Improved off-axis gamma curve in vertically aligned liquid crystal cell with single domain

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Abstract

We propose an improved gamma curve at horizontal line in single-domain vertical alignment (VA) liquid crystal (LC) cell. The proposed configuration consists of a negative C-plate, a λ/2 biaxial-plate and two A-plates. Optical optimization is performed by using the Stokes vector and the Polarization difference method. As a result, we confirmed that the proposed optical configuration showed better off-axis gamma curve property without sacrificing other optical properties compared with the conventional configuration.

1. Introduction

Recently, Liquid Crystal Displays (LCDs) take the important position in the display industry. The reason is that it has excellent properties such as low power consumption, small thickness, and light weight. As the case stands, the LCDs market has been expanded in the field of TV, Monitor, and mobile phone market. In order to achieve remarkable optical properties, many display modes such as VA mode [1], in-plane switching (IPS) mode [2], and fringe field switching (FFS) mode [3] have been developed in the display market. Particularly, the VA LCDs exhibit an excellent contrast ratio in the on-axis direction on account of zero retardation in that direction [4]. Thus, it has become important approach for LCD industries and is applied in many advanced devices. Although the conventional VA LC cell was demonstrated for wide viewing angle and high contrast ratio by using the optical plates [5], it has a serious gamma distortion at the off-axis direction. Thus, we proposed novel optical compensation method and structure to overcome this weak point.

The key point of the gamma curve is that it depends on the voltage-transmittance (V-T) curve and the observed direction [6]. The gamma curve in the off-axis direction is different from the on-axis direction. Therefore, it can make the gamma distortion lower if the decreased transmittance difference between on-axis and off-axis directions.

In this paper, we proposed the optical configuration that has a negative *C*-plate, a *λ/2* biaxial-plate and two *A*-plates. We confirmed that proposed configuration can show the improved gamma curve compared with the conventional VA LC cell.

2. Results and discussion

The deviated polarization occurring in the off-axis direction can be resolved by applying optical compensation plates to the VA LC layer. Fig.1 shows the conventional VA LC cell which has a negative *C*-plate and a *λ/2* biaxial-plate [5].

Although the conventional configuration shows the excellent dark state and wide viewing angle at the off-axis, the gamma curve at middle gray levels is severely distorted at the off-axis as shown in Fig. 2 (b). In order to reduce the gamma distortion at the off-axis direction, we have suggested the novel optical configuration which can control the middle gray levels transmittance. First of all, we analyzed the particular V-T curve point among the middle gray levels, approximately 2.5V point. Investigation through Stokes vector and polarization difference method [7], we can know the polarization state after passing through the conventional VA LC cell in the on-axis direction.

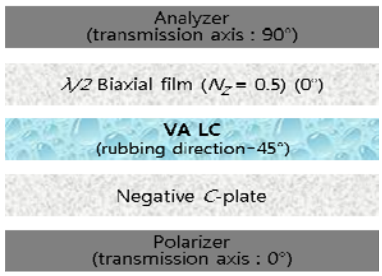
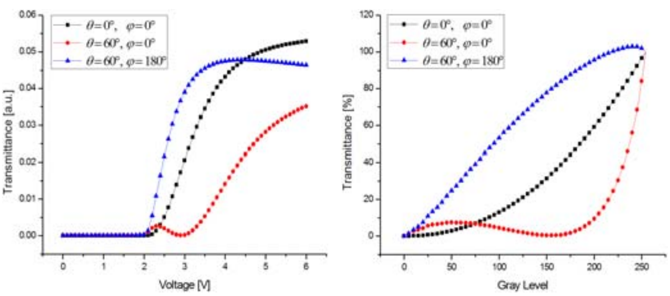


Fig. 1. Optical configuration of the conventional VA LC cell.



(a) (b)

Fig. 2. The V-T curve and Gamma curve properties of the conventional VA LC cell: (a) V-T curve (b) gamma curve.

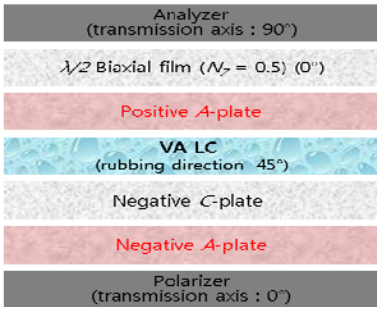


Fig. 3. Proposed optical configuration of the VA LC cell .

The Stokes vector after passing through the cell in the on-axis is S_K=(1, 0.8252, 0, 0.5648)^T, and the analyzer absorption position is S_H=(1, 1, 0, 0)^T. Therefore, we can know that the polarization difference between $S_{(H)}$ and $S_{(K)}$ is $\Delta P_{(H\text{-}K)}$=0.591. However, in the off-axis direction, (θ=60°, φ=0°) and (θ=60°, φ=180°) are $\Delta P_{(H\text{-}K\_0°)}$=0.909, $\Delta P_{(H\text{-}K\_180°)}$=1.203, respectively. In those polarizations difference, it causes the transmittance distortion in the off-axis. Therefore we focus on designing the novel optical configuration and adjusting the polarization difference of the off-axis to the on-axis level.

For the optimal gamma curve, it can be achieved by adding two *A*-plates to the conventional VA LC cell. Fig. 3 shows the proposed optical configuration. In that configuration, the two *A*-plates play an essential role to adjust transmittance in the middle gray levels at the off-axis direction. To optimize the transmittance in the middle gray levels, we have performed the analysis of polarization difference according to the *A*-plates conditions treated by optic axis and retardation. Fig. 4 shows the optimization value satisfied with our target of polarization difference value. After calculating the result from variable *A*-plates conditions, we can find the highly optimized *A*-plates conditions that φ =47° and Δnd=±320nm (550nm).

From the results, the polarization difference is $\Delta P_{(H\text{-}K\_0°)}$ =0.591 (θ=60°, φ=0°), $\Delta P_{(H\text{-}K\_180°)}$ =0.584 (θ=60°, φ=180°), respectively. Fig. 5 (a) shows the V-T curve through the on-axis (θ=0°) and off-axis (θ=60°, φ=0° and θ=60°, φ=180°) respectively. The results indicate that the slope of V-T curve of the off-axis tends to do what on-axis.

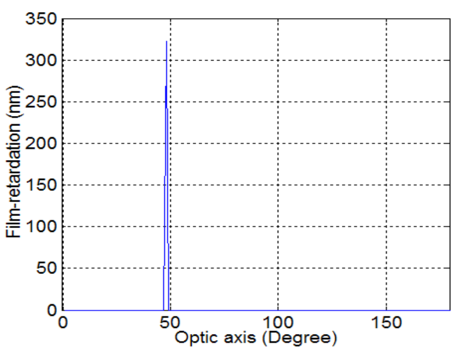
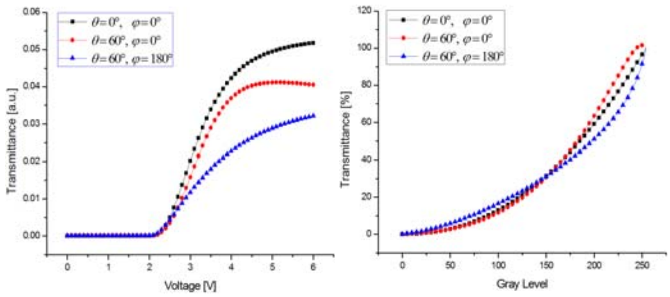


Fig. 4. The optimization graph according to plate's properties variation.

As a results, Fig. 5 (b) shows that for off-axis direction the gamma distortion greatly decreased, and gamma curve is nearly closer to that on-axis with gamma correction factor γ=2.2. We calculated its optical characteristics by using the commercial LC software *Techwiz* LCD provided by the SANAYI System Co. in Korea.



(a) (b)

Fig. 5. The V-T curve and Gamma curve properties of the proposed VA LC cell: (a) V-T curve (b) gamma curve.

3. Summary

In conclusion, we have proposed a novel method to diminish the gamma distortion by using polarization method. In order to adjusting the middle gray level transmittance, we used two *A*-plates which correct gamma distortion in the off-axis without sacrificing other optical properties. Our result makes possible for competitive benefit at mobile display application which is greatly important part of horizontal line image quality.

Acknowledgment

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