Designing low cost liquid crystal mode for Transflective LCD

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Abstract

We designed a low cost optical structure of transflective LCD that uses only a half number of retardation films compared to general active matrix transflective LCD. The prototype embodied by this design shows reasonable reflective and transmissive performance. This design would provide us thinner, lighter and cheaper product due to its reduced retardation film structure.

1. Introduction

Many transflective LCD modules have been developed and fabricated by LCD manufacturers for mobile appliances such as mobile phone and PDA [1]. Most of the current available active matrix Transflective LCDs use multiple layers of retarder to achieve good performance in both reflective and transmissive mode. However, there are many defects due to polarizing film structure integrated with multiple retarders, especially when size of a transflective LCD goes larger. Because the probability of foreign materials inflow is increased, provoked by multiple-layered film structure and its size. To alleviate this problem we suggested a transflective LCD mode design with single retardation layer two years ago [2]. However a prototype with that design shows poor CR characteristics in transmissive mode operation. But nowadays the importance of transmissive mode properties in transflective LCD is getting higher to fully express high information contents in mobile computing area [3]. In this paper, we suggested another compromised cost saving transflective mode design which improving transmissive characteristics drastically.

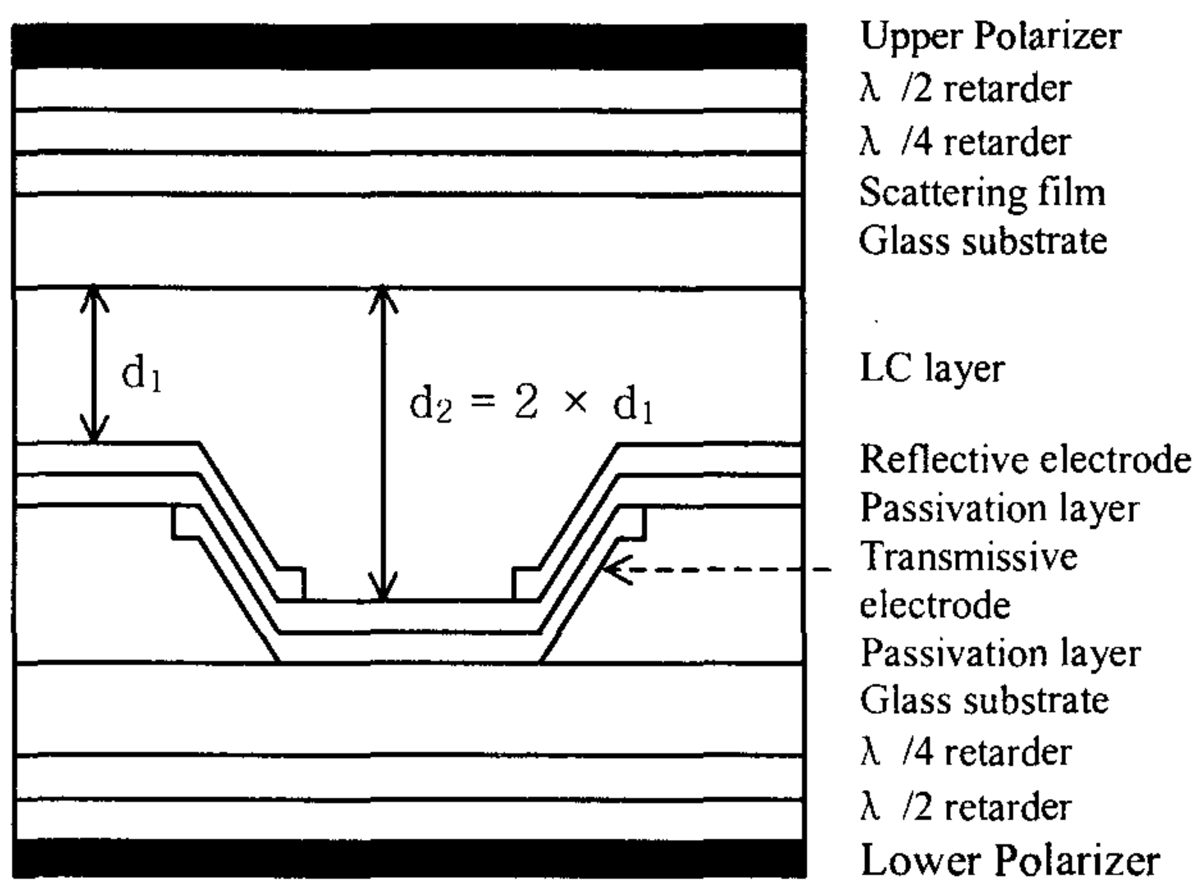
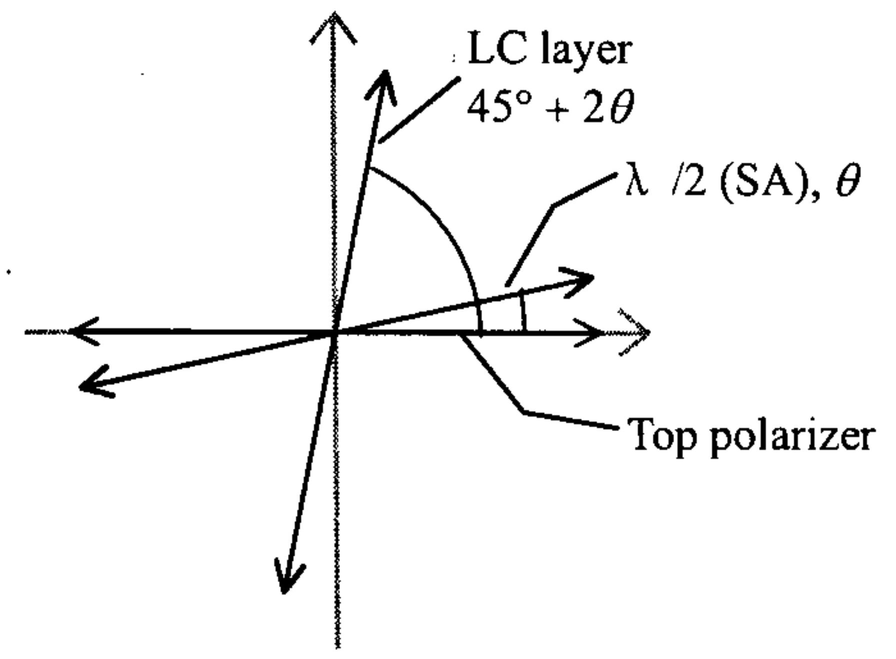


Figure 1. Vertical configuration of general transflective LCD.

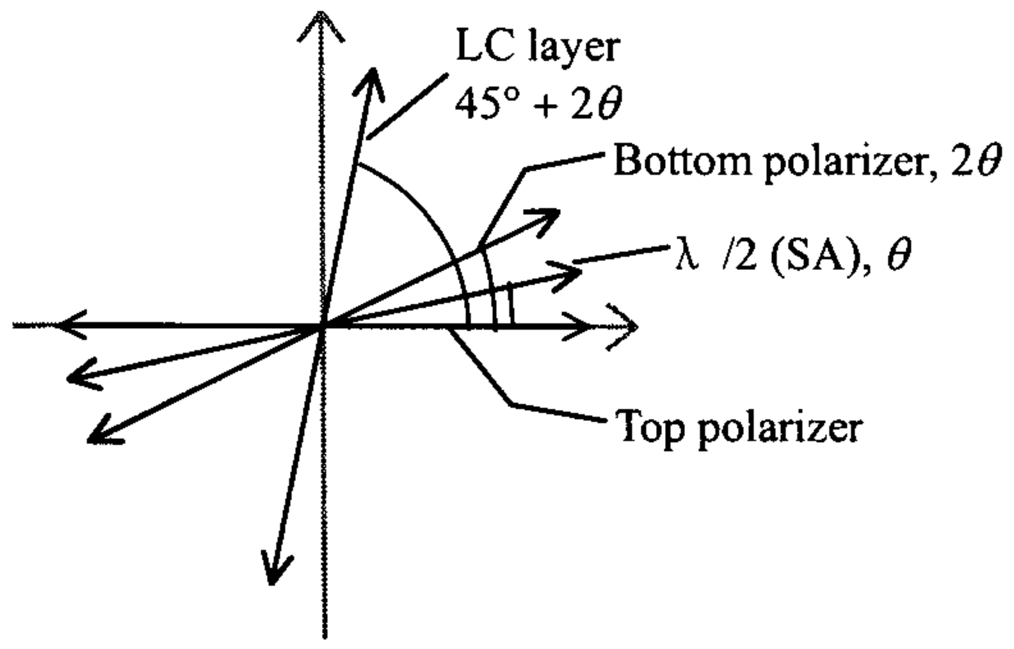
2. Results and discussion

Figure 1 shows vertical configuration of general transflective LCDs. Cell gap of transmissive region is twice larger than that of reflective to maximize light efficiency of LC layer in both reflective and transmissive region under the assumption that non-twisted LC mode is used. There are two layers of retarder on each side of glass substrate to achieve wide-band quarter wave plate configuration. And scattering film was used to form viewing angle in reflective mode but this scattering media could be replaced other scattering media such as micro mirror structure [4] or color filter with scatter layer [5].

We need two optical uniaxial media which function as $\lambda/2$ and $\lambda/4$ plate respectively and the relation between optic axis of two components was depicted in Figure 2.(a). Let us replace $\lambda/4$ plate with



(a)



(b)

Figure 2. Optical configuration of single retarder Transflective LCD mode; (a) reflective part, (b) transmissive part

non-twisted liquid crystal layer whose optical retardation is equal to that of λ/4 plate, then we could obtain normally black reflective display [2]. We could obtain transmissive display as well by configuring as depicted in Figure 2.(b). In case of transmissive mode, however, the contrast ratio was very low compared to that of conventional normally white mode transflective LCD. In addition to this, the dark state of that mode looks like dark blue state due to its unevenness of dark state spectrum shown as Figure 3. To improve evenness of dark state spectrum of transmissive mode, we added another λ/2 retarder on the lower substrate side.

Because configuration change is only occurred in the transmissive mode, there is no change in the reflective mode characteristics. Through multiple calculations, the optimal configuration shown as figure 4 was derived.

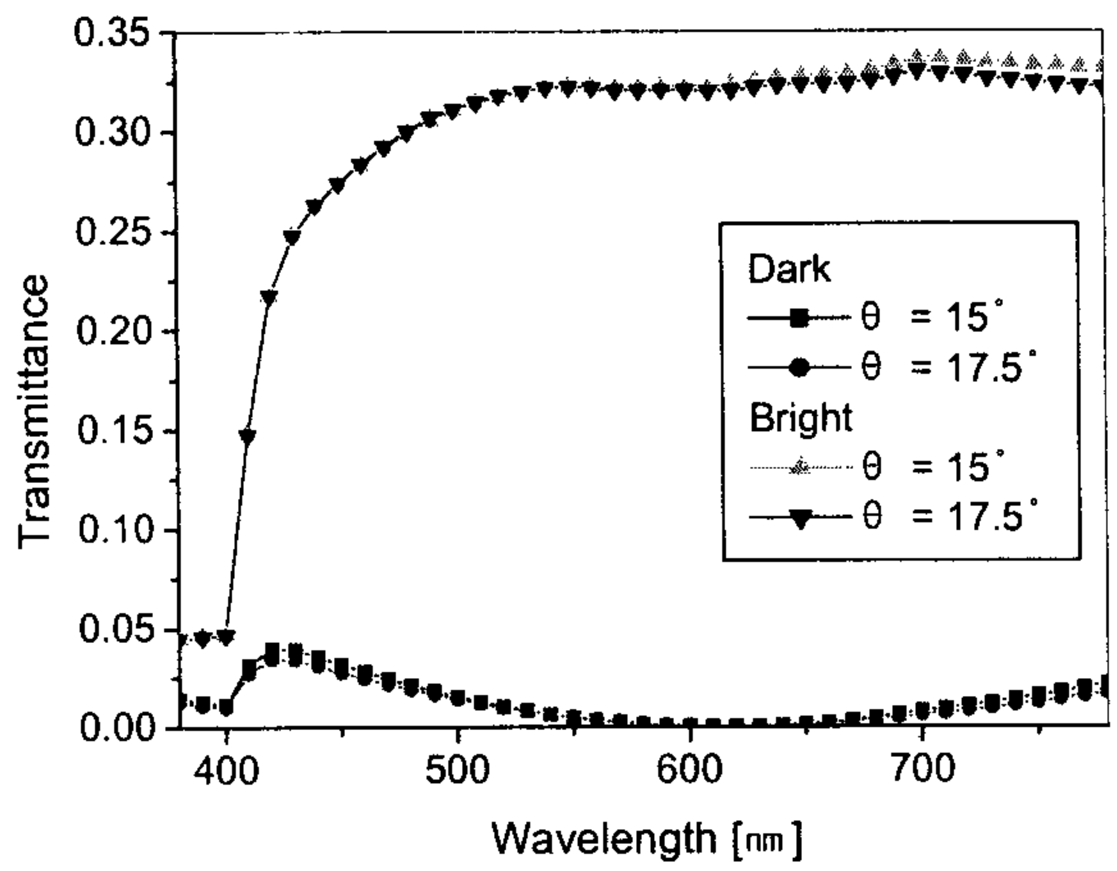


Figure 3. Wavelength characteristics of Figure 2(b) configuration at θ = 15, 17.5°

As you can see two λ/2 retarder and LC layer whose optical retardation is λ/2 are arranged with an angle of θ + 45° . So this configuration could be thought as an unfolded form of reflective part in which LC layer has λ/4 optical retardation. θ is the only parameter we should determine in the configuration shown in figure 4. We calculated the characteristics of both reflective and transmissive mode with θ as a parameter by using an optical simulator, before we applied this configuration to the test fabrication.

Figure 5 shows the wavelength characteristics with θ as a parameter. You can see that the dark state spectrum of transmissive mode was drastically

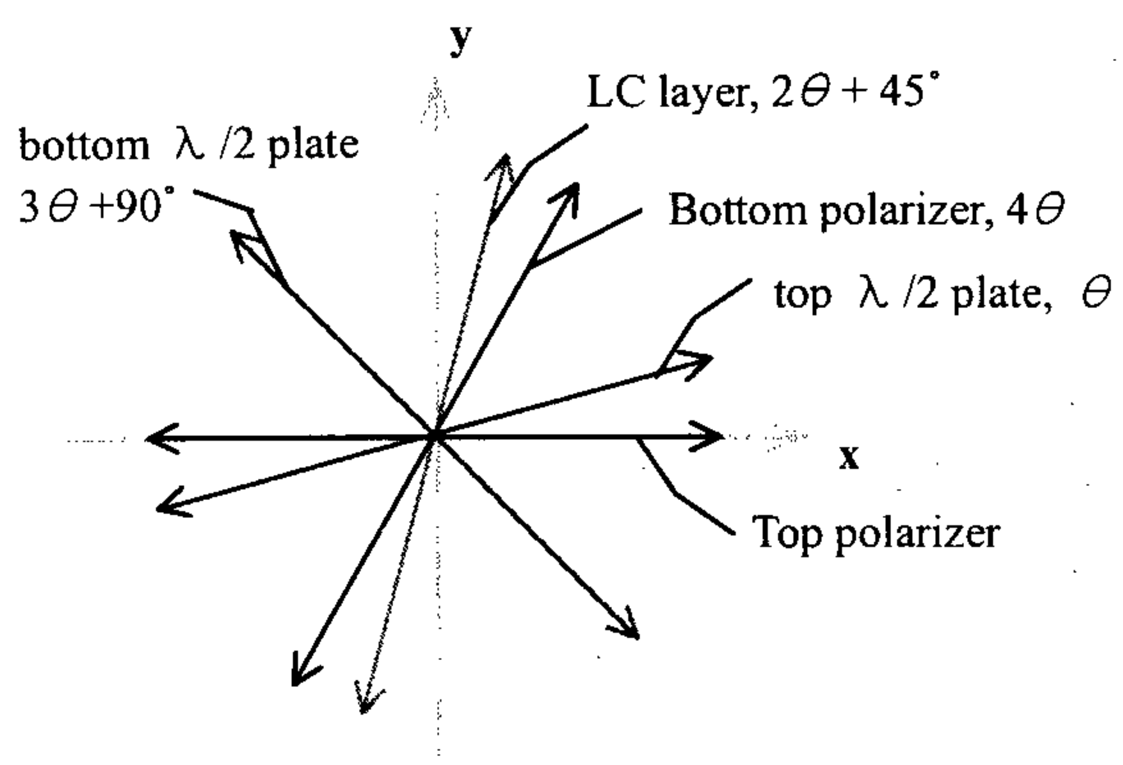
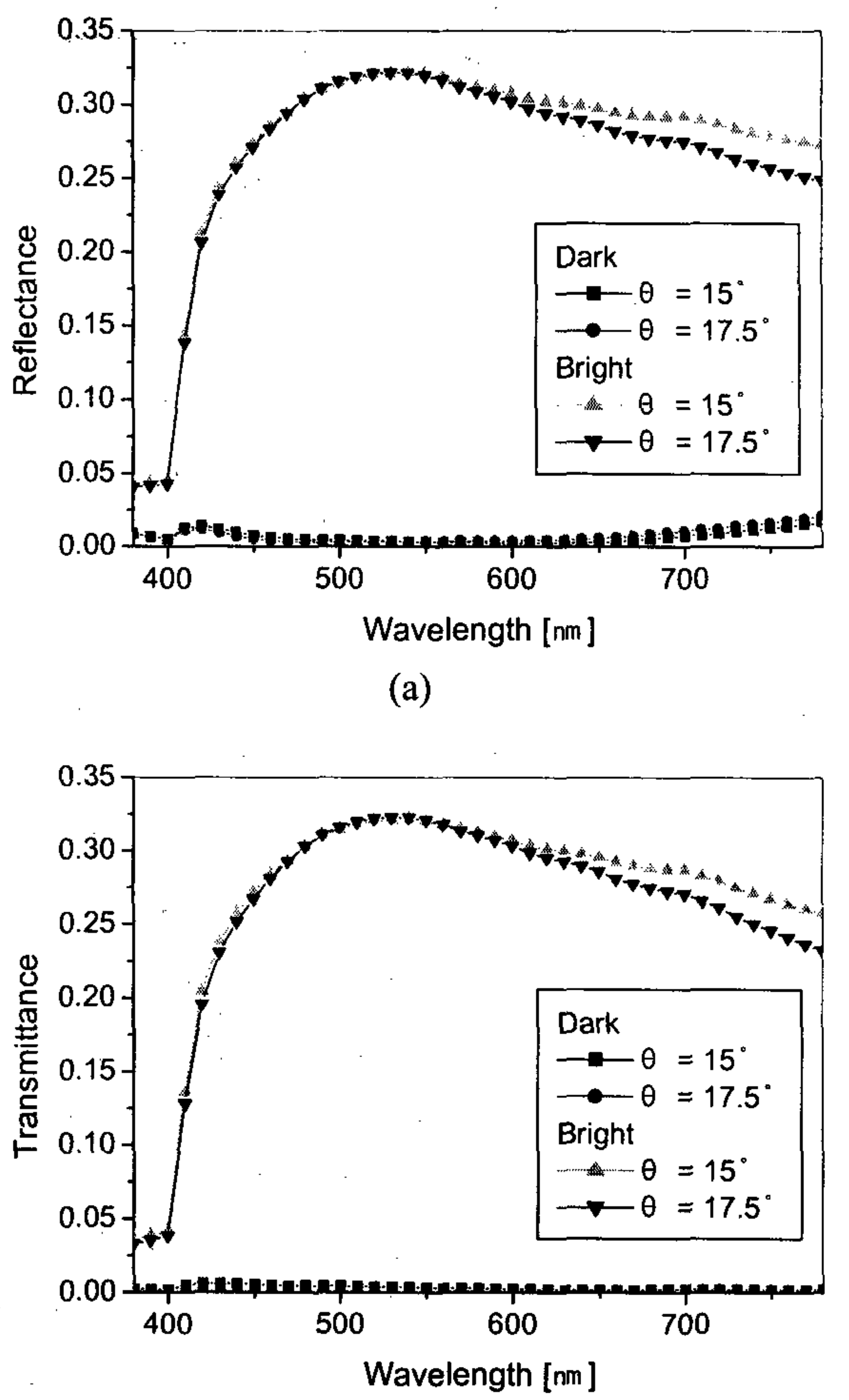


Figure 4. Optical configuration of dual retarder Transflective LCD mode



(b)

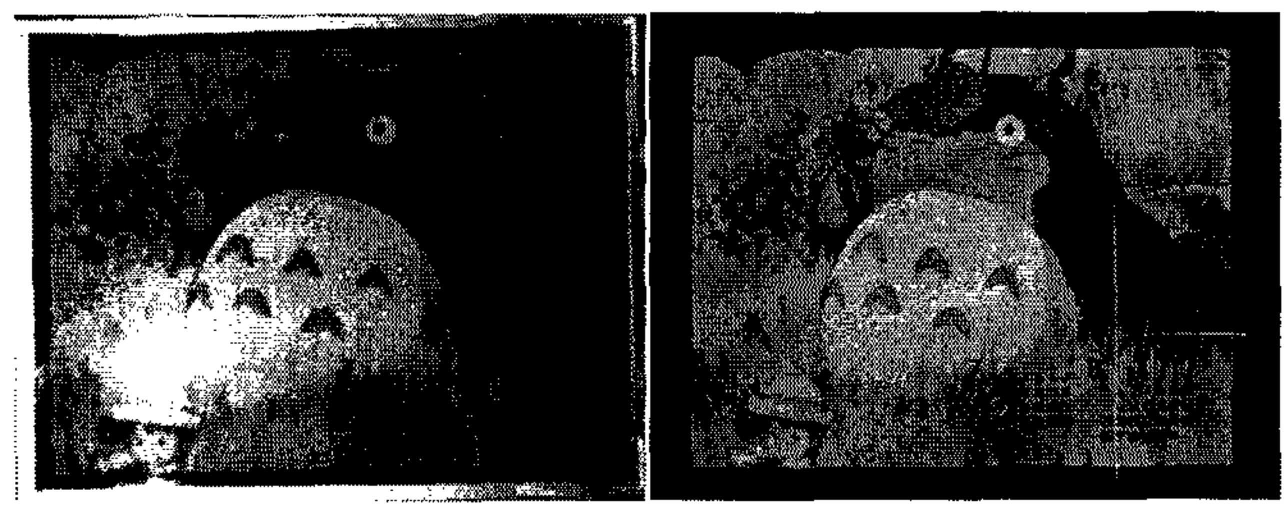
Figure 5. Wavelength characteristics of dual retarder Transflective LCD; (a) reflective mode, (b) transmissive mode, θ = 15, 17.5°

improved compared to that of Figure 3. Because the dark state spectrum is flat over visible wavelength range, it will be looked as dark black. Both reflective and transmissive characteristics are getting worse as θ increases especially in flatness of white spectrum.

Fortunately, the wavelength characteristics of LC and retarder material we used for test fabrication was very similar and showed good performance at θ = 17.5° than 15° . If the wavelength characteristics difference is larger, the performance will be worse and θ might be changed to compensate this difference.

	Normally white	Single retarder	Dual retarder
# of Retarder	4	1	2
Luminance (Reflectance)	130 (23%)	135 (20%)	135 (20%)
Reflective CR	20	10	10
Transmissive CR	60 ~ 70	20	50 ~ 60
Cell gap tolerance	O	×	△

Table 1. Measured data of three different type Transflective LCD



(a) (b)

Figure 6. Photograph image of dual retarder Transflective Prototype; (a) reflective mode, (b) transmissive mode

Table 1 shows measured data of test fabrication comes with other sample. They show that improved transmissive CR characteristics in dual retarder configuration. Figure 6 shows photograph image of 10.4" dual retarder transflective LCM prototype in reflective and transmissive mode.

3. Conclusion

We designed normally black transflective LCD mode by applying wide-band quarter wave plate configuration and this design provided reasonable characteristics. By this design, we could simplify the structure of polarizing film integrated with retardation layer. This makes integrated polarizing film be thinner, lighter and cheaper than conventional reflective polarizer. Therefore transflective LCD module with this design will also be thinner, lighter and cheaper. When it comes to module process, this will lead to LCD module yield improvement and potentially cost reduction by reducing rework ratio. We think this design will be more suitable to smaller size LCD because of its inherent normally black characteristics, which shows relatively low cell gap tolerance. Adding to this property, our design has another advantage; the efficiency of a back light system is 12% higher than that of other designs because light towards reflective region could be recycled. However, actual luminance was not much improved due to a little low LC mode efficiency.

4. Acknowledgements

We are very appreciative of all people concerned with offering polarizer samples we used in this experiments, especially those who work for Kyoshin and Nitto Denko Co.

5. References

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