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Pretilt Angle Control with High Process Margin

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We proposed the method to control the pretilt angle with high process margin. In this method, the pretilt angle is controlled according to the ratio of vertical polyimide (VPI) to planar polyimide (PPI). We achieved the high process margin by optimizing the thickness of heterogeneous PI layer.

1. Introduction

In liquid crystal display (LCD), the pretilt angle is one of the most important factors directly related to the electro-optical characteristics of LCD. So, it is very important to control the pretilt angle precisely. Generally, the pretilt angle of 0~10° and 80~90° can be obtained easily in VPI and PPI, respectively. However, it is very difficult to obtain the intermediate pretilt angle. If we can realize the intermediate pretilt angle, new kind of LCD modes will be available and it also can be applied to the conventional LCD mode to modify their characteristic. To obtain the intermediate pretilt angle, various method have been proposed: oblique evaporation of SiO_2 [1], ion beam exposure on PPI [2], formation of nanostructured surfaces by mixing VPI and PPI [3], and so on. However, the realization of intermediate pretilt angle is remained still under a challenge with many problems in terms of stability, productivity, reliability, process margin, and so on.

In this paper, we will introduce the method to control the pretilt angle with high process margin.

2. Experimental

We use the ØOIM23 (JSR, Japan) for VPI and the ROIM (JSR, Japan) for PPI. The mixture, PPI and VPI, is spin coated with 1000 rpm for 10 second and then 3000 rpm for 20s on indium-thin oxide (ITO) glass. To remove the solvents, the substrate is pre-baked at 80° C for 10 minutes. And then, for imidization of coated PI, the substrate is hard-baked at 180° C for 1 hour. We fabricate sandwich cells with 3um glass spacer.

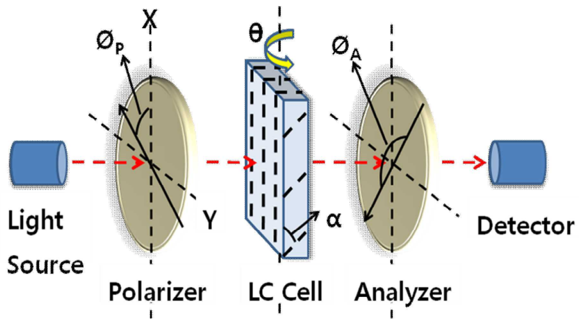

Fig 1. Schemetic diagram of polarizer rotation method

The rubbing direction between top and bottom substrates is antiparallel. We use the nematic LC of ZKC-5085XX(△n=0.15, Chisso).

To measure the pretilt angle, the crystal rotation method is widely used [4]. However, because this method can not measure intermediate pretilt angle, we use the polarizer rotation method which can be measure intermediate pretilt angle area [5]. The figure 1 shows schemetic 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 $\mathbf{Ø_p}$ and $\mathbf{Ø_A}$ are optic axes of polarizer and analyzer, respectively. In this situation, the minimum transmittance is not obtained in crossed polarizer state due to pretilt angle **α** and tilted angle **θ**. So, to achieve the minimum transmittance, we have to apply the deviation of optic axes of polarizers from crossed polarizer state according to the each pretilt angle. By rotating the polarizer and analyzer, we can find the $\mathbf{Ø_p}$ and $\mathbf{Ø_A}$ according to minimum transmittance. From these values, we can calculate the pretilt angle of LC cell from the follows formulas.

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

With

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

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

and

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

with

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

$$\tau = \frac{(n_g\sqrt{n_e'^2-\sin^2\theta}+n_g^{-1}n_o^{2}\sqrt{n_g^{2}-\sin^2\theta})\sin\theta}{n_0^{2}(\sqrt{n_e'^2-\sin^2\theta}+\sqrt{n_g^{2}-\sin^2\theta})} \tag{6}$$

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

Where $\mathbf{n_g}$, $\mathbf{n_o}$, and $\mathbf{n_e}$ are the refractive indices of glass, the ordinary and extraordinary director of LC, respectively.

Generally, VPIs have a more hydrophilic property than PPIs. So, the two PIs, VPI and PPI, are not mixed well [4]. As a result, the VPI is imidized on the PPI during the baking process. In Ref. [4], they form the nanostructure of VPI on PPI by using this property. In here, the pretilt angle is controlled by the competition of van der waals interaction of PPI and VPI region. However, the van der waals interaction is changed exponentially according to the thickness and size of VPI nanostructure. As a result, this method is difficult to have high process margin.

3 Result and Discussion

Figure 2 shows our measured pretilt angle results compared with previous mixing method. We expected that if the thickness of coated PI mixture is decreased, high pretilt margin can be achieved by minimizing the separation of VPI and PPI.

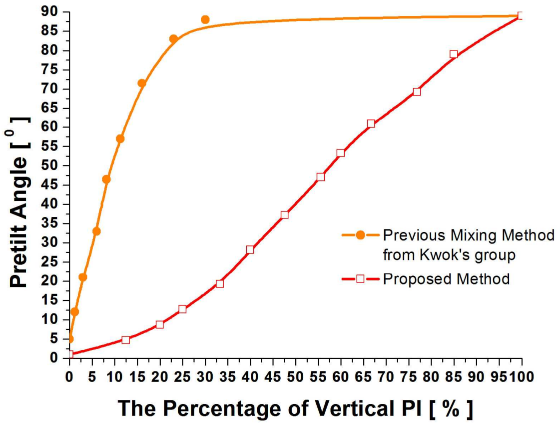

Fig 2. Graph of pretilt angle corresponding to the concentration of VPI

In the cases of previous mixing method, the control margin of pretilt angle is low in intermediate pretilt angle area. It is occured by a relatively large segregation of mixed polyimide. In our case, we can recognize the slope is directly proportional to the concentration of VPI. From these result, we can know that the segregation of VPI and PPI is critically decreased. Actually, the thickness of PI alignment layer is about 28 nm in our case. This thickness is thin enough for drastically reducing the layer separation. Consequently, in this condition, we can control the pretitl angle continuously in full range of 0~90° with extremely high process margin.

4. Conclusion

We propose a method to control the pretilt angle in full range, 0~90° , with high process margin. Contrary to the previous mixing method, we minimize the separation of VPI and PPI. As a result, we can control the pretilt angle with excellent control margin.

5. Acknowledgement

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6. References

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