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In this study, we have investigated the generation of pretilt angle in nematic liquid crystal (NLC) in the cell with oblique non-polarized ultraviolet (UV) light irradiation on two kinds of the polyimide (PI) surfaces. It was found that the monodomain alignment in NLC is obtained having a PI surface without side chain. We successfully observed that the generated pretilt angle of the NLC is about 3° with an angle of incidence of 70° on the PI surface without side chain. It is considered that the pretilt angle generation in NLC is attributed to the interaction between the LC molecules and the polymer surfaces due to photo-depolymerization reaction. Also, the uniform alignment of NLC is attributed to anisotropic dispersion force due to photo-depolymerization of polymer on PI surfaces.

Keywords: nematic liquid crystal; polyimide; ultraviolet; pretilt angle; photo-depolymerization; LC alignment

INTRODUCTION

Liquid crystal displays (LCDs) dominate the flat panel displays. The successful operation of LCDs requires uniform alignment and controlled pretilt of LCs on substrate surfaces. Most LCDs with pretilted homogeneous LC alignment are prepared using rubbed PI surfaces. The leading technology for LCD is based on twisted nematic (TN)-LCDs [1]. The pretilt angle prevents creation of reverse tilted disclinations in TN-LCD. The pretilt angle is also important in order to avoid stripe domains in super (S) TN-LCD [2]. The generation of pretilt angle in NLC on various alignment layers by unidirectional rubbing has been demonstrated and discussed by many investigators [3-7]. Rubbed polymer surfaces have been widely used for aligning LC molecules. Recently, rubbingless techniques for LC alignment are needed in thin-film-transistor (TFT)-LCD fabrication. In a previous paper, we reported that the TFTs are damaged by the induced static electricity produced during rubbing [8]. The photo-alignment method for LC alignment is expected to achieve the high resolution LCDs; Gibbons et al. have reported the new method for LC alignment by using polarized laser light [9]. It was shown that NLCs in an illuminated region be oriented perpendicular to the direction of the electric-field polarization of the laser and remain aligned the absence of the laser radiation. Also, the pretilt angle on Langmuir-Blodgett film has been controlled by regulation of the fraction of trans-azobenzene units using light wavelength tuning [10].

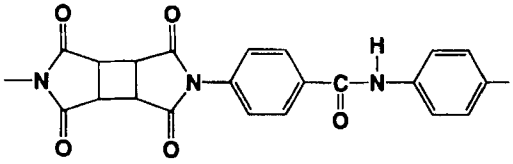
More recently, the LC alignment with polarized UV light irradiation poly(vinyl)cinnamate surfaces has been reported by some researchers [11-13]. The photo-polymerization reaction of a photo-polymer with polarized UV light irradiation has been shown to induce uniaxial orientation of NLCs on poly(vinyl)cinnamate surfaces. Also, recently the LC alignment by polarized UV light irradiation on PI surface has been reported by some researchers [14-16]. That the photo-depolymerization of PI main chains parallel to the electric field of deep polarized UV light (257nm) caused anisotropic dispersion force is discussed [14]. Finally,

recently Yamamoto et al. have reported the LC alignment in a cell with oblique irradiation of non-polarized UV light on PI surface [17]. The generated pretilt angle of NLC is about 0.8° on PI surface with side chains. However, this pretilt is not enough to avoid reverse tilted disclination in a TN-LCD. Most recently, we reported the pretilt angle generation in NLC with oblique non-polarized UV light irradiation on PI surface: it is successfully observed to about 3° [18]. The detailed mechanism of LC alignment by photo-alignment method has not been understood yet.

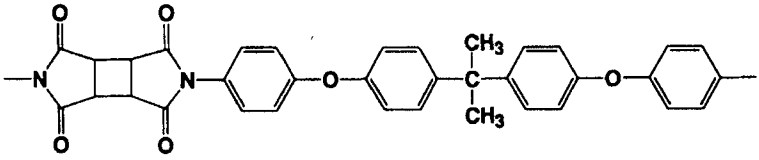
In this study, we report the monodomain alignment and pretilt angle generation in NLC with oblique non-polarized UV light irradiation on two kinds of the PI surfaces.

EXPERIMENTAL

In this experiment, we used two kinds of the PI materials. Figure 1 shows the chemical structure of two kinds of the PI materials. The PI films were coated on indium-tin-oxide (ITO) coated glass substrates by spin-coating, and were imidized at 250℃ for 1 hr. The thickness of PI layers was about 500 Å. The oblique non-polarized UV light (power : 1kW) irradiation system is shown in Figure 2. The substrates were irradiated for 3 hr using UV light at a wavelength of 365nm. The distance of UV light on PI surface was 300㎜ from UV light source. The LC was assembled in sandwich-type cells with antiparallel-UV irradiation direction. All the sandwich-type cells had LC layer thickness of 60㎛. After assembly, the cells were filled with NLC (ZLI-4792 : supplied from Merck Japan Co., Ltd.) in the isotropic phase. The LC orientation capability was evaluated by optical microscopic textures and generation of pretilt angles. To measure pretilt angles, we used the crystal rotation method and measurements were done at room temperature. Next, we observed the structure of surface morphology of the PI surface by using atomic force microscope (AFM). Also, we measured the induced optical retardation of the PI surface.



(a) PI-A



(b) PI-B

FIGURE 1 The chemical structure of two kinds of the PI materials.

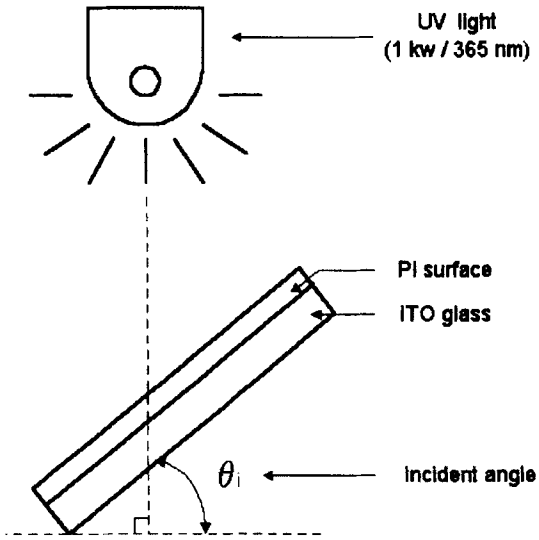


FIGURE 2 The used oblique non-polarized UV light irradiation system.

RESULTS and DISCUSSION

Figure 3 shows the AFM images on two kinds of the unrubbed PI surface. It is shown that the surface morphology on PI-A surface is smooth compared to PI-B surface. The AFM images on two kinds of the rubbed PI surface is shown in Fig. 4. It is shown that the structure of micro-groove is clearly observed along the rubbing direction on two kinds of the rubbed PI surface for medium RS (RS=262mm) ; it is similar to the results of previous work [19,20]. Figure 5 shows the AFM images with oblique non-polarized UV light irradiation of 70° on two kinds of the PI surface. It is shown that the micro-groove structure has not been formed with oblique non-polarized UV light irradiation on PI surface.

Next, we measured that the induced optical retardation is about 0.05 deg. with oblique non-polarized UV light irradiation on PI-A surface. In a previous paper, we reported that the induced optical retardation is about 0.3 deg. on rubbed PI-A surface[5]. It is considered that the induced optical retardation is low compared to rubbed PI surface; because the oblique non-polarized UV irradiation on PI surface is attributed to photo-depolymerization of polymer. Therefore, we suggest that the induced optical retardation with non-polarized UV light irradiation on PI surface strongly affected to LC alignment.

Figure 6 shows the microphotographs of aligned NLC in the cell with oblique non-polarized UV light irradiation on two kinds of PI surfaces (under crossed Nicols). It can be seen that the monodomain alignment of NLC is observed with oblique non-polarized UV light irradiation on PI-A surface without side chain. However, the reverse tilt disclination is observed with oblique non-polarized UV light irradiation on PI-B surface with side chain. Also, we estimated that the aligned NLC is parallel to the incident direction of UV irradiation. Therefore, we consider that the NLC are aligned due to photo-depolymerization of the polymer with oblique non-polarized UV irradiation on PI surfaces.

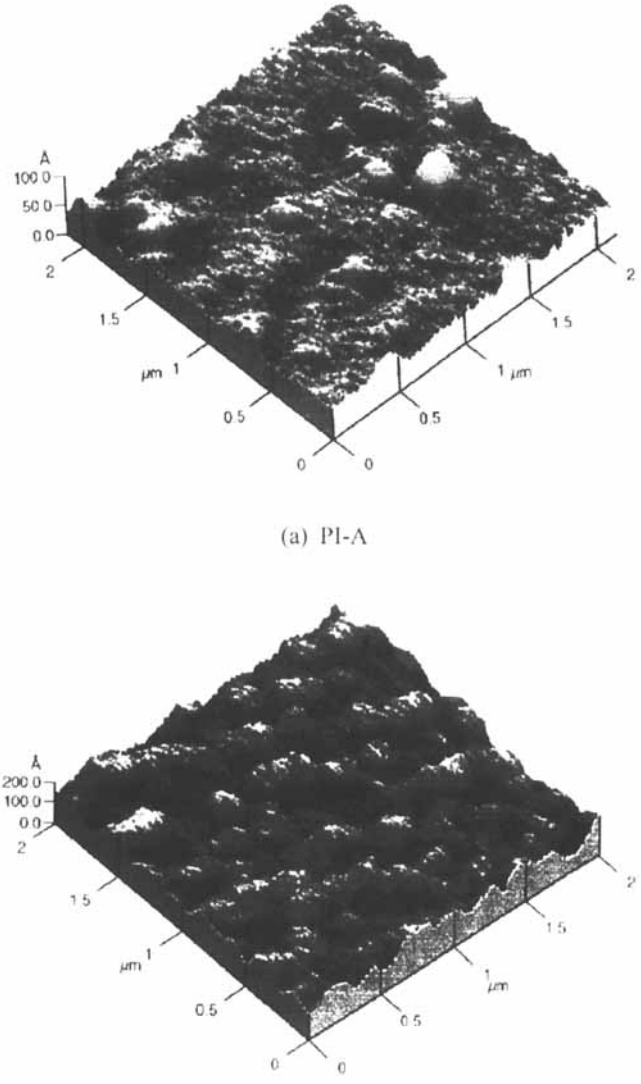
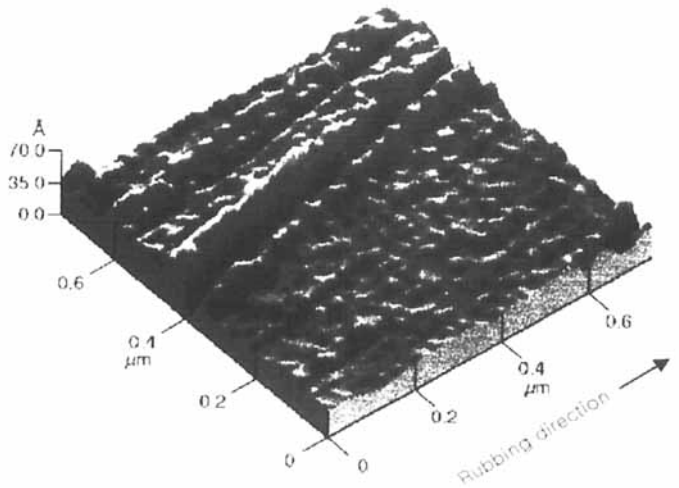
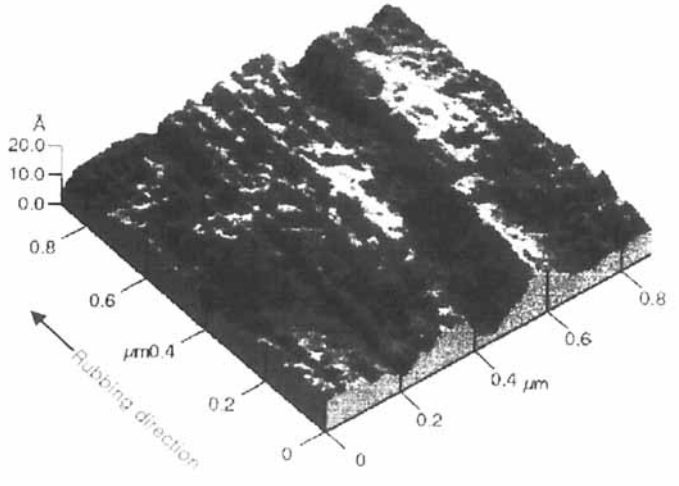


FIGURE 3 The AFM images on the two kinds of the unrubbed PI surface. (See color plate I at the back of this issue)



(a) PI-A



(b) PI-B

FIGURE 4 The AFM images on two kinds of the rubbed PI surface. (See color plate II at the back of this issue)

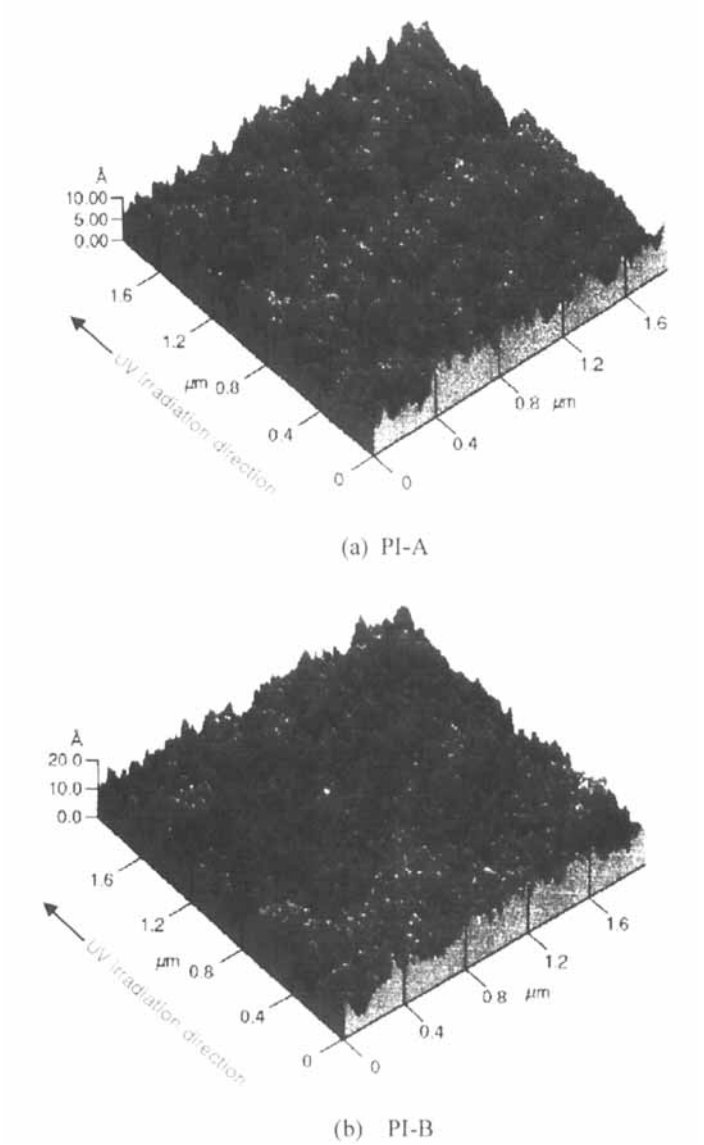
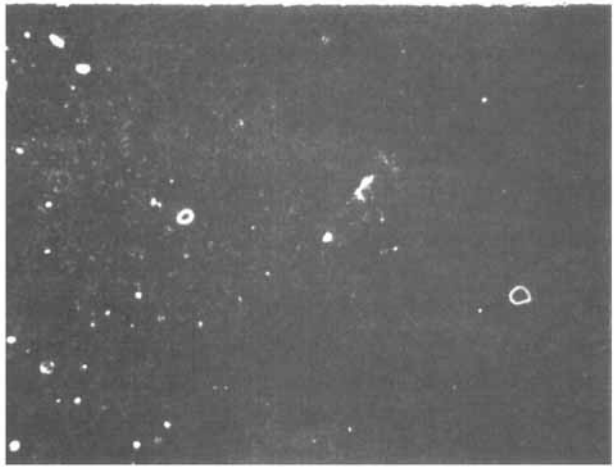
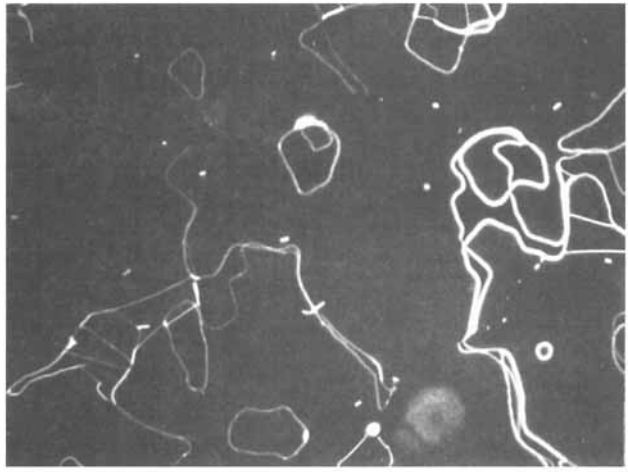


FIGURE 5 The AFM images with oblique non-polarized UV light irradiation of 70° on the two kinds of PI surface.
(See color plate III at the back of this issue)



(a) PI-A (at oblique angle of 70°)



(b) PI-B (at oblique angle of 80°)

FIGURE 6 The microscopic photograph of aligned NLC in the cell with oblique non-polarized UV light irradiation on two kinds of the PI surfaces (in crossed Nicols).

(See color plate IV at the back of this issue)

Figure 7 shows the generated pretilt angle of NLC in the cell with oblique non-polarized UV light irradiation on two kinds of the PI surface. It is shown that the pretilt angle of NLC increases with increasing the incident angle of oblique UV light irradiation on PI surface. The generated pretilt angle of NLC is about 3° with oblique non-polarized UV light irradiation of 70° on PI-A surface. It is shown that the obtained pretilt angle with oblique non-polarized UV light irradiation on the PI-A surface is almost same in comparison with the rubbed PI-A surface without side chain [5]. However, the generated pretilt angle NLC is about 1° with oblique UV light irradiation angle of 80° on PI-B surface; it is almost the same as that given by Yamamoto et al. [17]. Figure 8 shows the model of pretilt angle generation with oblique non-polarized UV light irradiation on PI surface using photo-depolymerization reaction. It is considered that the pretilt angles of NLC is attributed to the interaction between the LC molecules and the polymer surface due to photo-depolymerization of polymer with oblique UV light irradiation. Consequently, we consider that the pretilt angle of NLC strongly depends on irradiation angle and irradiation time of UV light.

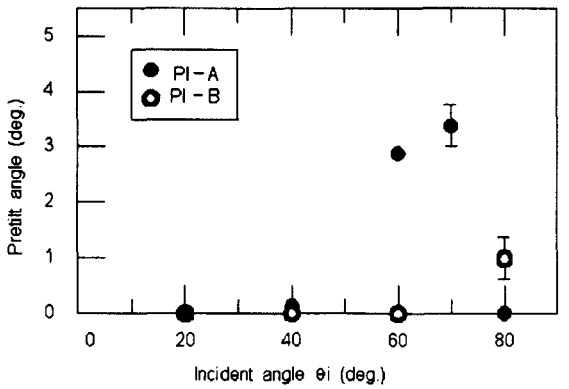


FIGURE 7 The generated pretilt angle of NLC in the cell with oblique non-polarized UV light irradiated on two kinds of the PI surfaces.

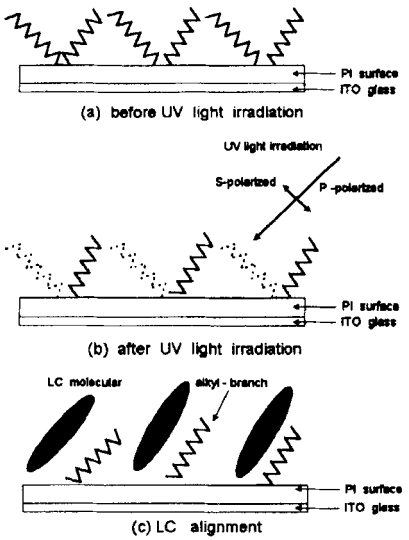


FIGURE 8 The model of pretilt angle generation in NLC with oblique non-polarized UV light irradiation on PI surface.

CONCLUSIONS

In summary, we have investigated the LC alignment and pretilt angle generation for NLC in the cell with oblique non-polarized UV light irradiation on two kinds of the PI surfaces. It was found that the monodomain alignment of NLC with an oblique non-polarized UV light irradiation of 70° on PI surface without side chains; the generated high pretilt angles of NLC is about 3° with an angle of incidence of 70° on PI surface without side chain. Therefore, we propose that the uniform alignment of the NLC is attributed to anisotropic dispersion force due to photo-depolymerization of polymer on PI surfaces.

Acknowledgments

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