

Continuous Pretilt Control Using Heterogeneous Polyimide Mixture

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Abstract

We proposed a technique controlling continuously pretilt angle in full range with high process margin. The proposed method is characterized by tuning thickness of heterogeneous polyimide (PI) layer that homeotropic PI is mixed with planar PIs.

1. Introduction

In nematic liquid crystal (LC) cell, the pretilt angle is the one of very important factors which has large influence on the characteristic of LCD. So, it is important to control the pretilt angle precisely. The most widely used method to define the pretilt angle is the rubbing technique. By rubbing process, not only the azimuthal orientation of LC director, but the polar direction, so-called pretilt angle are determined. In planar polyimide (PPI) layer, the pretilt angle of 0~10° is obtained easily by rubbing technique. The pretilt angle of 80~90° can be also easily obtained in homeotropic polyimide (HPI) layer. However, it is very difficult to obtain the intermediated pretilt angle of 30~60°. If the intermediate pretilt is obtained easily, new LCD modes with good electro-optical characteristics may be made and it also can be applied to the conventional LCD mode to modify the characteristic of LCD.

To obtain intermediate pretilt angle, various techniques have been reported: the oblique evaporation of SiO₂ [1], the ion beam exposure on HPI layer [2], the competition of the van der Waals interaction between crest region and trough region of the upper alignment layer in a dual alignment layer [3], novel double layer alignment films [4], rubbing the PI layer containing fluorine moieties [5, 6], the formation of nanostructured surfaces by mixing PPI and HPI [7], and so on. However, the realization of intermediate pretilt angle is still difficult due to low stability, productivity, and reprocess margin.

In this article, to control the pretilt angle continuously, we also use the mixture of PPI and HPI. Contrary to the previous method by nanostructured surfaces, we control the pretilt angle by varying the thickness of the hybrid PI layer. Consequently, by the anchoring competition between PPI and HPI with respect to LC, the pretilt angle is continuously controlled in the full range of 0~90° with high process margin.

2. Principle and experiments

Generally, The HPI is hydrophilic and the PPI is hydrophobic, relatively. So, the two PIs, PPI and HPI, are not mixed well especially in the solid form due to the different characteristic of PIs [7]. As a result, during the hard baking process of PIs, the HPI which is relatively hydrophilic than PPI is imidized on the PPI and then the bilayer is induced. In case of the dual PI layer, the pretilt angle is controlled by tuning the thickness of the upper layer. However, in this case, it is difficult to obtain the good process margin because the variation rate of pretilt angle is large according to the change of the thickness of the upper layer. Due to the difficulty, we try to control the pretilt angle by minimizing the separation of the mixed PIs for increasing process margin. If we decrease the thickness of the coated PI mixture on a substrate, the degree of separation of the mixed PI is also decrease. By optimizing the thickness of the coated PI mixture, we may minimize the separation of PIs and realize the technique to control the pretilt angle continuously with high process margin.

We use the ØOIM23 (JSR, Japan) for HPI and the ROIM23 (JSR, Japan) for PPI. To improve the characteristic of mixing, spin-coating, and alignment, several kinds of solvents were added to the mixed PI. To modulate the thickness of the coated PI mixture,

we control the content of solvents.

The mixed PI including solvents is spin coated on indium-thin-oxide (ITO) glass. The mixture is spin coated by two steps. The first step is 1000 rpm for 10s and second step is 3000 rpm for 20s. To remove the solvents, the substrate is pre-baked at 80° C for 10 minutes. And then the substrate is hard-baked at 180° C for 1 hour. We fabricate sandwich cells with 3 um glass space. The rubbing direction between top and bottom substrates is antiparallel. The nematic LC of ZKC-5085XX ($\Delta n=0.15$, Chisso) is injected to the cell.

To measure the pretilt angle, the crystal rotation method is most widely used because this method is more convenience than other methods and measurement error is also low [8]. However, this method is difficult to measure the intermediate pretilt angle because the optically symmetric point is ambiguous and the determination of symmetric point is difficult in the intermediate pretilt angle. So, we use the polarizer rotation method for measuring the pretilt angle [9]. Contrary to the crystal rotation method, the one do not rotate the LC cell but two polarizers. This method is also very convenience and can measure the pretilt angle in full range from 0 to 90°. Furthermore, the measurement error of pretilt angle is within 0.1° when high quality optical components, for example Glan-Thomson polarizer, and a PM tube detector are used. The Figure 1 shows schematic diagram of polarizer rotation method.

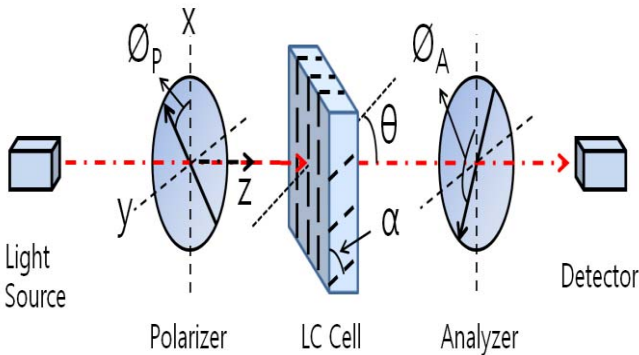


Fig. 1. Schematic diagram of polarizer rotation method

In Figure 1, the α is pretilt angle of LC cell, the θ is tilt angle of LC cell from x-y plane and the ϕ_P and ϕ_A are optic axes of polarizer and analyzer, respectively. The LC cell which is aligned homogeneously is put

between the polarizer and analyzer. The rubbing direction of LC cell is set to x direction and the LC cell is tilted at a certain angle θ from the x-y plan. In this situation, the minimum transmittance is not achieves in crossed polarizer. Because of the pretilt angle α and tilt angle of LC cell θ , the minimum transmittance is notobtained in crossed polarizer. So, to get the minimum transmittance, we apply the deviation of optic axes of polarizers from corossed polarizer state according to pretilt angle. To get the minimum transmittance, the optic axes angle of polarizers, the ϕ_P and ϕ_A , are found from the follows formulas.

$$\tan \phi_P = \frac{f_1(\theta, n_g, n_o, n_e)}{\tan \alpha} \quad (1)$$

With

$$f_1 = \frac{n_g \cos \theta + n_g^{-1} \sqrt{n_g^2 - \sin^2 \theta}}{\cos \theta + \sqrt{n_g^2 - \sin^2 \theta}} \cdot \gamma \quad (2)$$

$$\gamma = \frac{n_g \sqrt{n_o^2 - \sin^2 \theta} + n_g^{-1} n_o^2 \sqrt{n_g^2 - \sin^2 \theta}}{(\sqrt{n_o^2 - \sin^2 \theta} + \sqrt{n_g^2 - \sin^2 \theta}) \sin \theta} \quad (3)$$

and

$$\tan \phi_P = f_2(\alpha, \theta, n_g, n_o, n_e) \cdot \tan \alpha \quad (4)$$

with

$$f_2 = -\frac{n_g \cos \theta + n_g^{-1} \sqrt{n_g^2 - \sin^2 \theta}}{\cos \theta + \sqrt{n_g^2 - \sin^2 \theta}} \cdot \tau \quad (5)$$

$$\tau = \frac{(n_g \sqrt{n_e'^2 - \sin^2 \theta} + n_g^{-1} n_o^2 \sqrt{n_g^2 - \sin^2 \theta}) \sin \theta}{n_o^2 (\sqrt{n_e'^2 - \sin^2 \theta} + \sqrt{n_g^2 - \sin^2 \theta})} \quad (6)$$

$$n_e'^2 = \sqrt{\frac{n_e^2 n_o^2 + (n_e^2 - n_o^2) \sin^2 \alpha \sin^2 \theta}{n_e^2 \sin^2 \alpha + n_o^2 \cos^2 \alpha}} \quad (7)$$

Where n_g , n_o , and n_e are the refractive indices of glass, the ordinary and extraordinary refractive indices of LC, respectively. By rotating polarizer and analyzer, we can find the ϕ_P and ϕ_A according to minimum transmittance. All system is controlled automatically by computer. After we measure the ϕ_P and ϕ_A , we can calculate the pretilt angle of LC cell from eqs. (1) and (4). As a result, we can measure the full range pretilt angle by using the polarizer rotation method.

3. Results and discussion

Figure 1 shows the measured pretilt angle results for each condition. By varying the solvent concentration, we check the change of pretilt angle margin.

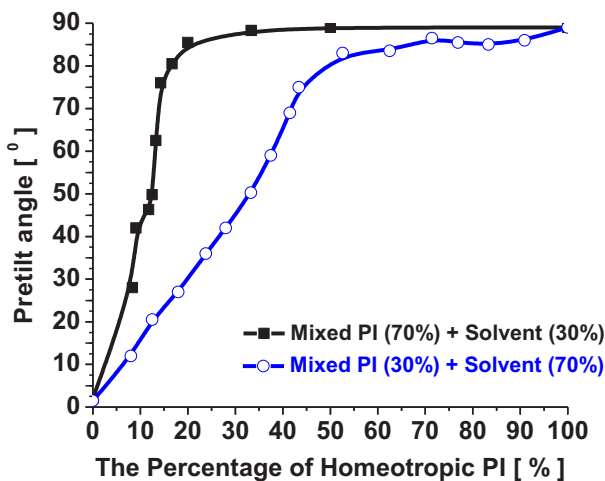


Fig. 2. Graph of pretilt angle corresponding to the concentrations of homeotropic PI

We expect that if the thickness of mixed PI coated on ITO glass is decreased, high pretilt margin can be obtained because the segregation of two polyimides are critically decreased. As our expectation, the Fig. 1 represents that the slope becomes gently by increasing the concentration of solvent. In other word, by decreasing the thickness of the hybrid PI layer, the changing rate of pretilt angle becomes gently. In the case of weight percent 30% of solvent, the control margin of pretilt angle is low in intermediate pretilt angle area. It is occurred by a relatively large segregation of mixed polyimide like previous works

[7]. In case of the weight percent 70% of solvent, the pretilt angle is controlled with high control margin according to the percentage of HPI. Contrary to the condition for which the concentration of solvent is 30%, the segregation of two polyimides may be critically decreased and two polyimides may be imidized nearly in one layer. Actually, the thickness of PI alignment layer is from about 30 nm to 40 nm at the concentration of solvent of 70%. The thickness about 30 ~ 40 nm is thin enough for drastically reducing the layer separation. Consequently, in this condition, we can continuously control the pretilt angle in full range of 0~90° with extremely high process margin. Furthermore, we can get the excellent reliability, uniformity, and productivity.

5. Summary

We proposed a technique controlling continuously pretilt angle in full range with high process margin. By varying the concentration of solvent, we can control the thickness of coated PI. In case of the concentration of solvent of 70%, the thickness is thin enough for drastically reducing the layer separation. So, we can decrease the large change of pretilt angle according to the content of HPI. Consequently, we can control the pretilt angle continuously in full range angle with high control margin.

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7. References

1. T. Uchida, M. Ohgawara, and M. Wada, *Jpn. J. Appl. Phys.* Vol. 19, 2127 (1980)
2. J.-H. Seo, H. J. Jang, S. R. Lee, D. H. Song, T.-H. Yoon, and J. C. Kim, *Digest of SID'08*, 389 (2008)
3. J. B. Kim, K. C. Kim, H. J. Ahn, B. H. Hwang, J. T. Kim, S. J. Jo, C. S. Kim, H. K. Baik, C. J. Choi, M. K. Jo, Y. S. Kim, J. S. Park, and D. Kang, *Appl. Phys. Lett*, Vol. 91, 023507 (2007)
4. K. Zhang, N. Liu, R. J. Twieg, and P. J. Bos, *ILCC'08*, 371 (2008)
5. D.-S. Seo, S. Kobayashi, and M. Nishikawa, *Appl. Phys. Lett*, Vol. 61, 2396 (1992)

6. D.-S. Seo and S. Kobayashi, Appl. Phys. Lett, Vol. 66, 1202 (1995)
7. F. S. Yeung, J. Y. Ho, Y. W. Li, F. C. Xie, Ophelia. K. Tsui, P. Sheng, and H. S. Kwok, Appl. Phys. Lett, Vol. 88, 051910 (2006)
8. T. J. Scheffer and J. Nehring, J. Appl. Phys, Vol. 48, No. 5, 1783 (1977)
9. S. B. Kwon, K. Y. Han and T. Uchida, J. IEICE, Vol. 94, No. 308, 13 (1994)