New Cellulose-Based Photopolymer with High Thermal and UV Stability

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Abstract

We report on the alignment properties of new cellulose based photopolymer. The LC alignment quality and image sticking property of the TN and IPS cells made by using the photopolymer were investigated. Thermal and UV stability of those properties were also investigated. Excellent LC alignment quality and stability were obtained particularly in IPS mode.

1. Introduction

Operation of liquid crystal (LC) devices requires uniform stability of the LC director on aligning surfaces. Recently, as the mother glass size of TFT-LCD production line became very large, Photoalignment technology, one of the non-contact methods, has been the subject of extensive research since the principle was reported [1~2]. The photoalignment method however is not yet applied to TFT-LCD manufacturing line mainly due to image sticking problem.

We have developed several cellulose based photopolymers and reported on the photoaligning properties [3-5]. Those photopolymers show high photo-sensitive reaction and good LC alignment properties. Some of the photopolymers showed the insufficient thermal stability in LC aligning property. We synthesized new cellulose based photopolymer modified from the previous photopolymers to improve the thermal stability of LC aligning properties. This new material has twice as much cinamoyl group in reactive functional group as previous photopolymers. In this paper, we report on the thermal and UV stability of new photopolymer investigated in TN and IPS LC cells.

2. Experimental

Photoaligning films were produced by spin-coating of the solution over glass substrates covered with ITO. The films were illuminated by UV light of a high pressure Hg-lamp. Homogeneous UV-light field was formed in the plane of the polymer film by a quartz condenser and a polarizing Glan-Thomson prism. Intensity of light in the plane of the substrate was about I = 20mW/cm^2. The exposure energy was in the range of 15~1800 mJ.

The macroscopic properties of the alignment were examined in a symmetric cells made from two identical substrates covered with the PG1(photopolymer1). The cells were filled by LC, MLC-6204-000 for the TN mode and the IPS mode in a nematic phase. The cell thickness was set in the range of 5μm and 50μm, depending on the experiment.

3. Results and discussion

To characterize thermal stability of the LC alignment, the cell was heated for 4 hours at 100℃ and then we put the LC cell between crossed polarizers and adjusted the cell position to get a minimal transparency of a probe laser beam (we used He-Ne laser, = 633nm). In this case the average direction of the director in a planar cell was parallel to the polarizer axis. In this geometry we measured the intensity of the probe beam behind analyzer, $I_{\perp}$. Then we rotated the analyzer for 90° and measured again the intensity of the probe beam, I_{II}, behind the analyzer. The ratio $\alpha = (I_{II} - I_{\perp})/(I_{II} + I_{\perp})$, which we call as aligning quality parameter, is equal to zero in the case of macroscopically random alignment and α = 1 when the director is oriented unidirectionally. To characterize UV stability of the LC alignment, the cell was irradiated by un-polarized UV light with energy of 72J/cm^2.

The cell rubbed Anti-parallel and has the cell gap of 50um. The thermal and UV stability result of this cell is shown in Figure 1.

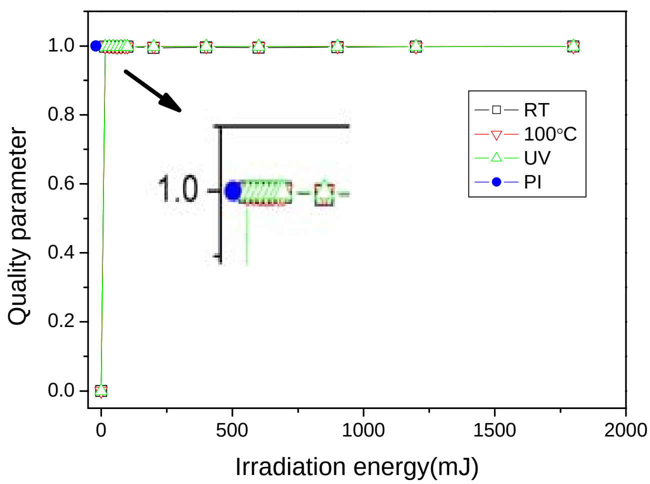

Figure 1. Thermal and UV stabilities of the aligning quality parameter.

The aligning quality parameter α for rubbed polyimide is also marked as close circle in the Figure 1. One can see that at $t_{exp}\approx$ 5 sec. (irradiation dose, D = It_{exp} = 15 mJ/cm^2) the α≈ 0.99 almost coincided with the aligning quality parameter of rubbed polyimide. We believe that the enhanced photosensitivity of PG1 is caused by presence of the additional double C=C bonds in the photosensitive side fragments of these polymers.

We found that the aligning quality of the PG1 has thermal and UV stability.

To estimate the azimuthal anchoring energy of the PG1, we used the reference cell technique [3]. The reference cell (thickness, L = 20 μm) made from rubbed Polyimide cell with strong planar anchoring for the LC. The substrate was covered with the new photopolymer. The angle between rubbing directions on the reference was φ_{ref} = 45°. We used a nematic mixture ZLI 4801-000 from Merck (optical anisotropy $\Delta n = n_e - n_o$ = 0.09, the dielectric anisotropy $\Delta\varepsilon$ = 5.1, T_c = 91℃). Our experimental conditions provided an adiabatic regime (Maugine regime) of propagation of light through the cell; the polarization of the test beam follows the director in the cell. This allows the orientation of the director to be determined on the surface using a polarizing microscope. The cell was set in the microscope so that the tested surface nearest the polarizer, and the direction of rubbing was parallel to the polarizer axis. The analyzer was rotated to obtain the minimum output in light intensity. In this position the angle between analyzer and polarizer axes corresponded to the twist angle, φ_{test}, between the director on the reference and tested surfaces. This angle is connected with the value of the azimuthal anchoring energy on the tested surface by the formula:

$$W_a = \frac{K_{22}}{L}\frac{2\sin\varphi_{test}}{\sin 2(\varphi_{ref}-\varphi_{test})},$$

where K_{22} is the twist elastic constant.

The numerical solution to this equation for W_a at the experimental data $\varphi_{test}(t_{exp})$ and parameters K_{22}=4.5X10^{-12} N; L =20 μm is shown in Figure 2 as a function of the exposure time, t_{exp}. One can see that PG1 demonstrates high photosensitivity and rather strong anchoring; the maximum anchoring energy W_a > 10^{-2} erg cm^{-2} is obtained in case of the UV exposure for longer than 60 secs. Figure 2 shows the PG1 has high thermal and UV stabilities for anchoring energy.

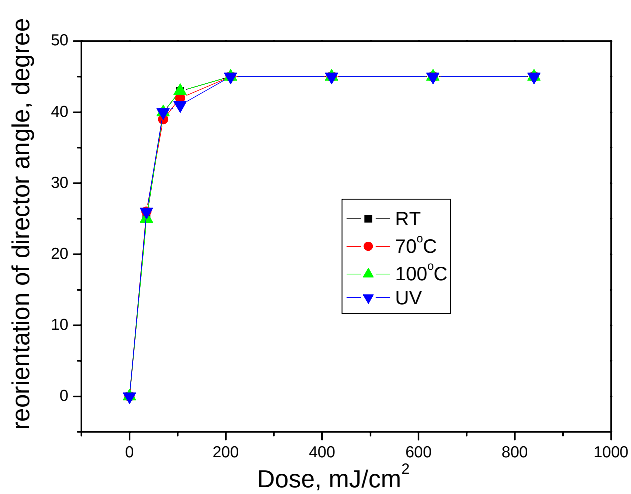

Figure 2. Thermal and UV stabilities of anchoring energy on exposure.

It is known that the image sticking effect prevents a wide application of photoaligning materials [6]. To study the sticking effect of PG1 material, we used the

90° twist-nematic(TN mode) cells and IPS(in-plane switching mode) with the photoaligning layers and MLC 6024-000. The UV exposure technique for the PG1 material was applied; t_{exp} = 60s at the UV light intensity 20mW/cm^2. We measured image sticking parameter used for BM-7 on the applied voltage at the voltage frequency ν = 1 kHz. The measurements were carried out in four times. We measured first V-T curve and short for 2 sec and second V-T curve and third V-T curve and then the applied electric field (TN; 5V, IPS; 15V, frequency; 1 kHz) for 60min. The forth V-T curve also was measured after 15min shortage. The relative difference between 3rd and 4th V-T curves, $S_0(V) = \left(\frac{\Delta T}{T_{max}}\right) \times 100\%$ is due to a sticking effect. Maximum value, S_o is the value of the sticking parameter. As the PG1 cell was comparable with the polyimide standard cell, we can estimate image sticking problem of PG1.

In Figure 3, We can see that the sticking parameter $S_o \approx$ 0.2~0.255 % on the TN mode. The value of the sticking parameter for the PG1 material is close to the standard value, $S_o \approx$ 0.217 % of the rubbed polyimide TN cell. We found that the thermal and UV stabilities of the PG1 TN are comparable with those of the rubbed polyimide TN cell.

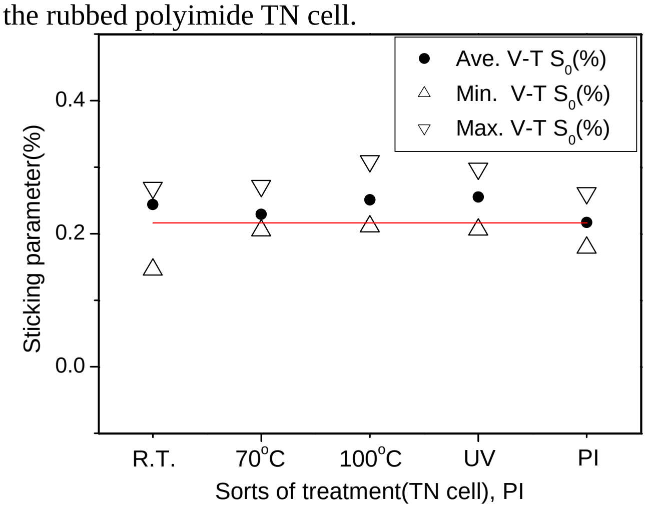

Figure 3. Sticking parameters of TN cell after 70, 100℃ treatment for 4 hour and UV treatment at 365nm for 1hour.

Figure 4 shows the results of the sticking parameter $S_o \approx$ 0.27~0.381 % in IPS cell. The value of the PG1 sticking parameters is close to the standard values $S_o \approx$ 0.249 % of the rubbed polyimide IPS cell. The thermal and UV stabilities of the IPS cell using PG1 are comparable with rubbed polyimide IPS cell.

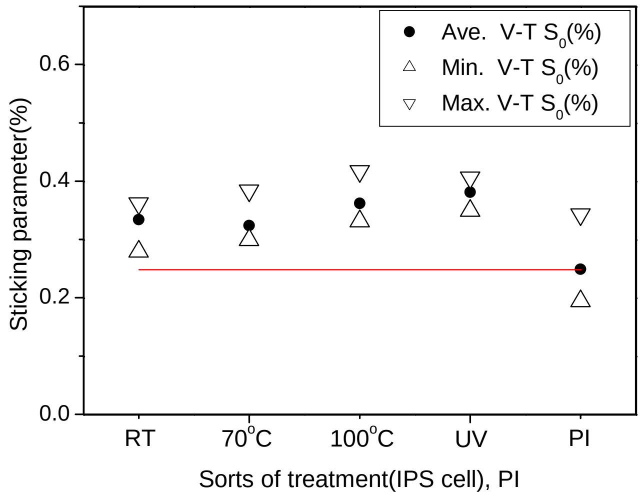

Figure 4. Sticking parameters of IPS cell after 70, 100° C treatment for 4 hour and UV treatment at 365nm for 1 hour.

To evaluate the overall image sticking effect of the cells, we used capacitance-voltage hysteresis method.

This method used LCR meter to measure capacitance according to voltage at the voltage frequency; 1 kHz. This method measured the total two C-V curves. We obtained first C-V curve and applied electric field (TN; 5V, IPS; 15V, frequency; 1 kHz) for 60min and shorted for 15min and then measured again second C-V curve. The difference between 1st and 2nd C-V curves calculates by this formula; $S_0(V) = \left|\left(\frac{C_2 - C_1}{C_2}\right)\right| \times 100(\%)$.

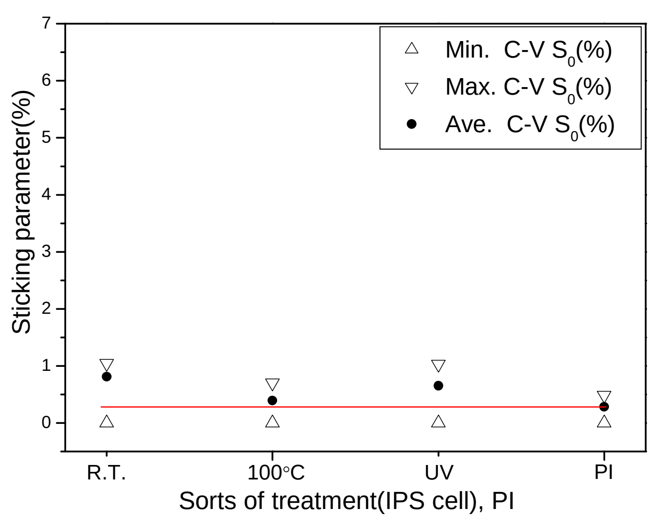

Figure 5. Sticking parameters of IPS cell after 100℃ treatment for 4 hour and UV treatment at 365nm for 1hour.

Figure 5 shows the results of the sticking parameter S_o

≈ 0.39 ~ 1.04 % in IPS cell. The sticking parameters of the PG1 is close to the standard value S_o ≈ 0.285 % of rubbed polyimide IPS cell.

It implies that the thermal and UV stabilities of the IPS cells made by using PG1 are comparable with the IPS cell made by rubbed Polyimide.

4. Summary

PG1 showed that the highly thermal and UV stable photoaligning properties including high anchoring and low image sticking properties, which are comparable with those of rubbed PI property. These results imply that new photopolymer can be a promising candidate for the TN and IPS mode LCD fabrication using photoalignment technique.

5. References

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