6-2: Inverse Four Domain Twisted Nematic Liquid Crystal Mode for High Transmittance and Wide Viewing Angle Characteristics

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Abstract

In this paper, we fabricated the inverse four domain twisted nematic liquid crystal cell using stacked vertical alignment layer on planar alignment layer for strong azimuthal anchoring energy. That makes possible twist structures under applied voltage without chiral-dopant, as a result, high transmittance and wide viewing angle could be revealed.

1. Introduction

The twisted nematic (TN) liquid crystal display (LCD) mode is most commonly used because of its various merits such as simple fabrication process, fast response time and high transmittance [1]. However, TN mode is hardly used in large size display application due to its narrow viewing angle characteristics caused by uniform director profile of LC molecules in the mid-planes of the LC cell and poor dark state with applied voltage under crossed polarizers because of strong anchoring of an alignment layer. For high contrast ratio with completely dark state, inverse twisted nematic (ITN) mode with vertical alignment at the initial state was proposed (Fig. 1(a)) [2]. In ITN mode, we would get the uniform non-twist structure using the negative LCs without chiral dopant when electric field applied (see Fig. 1(b)). So, to make the twist structure, we should introduce the chiral dopant, as shown in Fig. 1(c) [2]. Though ITN mode could get the real dark state, the asymmetric viewing angle problems still remained due to the one uniform domain over the whole panel area.

Recently, Sharp Co. proposed UV^{2}A mode [3], which attempted to fabricate an inverse FDTN (IFDTN) with vertical photo-alignment layer. However, they just could get the four uniform alignments, like as electrically controlled birefringence (ECB) LC mode, instead of the twist alignment with applied voltage even though different pretilt angles in each domain, as shown in Figs. 1(d) and (e). So, in order to have twist alignments, a chiral dopant should be introduced same as one-domain ITN mode, as mentioned above. However, since the chiral dopant make only one twist direction in the whole panel, the complicate fabricating process is required such as four times alignment process in each substrate for four domains with different twist senses.

Recently, we reported the IFDTN mode with stacked system and numerical approaches of the ITN structure [5]. In this paper, we focus on the electro-optical characteristics of the IFDTN LCD using stacked vertical alignment layer on the planar alignment layer with reverse rubbing process for strong azimuthal anchoring energy which make possible the twist structures when electric field applied (see Fig. 1(f)). Using this method, we could fabricate the IFDTN LCD without a chiral dopant and realize the high transmittance, wide viewing angle LC mode and fast response time.

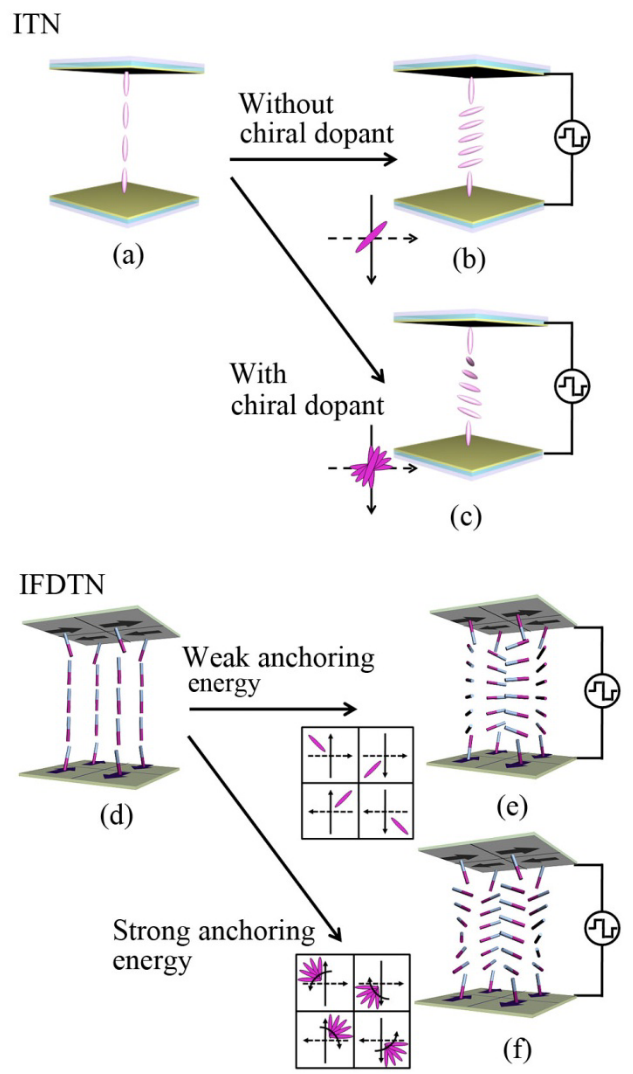

Figure 1. The schematic diagrams of ITN and IFDTN LC cell. (a) and (d) shows the initially dark state. When applied voltage in ITN LC cell, the LC has uniform (b) non-twist and (c) twist structure without and with chiral dopant, respectively. When applied voltage in IFDTN LC cell, the LC has uniform (e) non-twist and (f) twist structure with weak and strong azimuthal anchoring energy, respectively.

 ISSN 0097-966X/11/4201-0054-$1.00

2. Experimental Result

The weak azimuthal anchoring energy necessitated a chiral dopant for twist structure in the vertical alignment system with negative dielectric anisotropy LC, though the strong anchoring energy does not [2]. For enhanced the azimuthal anchoring energy, we used the method of the stacking the alignment layers. The planar alignment material (SE7492 from Nissan Chem.) was spin coated as a first layer of the alignment layers on the indium tin oxide (ITO) coated substrate (Fig. 2(a)) and baked onto the hot plate with 210°C for 2 hours. For controlling the thickness of vertical alignment layer, we diluted the vertical alignment material (AL1H659 from JSR) with solvent. And the vertical alignment layer was coated onto the planar alignment layer (Fig. 2(b)). Then the substrate was rubbed anti-parallel direction by shifting the shadow mask and the two substrates were assembled perpendicularly same as conventional TN mode (Figs. 2(c), (d)). A cell gap of 4 μm was maintained by glass spacers, and a LC with negative dielectric anisotropy (MLC-6608 from Merck). The pixel size was 300 μm X 300 μm, and the size of the sub-pixel was 150 μm × 150 μm.

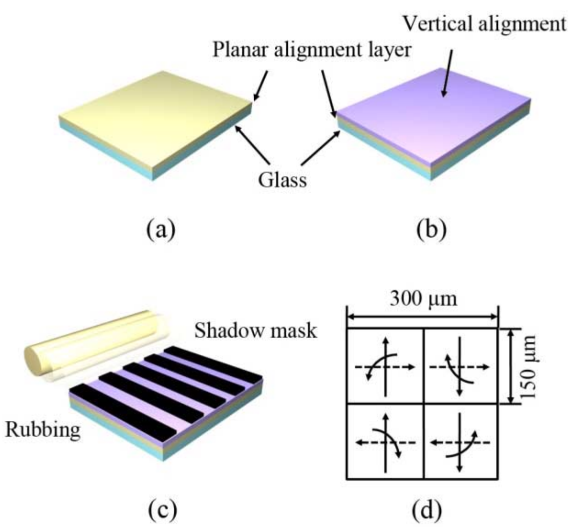

Figure 2. The schematic diagrams of the fabrication process.

3. Results

As mentioned above, the twist structure with applied voltage in IFDTN LC mode needs sufficient surface azimuthal energy to get over twist deformation energy. As controlling the thickness of vertical alignment layer, the pretilt angle of LC could be changed due to the competition of anchoring strength between planar and vertical alignment layers [4]. And the surface azimuthal anchoring energy on the vertical alignment layer could also be changed, as shown in Fig. 3. Though the anchoring strength of pure vertical alignment layer is weak (3.98×10^{-7} J/m^2) to induce the twist deformation in the bulk region, the stacked system has enhanced azimuthal anchoring energy due to the lower planar alignment layer which has strong anchoring energy. Therefore, it is important to select the thickness of the vertical alignment layer because we have to achieve the strong anchoring energy and vertical alignment at initial state. Since the anchoring energy of planar alignment layer is screened by extremely thick vertical alignment layer, we used the 5 wt% vertical alignment material for enhancing anchoring energy. In experience, the measured surface anchoring energy with 5 wt% vertical alignment layer was 6.6×10^{-7} J/m^2 which is 17 times larger than single vertical alignment layer and pretilt angle was 87º. And we have confirmed that vertical alignment of the LC molecules is not obtained with the lower concentration of the vertical alignment layer than 5 wt%. Also, if the thickness of the vertical alignment increases, the twist deformations are not occurred in the IFDTN sample due to the screened azimuthal anchoring energy.

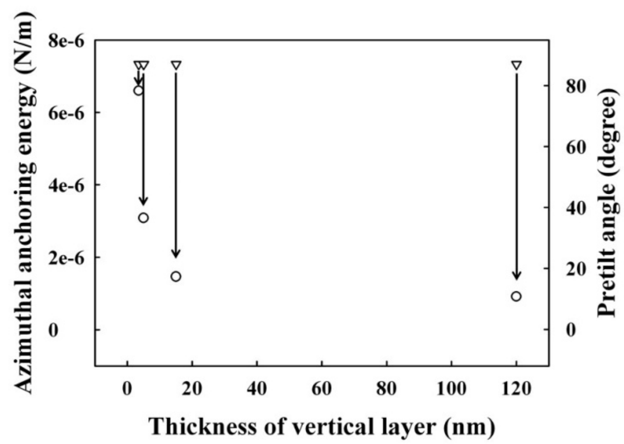

Figure 3. Pretilt angle and azimuthal anchoring energy according to thickness of vertical alignment layer.

However, due to the different twist senses at each sub-pixel for IFDTN cell, the response time is not so fast than conventional TN or ITN LC mode. For enhanced the response time characteristics, we introduce the reactive mesogens (RMs) into the vertical alignment layer. In previous our research, we reported the polymerized RMs increase the surface polar anchoring energy and improve the response time of LC cell [6-8]. In our experience, we mixed the RM monomers with diluted vertical alignment materials and fabricated the IFDTN samples. And then, same as conventional reported method, LC sample was exposed to the UV with applied field. Figure 4(a) shows the voltage-response characteristics comparing the before and after UV exposure to the IFDTN cell. As a result, we got about 10% enhancement of response time with RMs on driving voltage of the LC cell.

Figures 4(b)-(d) show the microscopic textures of the IFDTN cell. At initial state, LC molecules are aligned perpendicular to the substrate and dark state was observed in both two cases. However, the microscopic texture under crossed polarizers with 10 V shows uniform alignment and sharp domain boundaries (see Fig. 4(c)), as a result, transmittance could be enhanced about 16 % compare to the IFD-ECB cell. Using a λ/4 plate, we were able to observe different colors depending on the twist senses, as shown in Fig. 4(d), where we presented a schematic diagram of the twist directions in each sub-pixel in Fig. 4(e).

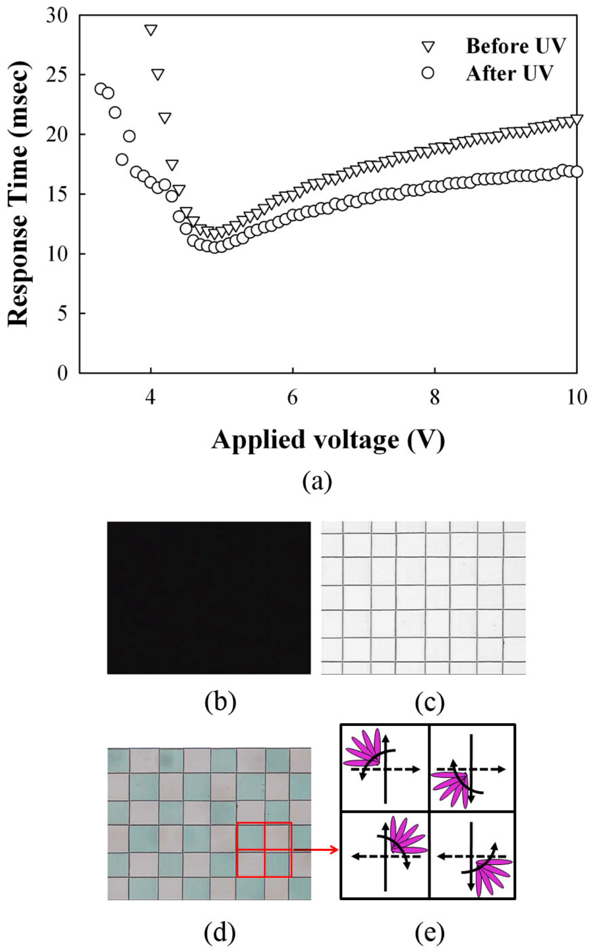

Figure 4. (a) Voltage-response time characteristics for IFDTN cell with RM before and after UV curing process. The microscopic images under crossed polarizers for (b) black state, (c) white state of IFDTN LC cell and (d) λ/4 plate introduced IFDTN LC cell. (e) The schematic diagram of the twist directions in each sub-pixel.

Figure 5 shows the measured viewing angle characteristics of the proposed IFDTN mode with/without optical compensation films. Viewing angle was measured by the commercial measurement equipment (EZcontrast from Edlim). At initial state, the black level (G1) of the IFDTN has some light leakages at off axis. And it comes from the effective angle between the polarizer and analyzer is not perpendicular at off axis view and retardation due to the vertically aligned LC molecules. Therefore, we used the bi-axial compensation films to reduce the light leakage at the off axis view. Using those polarizers, black state (G1) shows the almost zero luminance due to compensated retardation. Therefore, they show the wide and uniform viewing angle characteristics with no gray inversions at the off axis. And the contrast ratio of the sample is over 30:1 at the whole viewing directions.

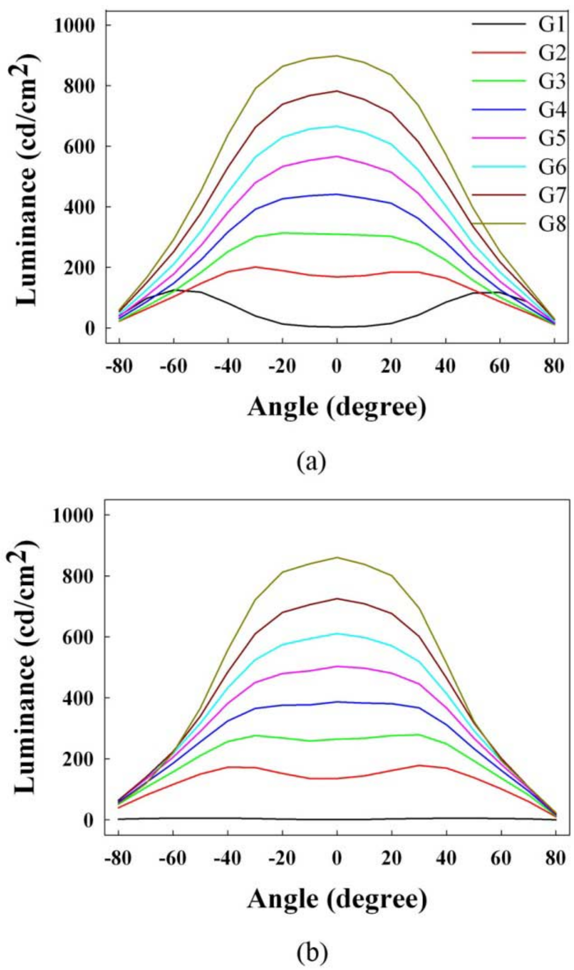

Figure 5. Measured viewing angle characteristics of the IFDTN LC mode cross section at the off axis (a) without compensation films, (b) with bi-axial compensation films.

4. Conclusions

We fabricated IFDTN LCD by enhance the surface azimuthal anchoring energy using staked alignment layer systems as first time. The strong azimuthal anchoring energy make possible to twist structure under applied voltage without chiral dopant and reverse rubbing process. The fabricated IFDTN cell shows the high transmittance, fast response time and wide and uniform viewing angle at any direction due to the four domain structure.

5. Acknowledgements

This research was supported by a grant (2010-000-0000-1526) from Samsung Electronics, Co. Ltd.

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