P-129: Stable Four-domain Twisted Nematic Structure using Stacked Alignment Layer

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Abstract

We proposed a stable four domain TN structure with high pre-tilt angle. A stacked alignment layer produced high pre-tilt angle and stabilized the four TN domains at even zero or low voltage regime. In our structure, the excellent viewing characteristics were obtained.

1. Introduction

The liquid crystal displays (LCDs) have been widely used in various display applications. Many kinds of liquid crystal modes such as twisted nematic (TN) [1], in-plane switching (IPS) [2], and patterned vertical alignment (PVA) [3] were developed for various purposes and applications. Among them TN mode is commonly used because this mode has several merits such as simple manufacturing process, high aspect ratio, high light efficiency and so on. However, although TN mode has these merits, due to its poor viewing angle characteristic, TN mode is hardly used in the field of monitors, television sets, and particularly large size and high display performance required display [4]. The poor viewing angle characteristic arises from the fact that their operations are based on optical anisotropy of liquid crystal molecules. To overcome this problem of conventional TN mode, many kinds of researches have been conducted. There are two main methods to improve TN viewing angle characteristics. One is using compensation films [5], and the other is multi-domain TN. The method to using negative birefringence films improves viewing angle characteristics but this method cannot compensate all gray levels. Multi-domain TN structures have been developed by many research groups with various methods [6-11] and the improvement in the viewing angle characteristic is clearly visible. Among them, the four-domain TN structure is the powerful method to improve viewing angle characteristics. However, conventional four-domain TN structures have problems of unstability at zero or low voltage during switching. The four-domain TN structure appears above certain voltage (stability voltage) [9-11]. Chen and co-workers [8] suggested the theoretical model to evaluate how the stability of four-domain TN display depends on geometry terms such as the tilt angle θ, sub-pixel dimension L, and the cell gap d. The suggested stability condition is as follows: $\theta^2 \geq \pi d/L$. Namely, high pre-tilt angle is required to form stable four-domain TN structure [12].

In this paper, we proposed a stable four-domain TN structure with high pretilt angle. The high pretilt angles were generated with stacked alignment layers of planar and vertical alignment layers by controlling the thickness of vertical alignment layers [13]. From this method, we could get a wide and uniform viewing angle characteristic.

2. Experiment

In our experiment, the high pre-tilt angle was realized by stacking of the vertical alignment layer on the planar alignment layer. We used a planar PI alignment layer (SE7492 from Nissan Chem.) and a vertical PI alignment layer (AL60101 from JSR) for the lower and upper layers, respectively. The planar alignment layer was spin coated and pre-baked at 100 °C for 10 min to evaporate solvent and then baked at 210 °C for 2 hrs for curing. We diluted the vertical PI materials with solvent consisting of a mixture of n-methyl-pyrrolidone, buthyrolactone and butoxyethanol to control the pre-tilt angle. This mixture was spin coated on the unrubbed planar alignment layer and pre-baked at 100 °C for 10 min and then cured at 180 °C for 1 hr. After the PI coating step, 1st and 2nd rubbing processes which of their directions are antiparallel each other were carried out on the stacked PI layer. We conducted reverse rubbing process by using rubbing mask (SUS, 30 μm thickness, 150 μm spacing) instead of using photolithography method. Because the photolithography method is complicate process and has a risk that PI layer could be damaged by the alkaline photoresist development process [6].

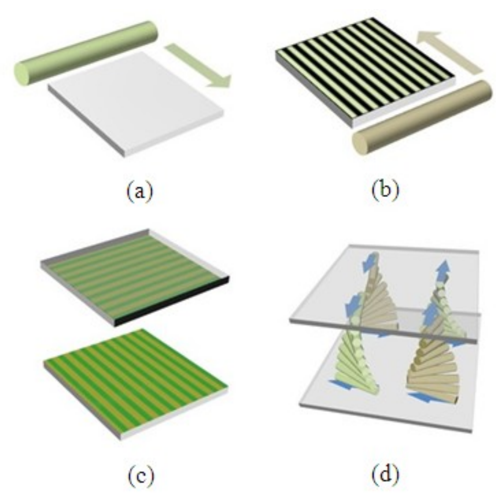

Figure 1. The schematic diagram of (a) 1st rubbing process, (b) 2nd (reverse) rubbing process with rubbing mask, and (c) assembly process. (d) shows the schematic view of the LC molecules configuration in four-domain TN structure.

The cell thickness was maintained using glass spacers of 5 μm and filled with LC material (ZKC-5085XX from Chisso). The schematic diagrams of the reverse rubbing method are shown in Fig.1. To realize four-domain TN structure, the reverse rubbed

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glasses assembled perpendicularly to each other (see Fig. 1(c)).As a result, our four-domain TN structure consists of two left-handed and two right-handed sub-pixels and the two sub-pixels which have same kind handedness has different azimuthal angles at initial state, as shown in Fig. 1(d). The four sub-pixels could bring optical compensation and leads to good viewing angle characteristics.

3. Results and Discussion

To produce the high pretilt angle, we used the method of the stacked alignment layers of vertical and planar alignment layers [13]. Figure 2 shows the pretilt angle of the LC as a function of the thickness of vertical alignment layer. The pretilt angles were controlled continuously in the range of 4°-89°. The pretilt angles were measured by polarizer rotation method [14]. These results are reproducible and reliable within error range. Since we used a conventional spin coating method, this method can easily be applied to conventional mass production of LCDs. In experimental, the used pretilt angle was 18° using the diluted vertical alignment layer with 3 wt%.

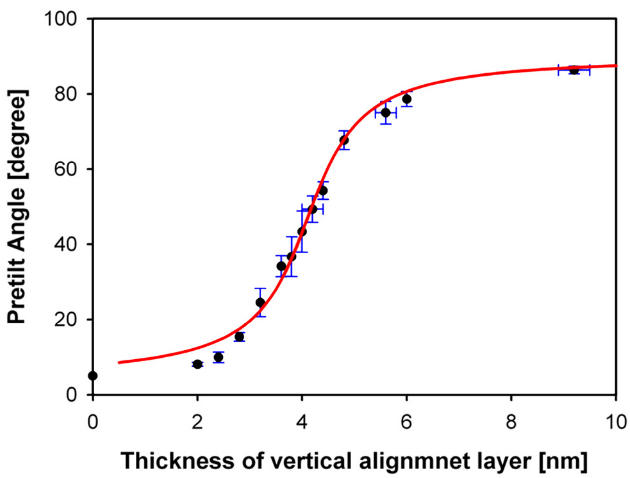

Figure 2. Pretilt angles as a function of the thickness of the vertical alignment layer.

Figure 3 shows the optical microscope images of the four-domain TN cells with different pre-tilt angles. It needs “initialization process” to form four-domain TN structure [8]. After high voltage (over 5V) is applied to the cell, the four-domain TN structure formed. Figure 2(a) shows for the four-domain images with pre-tilt angle 4° (i.e. only planar alignment material). With high electric field (10 V), the LC molecules are aligned vertically. As decreasing the voltage, the four-domain TN structure was formed and maintained until 1.3 V. But the four-domain TN structure started to disintegrate at 1.2 V and disappeared quickly. At the end, the LC molecules have one-domain TN structure at 0 V. However, if increasing the pretilt angle, the four-domain structures could be maintained at low or zero voltage. Figure 2(b) shows for the four-domain structure with high pretilt angle 18° using stacked alignment layers structure. In this case, the four-domain TN structure was maintained stably at even decreasing the voltage to 0 V.

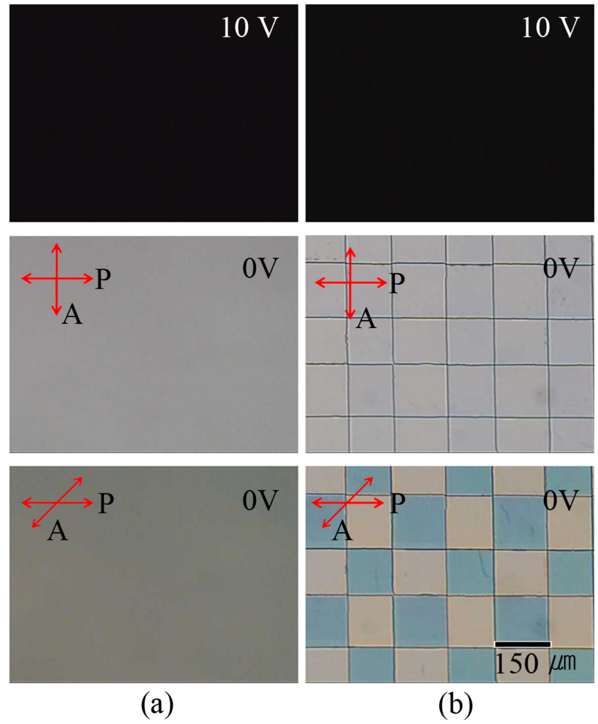

Figure 3. The microscopic images of the four-domain TN structures with pretilt angles of (a) 4° and (b) 18°.

Figure 4 shows the voltage-transmission characteristics of the stable four-domain TN cell and conventional one-domain TN cell at the same cell gap condition. Because the stable four-domain TN cell with high pretilt angle has lower effective retardation values than conventional one-domain TN cell with same cell gap, the transmittance was slightly reduced. If increasing the cell gap, the higher brightness could be secured, but the response time could be slow.

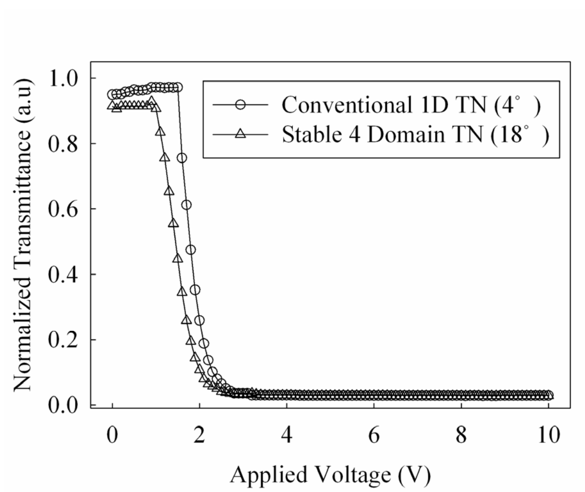

Figure 4. The voltage-transmittance characteristics of a conventional one-domain TN cell and a stable four-domain TN cell with pre-tilt angle 18°.

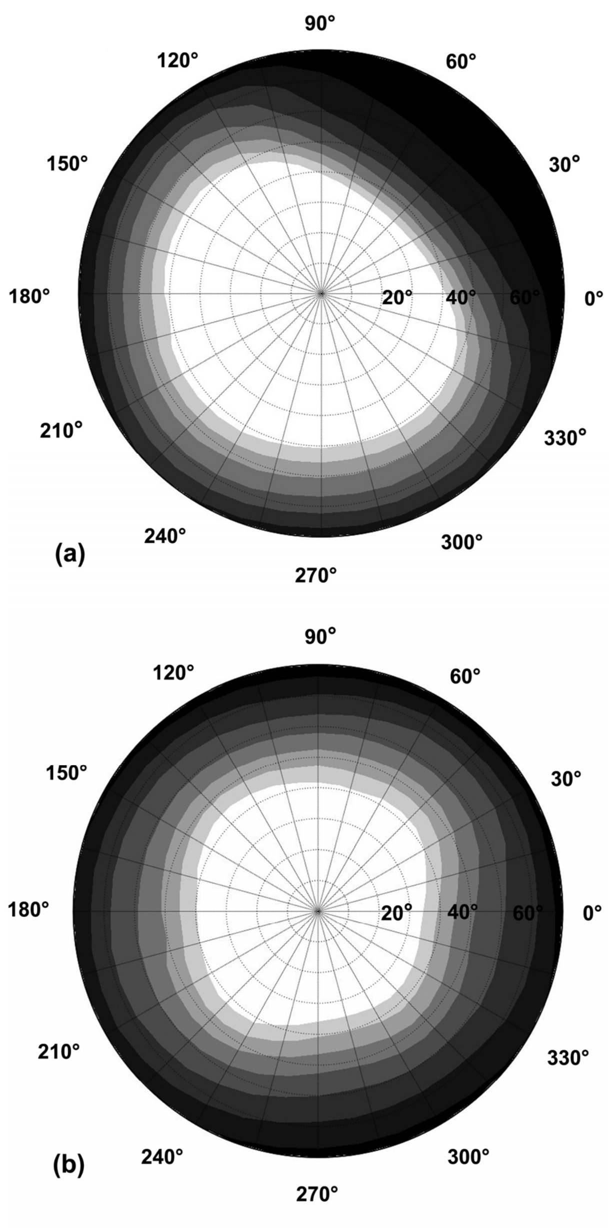

Figure 5. Viewing angle characteristics of (a) a conventional one-domain TN and (b) a stable four-domain TN cell at the middle gray voltage level.

Figure 5 shows the experimental results of viewing angle characteristics between conventional one-domain TN cell and proposed stable four-domain TN cell at the mddle gray voltage level. For the conventional one-domain TN mode, the viewing angle characteristics are not uniform at various polar and azimuthal angles because the effective retardation values are different for different viewing direction (see Fig. 5(a)). In our stable four-domain TN mode, the different twist senses and azimuthal angles compensated each other in sub-pixels, as a result, we can get the uniform transmittace characteristics for all azimuthal angles at each polar angle (see Fig. 5(b)).

4. Conclusion

We proposed a stable four-domain TN structure with high pretilt angle over all driving voltage regime. The high pretilt angle was produced using a vertical alignment layer which are stacked on the planar alignment layer. In our structure, the four-domain structure has two kinds of twist sense and azimuthal angles, as a result, wide viewing angle charactertistics are realized.

5. References

[1] M. Schadt and W. Helfrich, "Voltage-dependent optical activity of a twisted nematic liquid crystal," Appl. Phys. Lett. **18**, 127 (1971).

[2] M. Oh-e and K. Kondo, "Electro-optical characteristics and switching behavior of the in-plane switching mode," Appl. Phys. Lett. **67**, 3895 (1995).

[3] K. Sueoka, H. Nakamura, and Y. Taira, "Development of super-high-image-quality vertical-alignment mode LCD," Proceedings of the Society for Information Display Symposium, **203** (1997).

[4] A. Lien, H. Takano, S. Suzuki, and H. Uchida, "Symmetry property of a 90 degree twisted nematic liquid crystal cell," Mol. Cryst. Liq. Cryst. **198**, 37 (1991).

[5] Y. Yamagnchi, T. Miyashita, and T. Uchida, "Wide viewing angle display mode for the active matrix LCD using bend alignment liquid crystal cell," J. Soc. Inf. Disp., 277 (1993).

[6] Y. Koike, T. Kamada, K. Okamono, M. Ohashi, I. Tomita, and M. Okabe, "A full-color TFT-LCD with a domain-divided twisted-nematic structure," Proceedings of the Society for Information Display Symposium, 798 (1992).

[7] K. H. Yang, "Two-domain 80°-twisted nematic liquid crystal display for grayscale applications," Jpn. J. Appl. Phys. **31**, L1603 (1992).

[8] J. Chen, P. J. Bos, D. R. Bryant, D. L. Johnson, S. H. Jamal, and J. R. Kelly, "Four-domain twisted nematic liquid crystal fabricated by reverse rubbed polyimide process," J. Appl. Phys. **80**, 1985 (1996).

[9] J. Chen, P. J. Bos, D. R, Bryant, D. L. Johnson, S. H. Jamal, and J. R. Kelly, "Simple four-domain twisted nematic liquid crystal display," Appl. Phys. Lett. **67**, 1990 (1995).

[10] S. Varghes, G. P. Crawford, C. W. M. Bastiaansen, D. K. G. De Boer, and D. J. Broer, "Microrubbing technique to produce high pretilt multidomain liquid crystal alignment," Appl. Phys. Lett. **85**, 230 (2004).

[11] S. Varghes, G. P. Crawford, C. W. M. Bastiaansen, D. K. G. De Boer, and D. J. Broer, "High pretilt four-domain twisted nematic liquid crystal display by microrubbing: process, characterization, and optical simulation," J. Appl. Phys. **97**, 053101 (2005).

[12] M. Reichenstein, H. Stark, J. Stelzer, and H.R. Trebin, "Motion, creation, and annihilation of disclinations in multidomain structured nematic liquid crystal cells," Phys. Rev. E **65**, 011709 (2001).

[13] Y.-J. Lee, J. S. Gwag, Y.-K. Kim, S. I. Jo, S.-G. Kang, Y. R. Park, and J.-H. Kim, "Control of liquid crystal pretilt angle by anchoring competition of the stacked alignment layers," Appl. Phys. Lett. **94**, 041113 (2009).

[14] S. B. Kwon, K. Y. Han, and T. Uchida, "Polarizer rotation method for the measurement of LC pretilt angle in the full range of 0-90 degrees," J. Inst. Image Inf. Telev. Eng. **18**, 13 (1994).