Liquid Crystal Pretilt and Azimuth Angle Study of Stacked Alignment Layers

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Abstract

A new alignment layer is developed. This alignment layer is capable of generating arbitrary pretilt and azimuth angles for the liquid crystal. It is based on stacking both photo-aligned polymer and rubbed polyimide together. The alignment produced is robust. Moreover, the processing window is also maximized.

Keywords: Pretilt, Azimuth, Stacked Alignment Surface

1. Introduction

Heterogeneous surface for liquid crystal (LC) alignment has become increasingly attractive in recent years [1-2]. It is because such alignment surfaces are capable of generating arbitrary pretilt angles, especially in the range of 30º-60º. Many applications can be made possible if such pretilt angles are available, such as bistable display devices [3] and no-bias-bend fast switching display devices [4]. This type of alignment surface comprises two kinds of domains favoring different LC orientation. The arrangement of those surfaces can be in alternating stripped or checkerboard patterns. Alternatively a random nanostructure formed by precipitation can be used.

In this work, we propose a new alignment surface based on stacked alignment layers. The stacked alignment layers comprise of both photo-aligned horizontal polymer and rubbed vertical polyimide. The advantage is that photoalignment can be used so that further patterning of the pixel is possible. Here we show that this alignment layers are able to fill the technology gap which produce arbitrary multiple pretilt and azimuth angles on the same alignment substrate. The alignment produced is robust. Moreover, the processing window is also maximized.

2. Stacked Alignment Surface

The structure of the proposed stacked alignment layers is shown in Figure 1. The stacked structure consists of 2 layers of alignment materials. The bottom alignment layer is continuous, while the upper alignment layer is discontinuous.

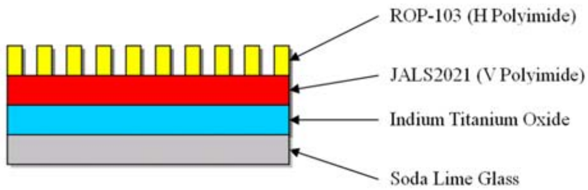


Figure 1. An overview of the proposed stacked alignment structure.

The most crucial step is to obtain the discontinuous alignment layers on top of the continuous layer reliably, without disturbing the alignment properties of the underlying continuous layer. The discontinuous alignment pattern can be obtained by self-organized structure formation techniques, i.e. Dewetting. It is found that this self-organized structure formation is generally regarded as the most promising bottom-up approaches to fabricate nanostructures beyond traditional lithography.

3. Experimental Results

In order to verify the theory, several experiments have been done. The following describes the details of the experiment procedure. Firstly, an ITO glass substrate is prepared. Figure 3 shows the AFM picture of the ITO crystalline pattern.

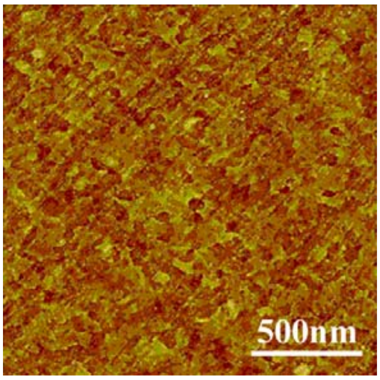


Figure 3. AFM picture of the ITO crystalline pattern.

Secondly, the vertical alignment polyimide JALS2021 form JSR Corporation is spin coated on the substrate. Then it is baked inside the oven, actually it is just the standard procedure for conventional polyimide alignment layer preparation. The main solvent of the JALS2021 is N-Methylpyrrolidone (NMP) which has a high viscosity constant, 1.67 cPa. It is expected no convection will occur during the baking. Figure 4 shows the AFM picture of the vertical alignment polyimide after the baking.

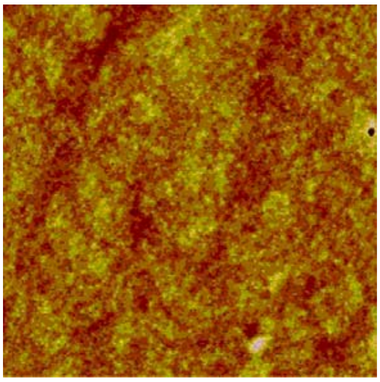
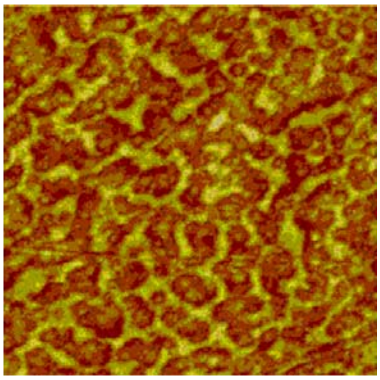
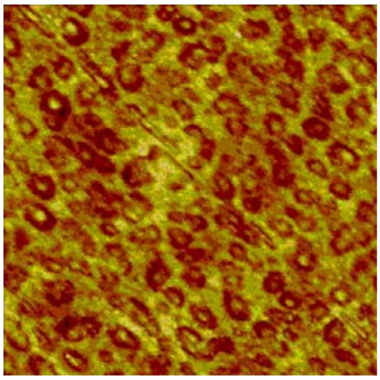


Figure 4. AFM picture of the continuous vertical alignment layer

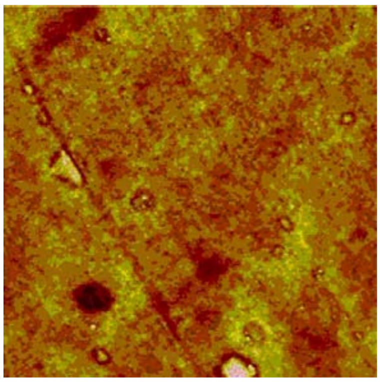
The vertical alignment polyimide completely covers the ITO crystalline pattern. The substrate is then rubbed so that the first principle pretilt θ_1 and azimuth ϕ_1 angles are obtained. Thirdly, the substrate is spin coated with different concentration of a photo-alignment material: ROP-103 from Rolic Ltd. The concentration of the ROP-103 can be adjusted by the solvent cyclohexanone. The viscosity of the cyclohexanone is 0.898 cPa. After that, the substrate is put on a hot plate for soft baking. At the end, the substrate is exposed by a linearly polarized light with a wavelength of 340 nm. So that the second principle pretilt θ_2 and azimuth ϕ_2 angles are obtained. Since a low viscosity solvent is applied, convection is expected to occur during the baking procedure. Figure 5(a)-(c) show the AFM pictures of the stacked alignment layers with different concentration of ROP-103. It can be seen that the upper photo alignment layers are indeed discontinuous and exhibit clear dewetting behavior. Figure 5(c) shows a continuous ROP-103 alignment layer completely covered the bottom alignment layer.



(a)



(b)



(c)

Figure 5. AFM pictures of the upper photo alignment layers with different concentrations of ROP-103 solutions. (a) 6% (b) 8% (c) 10%.

By using the stacked alignment layers, 2 principle alignment directions (θ_1=82°, ϕ_1) and (θ_2=0.5°, ϕ_2) can be generated by using JALS2021 and ROP-103 respectively. The resultant pretilt angle θ_H is measured by the crystal rotation method [7]. Figure 6 shows the relationship between the p and θ_H, where p is the area ratio of different ROP-103 concentrations and $|\phi_1$-$\phi_2|$=0. The relationship is linear, hence the processing window is maximized.

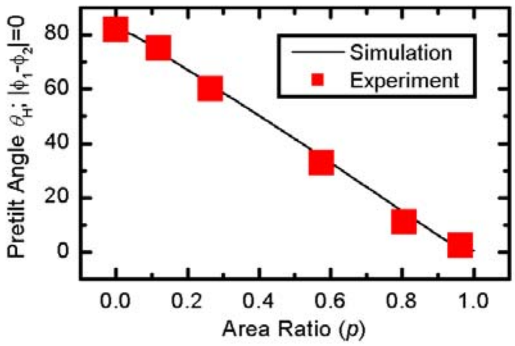
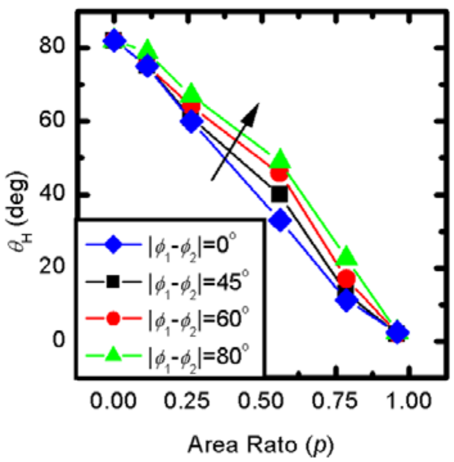
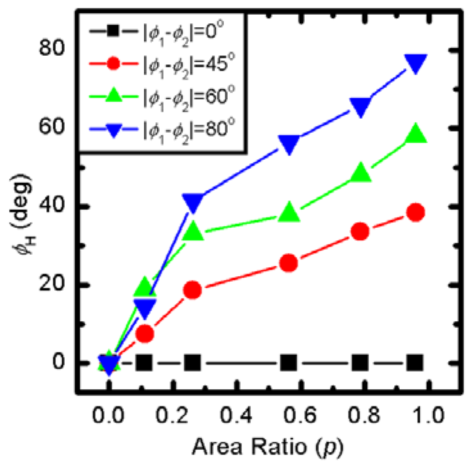


Figure 6. Homogenized pretilt angle θ_H versus area ratio p.

For the case $|\phi_1$-$\phi_2|$>0, a new parameter is induced, homogenized azimuth angle ϕ_H. Figure 7 shows the effect of the case $|\phi_1$-$\phi_2|$>0 on the homogenized pretilt and azimuth angle (θ_H, ϕ_H). It can be seen that as $|\phi_1$-$\phi_2|$ becomes larger, the θ_H with the same area ratio will always get slightly higher. This phenomenon is due to the twist elastic energy. The θ_H has to increase, so that the elastic energy caused by the twist effect can be minimized. Furthermore, as the concentration of ROP-103 increase, ϕ_H will switch from ϕ_1 to ϕ_2.



(a)



(b)

Figure 7. Effect of $|\phi_1$-$\phi_2|$>0 on (a) θ_H and (b) ϕ_H.

The anchoring energy values of different θ_H are also measured by high voltage method [8], as shown is Figure 8. The average value is about 1.2 mJ/m^2. Such value is high and is similar to conventional polyimide.

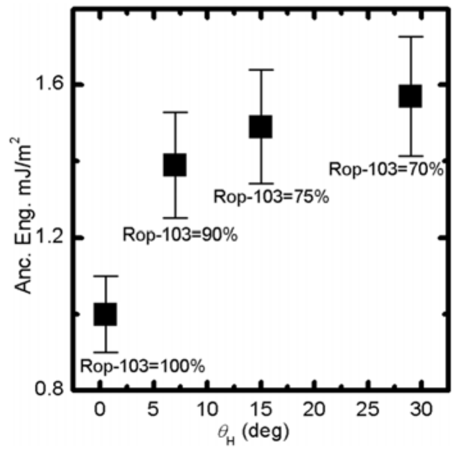
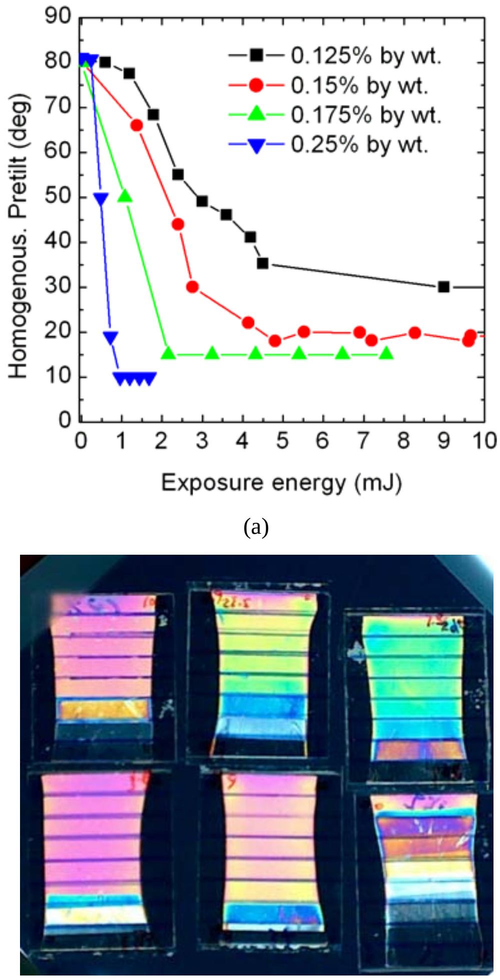


Figure 8. Anchoring energy of different θ_H.

In addition to the area ratio, the pretilt angle can be further controlled by applying different UV dosages to the ROP-103. The photo alignment polymer is partially polymerized by varying the UV dosage. Therefore, different pretilt angles can be obtained. The processing steps are exactly the same, except after the UV polymerization, solvent is used to rinse out the un-polymerized polymer. Figure 9(a) shows the measured pretilt angles versus different exposure energies with different concentrations of ROP-103. It can be seen that the resultant pretilt angles drop as the exposure energy increases. The reason is that as the exposure energy increases, more and more polymer gets polymerized and remains on the surface after rinse out. Hence, the area ratio of the homogeneous alignment layer to the homeotropic alignment layer increase, and the pretilt angle decreases accordingly. Moreover, the higher the concentration of ROP-103, the faster the decay rate. By this method, precise control the pretilt angle spatially is possible by controlling the exposure UV profile, as shown in Figure 9(b).



(a)

(b)

Figure 9. (a) Homogenized pretilt angle versus exposure energy (b) Sptially variable pretilt angles using different UV exposure intensity

4. Conclusion

We have demonstrated a new alignment surface that is capable of generating arbitrary pretilt and azimuth angle for liquid crystal. It is achieved by stacking two alignment materials. The processing window is maximized and the results are highly repeatable. Such alignment layer is particularly useful for large pretilt angles and multi-domain applications due to the use of photoalignment materials. Bistable displays, fast switching LC modes, switchable focal LC lenses, wide viewing angle displays and waveguide devices are examples of possible applications.

5. Acknowledgement

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6. References

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