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Improvement of an Azimuthal Anchoring Energy by stacking Photo-alignment Layer onto a Planar Alignment Layer

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We propose a method to improve an azimuthal anchoring energy in a photo-alignment layer. We stack a photo-alignment layer onto a planar alignment layer, and then, the stacked photo-alignment layer is exposed by linearly polarized UV to improve the azimuthal anchoring energy. Finally, in the fringe-field switching mode, we achieved the fast response time characteristics.

1. Introduction

In the present decade, liquid crystal displays (LCD) have been the most generally used in the field of display. And researchers have developed many kinds of LC modes to attain the high performances. Also, many kinds of LC alignment methods have been developed, for example, rubbing method of polyimide, ultraviolet (UV) exposure of photo-polymers, evaporation of silicon oxide (SiOx), and ion beam treatment on polymer substrate [1-3]. The rubbing method is the most often used method. But in rubbing method, some problems are occurred like mechanical damage and static charge because it is a contact process. It will degrade the LCD performances. The photo-alignment method is one of the potential methods to substitute for the rubbing method, because it is a non-contact method and it has an ability of multi-alignment. However, photo-alignment method has some downsides. Its stability of alignment is insufficient. And, it has relatively weak surface anchoring energy.

In this paper, we propose an advanced method to enhance an azimuthal anchoring energy for photo-alignment layer. We stacked photo-alignment layer onto a planar alignment layer without any rubbing process. And then, the stacked photo-alignment layer is exposed by linearly polarized (LP) UV. As a result, the azimuthal anchoring energy of the photo-alignment layer is improved. Finally, we achieved the fast response time characteristics in a fringe-field switching (FFS) mode by enhancing azimuthal anchoring energy.

2. Experiments

Figure 1 shows the schematic diagrams of the stacked photo-alignment layer system. At first, a planar alignment material (SE2414, Nissan Chem.) was spin coated as a 1st alignment layer and baked onto hot plate at 210 °C for imidization. It is shown in Fig. 1(a). The 2nd photo-alignment layer (RN2467, Nissan Chem.) was diluted with mixture of n-methyl-pyrrolidone, buthyrolactone, and butoxyethanol. The diluted material was spin coated with diverse conditions (2, 4, 8, 16 wt.%), onto the 1st alignment layer. The condition of spin coating is same. And it baked at 210 °C. Next, to define the azimuthal direction of the LC molecules, we exposed LPUV light (254 nm) as shown in Fig. 1(b). The important thing is that we didn't apply rubbing process for the planar alignment layer (1st alignment layer).

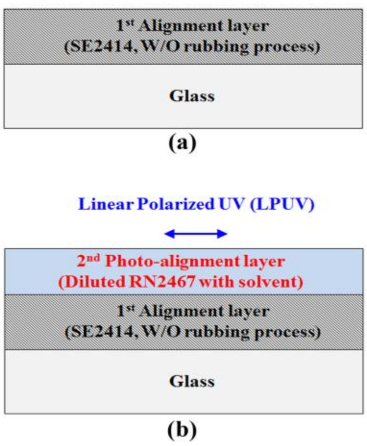

Figure 1. Schematic diagrams of the stacked photo-alignment layer system.

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We made FFS substrate which consisted of two indium tin oxide (ITO) layer and insulator (SiNx) layer with 40 nm and 400 nm thicknesses, respectively. On the bottom substrate, the upper and lower ITO layers were used as pixel electrode with 3 µm width and 5 µm intervals and common electrode without pattern, respectively. The top substrate has no electrode layer. The LC aligning direction by the LPUV exposure was rotated by 7° from the pixel electrode. The LC molecules are aligned perpendicular to the polarization direction of the LPUV. Using glass spacers of 2.7 µm, the cell thickness was maintained. And then, we filled with LC material (MLC0643 from Merck, Δn = 0.1023, and $\Delta\varepsilon$ = 6.9) by capillary action at isotropic phase temperature.

We measured the azimuthal anchoring energy using the torque balance method [4] and the electro-optic properties were measured using He-Ne laser (λ=633 nm), a digitized oscilloscope (TDS754D, Tektronix) and a photo-detector (PDA55, THORLABS).

3. Results and Discussion

Figure 2 shows the thickness of 2nd photo-alignment layer according to the concentration of RN2467. To measure the thickness of the photo-alignment layer, we used a spectroscopic ellipsometer (IUnisel-ER, Horiba). The thickness of 2nd photo-alignment layer was linearly proportional to the concentration of RN2467 with solvent mixture.

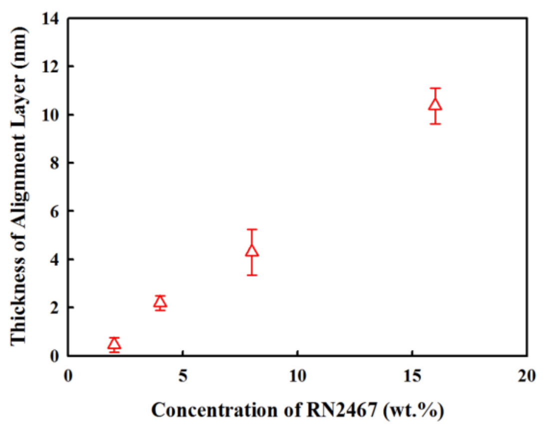


Figure 2. The thickness of 2nd photo-alignment layer according to concentration of RN2467 with solvent mixture.

The measured azimuthal anchoring energies of the photo-alignment layer and the stacked photo-alignment layer according to the concentration of RN2467 are shown in the Figure 3. Because, the interaction between photo-alignment layer (2nd photo-alignment layer) and the planar alignment layer (1st alignment layer) was improved, the azimuthal anchoring energy of stacked photo-alignment layer was increased at 2.70×10^{-5} J/m^2 (RN2467, 4 wt.%) and 3.26×10^{-5} J/m^2 (RN2467, 16 wt.%) compared to 1.20×10^{-5} J/m^2 (RN2467 only), respectively. When the concentration of RN2467 reached a certain standard, the azimuthal anchoring energy was saturated due to screening interaction with increasing thickness of 2nd photo-alignment layer [5].

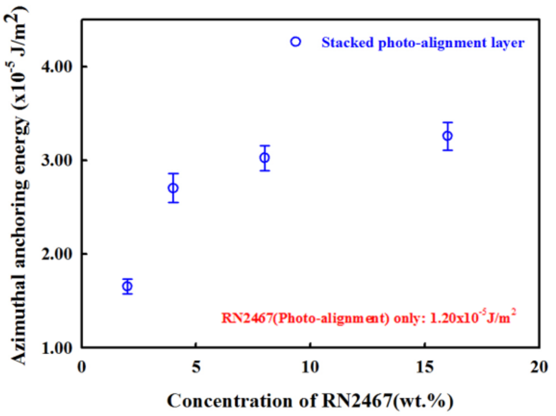


Figure 3. The azimuthal anchoring energies of photo alignment layer and stacked alignment layer as a concentration of RN2467 with solvent mixture.

Figure 4 shows the measured voltage-transmittance (V-T) characteristics of the FFS cell with the photo-alignment layer without stacking and the stacked photo-alignment layer. The result of stacked photo-alignment layer shifted to right and threshold voltage was increased compared to photo-alignment layer (RN2467 only). This phenomenon also led that the azimuthal anchoring energy was enhanced by using proposal method.

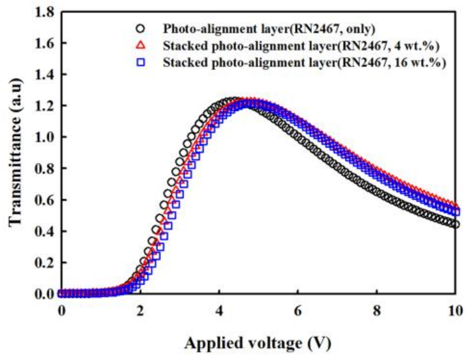
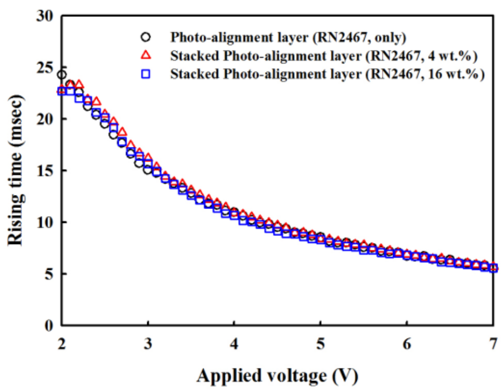
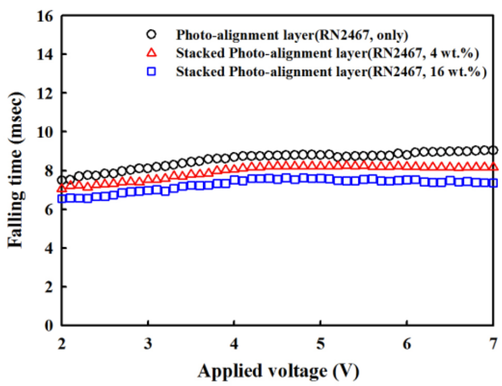


Figure 4. The measured V-T characteristics of photo alignment and stacked photo alignment in FFS mode.

Nie et al. proposed that in finite anchoring energy condition, the response time of LC will be reduced when its surface anchoring energy is strong [6]. So, large azimuthal anchoring energy leads the dynamic behavior of FFS mode applied an electric field.



(a)



(b)

Figure 5. The measured response time characteristics of the FFS cell with the stacked photo-alignment layer and without the planar alignment layer: (a) the rising time characteristics, (b) the falling time characterisitcs.

Figure 5 shows the response time characteristics as a function of applied voltage in the FFS cell with the photo-alignment layer without stacking and the stacked photo-alignment layer. In the rising time of the FFS cell, there was no noticeable difference in all applied voltage as shown in Figure 5(a). However, as shown in Figure 5(b), the falling time of the FFS cell with the stacked photo-alignment layer was faster than the photo-alignment layer without the planar alignment layer (1^{st} alignment layer). This difference of the falling time comes from improvement of the azimuthal anchoring energy due to interaction between photo-alignment layer (2^{nd} photo-alignment layer) and the planar alignment layer (1^{st} alignment layer).

4. Conclusion

In short, we proposed the advanced method to improve the azimuthal anchoring energy in the photo-alignment layer. We used a photo-alignment layer by stacking onto a planar alignment layer. The important thing is that our method doesn't need to do rubbing process. As a result, the azimuthal anchoring energy was approximately 2.7 times stronger than that of the photo-alignment layer without stacking. Because the azimuthal anchoring energy was increased, the response time characteristics of the FFS mode were improved, too. We expected that our proposal method would be a worthy method to improve the surface anchoring energy of the photo-alignment layers.

5. Acknowledgements

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