# Enhancement of an Azimuthal Anchoring Energy in a Photo-alignment Layer by Stacking Planar Alignment Layer

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## ABSTRACT

*We propose a method to enhance an azimuthal anchoring energy by stacking photo-alignment layer onto a planar alignment layer. The exposure of LPUV to the stacked alignment layers gave rise to the strong azimuthal anchoring energy. As a result, we achieved the fast response time characteristics in the FFS mode.*

## 1. INTRODUCTION

In the liquid crystal displays (LCDs), various LC alignment methods have been investigated such as rubbing method of polyimide, evaporation of silicon oxide (SiOx), ultraviolet (UV) exposure of photo-polymers, and ion beam treatment on polymer substrate, and micro-groove pattern [1-5]. Although the rubbing method is the most famous method for the mass-production, the contact process of the rubbing method generates some problems such as mechanical damage and static charge which degrade the LCD performances.

The photo-alignment method is one of the promising methods to replace the rubbing method since its non-contact processability and multi-alignment ability. However, the photo-alignment method has been insufficient alignment stability and relatively weak surface anchoring energy. Recently, UV curable reactive mesogen (RM) was introduced to overcome those demerits of the photo-alignment layer [6,7]. The photo-alignment layer coated with RM and/or mixed with RM increased azimuthal anchoring energy because directionally polymerized RMs produced a rotational preference in the azimuthal direction. As a result, the response time could be reduced and the stability of the LC could be dramatically improved.

In this paper, we propose an advanced method to improve an azimuthal anchoring energy for photo-alignment layer by stacking photo-alignment layer onto a planar alignment layer. Without any rubbing process for the planar alignment layer, the single exposure of linearly polarized (LP) UV to the stacked photo-alignment layer improved the azimuthal anchoring energy. As a result, we achieved the fast response time characteristics in a fringe-field switching (FFS) mode due to the strong azimuthal anchoring energy.

## 2. EXPERIMENTS

Figure 1 shows the schematic diagrams of the stacked photo-alignment layer system. Initially, a planar alignment material (SE2414, Nissan Chem.) was spin coated as a 1$^{st}$ alignment layer and baked onto hot plate at 210 °C for imidization as shown in Fig. 1(a). The 2$^{nd}$ photo-alignment layer (RN2467, Nissan Chem.) was diluted with mixture of n-methyl-pyrrolidone, buthyrolactone, and butoxyethanol. The diluted material was spin coated with various conditions (2, 4, 8, 16 wt.%), onto the 1$^{st}$ alignment layer, while keeping the spinning conditions constant and baked at 210 °C. Next, we exposed LPUV light (254 nm) for defining the azimuthal direction of the LC molecules as shown in Fig. 1(b). Note that no rubbing process for the planar alignment layer (1$^{st}$ alignmet layer) was applied.

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. Note that the LC is aligned perpendicular to the polarization direction of the LPUV. The cell thickness was maintained using glass spacers of 2.7 μm and filled with LC material (MLC0643 from Merck, $\Delta n$ = 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 [8] and the electro-optic properties were measured using He-Ne laser ($\lambda$=633 nm), a digitized oscilloscope (TDS754D, Tektronix) and a photo-detector (PDA55, THORLABS).

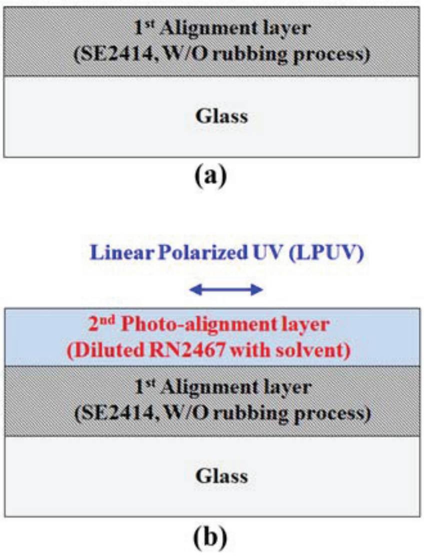



**Fig. 1 Schematic diagrams of the stacked photo-alignment layer system.**

### 3. RESULTS AND DISSCUSION

Figure 2 shows the thickness of 2nd photo-alignment layer depending on the concentration of RN2467. The thickness of the photo-alignment layer was measured by a spectroscopic ellipsometer (IUnisel-ER, Horiba). The thickness of 2nd photo-alignment layer was linearly proportional to the concentration of RN2467 with solvent mixture, while keeping the spinning conditions constant.

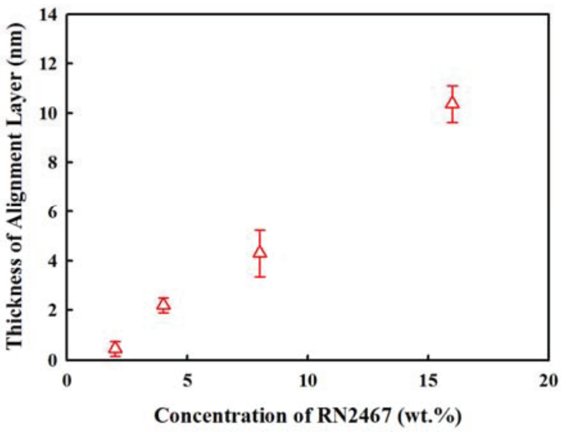



**Fig. 2 The thickness of 2nd photo-alignment layer as a function of concentration of RN2467 with solvent mixture.**

Figure 3 shows the measured azimuthal anchoring energies of the photo-alignment layer and the stacked photo-alignment layer as a function of concentration of RN2467. Due to the enhancement of interaction between photo-alignment layer (2nd photo-alignment layer) and the planar alignment layer (1st alignment layer), the azimuthal anchoring energy of stacked photo-alignment layer was increased at $2.70\times10^{-5}$ J/m$^2$ (RN2467, 4 wt.%) and $3.26\times10^{-5}$ J/m$^2$ (RN2467, 16 wt.%) compared to $1.20\times10^{-5}$ J/m$^2$ (RN2467 only), respectively. When the concentration of RN2467 was increased, the azimuthal anchoring energy was saturated due to screening interaction with increasing thickness of 2nd photo-alignment layer [9].

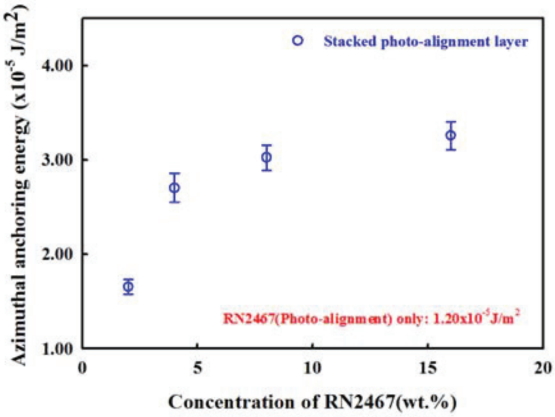



**Fig. 3 The azimuthal anchoring energies of photo alignment layer and stacked alignment layer as a function of concentration of RN2467 with solvent mixture.**

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

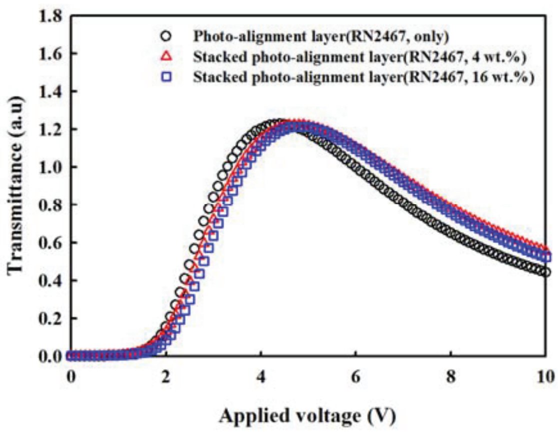
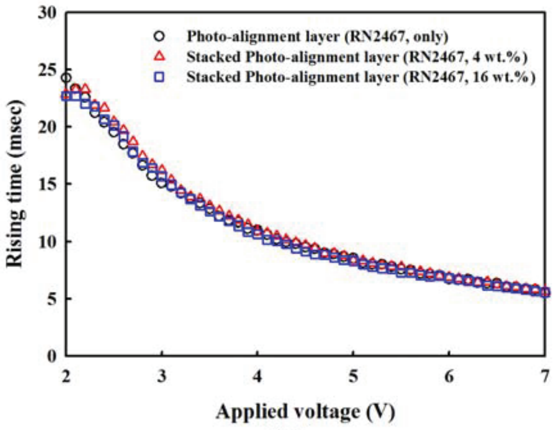



**Fig. 4 The measured V-T characteristics of photo alignment and stacked photo alignment in FFS mode.**

Nie et al. proposed that the stronger surface anchoring energy reduced the LC response time in finite anchoring energy condition [10]. So, the larger azimuthal anchoring energy affects the dynamic behavior of FFS mode when we apply an electric field.

Figure 5 shows the response time characteristics as a function of applied voltage for the FFS cell with the photo-alignment layer without stacking and the stacked photo-alignment layer. In the rising time of the FFS cell, no remarkable difference was observed in all applied voltage as shown in Fig. 5(a). However, as shown in Fig. 5(b), the falling time of the FFS cell with the stacked photo-alignment layer were faster than that with the photo-alignment layer without the planar alignment layer (1st alignment layer), which comes from enhancement of the azimuthal anchoring energy due to interaction between photo-alignment layer (2nd photo-alignment layer) and the planar alignment layer (1st alignment layer).



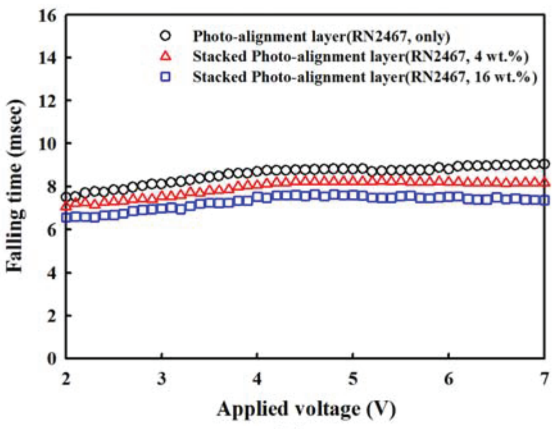




**Fig. 5 The measured response time characteristics of photo alignment and stacked photo alignment in FFS mode: (a) the rising time characteristics, (b) the falling time characterisitcs.**

## 4. CONCLUSION

In summary, we proposed the enhancement method of the azimuthal anchoring energy in the photo-alignment layer. Using the stacked alignment layer where the photo-alignment layer coated onto the planar alignment layer without rubbing process, the azimuthal anchoring energy was approximately 2.7 times stronger than that of the photo-alignment layer without stacking. As a result, the response time characteristics of the FFS mode were improved due to increase of azimuthal anchoring energy. We expected that our proposal method would be a valuable method to enhance the surface anchoring energy of the photo-alignment layers.

## 5. ACKNOWLEDGMENT

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