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# Preliminary communication

# Investigation of pretilt angle generation in nematic liquid crystal with oblique non-polarized UV light irradiation on polyimide films

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We investigated new rubbing-free techniques for liquid crystal (LC) alignment with non-polarized ultraviolet (UV) light irradiation on plates coated with two kinds of the polyimide (PI) films. It was found that monodomain alignment of nematic (N) LC is obtained in the cell having a PI surface without a 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 chains. This pretilt angle generation is attributed to interaction between the LC molecules and the polymer surfaces; the uniform alignment of NLC is attributed to anisotropic dispersion force effects due to photo-depolymerization of polymer on PI surfaces.



Liquid crystal displays (LCDs) dominate the flat panel display industry. The successful operation of LCDs requires uniform alignment and controlled pretilt of LCDs 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 the creation of reverse tilt disclinations in a TN-LCD. The pretilt angle is also important in order to avoid stripe domains in super (S) TN-LCDs [2]. The generation of a 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. Rubbing-free techniques for LC alignment would be desirable in thin film transistor (TFT) LCD fabrication, since as we reported, in a previous paper, TFTs are damaged by the induced static electricity produced during rubbing [8]. The photo-alignment method for LC alignment is expected to achieve high resolution LCDs; Gibbons *et al.* [9] have reported a new method for LC alignment by using polarized laser light. It was shown that NLCs in an illuminated region become oriented perpendicular to the direction of the electric field polarization of the laser and remain aligned in the absence of the laser radiation. In addition the pretilt angle of a Langmuir–Blodgett film has been controlled by regulation of the fraction of *trans*-azobenzene units using light wavelength tuning [10].

More recently, LC alignment on linearly polarized UV light irradiated polyvinylcinnamate films has been reported [11–13]. The photo-polymerization of a photopolymer with linearly polarized light was shown to induce uniaxial orientation of NLCs on polyvinylcinnamate surfaces. Also recently reported is LC alignment on a linearly polarized UV light irradiated PI surface [14–16], including a discussion on the anisotropic dispersion force caused by the photo-depolymerization of the PI main chains parallel to the electric field of far UV light (257 nm) [14]. Finally, Yamamoto *et al.* have reported LC alignment by oblique irradiation of non-polarized UV light on PI surfaces [17], yielding a pretilt angle of NLC of about 0·8° on a PI surface with side chains. However, this pretilt is not enough to avoid reverse tilt disclination in a TN-LCD. The detailed mechanism of LC alignment by the photo-alignment method is not yet understood.

In this letter, we report monodomain alignment and pretilt angle generation in NLC in a cell with oblique

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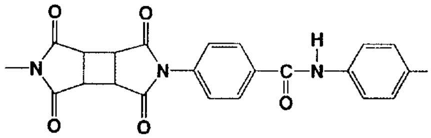
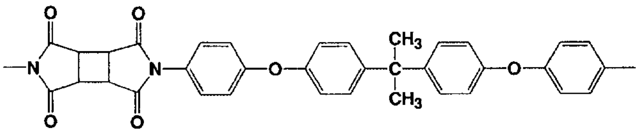
non-polarized UV light irradiation on two kinds of the PI films. In this study, we used two kinds of PI material; figure 1 shows their chemical structure. The PI films were coated onto indium tin oxide (ITO) coated glass substrates by spin-coating, and were imidized at 250°C for 1 h; the thickness of PI layers was about 500 Å. The oblique non-polarized UV light (power 1 kW) irradiation system is shown in figure 2. The substrates were irradiated for 3 h using UV light at a wavelength of 365 nm. The LC was assembled in sandwich-type cells with antiparallel-UV irradiation direction. All the sandwich-type cells had a LC layer thickness of 60 μm. After assembly, the cells were filled with NLC (ZLI-4792 supplied from Merck Japan Co., Ltd) in the isotropic phase. For the measurement of pretilt angles, we used the crystal rotation method; measurements were made at room temperature.

Figure 3 shows photomicrographs of the aligned NLC in cells with slanted non-polarized UV light irradiation using the two kinds of PI film (between crossed Nicol prisms). It can be seen that monodomain alignment of NLC is observed in the cell with the slanted non-polarized UV light irradiating the PI-A surface *without* side chains. However, the reverse tilt disclination is observed in the cell with slanted non-polarized UV light



(a) PI-A



(b) PI-B

Figure 1. The chemical structure of the two kinds of PI material used in this study. (*a*) PI-A; (*b*) PI-B.

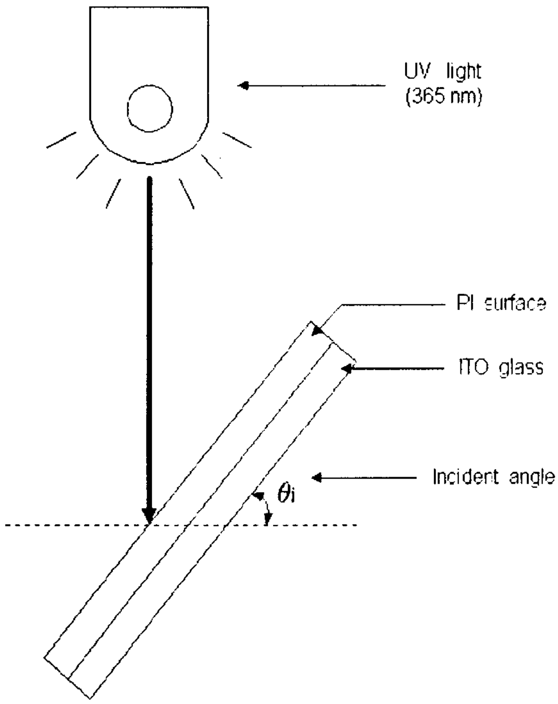
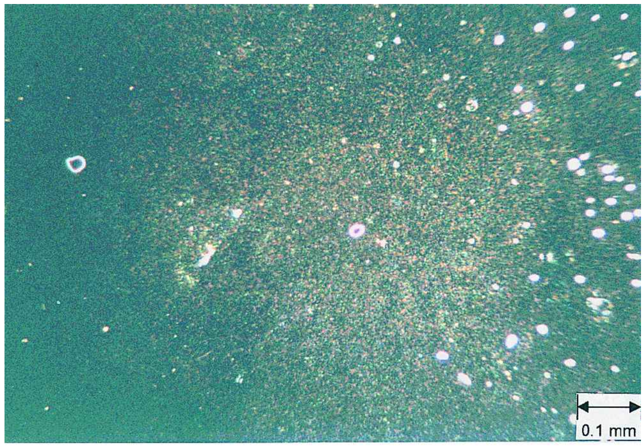



Figure 2. The oblique incidence non-polarized UV light irradiation system.




(*a*)


(*b*)

Figure 3. Photomicrographs of aligned NLC in cells with oblique non-polarized UV light irradiation on the two kinds of PI films (crossed Nicols). (*a*) PI-A at 70° incidence of UV light irradiation; (*b*) PI-B at 80° incidence of UV light irradiation.

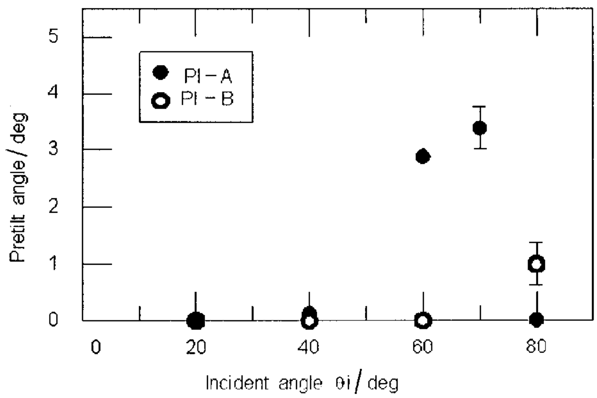



Figure 4. The pretilt angle generation for NLC in cells with oblique non-polarized UV light irradiation on the two kinds of PI film.

irradiated PI-B surface *with* side chain. Also, we observed that the aligned NLC was parallel to the incident direction of UV irradiation on PI surfaces. Therefore, we consider that the NLCs are aligned due to the photo-depolymerization of polymer on oblique non-polarized UV irradiated PI surfaces.

Figure 4 shows the pretilt angle generation in NLC in cells with oblique non-polarized UV light irradiation on the two kinds of PI film. It is shown that the pretilt angle of NLC increases with increasing incident angle; $Gh_i$. The generated pretilt angle of the NLC is about 3° in the cell with $\theta_i = 70°$. This pretilt angle obtained with oblique non-polarized UV light irradiation on the PI-A surface is almost the same value as that found with a rubbed PI-A surface without side chain [5, 7]. However, the pretilt angle for NLC is about 1°, with $\theta_i = 80°$ and a PI-B surface, a value almost the same as that given by Yamamoto *et al.* [17]. Therefore, the pretilt angles of NLC is attributed to interaction between the LC molecules and the structure of the UV photo-depolymerizated surface.

In conclusion, we have investigated the LC alignment and pretilt angle generation for NLC in a cell with slanted non-polarized UV light irradiation on two kinds of PI film. We successfully observed the monodomain alignment of NLC on a PI surface without side chains. We obtained a high NLC pretilt angle of about 3° in the cell with a UV angle of incidence of $\theta_i = 70°$ on a PI surface without side chains. Therefore, we propose that the uniform alignment of the NLC is due to anisotropic dispersion force effects as a result of photo-depolymerization of polymer on PI surfaces.

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