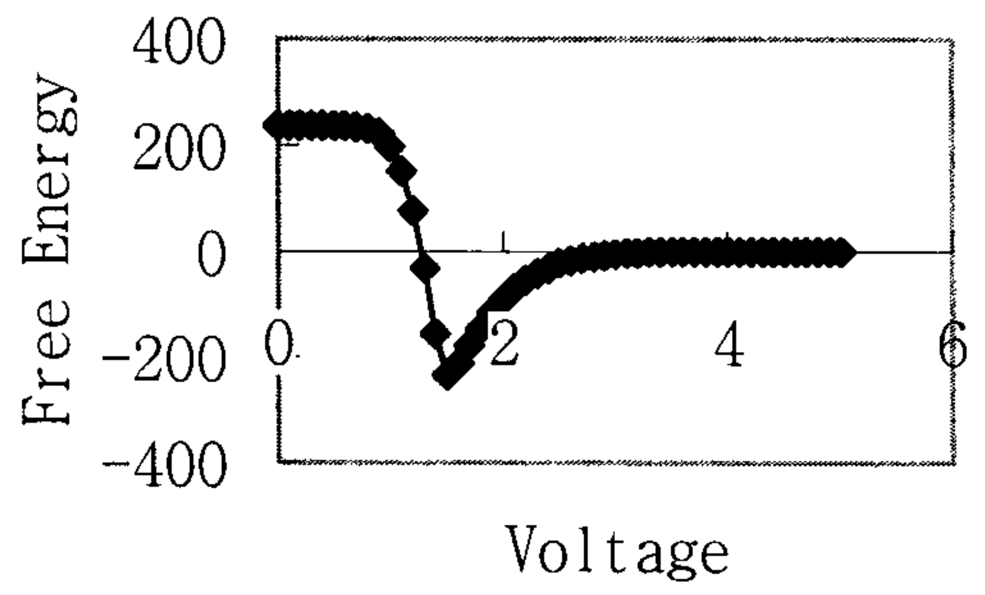


Fig. 1. Free energy difference curve of 60° and 240°

### 2)For the Stripe Domain

We tried to calculate the critical voltage(Vc) for domain formation and the long pitch cholesteric to nematic phase transition threshold voltage(Vth) derived by Chigrinov et al. and by Breddels et al. respectively[2,3]. We obtain the minimum voltages where the nonzero perturbation starts to occur for each k value from the differential equations with zero pretilt angle and select the minimum(the lowest point in Fig. 2) of them as Vc. M. Akatsuka et al.[4] assumed that the domain formation could occur under the condition of Vc<Vth. Fig. 3 shows that the cross point of two curves(Vc/Vf and Vth/Vf) is the starting point of domain where

$$V_{th} = \left(\frac{\{4\pi(d/p_o)k_{22} - [k_{33} - 2(k_{33} - k_{22})\cos^2\theta_o]\phi_T\}\phi_T}{\varepsilon_a}\right)^{1/2}$$

$$V_f = \pi\left[\frac{(K_{11} + (K_{33} - 2K_{22})/4)}{\varepsilon_a}\right]^{1/2}$$

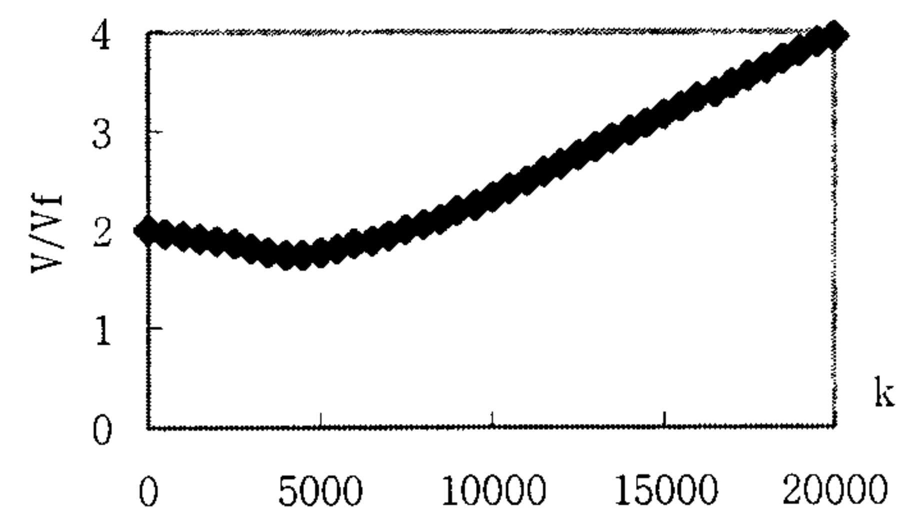


Fig. 2. The graph of the minimum voltage where the nonzero perturbation starts to occur for each k.

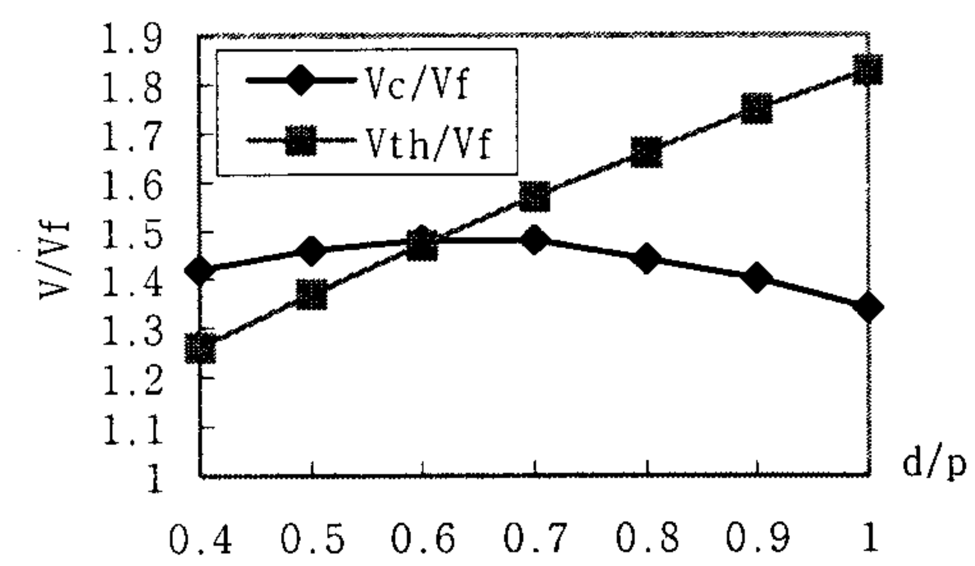


Fig. 3. d/p dependence of both Vc and Vth. The right area of cross point is the domain region.

At this point there is an insufficient point in the above theory. The dependencies of the critical voltage , the threshold voltage and the Freedericksz transition voltage on the anomalous dielectric constant $\triangle\varepsilon$ are all same as $(\triangle\varepsilon)^{(-1/2)}$. The d/p value where the stripe domain emerges doesn't depend on $\triangle\varepsilon$

followed by the above evaluation method. Why this happens is that the stripe domain is related not only with Vc/Vf and Vth/Vf but also is related with steepness of transmission curve vs V/Vf. Although the value of Vc/Vf or Vth/Vf doesn't change according to $\triangle\varepsilon$ variation, the steepness of transmission curve vs V/Vf can change. We know that the stripe domain depends on the steepness of curve and the bigger the $\triangle\varepsilon / \varepsilon_\perp$ goes the smaller the steepness goes and the fewer the stripe domain appears. So we included that effect by using the compensation factors.

**Evaluation of d/p**

We calculated both d/p where the stripe domain appear and d/p where the low twist appear and compared them with the experimental data of 5 kinds of LC(see Table 1)

(Table 1 )

| No | name of LC | $\triangle\varepsilon / \varepsilon_\perp$ | $K_{33}/K_{11}$ | $(\triangle\varepsilon / \varepsilon_\perp)/(K_{33}/K_{11})$ |
|---|---|---|---|---|
| 1 | ZLI-0001 | 2.6 | 1.78 | 1.4848 |
| 2 | ZLI-0002 | 2.4 | 1.43 | 1.7056 |
| 3 | ZLI-0003 | 2.2 | 1.23 | 1.7886 |
| 4 | ZLI-0004 | 3.0 | 1.32 | 2.3005 |
| 5 | ZLI-0005 | 4.0 | 1.41 | 2.8124 |

It was needed to consider the pretilt effect because the boundary value of stripe domain was calculated with zero pretilt. The pretilt effect contributes to span the boundary value and the compensation factor of 0.3/5.5 from the experimental graph of the d/p vs. pretilt was used[4]. For the 3.5° pretilt , d/p(with pretilt) = d/p(without pretilt) + 0.3/5.5*3.5. The boundary value of the stripe domain is much difference whereas that of the low twist is much the same(Fig. 4, 5). We explained the above why it was different. Now we assumed that when $\triangle\varepsilon / \varepsilon_\perp$ was larger than 4 its steepness would small enough and would not contribute to decrease the boundary value of stripe domain and when $\triangle\varepsilon / \varepsilon_\perp$ was smaller it would contribute to decrease the boundary value. The compensation factor of $(\triangle\varepsilon / \varepsilon_\perp)^{(3/7)}/(4)^{(3/7)}$ multiplied by the calculated d/p was used here.

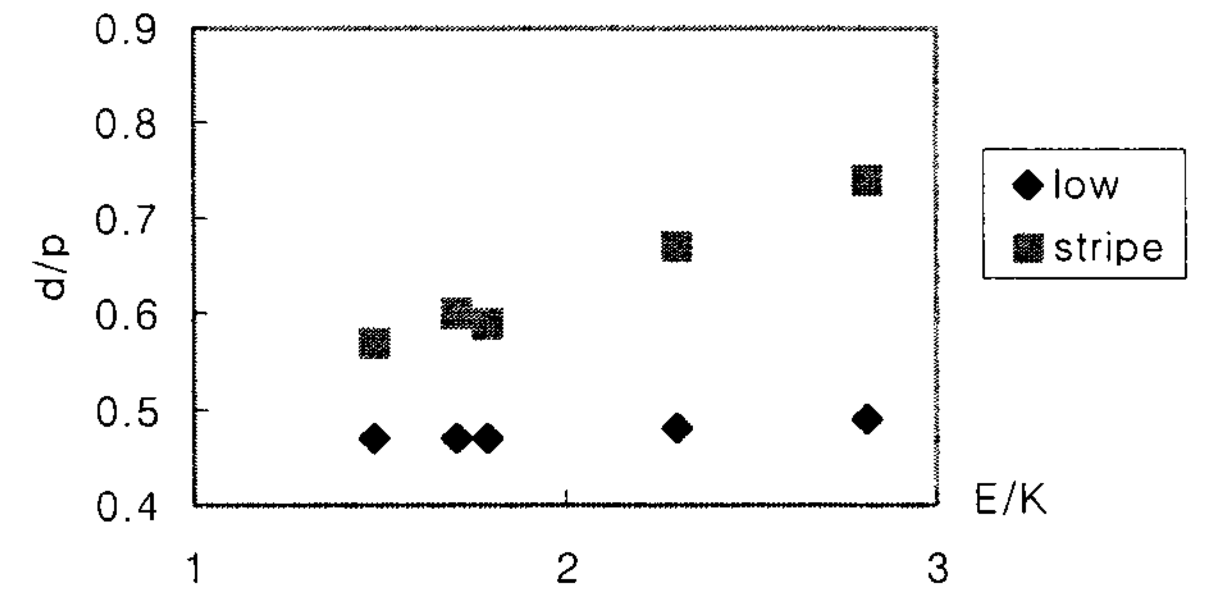


Fig. 4. Experimental data of d/p vs E/K for 240° twist angle where E/K = $(\triangle\varepsilon / \varepsilon_\perp)$/(K33/K11)

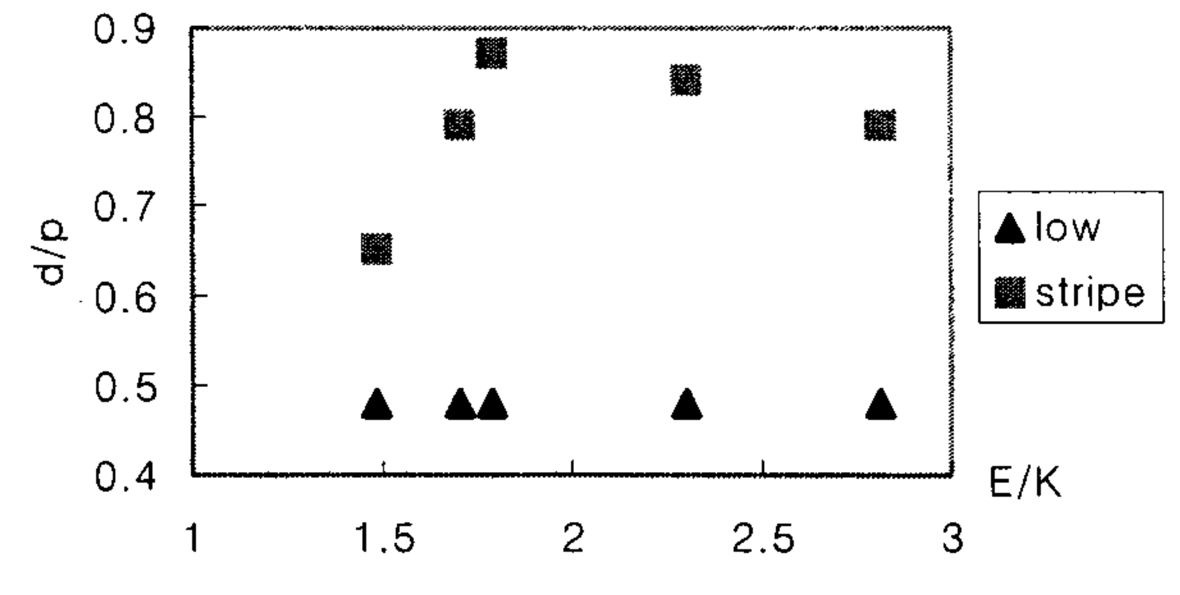


Fig. 5. The simulation data of d/p vs E/K for 240° twist angle without the compensation.

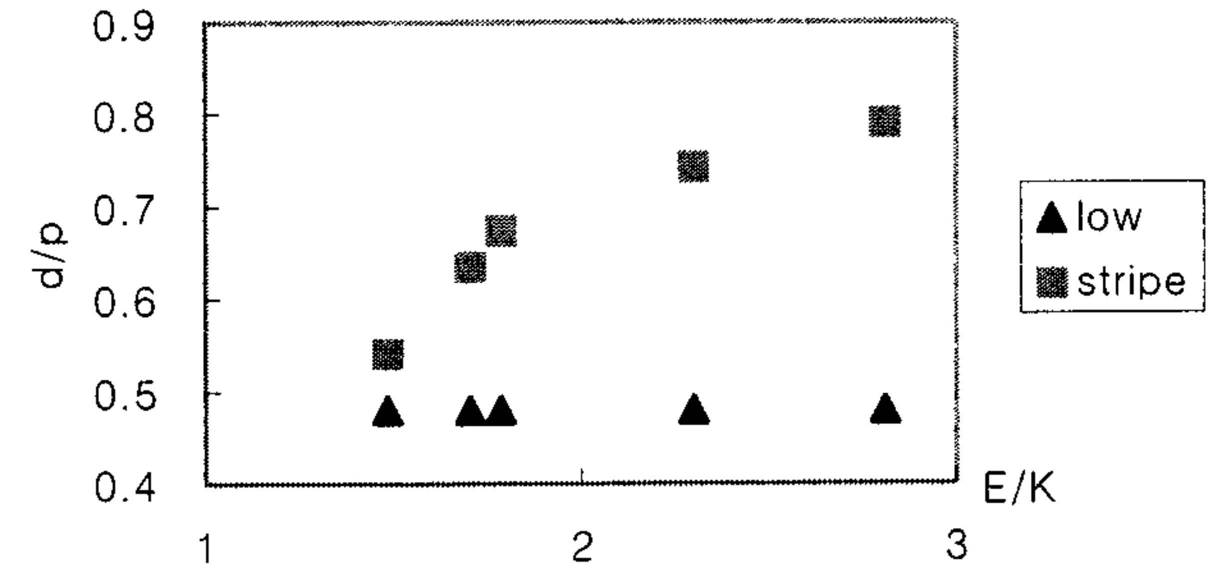


Fig. 6. The simulation data of d/p vs E/K for 240° twist angle with the compensation

We obtained the simulation results for both 220° and 240° twist case and compared them with the experimental data. The data of 220° case weren't put in this paper. We confirmed that the simulation data are similar to the experimental data(Fig. 4,Fig. 6). We also performed the simulation for 250° twist case. We could see that as $(\triangle\varepsilon / \varepsilon_\perp)$/(K33/K11) went larger the boundary value of the stripe domain went larger , the curve shape were all much the same for 3 kinds of twist angles and d/p margin went smaller for the higher twist case from Fig. 7. It agreed well with the known fact that as the twist angle goes larger d/p margin goes smaller. Especially the boundary value of the stripe domain changed a little whereas that of low twist changed a lot as the twist angles changed. We conclude that why d/p margin goes smaller as the twist angle goes larger is due to increase of low twist region.

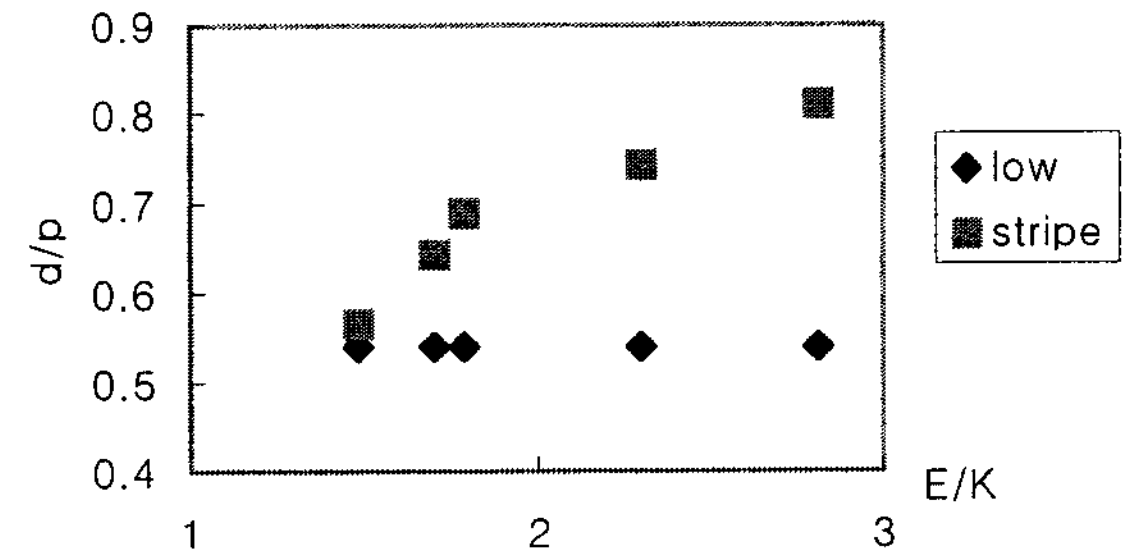


Fig. 7. Fig. 6. The simulation data of d/p vs E/K for 250° twist angle

**Conclusion**

We congregated several theories to calculate d/p margin with the compensation factors. We confirmed that the calculated d/p margin data were similar to the experimental data. And we calculated d/p margin of 250° twist case by the computer simulation without experiment.

**Reference**

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