Inverse Twist Nematic Mode without Chiral Dopant using Stacked Alignment Layer

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ABSTRACT

We propose an inverse twisted nematic mode without chiral dopant. Using a doubly stacked alignment layer, the enhancement of azimuthal anchoring strength is obtained on the vertical alignment layer and gives rise to a stably twisted configuration in the presence of an applied voltage.

1. INTRODUCTION

Liquid crystal displays (LCDs) have been extensively used for a wide range of display applications because of their excellent image performances. Various LC modes such as twisted nematic (TN), vertical alignment (VA), in-plane switching modes were introduced [1-3]. The TN mode is widely adopted in commercial LCD devices due to its high transmittance and aperture ratio, and the simple fabrication with low cost. However, the TN mode has intrinsically poor black level because the LC molecules near a surface are not fully arranged parallel to the field direction due to hard anchoring energy on the surface. In order to overcome this problem, Patel, *et al.* reported an inverse twisted nematic (ITN) mode [4]. In the ITN mode, LC molecules with negative dielectric anisotropy are initially aligned in vertical direction promoted by a conventional vertical layer but twisted by a chiral dopant in the presence of an applied voltage [5]. The chiral dopant in the ITN mode is mandatory for generating stable TN structure in the presence of the applied voltage because the azimuthal anchoring strength on a rubbed VA layer is not enough to overcome twisted distortion energy in bulk [5].

Recently, Kim, *et al.*, reported a doubly stacked alignment layer of the planar and vertical alignments for controlling a pretilt angle [6]. In the stacked alignment layer, the planar alignment layer under the vertical alignment layer provides the enhancement of the azimuthal anchoring strength even in the VA mode. Here, we propose an ITN LC mode without a chiral dopant using the doubly stacked alignment layer. The strong azimuthal anchoring energy of the stacked alignment layer gives rise to the stably twisted configuration without the chiral dopant and the fast response time.

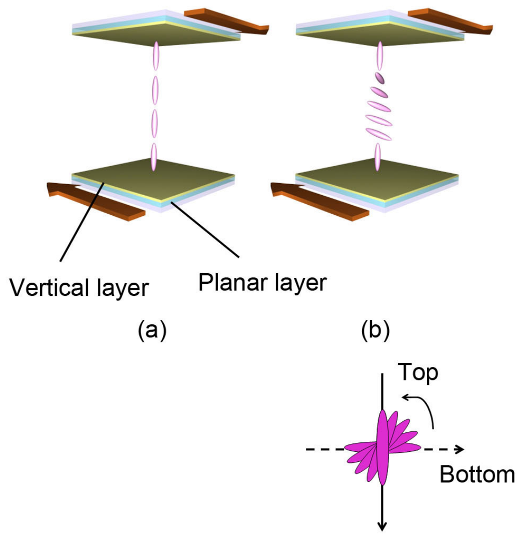

Fig. 1 The schematic diagrams of the ITN sample fabricated by the doubly stacked alignment layer without a chiral dopant at (a) an initial vertical configuration (field-off) and (b) a twisted one (field-on).

2. Experimental

For comparison, we prepared three samples of a conventional ITN sample without chiral dopant, a conventional ITN sample with dopant, and the proposed ITN sample. For two conventional ITN samples, the vertical alignment layer was spin-coated and rubbed unidirectionally. After assembling perpendicularly, the LC of MLC-6608 (E. Merck) with/without chiral dopant of R-811 (E.

Merck) was injected. For the proposed ITN sample, the first layer was coated with planar alignment material by using the spin-coating method and the coated substrate was baked on the hot plate for full imidization. Next, the diluted VA material was spin-coated onto the planar alignment layer as shown in Fig. 1. Two substrates were rubbed and assembled in perpendicular directions. The MLC-6608 with negative dielectric anisotropy was injected at isotropic phase without chiral dopant. The cell gaps of all samples were maintained with glass spacers about 5 μm thick.

Optical microscopic textures were obtained with the polarizing microscope (Nikon Eclipse E600 POL) and the electrooptic properties were measured by a digitized oscilloscope (Tektronix TDS754D) and He-Ne laser system.

3. RESULT

In general, the elastic deformation energy for a twisted distortion is about 10^{-6} N/m. However, the azimuthal anchoring strength varies from 10^{-5} to 10^{-9} N/m depending on the pretilt angle from 1.6° to 87.2° [7]. Therefore, in the conventional ITN configuration without chiral dopant, the twisted configuration cannot be obtained in the presence of the applied field due to the insufficient azimuthal anchoring strength. As a result, the LC molecules are arranged homogeneously similar to the configuration in the electrically controlled birefringence mode. In this configuration, the dark state was observed at 45° with respect to one of the crossed polarizers as shown in Fig. 2(a).

Introducing the chiral dopant, in spite of the weak surface anchoring energy, the twisted structure was obtained in the presence of the applied voltage. In the TN configuration, transmittance under crossed polarizers is expressed as [8],

$$T = \cos^2\beta + \frac{\alpha^2}{1+\alpha^2}\cos^2(2\theta)\sin^2\beta\,,$$

$$\alpha = \Gamma / 2\Phi\,,$$

$$\beta = \Phi\sqrt{1+\alpha^2}\,.$$

where Γ, Φ, and θ represent a phase retardation, a total twisted angle, and a different angle of the LC layer between a polarizer and a LC aligned direction on the polarizer side, respectively. From these equations, no dark state was observed for rotating the sample under crossed polarizers. Fig. 2(b) shows the polarizing microscopic textures of the ITN sample with the chiral dopant to generate twisted configuration with *d*/*p* = 0.25. Here, *d* and *p* represent a cell thickness and a helical pitch, respectively. The similar textures were observed in our proposed ITN sample without the chiral dopant as shown in Fig. 2(c). As a result, the doubly stacked alignment layer stabilizes the twisted configuration in the presence of the applied voltage, which is mainly expected to be originated from the enhancement of the azimuthal anchoring strength.

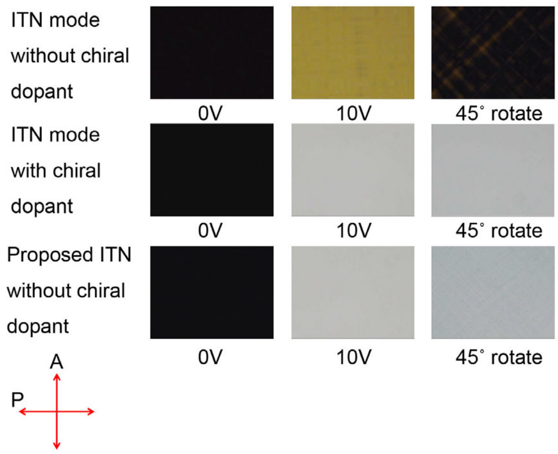

Fig. 2 Polarizing microscopic textures of various samples.

Figure 3 shows the electrooptic transmittances of the conventional ITN sample with th e chiral dopant and the proposed ITN sample. As shown in Fig. 3, our proposed ITN sample (Stack-PI) shows a low threshold voltage and thus a low driving scheme is adoptable. It is expected that the anchoring strength of the planar layer devotes the threshold voltage to shift to be low. In our ITM samples, the contrast ratio was measured to be about 700:1 which was much higher than that of the normally white TN sample (500:1) under the same cell condition due to an excellent dark state in the vertical configuration.

Figure 4 shows the measured dynamic reponses of the conventional ITN sample with the chiral dopant and the proposed ITN sample to the applied voltage with a bipolar square wave form of 5 V at 1 kHz. The field-driven switching times of the conventional and proposed ITN samples were 16 and 10 ms, respectively. The response time of our proposed ITN sample is comparable to that of the conventioanl TN sample fabricated with the rubbed planar alignment layer. When the external voltage was applied, the LC molecules with negative dielectric aniotropy fell to the surface. In this situation, the azimutally falling direction is predetermined by the rubbing direction and the switching speed is improved by the strong azimuthal anchoring strength produced by the underlying planar alignment layer.

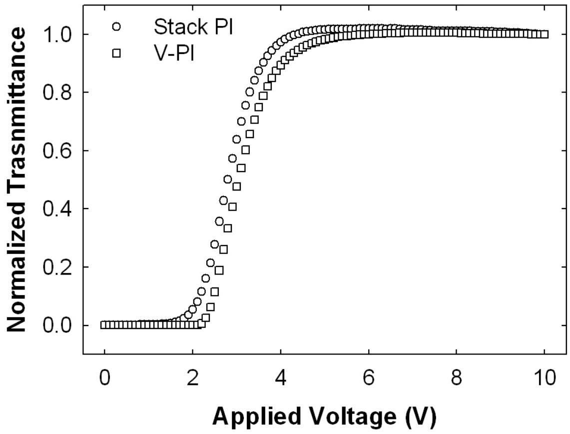

Fig. 3 Measured electrooptic properties of the conventional and proposed ITN samples.

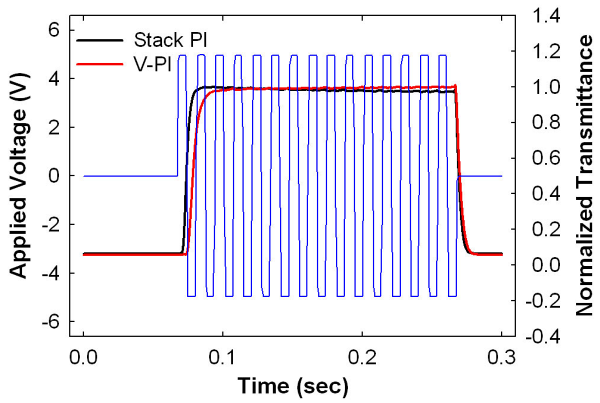

Fig. 4 Measured response time characteristics of the conventional proposed ITN samples.

4. CONCLUSION

We demonstrated the ITN mode without a chiral dopant by stacking the planar and vertical alignment materials. In the doubly stacked alignment layer, the excellent dark state was achieved in the initially vertical alignment and the stable TN configuration was obtained without the chiral dopant in the presence of the applied voltage. Also, the response time reached that in the conventional TN mode with the improved contrast ratio. Furthermore, our ITN mode is applied to the multi-domain TN modes [9] in the inverse configuration for compensating the viewing characteristics in the inverse due to no requirement of a chiral dopant.

5. REFERENCES

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