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Inverse Twisted Nematic Mode by Stacking Photo-Alignment Layers

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We propose an inverse twisted nematic mode using photo-alignment method by stacking two different alignment layers. By stacking the two photo-alignment layers, we can increase the azimuthal anchoring energy of the surface and it can be possible to make twist structures under electric field.

1. Introduction

Recently, liquid crystal displays (LCDs) are one of the most popular flat panel display (FPD) devices due to its intrinsic advantages such as simple fabrication process, high definition, and flexible application. Therefore, many LC modes have been introduced such as twisted nematic (TN) mode, patterned vertical alignment (PVA) mode, in-plane switching (IPS) mode [1-3]. Among them, TN mode is most commonly used in LCDs with high transmittance, fast response time, and low fabrication cost. However, it is difficult to obtain complete black level. Because the LC molecules near the surface are strongly attached to the surface and not fully arranged to the applied field direction. But VA mode has excellent contrast ratio due to their initially vertical alignment of LCs. So, to overcome the problem of TN mode, inverse TN (ITN) mode using initially vertical alignment state and twisted structure by applying voltage was developed. ITN mode has high contrast ratio because of initially vertical alignment and high transmittance because of twisted structure with applying voltage. There has been introduced two ways to generate ITN mode such as using chiral dopant to maintain twist structure of LCs with applying voltage [4] and enhancing azimuthal anchoring energy by stacking two alignment layers without chiral dopant [5]. In ITN mode, LC molecules which have negative dielectric anisotropy are initially vertical aligned and arranged perpendicular to the applied voltage direction. However, in both of two methods, they use the rubbing method to the surface. Rubbing method can cause the disadvantages such as contamination or scratch on polyimide layer or image sticking with residual DC voltage by electrostatic charge. So currently, rubbing-free techniques for LC alignment are needed and photo-alignment method has been proposed to improve alignment condition and achieve high resolution.

In this paper, we attempt to obtain the enhanced azimuthal anchoring energy of the surface using photo-alignment method which is non-contact technique by stacking two photo-alignment layers. In the stacked alignment layer system, the planar alignment layer under the diluted vertical alignment layer has a decisive effect on LC layer to be arranged parallel to the surface anisotropic direction during applying voltage due to enhanced surface azimuthal anchoring energy. In this paper, we proposed ITN mode by stacked photo-alignment layer system which maintains stable twist structure using.

2. Experiments

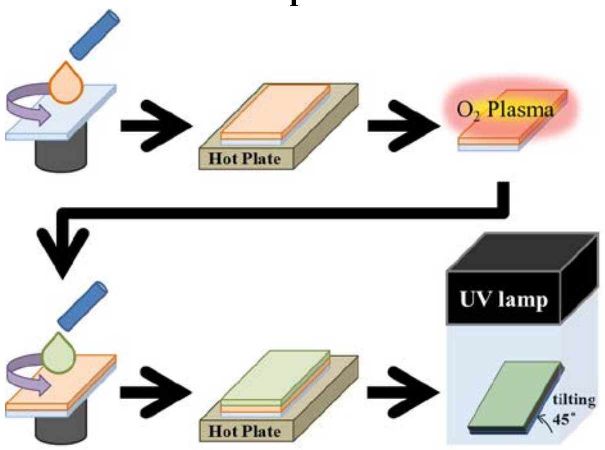

Figure 1. The schematic diagrams of fabrication process.

Figure 1 shows the fabrication process of ITN mode using stacked photo-alignment layer. At first, planar photo-alignment material (from Chisso) was spin-coated onto the indium-thin-oxide (ITO) glass. And then, sample was treated by O_2 plasma to enhance the coating property between two photo-

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alignment materials. Then, diluted vertical photo-alignment material (from Chisso) was spin-coated onto the first layer. After fully imidization, the substrate stacked with two photo-alignment materials was exposed to non-polarized UV (NPUV) shown as fig. 1. And the intensity of NPUV was about 18mW/cm^2. The substrate was tilted 45 degree from the ground to generate the pretilt angle on the substrate. The used UV light source was non-polarized UV light at a wavelength of 365nm to the PI surface and generates pretilt angle shown as fig. 2 (a). After UV exposure, two substrates were assembled perpendicularly and maintained by glass spacers about 5μm. The MLC-6608 (from Merck) which has negative dielectric anisotropy was injected into the sandwiched cell at isotropic phase.

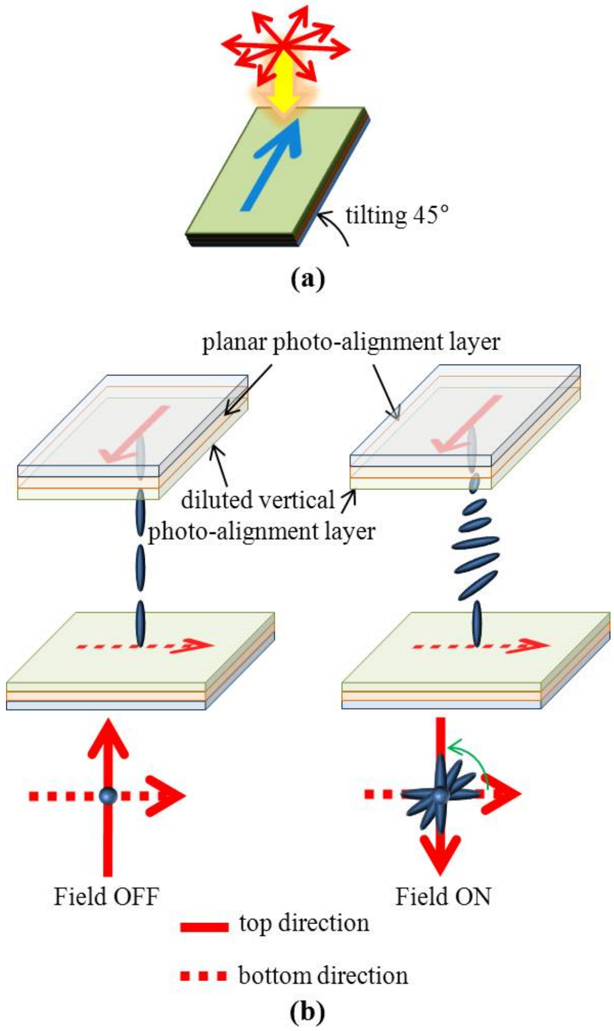

Figure 2. The schematic diagrams of (a) induced surface anisotropic direction in our UV exposure condition and (b) ITN mode with applying voltage.

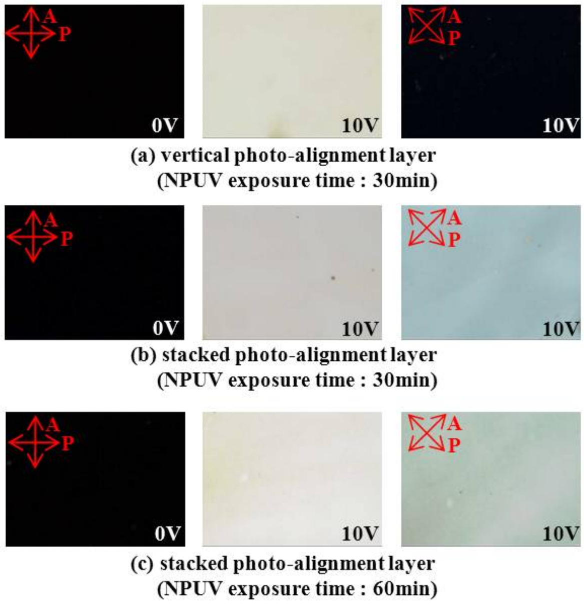

Figure 3. Microscopic images of ITN mode using photo-alignment method with (a) vertical photo-alignment layer only, (b) stacked photo-alignment layer exposed to NPUV for 30min and (c) stacked photo-alignment layer exposed to NPUV for 60min under crossed polarizers.

As shown in fig. 2 (a), the substrate by stacking two photo-alignment materials induced surface anisotropic direction toward the NPUV exposure direction. Similar to the conventional research, we can achieve the relative strong surface azimuthal anchoring energy.

layer system	surface azimuthal anchoring energy
planar photo-alignment layer system (NPUV exposure time : 30min)	1.20×10^{-5} N/m
planar photo-alignment layer system (NPUV exposure time : 60min)	1.62×10^{-5} N/m
vertical photo-alignment layer system (NPUV exposure time : 30min)	8.96×10^{-7} N/m
vertical photo-alignment layer system (NPUV exposure time : 60min)	1.23×10^{-6} N/m
stacked photo-alignment layer system (NPUV exposure time : 30min)	7.27×10^{-6} N/m
stacked photo-alignment layer system (NPUV exposure time : 60min)	1.16×10^{-5} N/m

Table 1. Measured surface azimuthal anchoring energy in each layer systems exposed to NPUV for 30min.

Figure 3 shows the microscopic textures under crossed polarizers for various conditions of ITN mode. Compared to the vertical photo-alignment layer case, stacked photo-alignment layer has high transmittance when rotating the sample 45 degree under crossed polarizers shown as fig. 3 (b), (c).

And we check the azimuthal anchoring energy by measuring the twist angle of the LC molecule with different chiralities [6] in various NPUV exposure time. As shown in table 1, the surface azimuthal anchoring energy is enhanced by the NPUV exposed time increased. Also, the surface azimuthal anchoring energy of stacked photo-alignment system is about 9 times larger than that of vertical photo-alignment layer because planar photo-alignment layer under vertical photo-alignment layer contributes to LCs layer of being maintained to the surface.

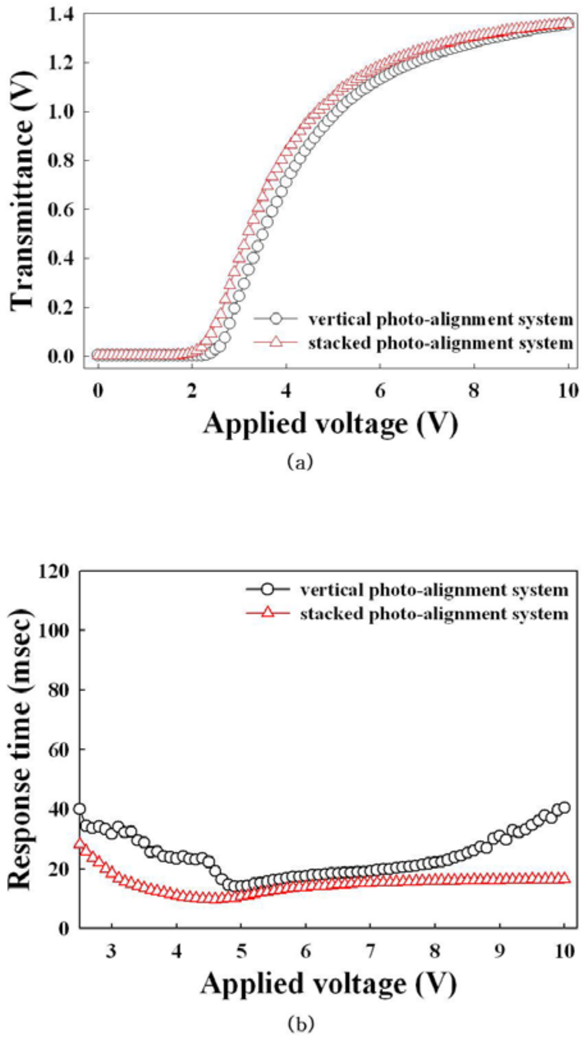

Figure 4. (a) The voltage-transmittance curve and (b) response time curve of vertical photo-alignment layer system and stacked photo-alignment layer system with 60min of NPUV exposure.

Figure 4 shows the voltage-transmittance characteristics of the fabricated samples. The screen effect of the planar alignment material decreases the threshold voltage about 0.5 V than vertical PI only case. And the response time is about 5 msec faster in 6 V and 24 msec faster in 10 V than those of vertical PI only.

In high voltage, the reorientation process is reduced and LCs are directly fall down to the surface due to relatively strong surface anchoring energy in stacked PI system than conventional method.

3. Conclusion

We proposed ITN mode using photo-alignment method by stacking two different photo-alignment materials. By stacking two materials, we can enhance the surface azimuthal anchoring energy and obtain twist structure without chiral dopant. And also, our proposed method can be expands to the mass-production with multi-domain devices to compensate the viewing angle using mask shifting method.

4. Acknowledgements

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