Inverse Four Domain Twisted Nematic Liquid Crystal Mode Generated by Photo-Alignment Method

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Abstract

We fabricated an inverse four domain twisted nematic (IFDTN) mode using a stacked photo-alignment layer enhancing the azimuthal anchoring energy. The strong anchoring energy generates the stable 4D twist structures under an applying voltage. High transmittance and contrast device is achieved without complex rubbing processes.

Author Keywords

Twist nematic, four domain, liquid crystal display, azimuthal anchoring energy

1. Introduction

Nowadays, liquid crystal display (LCD) has been front leading device among the various display devices due to its light weight, low driving voltage, high resolution and low fabrication cost. A lot of researches have been introduced to overcome problems such as narrow viewing angle and low transmittance. The twisted nematic (TN) mode is most widely used with high transmittance, fast response time, and low fabrication cost [1]. However, TN mode is merely used in large size display application due to the asymmetric viewing angle caused by the uni-directional director in mid-plane and low contrast ratio because of strong anchored LC molecules near the surface. For achieving the complete dark state, Patel and Cohen reported the inverse twisted nematic (ITN) mode using initially vertical alignment state using chiral dopant to generate the twist structure under electric field [2].

Multi-domain inverse TN mode is expected to be best for obtaining not only the contrast ratio but also wide viewing angle characteristics. In our previous research, inverse four domain TN (IFDTN) mode was proposed by increasing the azimuthal anchoring energy using stacked alignment layer system as shown in Fig. 1(c) [3]. We also reported that the IFDTN mode shows the higher transmittance than that of IFD electrically controlled birefringence (IFDECB) mode due to the sharp boundary at the edge of the sub-pixel. However, we used the rubbing method to generate the two different pretilt angles and this method is difficult to be applied to large panel fabrication process due to the limitation in rubbing roller and shadow mask. So currently, non-contact techniques for LC alignment are needed for application of the IFDTN mode. Recently, UV^{2}A mode is developed by K. Miyazaki and adopted in mass production (Gen 10) using photo alignment technique [4]. Similar concept was used in both UV^{2}A and IFDTN mode. However, UV^{2}A mode shows the IFDECB structure when the electric field is on state due to the weak anchoring energy of the surface.

In this paper, we attempt to obtain IFDTN mode using photo-alignment method which is non-contact technique similar to the UV^{2}A mode. Using stacked photo alignment materials, we can increase the azimuthal anchoring energy and thus obtain the twist structure under electric field same as conventional IFDTN mode. Our device shows the high transmittance and wide viewing angle characteristics.

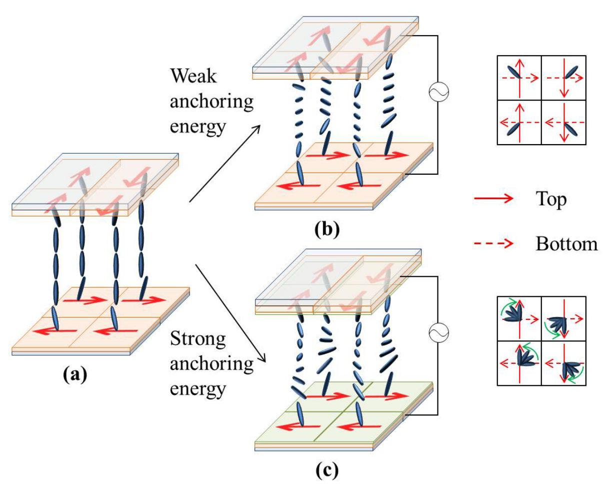

Figure 1. The schematic diagrams of (a) initially vertical alignment state, (b) IFDECB mode with weak azimuthal anchoring energy and (c) IFDTN mode with strong azimuthal anchoring energy

2. Experimental

To obtain the photo-aligned IFDTN structure, we have to increase the surface azimuthal anchoring energy with stacking two different photo-alignment materials (Chisso Inc.) as reported in our previous research [5]. First, planar photo-alignment layer was deposited using spin-coating method and baked at 210 °C for 1 h. Then, O_2 plasma treatment was followed to enhance the coating property between two photo-alignment materials. After that, diluted vertical photo-alignment layer was spin-coated onto the planar photo-alignment layer. After full imidization, the substrate stacked by two photo-alignment materials was exposed to non-polarized ultra-violet (NPUV) as shown in Fig. 2 for 30 min. The intensity of NPUV was 18 mW/cm^2 at the wavelength of 365 nm. During the UV exposure process, the substrate was tilted 45 degree from the ground for defining the azimuthal direction by generating the pretilt angle. As shown in Fig. 2, we used shadow mask shifting method to generate two different domains and size of the sub-pixel was 150 × 150 μm. Two substrates were assembled in perpendicular direction which is similar to the conventional FDTN mode [6]. The cell gap is 5.5 μm and the MLC-6608 (E. Merck) which has negative dielectric anisotropy was injected into the sandwiched cell at isotropic phase.

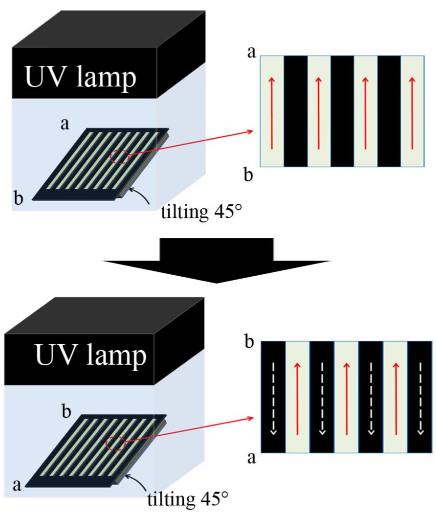

Figure 2. The schematic diagrams of fabrication process of the photo-aligned IFDTN mode. Red arrows and dashed white arrows inside the figure indicate the azimuthal direction of the LC molecules in the surface

3. Results

As we already reported, sufficient surface azimuthal anchoring energy is needed to maintain the twist structure by overcoming the twist deformation energy of the LC layer with electric field. Therefore, we control the thickness of the vertical alignment layer to increase the surface azimuthal anchoring energy. And, we found that the inverse twist structure was obtained at the thickness of the diluted vertical photo-alignment layer below the 50 nm. We think that azimuthal anchoring energy is increased by decreasing the thickness of the second layer because of the screen effect of the first layer.

Figure 3 shows the measured voltage-transmittance characteristics and polarized microscopic textures for IFDECB and IFDTN cell. The IFDECB and IFDTN cells were obtained using only vertical photo alignment layer and stacked photo alignment layers, respectively.

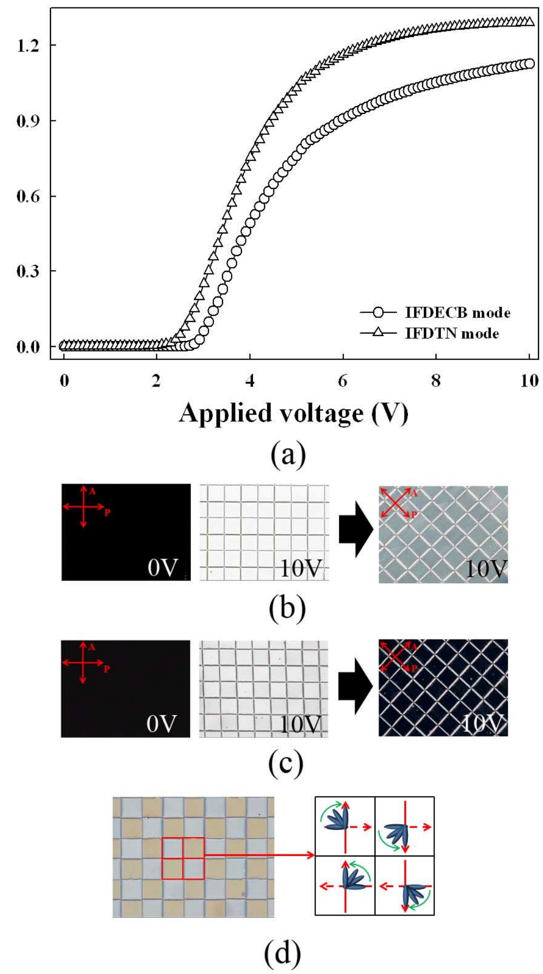

Figure 3. (a) Measured voltage-transmittance characteristics for IFDECB and IFDTN mode. And microscopic textures of the (b) IFDTN mode and (c) IFDECB mode and (d) λ/4 plate introduced IFDTN mode

The transmittance of IFDECB mode using vertical photo-alignment material is lower than that of IFDTN mode using stacked photo-alignment system about 19 % due to the splay deformation at the boundary of the sub-pixel. And, we can see the twist structure of the IFDTN cell by rotating the LC cell about 45 deg under crossed polarizers. In this situation, the azimuthal direction of the LC molecules is parallel to the one polarizer in case of the IFDECB cell and it shows the dark state under the crossed polarizers. However, in case of IFDTN cell, the transmittance characteristics are always white by rotating the cell. And, by adopting the λ/4 plate, two different chiralities at one sub-pixel can be shown in Fig. 3(d).

4. Conclusions

We fabricated the IFDTN mode by enhancing the surface azimuthal anchoring energy using staked photo-alignment layer system. The strong azimuthal anchoring energy makes possible to generate twist structure of LCs under applied voltage without chiral dopant and rubbing process. The fabricated IFDTN cell shows the high transmittance and widely uniform viewing angle at any direction due to the foudr domain structure. Also, using photo-alignment method, our proposed method is expected to expand to the mass-production with easy and simple fabrication process.

5. Acknowledgements

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6. References

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