Polar Anchoring Properties of Photoalignment Polyimide Films

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Abstract

The polar anchoring properties, such as pretilt angle and anchoring energy, of commercial photoalignment polyimide films were studied in the vertical alignment nematic liquid crystal cells. The influences of the irradiation energy of linear polarized UV light on anchoring properties were investigated. The polar anchoring energy is ~5x10^{-5} J/m^2, and the pretilt angle is around 89.5º.

1. Introduction

Liquid crystal (LC) alignment is the most important process for LC devices (LCDs) [1,2]. The alignment properties produce great influences on the electro-optical properties of LCDs, such as viewing angle, contrast ratio, response time, and image sticking. There are many techniques having been developed for LC alignment to provide a uniform and reliable orientation of LC molecules on alignment films. Rubbing process using a roller with a cloth on polyimide films is still the dominant alignment process in LCDs industry, although it has been proposed for a long time since Mauguin reported this approach to align LC molecules 100 years ago [3]. The rubbed polyimide films can then controls both the azimuthal and polar angles of the LC alignment. Although the rubbing process is simple and low cost, it still has many drawbacks for the image quality and reliability of the LCDs, such as 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 [1,2,4,5], ion-beam bombardment [1,2,6], 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 [7]. The photoalignment is a non-contact process and it also 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^{2}A) mode [7]. Although UV^{2}A 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^{2}A photoalignment polyimide films were studied.

2. Experimental Procedures

The commercial UV^{2}A 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 UV light source, propagating along the x-axis with an angle about 40 degree. The illumination duration was changed from 2 to 17 seconds. To determine the anchoring properties of LC molecules on UV^{2}A photoalignment polyimide films, the antiparallel LC test cells were fabricated with LC molecules with negative dielectric anisotropy (Δ n=0.096, $\Delta\varepsilon$ = -2.8). The electro-optical properties of the LC cells were evaluated by means of the polarizing optical microscope (POM) and phase retardation-voltage (PV) measurements. The pretilt angles of LC cells were measured by the crystal rotation method. The polar anchoring energy (PAE) of the UV^{2}A alignment films was measured by using the high electric field method [8].

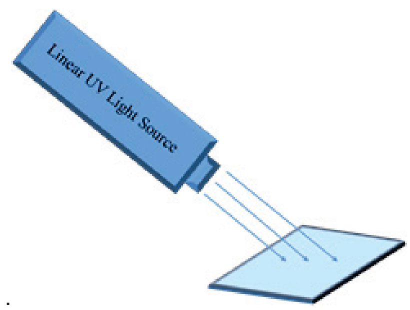

Fig. 1. The experimental setup for UV2A process.

3. Results and discussion

The POM photos of UV²A LC cells under UV treatment of 2, 4 and 8 seconds operated at bright state are shown in Fig. 2(a), 2(b) and 2(c), respectively. It was observed that the LC cell with 8 seconds UV exposure time exhibit a good unidirectional alignment.

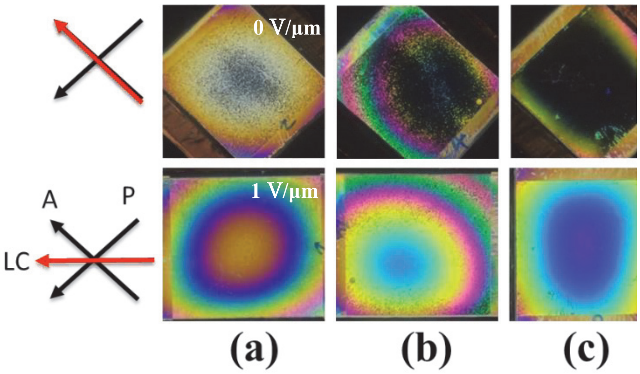

Fig. 2 The POM photos of UV²A LC cells under UV treatment of (a) 2, (b) 4 and (c) 8 seconds.

In order to know the influence of irradiation energy on UV²A alignment films, we increase the UV exposure time from 11 to 17 seconds as shown in Fig. 3. It also shows a good alignment for larger UV exposure energy.

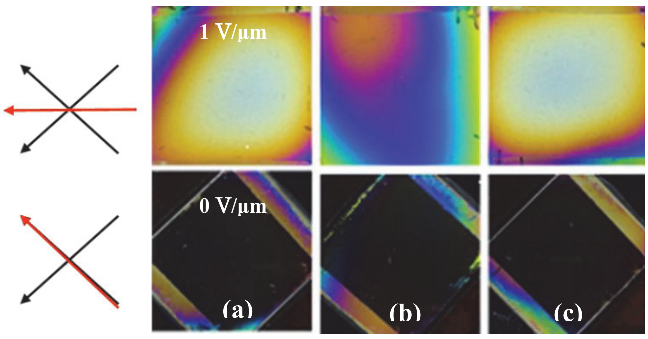

Fig. 3 The POM photos of UV²A LC cells under UV exposure of (a) 11, (b) 14 and (c) 17 sec.

A typical result of rotation angle dependent phase retardation of UV²A LC is shown in Fig 4. By finding the angle with the maximum phase retardation, we can determine the pretilt angle according the theoretical model, and the pretilt angle is calculated as 89.5°. A typical result of voltage dependent phase retardation of UV²A LC cell is shown in Fig. 5. According to the theoretical model [8], one can determine the anchoring energy W from a simple linear fit of Fig. 6 by the equation:

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

where R is the phase retardation, V is the applied voltage, and d is the cell gap. K is the splay constant, and

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

The anchoring energy can then be calculated as ~5.0 x 10^{-5} J/m² according to the Fig. 6.

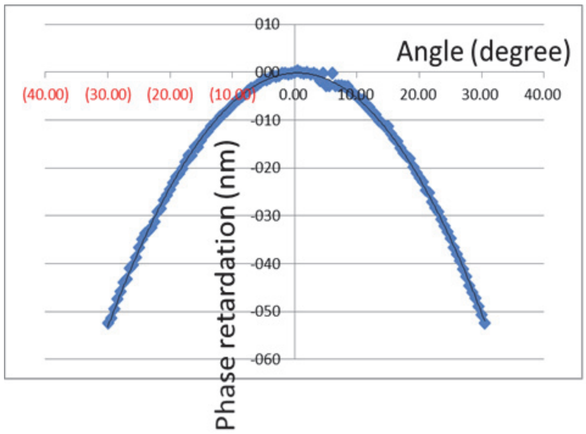

Fig. 4. The results of rotation angle dependent phase retardation of UV²A LC cell.

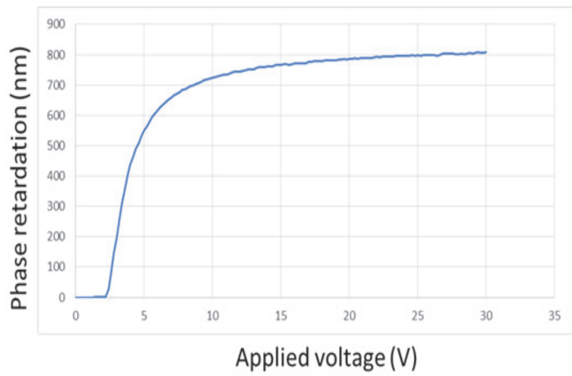

Fig. 5. The results of voltage dependent phase retardation dependent of UV²A LC cell.

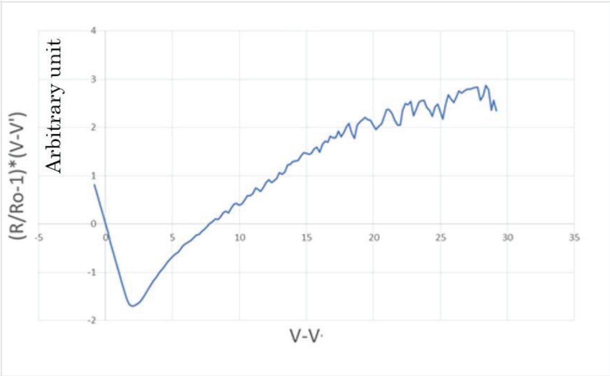

Fig. 6. R(V-V”) vs (V-V”) for the UV^{2}A LC cell.

The polar anchoring properties, anchoring energy and pretilt angle, for different exposure UV time are summarized in Table 1, and it shows the anchoring properties do not change with UV energy as long as the required UV exposure time is larger than 8 seconds. Whether the UV exposure energy produces influences on impurity charge of UV^{2}A alignment films will be studied in the near future.

Table 1: The polar anchoring properties for different UV exposure time

Exposure time (s)	8	11	14	17
Anchoring energy (10^{-5}J/m^2)	3.7	5.6	3.6	6.2
pretilt angle (degree)	89.5	89.9	89.9	89.8

4. Conclusions

In this paper, we studied the polar anchoring properties, including pretilt angle and anchoring energy, of commercial photoalignment polyimide films under different UV exposure time. It shows the anchoring properties do not change with UV energy as long as the required UV exposure time is larger than 8 seconds. The polar anchoring energy is ~5x10-5 J/m^2, and the pretilt angle is around 89.5^o for the UV^{2}A alignment film.

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