Pretilt Angle Effects on Electro-Optic Characteristics of the Fringe-Field Switching (FFS) Mode

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Abstract

The fringe-field switching (FFS) display is known to exhibit wide-viewing-angle and high transmittance. We have simulated pretilt effects on electro-optic characteristic of the device when a liquid crystal with positive and negative dielectric anisotropy is used. The results show that asymmetry in contour of luminance and light leakage in the dark state are increased but voltage-dependent transmittance curves remain about the same, as the pretilt angle increases to 10°.

Introduction

The liquid crystal display (LCD) associated with in-plane rotation of nematic liquid crystal like conventional in-plane switching (IPS) mode[1] is known to exhibit wide-viewing-angle. However, the device shows low transmittance due to no rotation of the LC director above electrodes. Recently, new display device, fringe-field switching (FFS) overcomes such problem.[2-4] In FFS device, fringe field, instead of horizontal field like the conventional IPS mode controls the LC molecules. As the result, the electro-optic behaviors depending on pretilt angle, dielectric anisotropy of liquid crystal, and rubbing direction are quite different from those of the IPS mode. In the IPS mode, the viewing angle characteristics are deteriorated as the pretilt angle increases but voltage-dependent transmittance curve depending on the pretilt angle has not been studied.[5] The analysis of light efficiency of the FFS device depending on the structure of electrodes and the type of LCs has been reported previously.[6] In this paper, we simulated the FFS device to see how the pretilt angle (Θ_p) affects the viewing angle and V-T curves, and compare the differences between the IPS and the FFS modes.

Simulational Results and Discussion

For a simulation based on 2x2 Jones matrix, the retardation of the LC layer was 0.3 μm. For both negative (Nn) and positive (Np) nematic liquid crystals, the same elastic constants and viscosity are assumed, but the dielectric anisotropies of them are −4 and +8, respectively.

Figure 1 shows iso-luminance contour for fully bright, grey and dark states as varying the pretilt angle using Nn and Np LCs. For Nn cell, a rubbing direction is 12°, but 78° for Np one. In the FFS device, the transmittance is given by

$$T = T_o \sin^2(2\chi)\sin^2(\delta/2)$$

where χ is an angle between the transmission axes of polarizers and optic axis of the LC director, and δ, phase retardation of the cell. In the off state of a cell with Nn and $\Theta_p = 0$, the light leakage occurs mainly in the sectional planes passing from 57° to 237° and from 147° and 327°, where ordinary and extra-ordinary light incidents at off normal directions. In the grey level, the shape of iso-luminance contour becomes elliptic due to anisotropy of phase retardation when the homogeneously aligned LC director rotates in direction. As the pretilt angle increases to 10°, the iso-luminance contour of grey level becomes distorted though it is less elliptic than that with $\Theta_p = 0$ for fully bright state. In addition the area of light leakage in the dark state is changed, that is, it is reduced in overall but widened in both sides of rubbing directions. According to previous report of the IPS cell[5], the iso-contrast contour for a cell with $\Theta_p = 0$ is not different from that of cell with low pretilt angle and non-reversal regions of grey scales is same though the pretilt angle increases to 20°, implying that the image quality is about the same. However, in the FFS device, which is driven by fringe-field instead of in-plane field, the data show that image quality in grey scales is deteriorated. Comparing the results with those of the cell with Np, the distortion of iso-luminance in grey and bright levels become worse. In the IPS cell, the difference is minor, but in the FFS device when the Np LC is used, the degree of tilt-up of the LC director along fringe field is strong such that the asymmetry in iso-luminance is increased. Therefore, in order for the FFS device to show high image quality, the low pretilt angle is favored.

We have also checked voltage-dependent transmittance (V-T) curves as a function of pretilt angles as shown in Figure 2. As the pretilt angle increases from 0° to 10°, the V-T curves slightly shift to the right direction irrespective of type of LCs. This means that the dielectric torque between homogeneously aligned LCs and fringe field is weakened as the pretilt angle increases, causing slightly increased threshold voltage. In addition, the voltage at which transmittance becomes maximum is about the same. Further increase of pretilt angle up to 20°, not only higher threshold voltages but also lower transmittance is revealed. Especially, the transmittance is much lowered for a cell with Np. This indicates that the LC director just tilts up along the fringe field line, instead of rotating. In the IPS device, there is no transmittance difference between two types of LCs though the pretilt angle changes because in-plane field drives the LC director. Therefore, in the FFS device, low pretilt angle is favored for low driving voltage and high transmittance.

Conclusion

We have simulated the FFS device to understand the viewing-angle and voltage-dependent characteristics as a function of pretilt angle for both positive and negative LCs. The results show that the low pretilt angle is favored in the FFS device for wide-viewing-angle and high transmittance. However the driving voltage remains about the same though the pretilt angle increases up to 20°.

References

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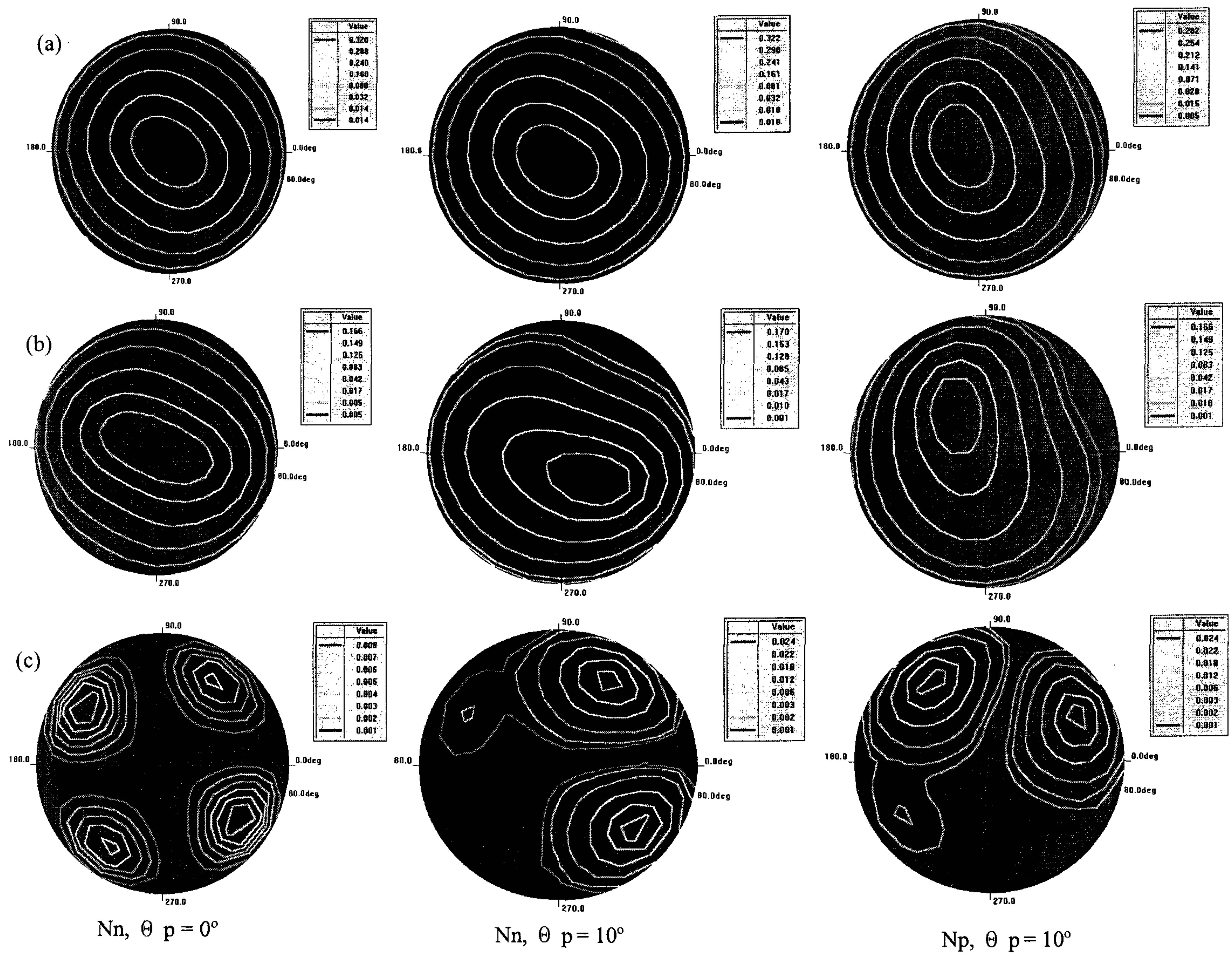

Fig. 1 Iso-luminance contours for (a) bright, (b) grey, (c) dark states as a function of pretilt angle and LC type.

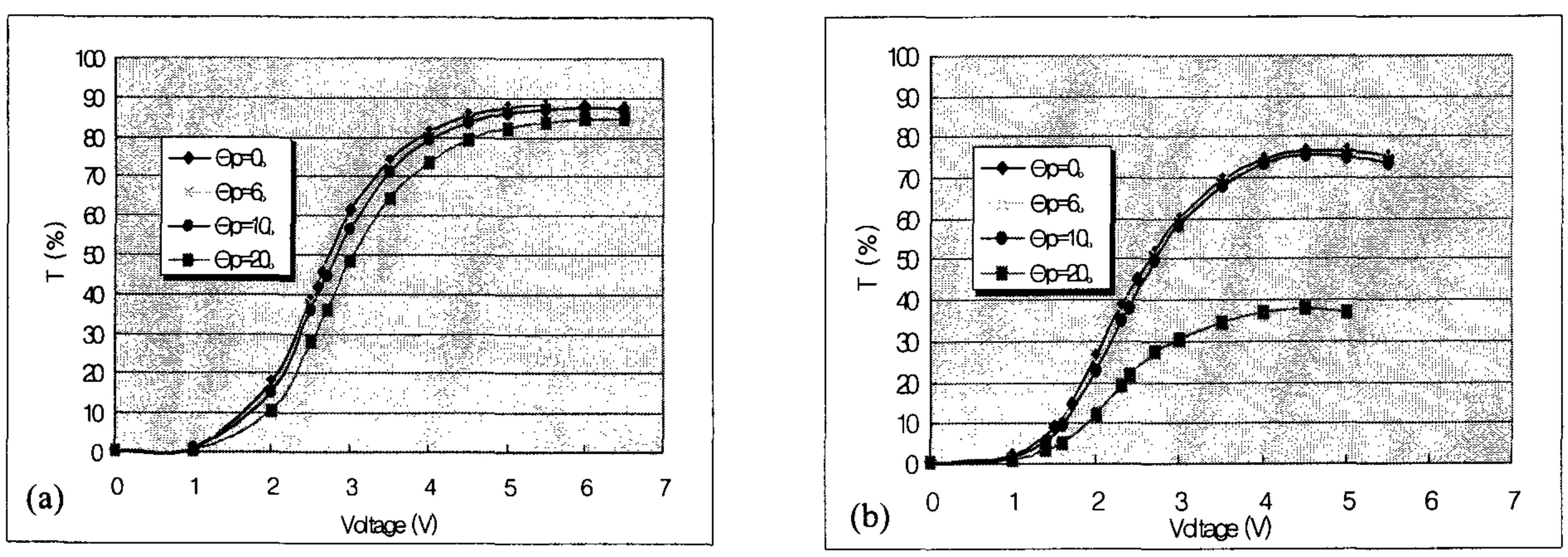

Fig. 2 Voltage-dependent transmittance curves as a function of pretilt angle for (a) Nn and (b) Np.