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Pretilt angle generation by UV exposure during imidization of polyimide

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Pretilt angle generation by UV exposure during imidization of polyimide

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We investigated pretilt angle generation and liquid crystal (LC) alignment by ultraviolet exposure during the imidization of polyimide (PI). The generated pretilt angle of a nematic (N) LC using an *in situ* photo-alignment method is smaller than that using a conventional photo-alignment method on a surface of PI having side chains. The NLC pretilt angles using an *in situ* photo-alignment method injected at isotropic phase increased with annealing were observed.

1. Introduction

Nowadays, information display technologies are developed with the increasing growth in information communication. Among them, liquid crystal displays (LCDs) have many advantages such as flatness, portability, lower power consumption, and high resolution. It is required to have uniform alignment of LC molecules on surfaces and to control a stable pretilt angle in order to realize these LCDs. The nematic LC NLC pretilt angle plays an important role in preventing reverse-tilted disclinations in TN (twisted nematic)-LCDs.

Recently, the LC aligning capability of photo methods such as photo-dissociation [1–11], photo-dimerization [12, 13], and photo-isomerization [14] have been investigated. Utilizing the photo-dissociation reaction, a fraction of molecules oriented in a specific direction on a polymer surface such as polyimide (PI) are split with either linearly polarized or unpolarized UV light. Kim *et al.* [15] reported that LC molecules were aligned uniformly by an *in situ* photo-alignment method, which produces higher thermal stability of LC alignment, compared with conventional photo-alignment methods. However, the generation of pretilt angle using *in situ* photo alignment has not yet been reported. In this study, we report on the LC aligning capabilities and pretilt angle generation for NLC using an *in situ* photo-alignment method on polymer surfaces having side chains.

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2. Experimental

In this experiment, side-chain polymers (AL-3046, Japan Synthetic Rubber Co. Ltd) were used. The polymer was prepared uniformly by spin-coating on ITO electrodes. The polymer used in a conventional UV photo-alignment method was baked at 180°C, while the polymer for *in situ* UV photo-alignment was soft baked at 80°C for 30 min. The PI layer thickness was 500 Å. The UV exposure system is shown in figure 1. Oblique UV light with a wavelength of 365 nm was incident on the polymer surfaces. The cell then fabricated was of the sandwich type, of LC thickness 60 μm. The NLC mixture (T_c = 87°C) was injected in both the nematic and isotropic phases respectively. The LC aligning capabilities were characterized by observation of photomicrographs and measurement of the pretilt angle, determined by the crystal rotation method at room temperature.

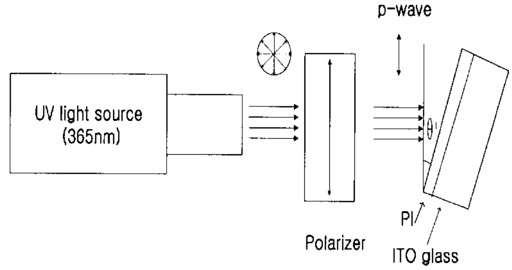

Figure 1. UV exposure system.

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3. Results and discussion

Figure 2 shows NLC pretilt angles formed by UV exposure of a PI surface as a function of angle of incidence. The pretilt angle maximum was observed at an angle of incidence of 30°. It was also observed that the generated NLC pretilt angle using the conventional photo-alignment method was larger than that using the *in situ* method. In the conventional photo-alignment method, the PI surface was exposed to UV after imidization of the PI; the photo-dissociation reaction was more complete and this produces the high pretilt angle.

Figure 3 shows the NLC pretilt angles obtained by UV exposure of a PI surface as a function of exposure time. Using the conventional photo-alignment method, the pretilt angle increased with increasing exposure time until 20 min, at which time the peak value was observed. Beyond 20 min exposure, the pretilt angle tended to decrease. These results coincide well with previous results [4, 11]. We propose that the energy density of incident UV for 20 min is adequate to generate high pretilt angles. On the other hand, NLC pretilt angle generated by the *in situ* photo-alignment method had a tendency to increase linearly with increased exposure time. Thus it seems that high NLC pretilt angle could be obtained by increasing the exposure time. From these results, it can be seen that the conventional photo-alignment method was more reliable than the *in situ* method in generating high pretilt angles during a short exposure time.

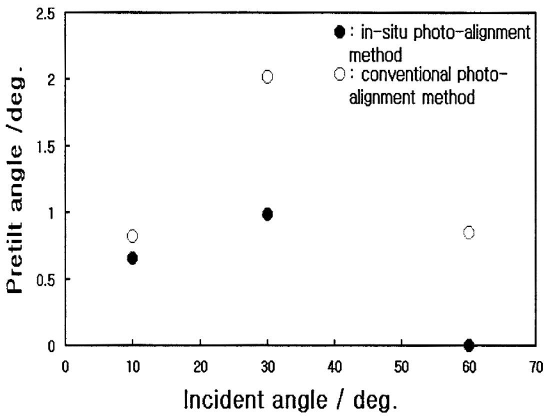

Figure 2. NLC pretilt angles obtained by UV exposure of a PI surface as a function of angle of incidence.

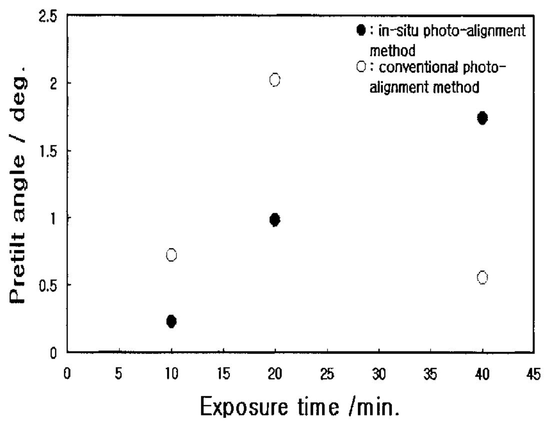

Figure 3. NLC pretilt angles obtained by UV exposure of a PI surface as a function of exposure time.

Figure 4 shows the NLC pretilt angles obtained by UV exposure of a PI surface as a function of annealing time. In the nematic phase after injection, the pretilt angle was improved by annealing as shown in figure 4 (*a*). The pretilt angle may increase because of re-alignment of residual polymers through annealing. In the nematic phase, with no annealing after injection in the isotropic phase, the pretilt angle was 0° as shown in figure 4 (*b*); it then increased with annealing time. Thus the annealing effect on pretilt angle can be attributed to LC alignment by the photo-dissociation reaction.

Photomicrographs of aligned NLC using the *in situ* photo-alignment method are shown in figure 5. With no annealing, a large reverse tilt disclination for the NLC was generated as shown in figure 5 (*a*). However, with annealing for 60 min, the LC molecules were uniformly aligned as shown in figure 5 (*b*).

Figure 6 (*a*) shows photomicrographs of aligned NLC, injected into the cell in the isotropic phase and treated by the *in situ* photo-alignment method. In this case, a small reverse tilt disclination appeared with no annealing. However, as shown in figure 6 (*b*), there was uniform LC alignment after annealing for 60 min. From figures 5 and 6 we see that, in using the *in situ* photo-alignment method, annealing is useful in avoiding reverse tilt disclinations. The LC alignment using the *in situ* photo-alignment method coincides well with previous results [15].

4. Conclusion

We have investigated pretilt angle generation and LC alignment effects caued by UV exposure during the imidization of PI. The generated NLC pretilt angle using an *in situ* photo-alignment method was smaller than that using the conventional photo-alignment method. Also, NLC pretilt angles using the *in situ* photo-alignment method with injection in the isotropic phase, increased with annealing.

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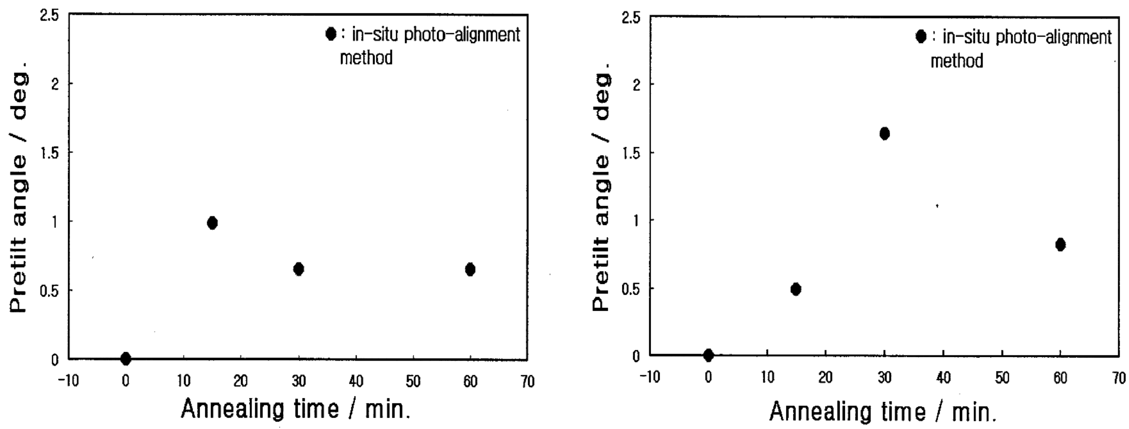
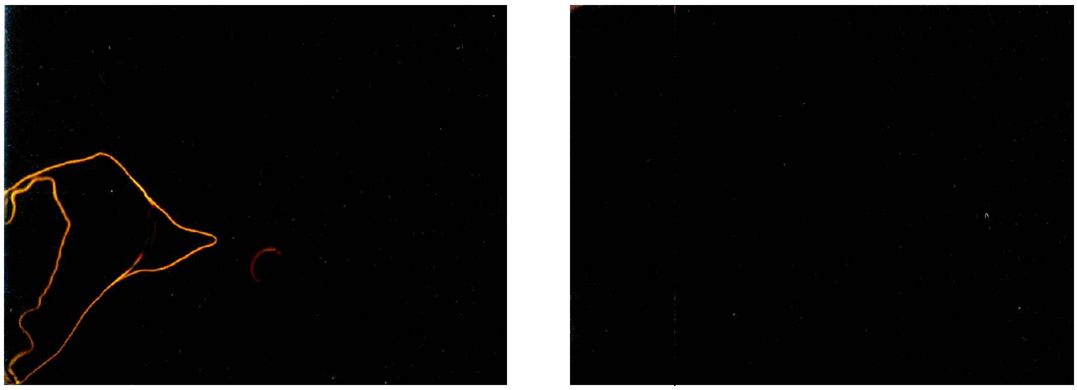


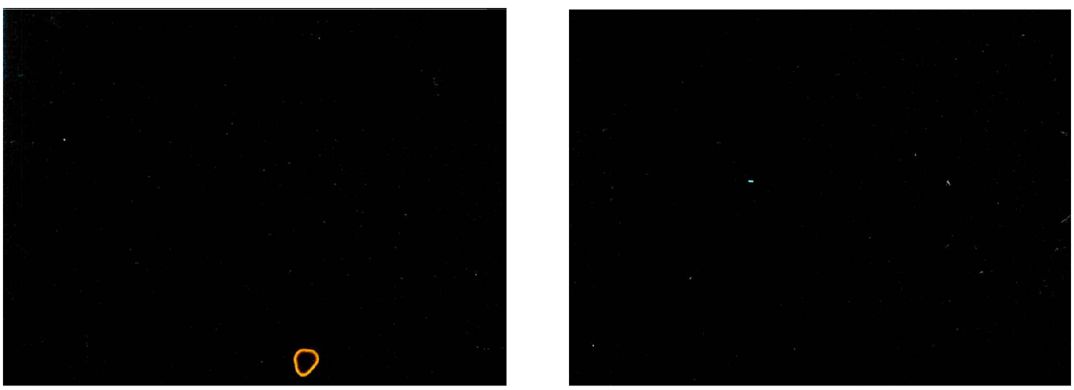
(*a*) (*b*)

Figure 4. NLC pretilt angles obtained by UV exposure on a PI surface as a function of annealing time. (*a*) Nematic phase injection; (*b*) isotropic phase injection.



(*a*) (*b*)

Figure 5. Photomicrographs of aligned NLC by the *in situ* photo-alignment method injected in the nematic phase. (*a*) No annealing; (*b*) 60 min annealing.



(*a*) (*b*)

Figure 6. Photomicrographs of NLC aligned by the *in situ* photo-alignment method after injection in the isotropic phase. (*a*) No annealing; (*b*) 60 min annealing.

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