P-139: Control of Liquid Crystal Pre-tilt Angle Using Reactive Mesogen

Yeon-Kyu Moon[1], Tae-Min Kim[1], Min-Geon Choi[1], Jin-Hee Jeong[2], You-Jin Lee[1], Chang-Jae Yu[1, 2], Young Min Kim[3] and Jae-Hoon Kim[1, 2*]

[1] Dept. of Information Display Engineering, Hanyang University, Seoul 133-791, Korea

[2] Dept. of Electronics Engineering, Hanyang University, Seoul 133-791, Korea

[3]School of Electronic and Electrical Engineering, Hongik University, Seoul 121-791, Korea

Abstract

We proposed a method to control pre-tilt angle of liquid crystals by coating vertical alignment reactive mesogen(RM) material on the planar alignment layer. The pre-tilt angle can be precisely and simply controlled in full range (0° ~ 90°). We also easily obtained a patterned alignment layer using this method.

1. Introduction

The pre-tilt angle is one of the most important parameters in the liquid crystal displays (LCDs) because the characteristic of LCDs is largely influenced by the determined pre-tilt angle. Nowadays, most commercialized LCDs use planar alignment layer which has pre-tilt angle of 0° ~ 10° or vertical alignment layer which has pre-tilt angle of 85° ~ 90°. However, the demand for intermediate pre-tilt angle has been gradually increased for new LCD modes and applications such as stable four domain twisted nematic (TN) mode [1] or fast response no-bias-bend mode [2, 3]. Recently, various methods for controlling pre-tilt angle have been reported such as mixed alignment layers [4, 5], stacked alignment layers [6], composite alignment layers using liquid crystal polymer (LCP) pillars [3]. These methods obviously show that the pre-tilt angle is controllable through an anchoring competition of planar and vertical alignment components. However, the controlling of intermediate pre-tilt angle is still difficult problem due to reproducibility and process margin and so on. Moreover, these methods are not suitable for mass production due to complex process.

In this paper, we proposed a simple method for controlling pre-tilt angle by coating vertical alignment reactive mesogen (RM) on the rubbed planar alignment layer. The pre-tilt angle can be precisely and easily controlled from 0° to 90°. We also simply realized a patterned alignment layer structure using this method.

2. Experiment

Figure 1 shows the schematic diagram of the experimental process. The planar alignment material (RN-1199 from Nissan chemical) was spin-coated on the indium-tin-oxide (ITO) coated glass and soft baked at 100 °C for 10 min, followed by curing for imidization at 210 °C for 2 hrs. After PI coating step, the rubbing process carried out to define azimuthal direction. We dissolve the reactive mesogen (RM) mixture that consists of vertical alignment RM monomer (RMM-28B from Merck) and photo-initiator (IRGACURE 651 from Ciba chemical) in propylene glycol monomethyl ether acetate (PGMEA) solvent to coat on the planar alignment layer. This RM mixture dissolved in PGMEA solution was spin-coated on the rubbed planar alignment layer and then baked 60 °C for 90 sec to evaporate solvent. And then, we conducted the UV curing process for 10 min to polymerize the RM monomers by blowing with nitrogen gas. The intensity of 365nm ultra-violet (UV) light from mercury lamp is approximately 17.8 mW/cm^2. Then, the RM coated glasses assembled anti-parallelly to each other and filled with LC material (ZKC-5085XX from Chisso). We used the polarizer rotation method [7] to measure pre-tilt angles with vertical RM wt%. Unlike crystal rotation method [8], this method is possible to obtain accurate measurement for intermediate pre-tilt angle area.

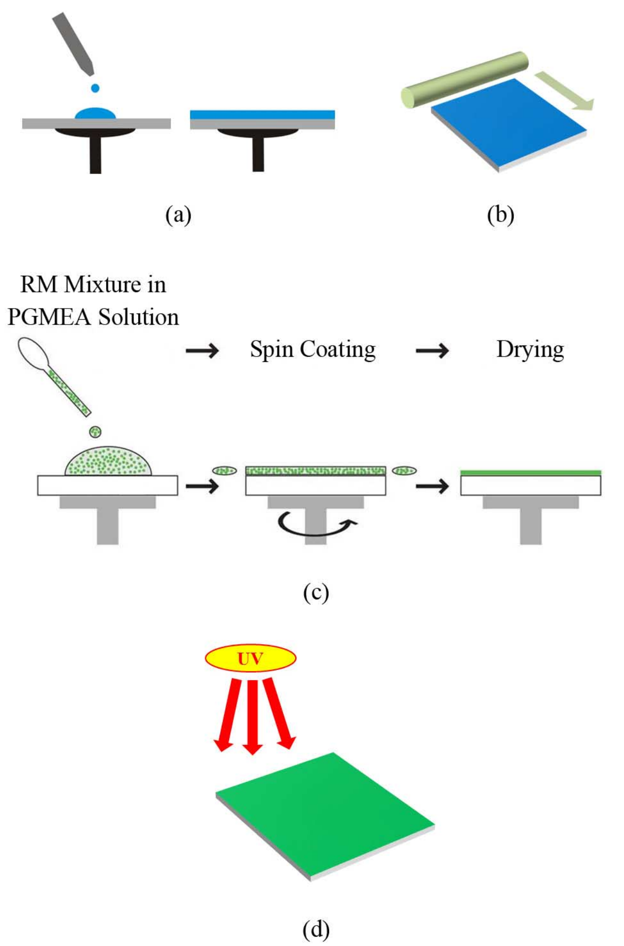


Figure 1. The flow chart of the experimental process for (a) spin coating PI, (b) rubbing process, (c) RM coating process, (d) UV curing process.

 ISSN 0097-966X/11/4203-1630-$1.00 © 2011 SID

3. Results and Discussion

Figure 2 shows the atomic force microscope (AFM, Park System, XE 100) image of the vertical alignment reactive mesogen (RM) coated polyimide (PI) film. The AFM measurements were conducted in non-contact mode at a scan rate of 0.5 Hz. We can ascertain that the vertical alignment RM protrusions are aligned with the rubbing direction on the surface of the planar alignment layer. The pre-tilt angle can be determined by the anchoring competition between this vertical alignment RM protrusions and planar alignment PI layer. Therefore, the pre-tilt angle is controllable with spin coated vertical alignment RM wt%.

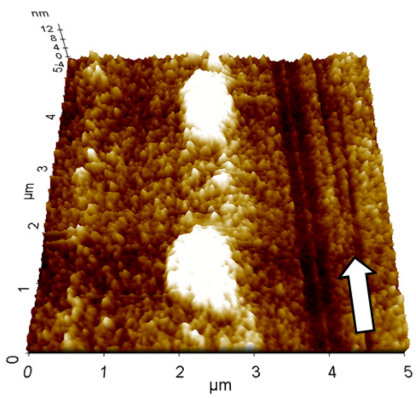


Figure 2. Surface morphology obtained by AFM for vertical RM coated PI film. (The white arrow indicates the rubbing direction.)

Figure 3 shows the pre-tilt angles of LC with the coated vertical alignment RM wt%. The pre-tilt angle was precisely and easily controlled in the range of 3° ~ 85° by varying the concentration of vertical alignment RM from 0 to 1 wt%. The measured pre-tilt angles are reproducible and reliable within error range. Since we used a conventional spin-coating method, this method can simply be applied to conventional mass production without changing existing facilities.

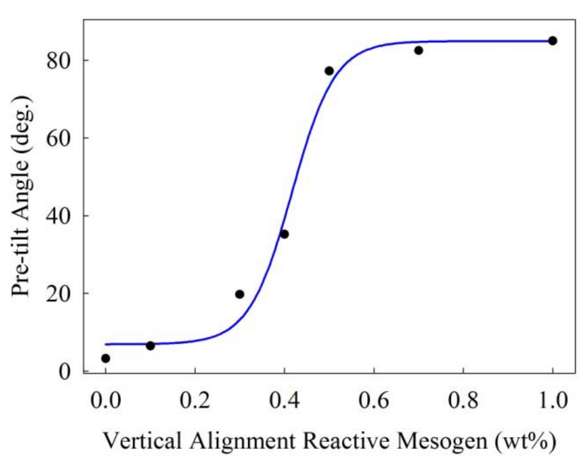
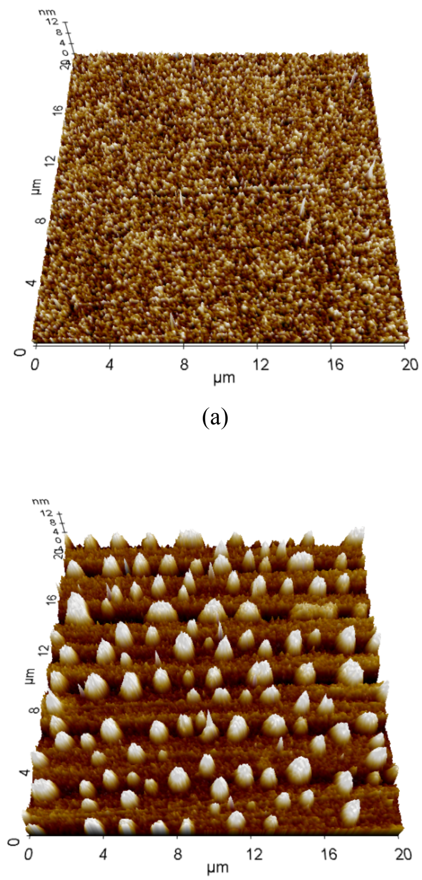


Figure 3. Pre-tilt angles as a function of the coated vertical alignment RM wt%.

Our suggested method is also useful to pattern an alignment layer with different pre-tilt angles. The coated vertical alignment RM monomers which did not polymerized can be easily removed by the PGMEA cleaning process. On the other hand, the polymerized RMs by UV cure process bore up against the PGMEA cleaning process. The surface morphologies of the RM coated layer before and after UV curing process were observed using an AFM. As shown in Fig 4. (a), for the PGMEA cleaning process was conducted before UV curing, the RM coated layer was washed away by the PGMEA cleaning process because the RM monomers do not polymerized. However, for the PGMEA cleaning process was conducted after UV curing, the RM coated layer was not washed away by PGMEA cleaning process because the aligned RMs are polymerized with UV (Fig 4. (b)).



(b)

Figure 4. AFM images of the RM coated PI film after PGMEA cleaning process (a) before and (b) after UV curing process.

Therefore, if we conduct a selective UV curing process using the UV shadow mask and PGMEA cleaning process, it is possible to easily obtain the patterned alignment layer structure. Figure 5 shows domain divided cell which realized by our proposed method. The right region was covered with UV shield mask during the UV curing process. Thus, the vertical alignment RM monomers in the right region were washed away by the PGMEA cleaning process. On the other hands, the left region was opened during the UV curing process. Therefore, the vertical alignment

RMs in the left region bore up against the PGMEA cleaning process. As a result, we can easily obtain a patterned alignment layer which has a low pre-tilt angle and a high pre-tilt angle.

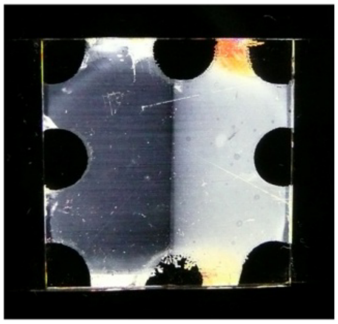


Figure 5. Photographs of the domain divided cell under crossed polarizer. (Vertical alignment RMs remained in the left region and removed in the right region by selective UV exposure process and PGMEA cleaning process.)

4. Conclusion

We proposed a method to control the pre-tilt angle of liquid crystals by coating vertical alignment RM material on the planar alignment layer. The pre-tilt angles were controlled continuosly in the full range. We also easily obtained a patterned alignment layer structure through selective UV curing process. We will expect that this method is very useful to realize multi-domain LCD structure for wide viewing angle characteristics.

5. References

[1] J. Chen, P. J. Bos, D. R. Bryant, D. L. Johnson, S. H. Jamal, and J. R. Kelly, "Four-domain twisted nematic liquid crystal fabricated by reverse rubbed polyimide process," J. Appl. Phys. **80**, 1985 (1996).

[2] F. S. Y. Yeung, Y. W. Li, and H. S. Kwok, "Fast response No-Bias-Bend LCD," IDW'05, 41 (2005).

[3] G. M. Wu, H. W. Chien, J. W. Huang, and H. L. Zeng, "Intermediate pre-tilt angle control by a composite alignment thin film structure for liquid crystal displays," Nanotechnology **21**, 134022 (2010).

[4] F. S. Yeung, J. Y. Ho, Y. W. Li, F.C. Xie, O. K. Tsui, P. Sheng, and H. S. Kwok, "Variable liquid crystal pretilt angles by nanostructured surfaces," Appl. Phys. Lett. **88**, 051910 (2006).

[5] Y.-K. Kim, J. S. Gwag, S. I. Jo, and J.-H. Kim, "Pretilt angle control with high process margin," IMID 08 Dig., 1584 (2008).

[6] Y.-J. Lee, J. S. Gwag, Y.-K.Kim, S. I. Jo, S.-G. Kang, Y. R. Park, and J.-H. Kim, " Control of liquid crystal pretilt angle by anchoring competition of the stacked alignment layers," Appl. Phys. Lett. **94**, 041113 (2009).

[7] S. B. Kwon, K. Y. Han, and T. Uchida, "Polarizer rotation method for the measurement of LC pretilt angle in the full range of 0-90 degrees," J. Inst. Image Inf. Telev. Eng. **18**, 13 (1994).

[8] T. J. Scheffer, and J. Nehring, "Accurate determination of liquid-crystal tilt bias angles," J. Appl. Phys. **48**, 1783 (1977).