Influence of UV Irradiance Strength on Polar Anchoring Properties of Photoalignment Polyimide Film

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ABSTRACT

The difference of polar anchoring properties such as anchoring energy and pretilt angle of liquid crystal cell under different UV irradiance strength in photoalignment process are presented. In this work, vertical alignment nematic liquid crystal cell with commercial photoalignment polyimide film is used.

1. INTRODUCTION

Liquid crystal (LC) alignment is the most important technique in LC devices (LCDs) industry [1,2]. Alignment quality influences the electro-optical properties of LCDs such as viewing angle, contrast ratio and image sticking. Lots of alignment techniques have been developed and claimed that those techniques are able to achieve uniform and reliable orientation of LC molecule. Among those technique, rubbing process is simple and low cost, and azimuthal and polar angles can be controlled by it. With those benefits above, rubbing process becomes the dominating alignment technique. Nevertheless, rubbing process still has lots of drawbacks for image quality and reliability of the LCDs like unevenness, electrostatic charges, impurities and mechanical damage of the surface.

To overcome these problems caused by the contact buffing process, several non-contact LC alignment approaches have been demonstrated, such as SiOx oblique evaporation [1,2,3,4], ion-beam bombardment [1,2,5], and photoalignment [1,2].

Photoalignment for producing LC alignment films has been studied for a long time [2], and it has been commercialized by Sharp in 2010 [6]. Photoalignment is a non-contact orientation technique which means no mechanical damage appearing. Furthermore, comparing photoalignment with rubbing process, the former can achieve finer orientation pattern. Although AFM (atomic force microscopy) probe nanoscale rubbing can also achieve [7], it's time-consuming and not practical for business use. With this property, photoalignment technique enables a pixel of LCD to be divided into several domains and improves the viewing angle. Sharp has successfully implemented photoalignment processes for fabricating large size LCD-TV panels, and they named it ultraviolet induced multi-domain vertically aligned (UV^2A) mode [6]. Although UV^2A has been developed for almost one decade, the influences of the irradiation energy of linear polarized UV light on anchoring properties were rare investigated in literatures. The mechanisms of the photoalignment can be clarified as: (i) photochemical dimerization or isomerization in polymers, (ii) photo-induced crosslinking in alignment materials and (iii) photodegradation in polyimide materials [1,2]. In this work, the polar anchoring properties such as pretilt angle and anchoring energy of commercial UV^2A photoalignment polyimide films were studied.

2. EXPERIMENT

There are mainly two parts in the experiment procedure. The first part is LC cell preparing, and the second part is polar anchoring property measurement. In the first part, the detail of LC cell manufacture process is presented. In the second part, the measurement methods of anchoring energy and pretilt angle, the high electric field method [8] and the crystal rotation method respectively, are presented.

2.1 LC Cell Preparing

As Fig. 1 shown. The commercial UV^2A photoalignment polyimide material was spin-coated on the ITO glass substrates to obtain a thin alignment film. The alignment mechanism is based on the photo-crosslinking in this work. Afterward, a prebaking at 70°C for 2 minutes and post baking at 200°C for 40 minutes, were applied to cure polyimide solution to form the alignment films. The films are then treated by a linear polarized UV light as shown in Fig. 1. The linear polarized UV light propagate along the x-axis with an angle about 40 degree. The illumination duration was changed from 5 to 17 seconds. To determine the anchoring properties of LC molecules on UV^2A photoalignment polyimide films, the antiparallel LC test cells were fabricated with LC molecules with negative dielectric anisotropy (Δn=0.096, $\Delta\varepsilon$= -2.8).

2.2 Polar Anchoring Property Measurement

The pretilt angle is attained by using the crystal rotation method. With the measurement of LC cell rotation angle dependent phase retardation, we can attain the pretilt angle by finding the angle with the maximum phase retardation, and the pretilt angle can be determined according to the theoretical model.

As for the anchoring energy, high electric field method is used. With the measurement of applied voltage dependent

phase retardation, we can attain the anchoring energy W (J/m^2) by simple linear fitting according to the following equation.

$$(\frac{R}{R_0}-1)(V-V") = \frac{2K_{33}}{Wd}(V-V")$$

$$V" = \frac{1}{\pi}\int_0^1 \frac{(1+\frac{\varepsilon_\perp-\varepsilon_\parallel}{\varepsilon_\parallel})(1+kx)}{x(1+\frac{\varepsilon_\perp-\varepsilon_\parallel}{\varepsilon_\parallel}x)}dx \cdot (1-\frac{\varepsilon_\parallel}{\varepsilon_\perp})V_{th}$$

R: Phase retardation

Ro: The maximum phase retardation

V: Applied voltage

d: Cell gap

K_{33}: bend elastic constants

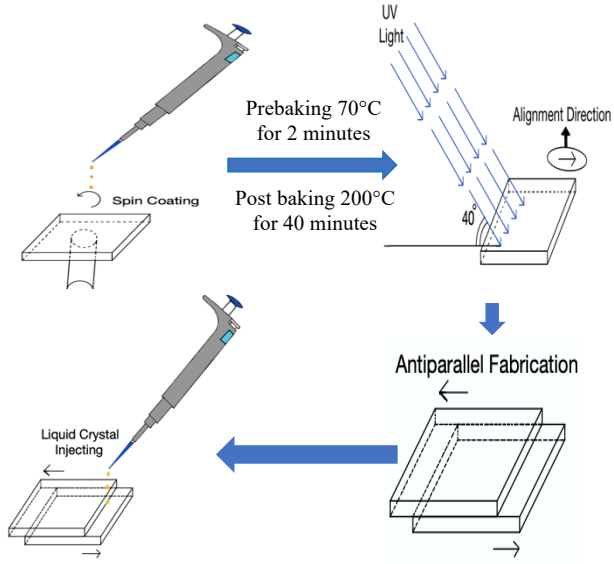

Fig. 1 Procedure of LC cell preparing.

3. RESULT and DISSCUSSION

The polar anchoring properties such as anchoring energy and pretilt angle under different process condition are presented. Whether it exists correlation between UV exposure time and polar anchoring property or not is examined. In order to enhance the reliability of the following result, systematic error is considered and error bar is provided on the result plot.

3.1 Pretilt Angle

With the measurement of the LC cell rotation angle dependent phase retardation (as Fig.2 shown), we can find the extremum by polynomial fit to the curve. The pretilt angle can be found according to the theoretical model.

Fig. 3 shows the pretilt angle under different UV exposure time on photoalignment polyimide. We can observe that the pretilt angle increases as the UV exposure time increases. Then the pretilt angle tend to saturation as the UV exposure time reach 14 seconds. Table. 1 shows the detail number of the result including the standard deviation, and it shows that the pretilt angle ranges from $89.57^o \pm 0.05$ to $89.97^o \pm 0.01$ as the UV exposure time changes from 5 to 17 seconds.

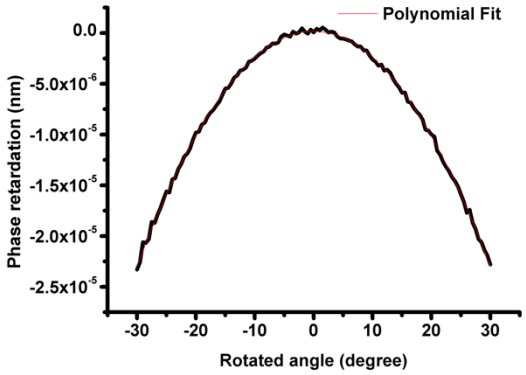

Fig. 2 Rotation angle dependent phase retardation.

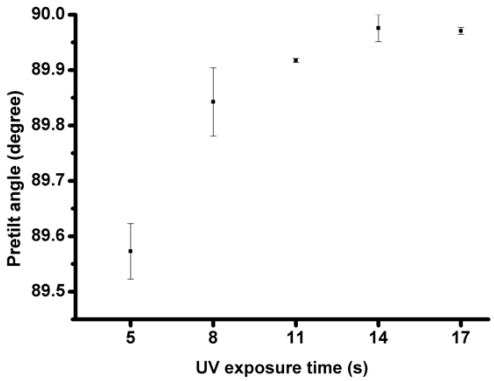

Fig. 3 Pretilt angle under different UV exposure time.

Table. 1 Pretilt angle under different UV exposure time.

UV exposure time (s)	Pretilt angle (degree)	Standard deviation
5	89.57	0.05
8	89.84	0.06
11	89.92	0.004
14	89.98	0.02
17	89.97	0.01

3.2 Anchoring Energy

As finish the measurement of the applied voltage dependent phase retardation (as Fig. 4 shown), we need to do formula conversion according to the equation mentioned in **2. EXPERIMENT**. After doing formula conversion, we can achieve another curve plot as Fig. 5 shown. With linear fit to the curve of Fig. 5, we can achieve anchoring energy according to theoretical model [8].

Fig. 6 shows the anchoring energy under different UV exposure time on photoalignment polyimide. We can observe that the anchoring energy increases as the UV exposure time exceeds 8 seconds. As the UV exposure time exceeds 11 seconds, the anchoring property seems to be saturation by the reason of the overlapping of the error bar. Table. 2 shows the

detail number of anchoring energy under different UV exposure time including the standard deviation, and it shows that the anchoring energy ranges from $(5.46 \pm 0.66) \times 10^{-5}$ to $(7.78 \pm 0.4) \times 10^{-5}$.

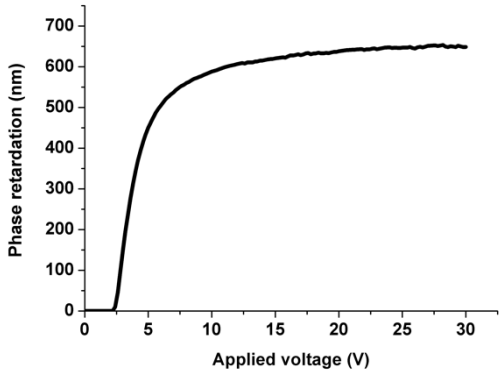

Fig. 4 Voltage dependent phase retardation.

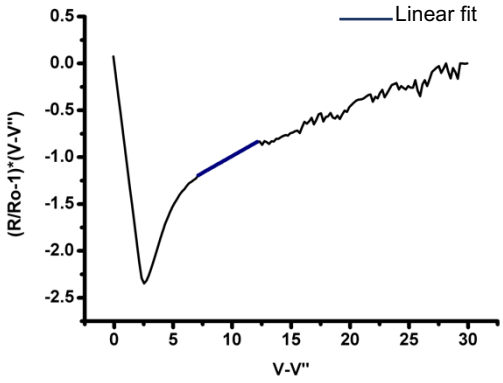

Fig. 5 Illustration of linear fit according to theoretical model.

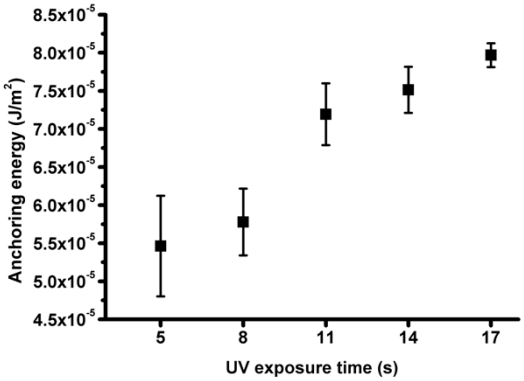

Fig. 6 Anchoring energy under different UV exposure time.

Table. 2 Anchoring energy under different UV exposure time.

UV exposure time (s)	Anchoring energy (J/m^2)	Standard deviation
5	5.46E-05	6.61E-06
8	5.78E-05	4.39E-06
11	7.19E-05	4.06E-06
14	7.51E-05	3.03E-06
17	7.78E-05	4.02E-06

4. CONCLUSION

In this work, we study the anchoring properties such as pretilt angle and anchoring energy of commercial photoalignment polyimide films under different UV exposure time. With the increase of UV exposure time, we observe that the pretilt angle and anchoring energy also increase. However, the increase amplitude seems to be little. The pretilt angle still remains in the range from 89^o to 90^o. As for the polar anchoring energy, it only changes in one-decade range.

Photoalignment is a trendy technique, especially for very fine alignment such as multi-domain process. In order to enhance the reliability of LCDs, stronger surface anchoring is required [7]. This issue is still the future work of us.

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