Analysis of L0 State Using Inner retarder Film

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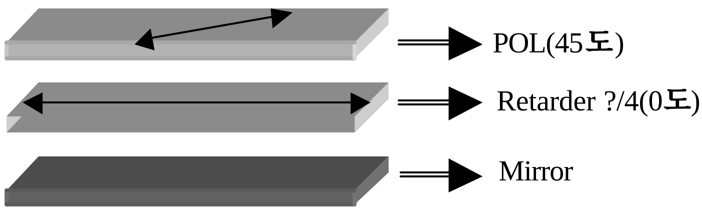
Abstract
We report experimental and simulation results of L0 state using inner retarder film compared with normal retardation film. In short wavelength range, the reflectance of inner retardation film is three times compared with that of normal retardation film. This results in blue color of L0 state, as retardation decreases or polar angle increases, the color shifts toward purple, finally yellow color, as expected in the simulation results.

1. Introduction
It is essential to maintain contrast ratio in reflective part toward CR level in transmissive part for transflective LCD with excellent performances.[1, 2] So recently, single gap transflective LC modes driven by in-plane electric field such as in-plane switching (IPS) and fringe-field switching (FFS) have been investigated by many researchers due to advantage of wide viewing angle. However, for excellent transmittance and reflectance efficiency, the process to fabricate ?/4 retardation film inside LC cell is essential. Inner retardation film should be fabricated on pixel electrodes after array processes due to instability in high temperature (>200°C) of RM material. Compared with conventional retardation film (˜80μm), it is expected that inner retarder film (<1μm) presents inferior L0 state due to no perfect arrangement by rubbing and relatively large ?n[3-5] In other words, the inferior L0 state indicates low contrast ratio.

In this project, we compared L0 state (wavelength dependent reflectance) of inner retardation film and conventional retardation film in reflective part. The reasons inferior L0 state occurs are analyzed by simulation and experimental results.

2. Results and discussions
We executed simulation after inserting wavelength-dependent birefringence data (Δn=0.155 at 550 nm) of RM material (RMS03-013 by Merck.) into LCD Master simulator. And we spincoated RM material onto rubbed PI glass to check the color of L0 state. To change the thickness or retardation of coated RM material, we diluted RMS03-013 from initial solid content=33% using solvent PGMEA and varied rpm (=spin speed) of spincoater. And after spincoating, coated RM is cured using ultraviolet light under atmosphere circumstance.



<Structure>

Figure 1. Basic optical system for L0 state using ?/4 retardation film in reflective part.

Figure 1 shows basic optical system for L0 state using ?/4 retardation film in reflective part. In case of assuming retardation film of retardation=0.1375 μm, pure black color occurs. However, in reality, because the characteristic of wavelength dispersion in conventional retardation film or inner retardation film exists, pure black color does not occur despite retardation=0.1375 μm. For perfect dark state, wide-band retardation film is required.

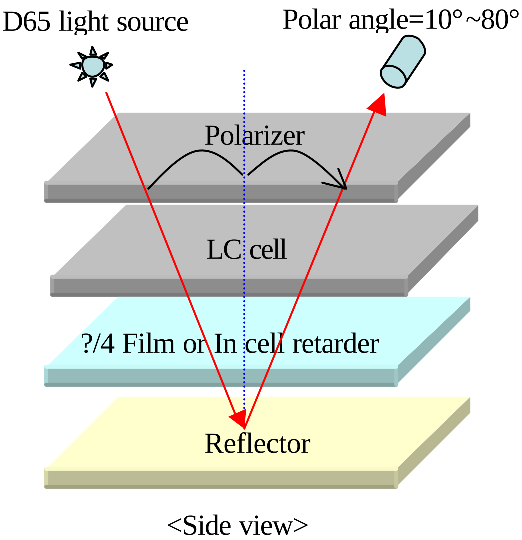
And Figure 2 shows color of L0 state observed in azimuth angle=0° regarding inner retardation values controlled by RM concentration and spin speed using spincoater. As shown in Fig. 2, in the retardation ranges beyond 0.1375 μm, blue color occurs and as retardation decreases, the color shifts toward purple, finally yellow color.

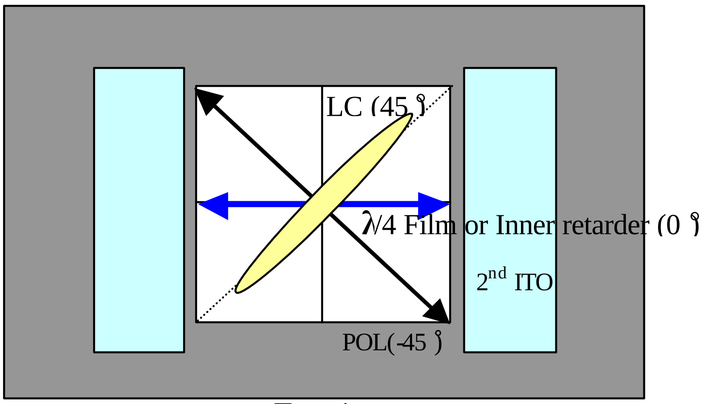
(a) 3000rpm, 28%-0.1387 µm

(b) 3500rpm, 28%-0.134 µm

(c) 3000 rpm, 26%-0.127 µm

Figure 2. Optical photographs regarding inner retardation values using optical system shown in Fig. 1.



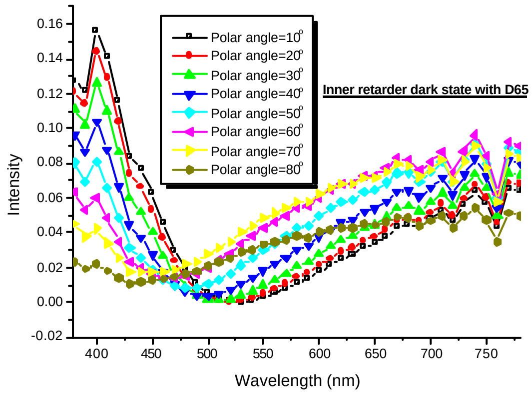


<Top view >

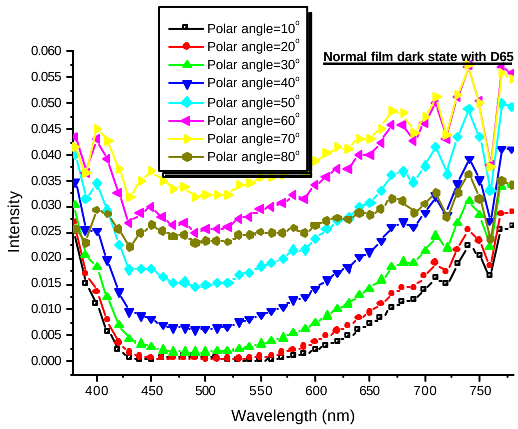
Figure 3. Schematic views of reflective part including LC cell in transflective mode : (a) side view (b) top view.

Figure 3 shows schematic views of reflective part (rubbing angle=45°) in transflective mode for simulation. Because retardation film exists on reflector with embossing structure and parallax issue exists, retardation film should be located on inside cell. In simulator, total reflection of D65 light source is assumed and the reflected light is observed at azimuth angle=0° under polar angle=10°~80°. In this system, LC director makes 45° with respect to slow axis of conventional or inner retardation film for dark state such as that in general reflective optical configuration. In this system, the dark state kept well regardless of the retardation of LC cell. If LC directors is averagely rotated by 22.5° in clockwise direction, the efficiency of reflectance is maximized.

Figure 4 shows wavelength-dependent reflectance of LC cell including D65 wavelength spectrum in case of inner retardation film and conventional retardation film, respectively. In short wavelength ranges, the reflectance of inner retardation film is three times compared with that of normal retardation film. This phenomenon is expected to be caused by much severe variation of wavelength-dependent birefringence resulting from low thickness and large ?n (~0.155). Using inner retardation film, the reflectance leakage in short wavelength is more significant compared with those in middle and long wavelength regions. Those results in blue color of L0 state and low contrast ratio compared with using conventional retardation film. As polar angle increases, the intensity of short wavelength decreases, in other words, the phenomenon of bluish color diminishes. However, the reflectance leakage of middle and long wavelength regions continuously increases until near polar angle=70°. Although using conventional retardation film, the reflectance leakage in short and long wavelength remains. As polar angle increases, the reflectance leakage of all wavelength region increases except polar angle=80°. It is manifest that the increase term of intensity of middle wavelength is more significant compared with any other wavelength region. Therefore, in high polar angle, it is expected that the chromaticity shifts toward x=0.32, y=0.33, the values in white state of real panel.



(a)

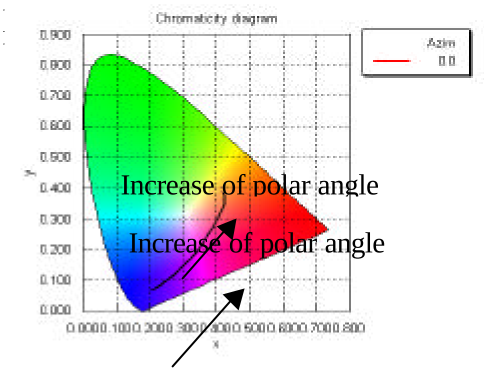


(b)

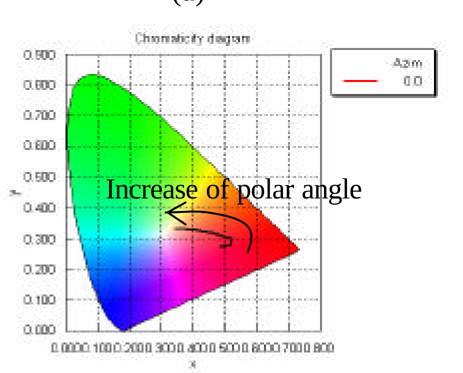
Figure 4. Wavelength-dependent reflectance of LC cell including D65 wavelength intensity : (a) inner retardation film (b) conventional retardation film.

Figure 5 shows that as polar angle increases, color shift in inner retardation film is significantly extreme compared with that in conventional retardation film. These results come from decrease of relatively large retardation due to large ?n and low thickness (~1/80 compared with conventional retardation film) of inner retardation film. The increase of polar angle in homogeneously aligned LC cell has effect on the increase of cell gap and the decrease of ?n. However, the effect of decreasing ?n term is dominant, in the end increase of polar angle means decrease of retardation value, the result of Fig. 5(a) coincides with the experimental results of Fig. 2. As the polar angle increases, the color of L0 states shift from bluish color to purple, yellow color due to decrease of reflectance leakage in short wavelength. Using conventional retardation film, as polar angle increases, the chromaticity shifts toward x=0.32, y=0.33 due to

leakage in

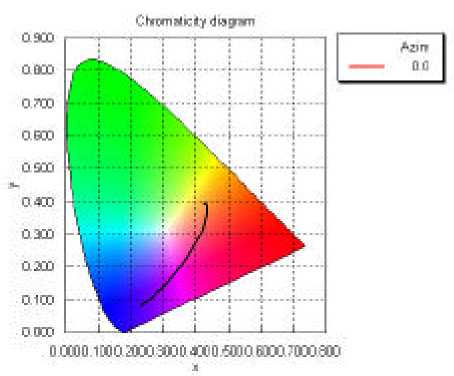


(a)

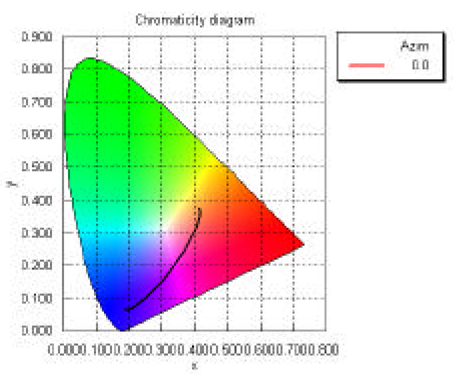


(b)

Figure 5. Comparison of chromaticity between (a) inner retardation film (thickness=0.88 µm) and (b) conventional retardation film.



(a) thickness=0.86 µm



(b) thickness=0.90 µm

Figure 6. Comparison of chromaticity regarding retardation of inner retardation film.

Figure 6 shows chromaticity results under polar angle=10°~80° regarding retardation of inner retardation film. As expected, as inner retardation value increase, in case of coating thickness=0.90 µm, chromaticity shifts toward blue color compared with thickness=0.88 and 0.86 µm.

3. Summary

We compared the simulation results after inserting RM wavelength characteristic into simulator with experimental results. The reflectance leakage in short wavelength is three times compared with conventional film. This results in bluish color and low contrast ratio. However, polar angle increases, in other words, retardation of film decreases, bluish color shift toward purple and yellow color.

4. References

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