Electro-Optic and Ionic Properties of Twisted Nematic Cells With Different Chiral Pitch

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Abstract

We investigated electro-optic and ionic properties of twisted nematic cells by using control of chiral pitch. These properties are observed in practical experiment and simulations. C-V and V-T curve characteristics were obtained from three types of cells with d/p. It is shown that d/p ratio of short cells exhibit faster response time improved by 20% than normal cell. Also, inter-gray response time is improved each rise time and decay time. And, the increase of saturation voltage is happened because of the small twist angel change from initial state at high voltage near 5V. To compensate for longer black level tail, gamma curve index was varied from g = 2.2 to g = 2.7 in module status. Additionally, adding chiral dopant into TN cells improved ionic characteristics such as increasing VHR, Ion density and DC Hysteresis were decreased..

1. Introduction

Active matrix liquid crystal display (AMLCD) has been widely used for mobile application such as digital cameras, notebook PC, car navigation systems etc. because it is light, thin, and it has low power consumption. Recently it is superseding CRTs in the monitor market and television applications. However, conventional LCDs are inferior to CRTs for displaying motion pictures. Therefore, there have been many studies to improve slow response time of liquid crystal. Development of new mode in capable of fast optical switching such as vertical alignment mode [1] has been tried and progressed as well as OCB mode [2] and ferroelectric liquid crystal [3]. Even though these methods are pretty much reliable ways considering response time but fast switching is getting more interests in TN mode because TN mode liquid crystal dominates major portion of the active matrix LCD.

In our previous report, we observed response time of normally white TN mode devices by using helical pitch adjustment and its electro-optic characteristic by using retardation compensation film to improve black level [4].

In this report, we investigated basic origin of response time improvement and ionic properties of normally white TN mode devices by using helical pitch adjustment

2. Simulation and Experiment

The response time of Liquid Crystal Displays is limited due to several restrictions, dielectric anisotropy, rotational viscosity of LC material and requiring small driving voltage etc. It was recently introduced that it has 5ms of rising time (Tr) and 20 ms of decay time (Td) [4]. Rising time depends on mutual relationship between rotational viscosity(γ) and dielectric anisotropy($\Delta\varepsilon$) of liquid crystal and applied voltage and cell gap.

Td is mostly depending on elastic constant (K11; Spray, K22; Bend, K33; Twist), rotational viscosity and cell gap. In other words, when applied voltage and dielectric anisotropy are high, rising time decrease and when increasing elastic constant K, Td decreases. It is difficult to control the elastic constant K intentionally considering intrinsic property of liquid crystal molecule but changing chiral pitch by adding chiral dopant into liquid crystal can increase it.

We controlled quantity of chiral dopant with same LC with Chisso liquid crystal mixture controlled quantity of same chiral dopant. Chiral pitch of Sample A, B and C are 61.7, 20.2 and 15.2㎛ respectively. Cell gap of these samples is 4.2㎛.

Fig1. shows the relationship between the chiral pitch and response time of the panel state. With increasing the quantity of chiral dopant, the d/p ration changed from 0.07 to 0.27 and the decay time decreased. And, the d/p ratio of 0.27 saturated decay time than the rise time. Rising time (Tr) was decreased by increasing operation voltage (Vop). This result was caused by increasing of elastic constant K and increasing of saturation voltage. Therefore, proper d/p can be determined without reaching the higher limit of Vop. Accordingly in order to improve the response time we don't need to use increasing of chiral dopant resulting from higher Vop.

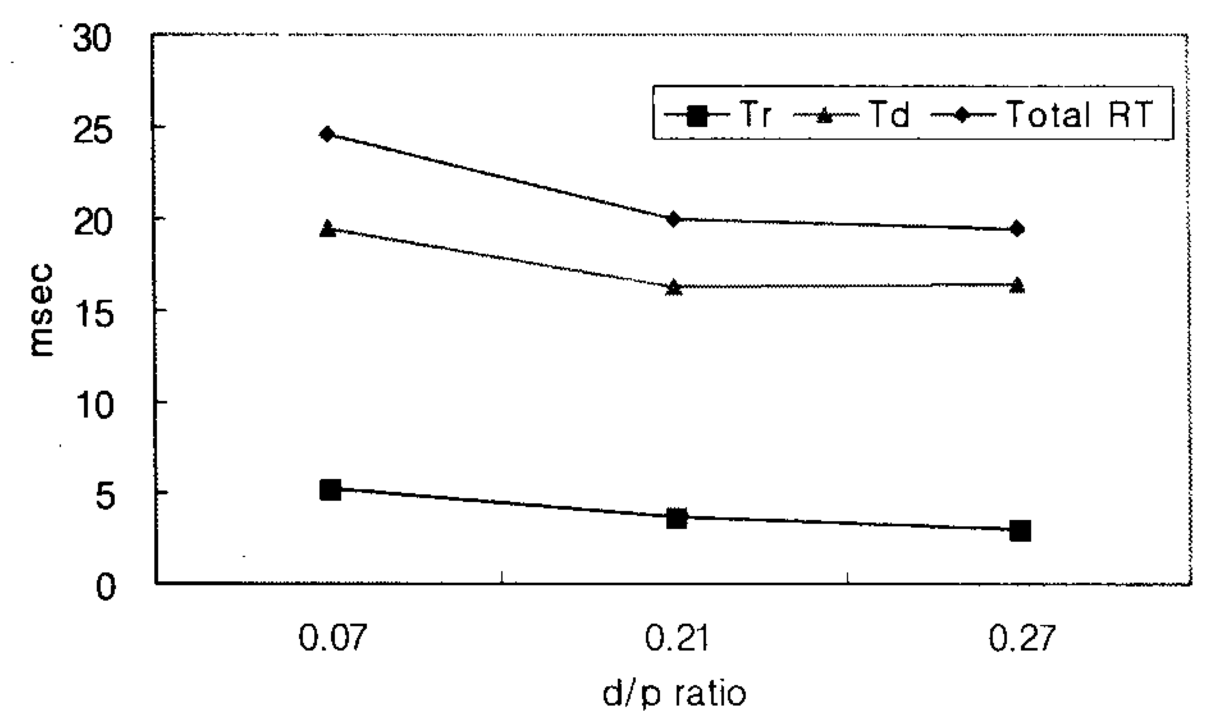
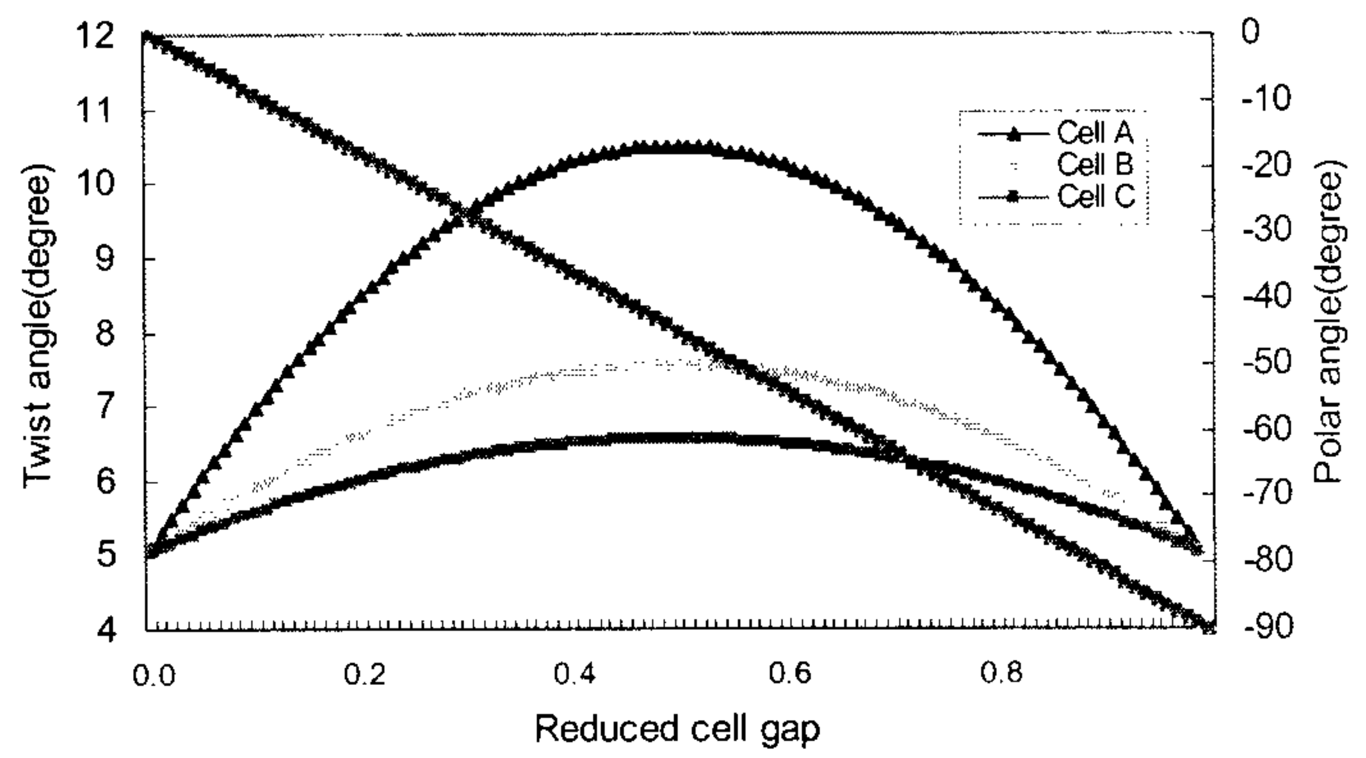


Fig. 1. Response time of samples depending on the quantity of chiral dopant(d/p ratio)

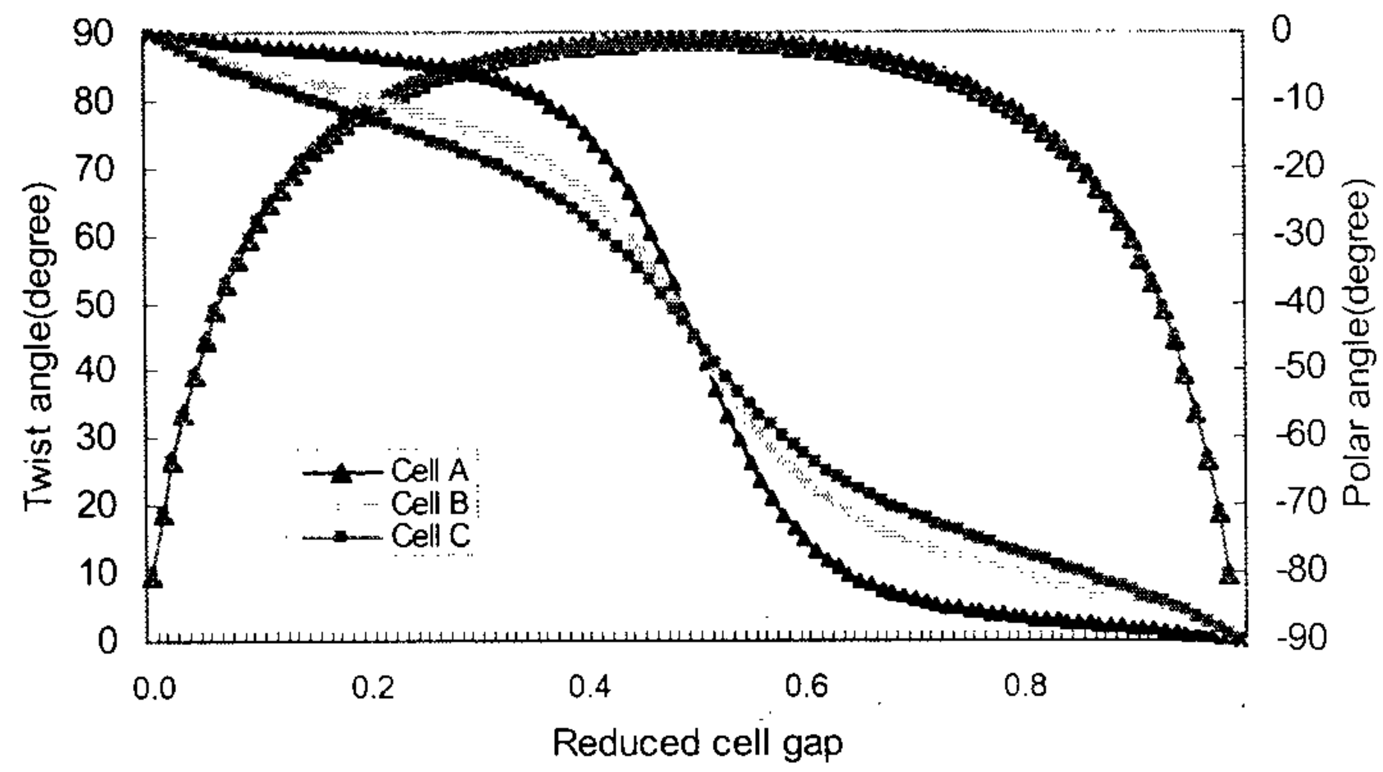
Fig2. shows distribution of liquid crystal director of polar angle and twist angle according to various chiral dopant when applying voltage by using a 1D director modeling. On the applied voltage nearly 1V, the polar angle of the directors around the central part of d/p ratio of 0.27 increased faster than the d/p ratio of 0.07. Decreasing of polar angle of director in the middle layer drove the flow of LC induced by the horizontal force due to the between LC and chiral dopant interaction, these directors which were far from the substrate could be rotated more difficulty by the external field. After operation voltage about 5V, the polar angle distribution took about 88o of less than 90 o to reach its saturated value in the various cells.

It is shown in fig2. b) that twist angles of each sample are not same that the twist angle of cell A is crossed with about 90o throughput wide range but twist angle of cell B and C is only narrow range of near upper side and lower side. It is shown that reduction of the twist angle causes the polarization effect of a short pitch cell to become more asymmetry of the birefringence for the magnitude of cell compensation. In general, for the standard twisted nematic LC device, the twist angle of LC molecular alignment near upper and lower polarizers is crossed with 90o to each other, so the light polarization becomes no transmission of light at operation voltages. Quantity of offseted light of cell B, C is smaller than cell A between crossed polarizers. Therefore, the increasing of saturation voltage as a function of the polarizer orientation according to shortening the chiral pitch was originated from the small twist angle between crossed polarizes. By operating a liquid crystal cell in the intermediate voltage region between the threshold and saturation voltages, one can obtain an optical shutter that possesses a variable transmittance depending on the magnitude of the applied voltage.

In the region of low voltage 1V, polar angle of LC director in the Cell A is beginning to vary and in turns B and C according to increasing voltage but transmittance is not varied in all cells. This means that transmittance of low voltage region is due to twist angle change of LC before threshold voltage. The dynamic change of the LC direct verified by measuring of capacitance according to applied voltage. Capacitance level of TN cell depends on the polar angle change.



a) Polar angle and twist angle when 1V was applied



b) Polar angle and twist angle when 5V was applied

Fig. 2. Simulation result of polar angle and twist angle in the cells with other chiral pitch at a) 1V b) 5V.

Fig3 shows V-T and C-V curve of the effects of adding chiral dopant into unit cell. The capacitance is beginning transition at the lower voltage and then transmittance observed. In a point of chiral pitch, the transition of capacitance is generated which the Cell A is faster than that in Cell C sample. And transmittance of cell A happened faster than that Cell C sample but slightly late than capacitance transition. This implies that free energy of LC in initial LC orientation state is affected on the behavior of LC director. Therefore, the free energy of the shorter chiral pitch level in initial state is lower than that in normal chiral pitch, so it needs the larger electric energy to behavior of LC director.

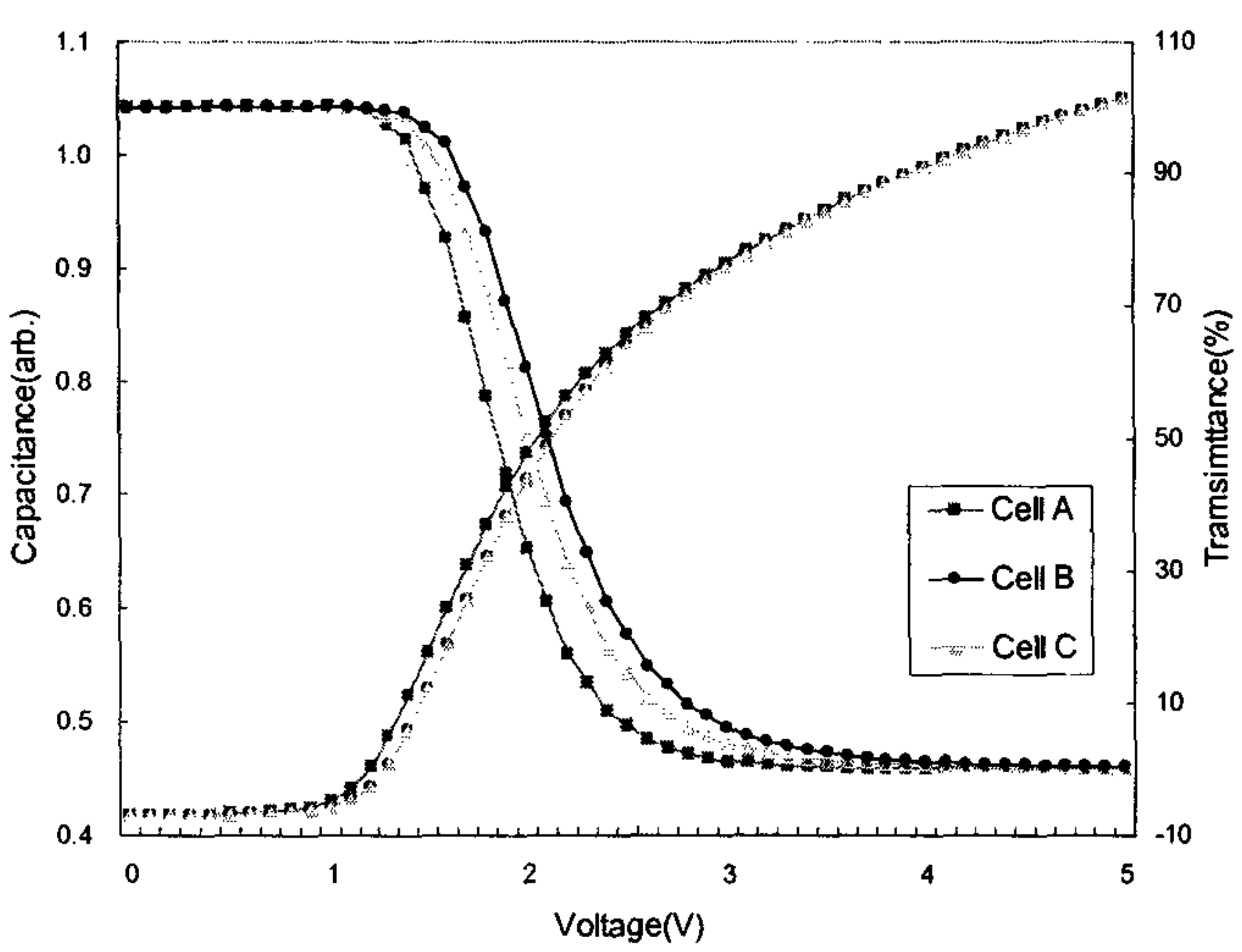


Fig. 3. Transmittance and capacitance vs. applied voltage.

The effects of adding chiral dopant into TN cell are not only decreasing Td by being larger K value of TN cell but also decreasing Tr by being larger saturation voltage.

Fig4. shows inter-gray response time of cell A and cell C. The whole response time of cell C are shorter than those of cell A. Rising to the full black and decay to the full white was the most improved.

In TN note-book module using small driving voltage range, increase of saturation voltage brings to difficulty in tuning gray level.

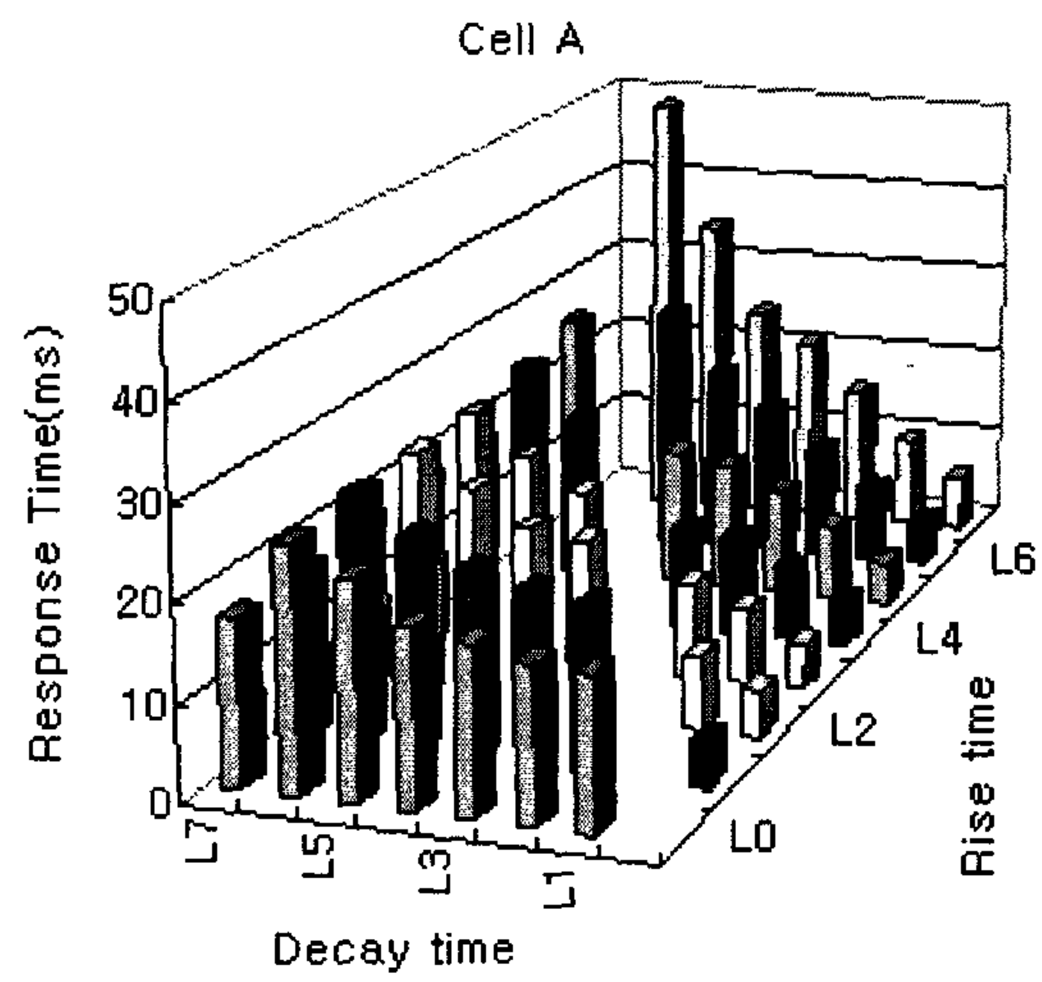
Transmittance of black level is slightly larger by adding chiral dopant, so contrast ratio of module deteriorates.

To more improve response time in module, white level voltage can be tuned from 99% to 100% of transmittance.

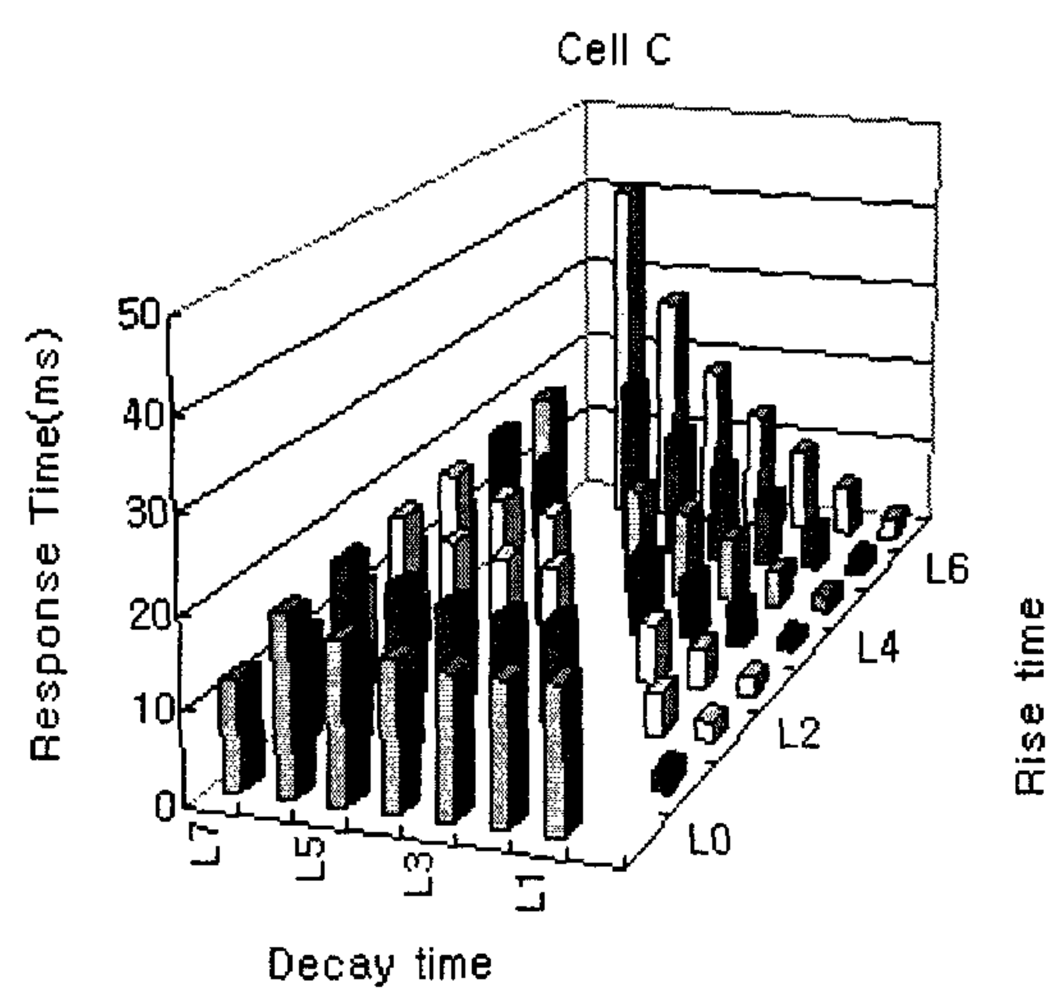
In generally, gamma curve of LCD is controlled to have g = 2.2.

In order to prevent deterioration of CR and improve RT, we controlled black level and white level reference so gamma curve index was varied from g = 2.2 to g = 2.7.

This control of gamma level is compensation for longer black level tail.



a) Response time of cell A



b) Response time of cell C

Fig. 4. Response time of gray to gray level

Other effects of adding chiral dopant into TN LCD is investigated as VHR (voltage holding ratio), ion density & DC hysteresis (VHR, ion density and DC hysteresis were measured by VHRM-103, MTR-1, HP-4284A)

These ionic characteristics are measured by TN unit cell, where the gap and electrode area are 4㎛ and 2.72cm2, respectively.

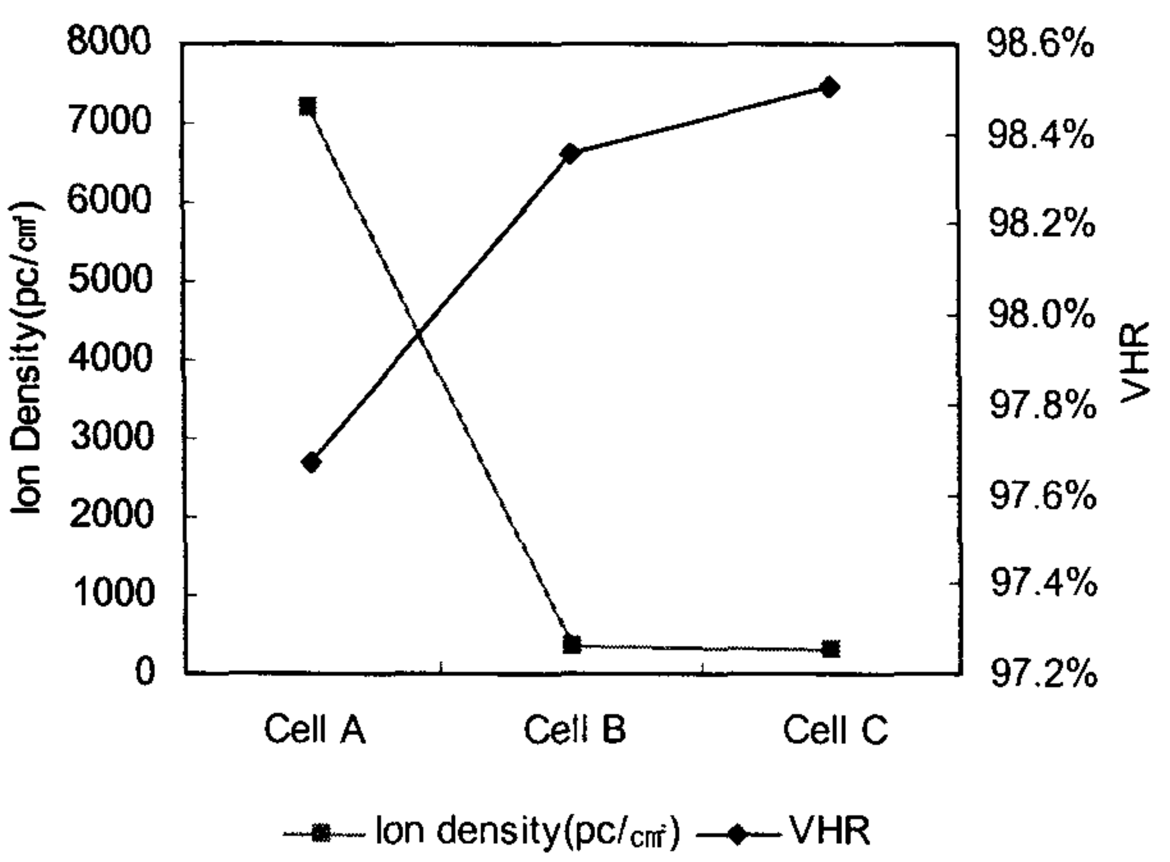


Fig. 5. Helical pitch dependence upon VHR & ion density of cell A, B, & C

Fig4 shows ion density, VHR and DC hysteresis using the Cell A, B and C respectively. VHR becomes larger as the chiral dopant of the ion density decreases. The value of the capacitance difference varies with the quantity of chiral dopant. The DC hysteresis becomes larger as the quantity of chiral dopant decreases. It is like to result of ion density measurement. It means that our samples are decreasing impurity ions and components of residual DC by more adding chiral dopant.

4. Conclusion

We studied the characteristics of TN mode having short chiral pitch by adding chiral dopant. The effects of adding chiral dopant into TN cell are not only decreasing Td by being larger K value of TN cell but also decreasing Tr by being larger saturation voltage. The increasing of saturation voltage was originated in the small twist angel change from initial state at high voltage near 5V. It was shown that our short pitch samples exhibit faster response improved by 20% than normal cell in total response time and inter-gray response time. Gamma curve index was varied from g = 2.2 to g = 2.7. in module for tuning black level.

The other effect was improvement in ionic characteristics such as VHR, ion density, and DC hysteresis.

6. Acknowledgements

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7. References

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