A Study of viewing angle characteristics of the film compensated TN mode

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Abstract

Because of its weak points that narrow viewing angle and grayscale inversion, 'bare' twisted nematic (TN) LCD has some limits to use as a display device, though its great strong points that low cost, high yield, simple design, high transmittance and normally white. The 'WideView(WV)' film which introduced by Fuji co., has been good solution to extend the viewing angles of TN mode, therefore that film have been used generally for TN panels needed wide viewing angle. This paper introduce the research to find the parameters of the Wide view film and a TN panel which affect viewing angle characteristics and how to adjust those parameters.

1. Introduction

Normally white mode TN panel shows wide viewing angle at white state. Because TN liquid crystal directors at white state lay parallel to alignment layer and splay widely as helical formation. The viewing angle problem occurs when a TN pixel drives darker gray. To represent darker gray, the directors in the pixel come together to one direction from splayed formation, and tilt-up one side of each directors. That increases optical asymmetry, and 'optical asymmetry' drives narrow transmittance uniformity and makes 'viewing angle problems'. The optical asymmetry reaches the peak at black, the darkest state. Generally, the viewing angle character is defined by contrast ratio (CR = white⁄black), therefore the black state effects definitely.

Fuji company's "WideView(WV)" film compensate this asymmetry transmittance of TN black state and expand viewing angles. WV film has discotic liqid crystal layer or optical polymer layer which similar to discotic liquid crystal layer optically, and the discotic LC is arranged just like TN liquid crystal arrangement at black state. The discotic liquid crystal has opposite optical character to rod like liquid crystal in the TN panel, so that discotic liquid crystal compensates the birefringence made by rod like liquid crystal in the panel.

WV film expands the upper to lower direction viewing angle to 160° and the left to right direction viewing angle to 170° when applied well designed TN panel. The viewing angle of 'bare' TN panel is 45° at the upper to lower direction and 90° at the left to right direction viewing angle.

This study concerned about optical characters of WV film and TN panels and how to achieve the target viewing angles.

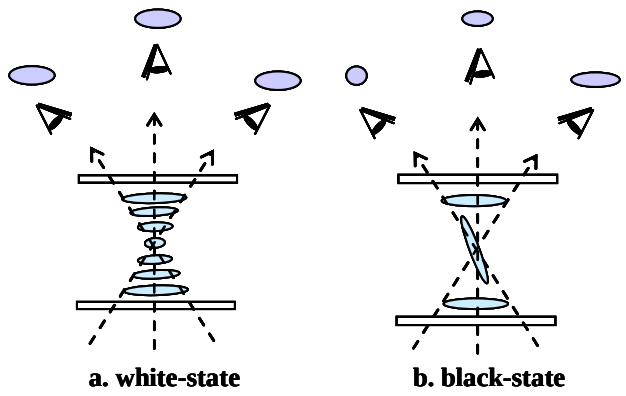


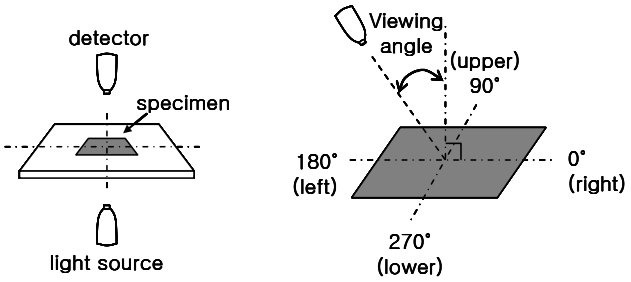
Fig. 1 Viewing angle retardation of TN panel at a. white-state and b. black-state

2. Experimental

At first, the principle of TN compensation by WV film had to be proved. According to the principle, the arrangement of discotic liquid crystal in WV film would be similar to that of black state TN panel. Therefore WV film would show similar retardation characters of black state TN panel. The retardation belonged to viewing angle of TN panel which

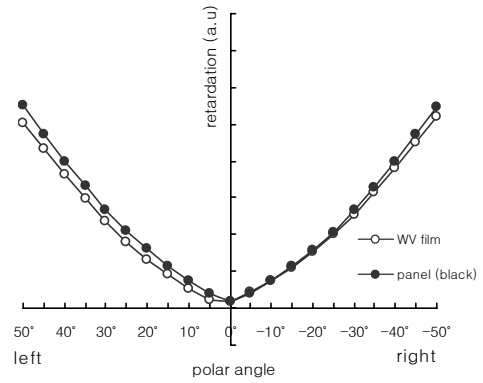
removed WV film was measured like following method.

The measuring instrument was 'Axoscan' made by Axometrics, Inc. Measure system and definition of the viewing angle showed at figure 2.

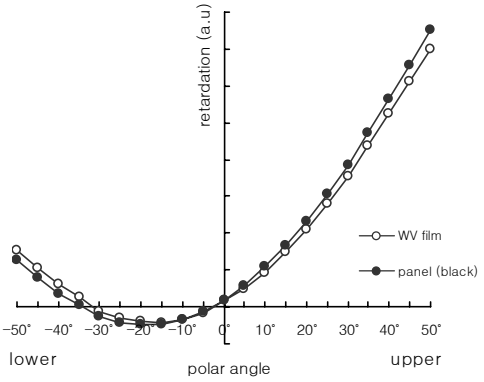


a. Measure system **b. Viewing angle**

Fig. 2 Measure system and viewing angle



a. Left to right retardation



b. Lower to upper retardation

Fig. 3 The viewing angle retardation of TN panel at black state and WV film

To measure the black state retardation, panel was added black state voltage during measurement. To measure the retardation of WV film, the film was attached at glass just like the way of attaching at panels. And, WV film was measured by the same way as panel.

As a result, the retardation belongs to viewing angle of WV film and the black state of TN panel was very similar each other. Therefore it could be concluded the principle of TN panel compensation by WV film is true. And also, it could be assumed that the retardation of TN panel is positive, and that of WV film is negative.

By the principle of panel compensation, the root cause of decreasing contrast ratio(CR) at viewing angle was defined as 'the residual retardation' which was unintended retardation between two polarizers. At the WV film applied TN panel, the residual retardation was defined as the gap between the panel and WV film. We thought this 'residual retardation' could be a parameter that determining the viewing angle of the WV film applied TN panels. The factor could be represented briefly like that

$$ret_{residual} = \left| ret_{panel} - ret_{WideView} \right|$$

To correlate between the residual retardation and contrast ratio of viewing angles , the 'Residual retardation' and contrast ratio were measured at azimuth angle 0°, 90°, 180°, 270° with polar angle 50°. These azimuth angle 0°, 90°, 180°, 270° represent right side, upper side, left side, lower side respectively.

From the result, the residual retardation and viewing angle contrast ratio showed strong correlation at left side, right side, and upper side viewing angle.

It means that the residual retardation could be useful parameter that determining viewing angle. But at the lower side, the correlation was not very strong. It means another factor has to be searched for determining lower viewing angle.

3. Results and discussion

Next, we approved that influencing power between panel retardation and WV film retardation to viewing angle contrast ratio. The influencing power was estimated from the coefficients of the panel and WV film which are driven by regression analysis.

As shown in table 1, panel and WV film influenced to the viewing angles as the ratio of about 1:1 at the left and right and upper side. It was a well matched

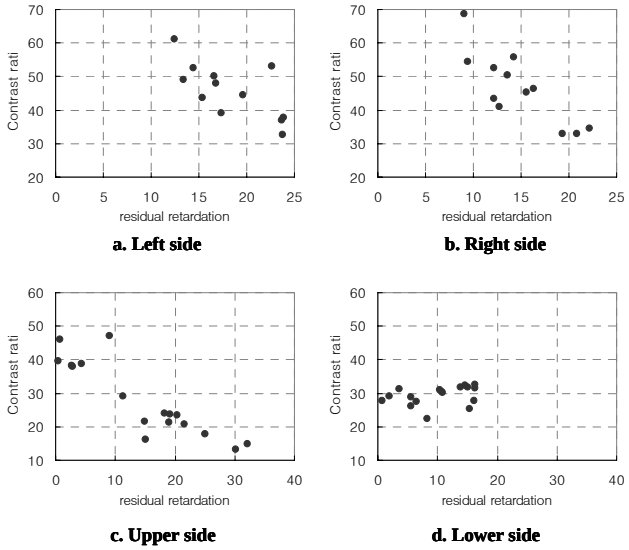


Fig. 4 The relationship between residual retardation and viewing angle contrast ratio

result with the 'hypothesis of the residual retardation'. Therefore the hypothesis was proved once again.

We have to mention about left side result. It was failed to satisfy statistic fitness. Therefore it was written with parenthesis mark. Though the result was meaningless statistically, it could be assumed as reasonable based on right side result.

As the third, the panel design parameters were studied. A panel designer would be requested to adjust panel parameters rather than to change film design to obtain the viewing angle contrast ratio. The effective panel design factors for determining viewing angles are total retardation of panel (dΔn, cell gap× birefringence of liquid crystal) and driving voltage especially at black state. And the twist angle and the tilt angle of the liquid crystal are also considered as minor factors. More over, total retardation of the panel has to be adjusted to the total retardation of the films. From the study of panel parameter, total retardation

Table. 1 The power of influence to the viewing angle (relative value to panel)

	Panel	WV
Upper side	1	1.04
Left side	1	(1.03)
Right side	1	1.18

was determining of the left and right side viewing angle. But, for viewing angle fine adjusting, the total retardation of panel is not recommendable parameter because the total retardation is related to other important characters like transmittance, white color, response time. It is true that there are some difficulties to change for only viewing angles. And we have to note that total retardation of panel concerns white state characters, but viewing angle is determined by black state.

The parameter that determines the black state is 'driving voltage'. Though it wasn't supported static analysis in this experiments, driving voltage kept higher relationship than other panel parameters with viewing angle contrast ratio. Driving voltage was strong correlation with upper side especially. With the left and right side, correlation of driving voltage was relatively small, and it was as same as the total retardation. Therefore, voltage is recommendable parameter to adjust upper viewing angle contrast ratio. If driving voltage for black state is increased, the retardations of left and right side and upper side are decreased, and that of lower side is turned to increase after decrease. It is shown at figure 5. Generally, the retardation of panel at black state is larger than that of WV film, therefore increasing the driving voltage of

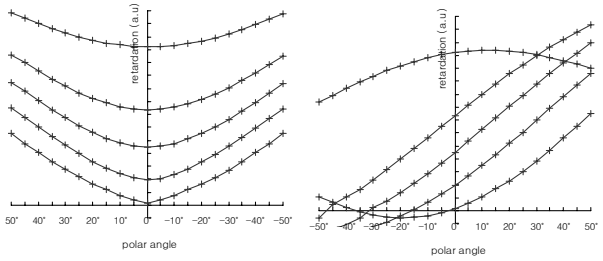


Fig. 5 The change of retardation belong to driving voltage (bare TN panel)

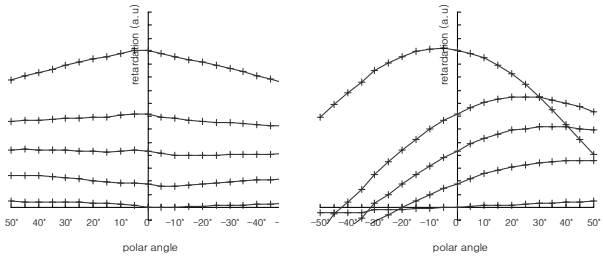


Fig. 6 The change of retardation belong to driving voltage (WV applied TN panel)

black state will be good approach to obtain the viewing angle contrast ratio.

For the last, it could be explained the grayscale inversion reducing effect of WV film by the same way how WV film compensate TN panel. The gray scale inversion occurs upper side and lower side, and that of lower side is more sever. Lower side grayscale inversion occurs by the black transmittance increase and out run near brighter gray level. WV film lower the black state retardation and make it occur darker position.

4. Summary

In this paper, we studied the principle of compensating TN panel by WV film and showed new parameter, the residual retardation, determining the viewing angle character of the panels, and approved the usefulness of that parameter. And we also searched most effective design parameter to achieve viewing angle contrast ratio and explain the grayscale inversion reducing effect.

The characters of WV film itself still isn't known very well, and we have to know that to improve the performances and qualities include the lower side viewing angle of the TN panels.

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