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Preliminary communication

Novel alignment method for control of high pretilt angle by using a solvent dipping effect on polymer surfaces

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A novel alignment method for control of high pretilt angle in nematic liquid crystals (NLC), using a solvent dipping effect on various alignment layers, was successfully investigated. The pretilt angle of a NLC is increased by dipping before rubbing treatment on three kinds of rubbed polyimide (PI) surfaces. The pretilt generated by the dipping after rubbing a PI surface with a short side chain is high compared with a PI surface with a long side chain. The pretilt generated by dipping before rubbing homeotropic layer of a positive type NLC ($\Delta\varepsilon > 0$) is lower than that of the negative type NLC ($\Delta\varepsilon < 0$). The generated NLC pretilt angle is attributed to the perpendicular component of the permittivity $\varepsilon_\perp$ of the NLC.

Thin film transistor (TFT) liquid crystal displays (LCDs) are widely utilized in information displays such as notebook computers, monitors, and televisions because they have an excellent resolution quality. However, TFT-LCD performance has been unsatisfactory because of the narrow viewing angle. Thus various techniques developed to improve the viewing angle characteristics have been presented, such as the addition of birefringent films [1], the domain divided twisted nematic [2], the in-plane-switching (IPS) mode [3], and the vertical alignment (VA) mode [4, 5]. The VA-LCD is expected to achieve a wide viewing angle, fast response time, and high contrast ratio. A method of dividing each pixel into multidomains is needed in the VA-LCD; control of high pretilt angle is required to achieve multidomains.

The generation of pretilt angle in a nematic liquid crystal (NLC) on various polyimide (PI) layers by unidirectional rubbing has been demonstrated and discussed by many investigators [6–15]. Rubbed PI surfaces have been widely used to align LC molecules.

In this study, we report a novel alignment method for control of high pretilt angle in NLCs by using solvent dipping effects on various PI surfaces. In these experiments, the three kinds of polymer used were as follows:

PI-1: AL-3046 (for high pretilt; Nissan Chemical Industries Co., Ltd.),
PI-2: SE-150 (for medium pretilt; Nissan Chemical Industries Co., Ltd.),
PI-3: JALS-696-R2 (for homeotropic alignment; Japan Synthetic Rubber Co., Ltd.).

The PI films were coated on indium tin oxide (ITO) coated glass substrates by spin-coating, and were imidized at 250°C (PI-2) and 180°C (PI-1 and PI-3) for 1 h. The thickness of the PI layers was 500 Å. The PI films were dipped in solvent for 0–20 min before rubbing or after rubbing. The solvents used for dipping were as follows: ITO etchant; NMP (*N*-methyl pyrrolidone); IPA (isopropyl alcohol); acetone; TMAH (tetramethylammonium hydroxide).

The PI films were rubbed using a machine equipped with a nylon roller (Y_o-15-N, Yoshikawa Chemical Industries Co., Ltd.). The definition of the rubbing strength (*RS*) was given in previous papers [11, 12]. LC cells were assembled with the rubbing directions antiparallel. The LC layer thickness was set at 60 µm. The physical properties of the two NLCs used are shown in the table. To measure pretilt angles, we used the crystal rotation method at room temperature (22°C).

Table. Physical properties of NLCs used.

NLC	$\varepsilon_\parallel$	$\varepsilon_\perp$	$\Delta\varepsilon$
LC-1 ($\Delta\varepsilon > 0$)	10.8	3.4	7.4
LC-2 ($\Delta\varepsilon < 0$)	3.5	7.3	− 3.8

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Figure 1 shows the pretilt angle of NLC in cells with ITO etchant dipping on a PI-1 surface, as a function of dipping time. The NLC pretilt angle before treatment is increased by the dipping of PI-1 surfaces. However, the NLC pretilt angle after a rubbing treatment is decreased by the dipping. The NLC pretilt angle after rubbing also decreases with increased dipping time; this is considered to be due to depolymerization of the polymer film.

The dependence of pretilt angle in dipping time in cells using two kinds of dipping solvent on rubbed PI-2 surface is shown in figure 2. The NLC pretilt angle with ITO etchant dipping before rubbing treatment increases with increased dipping time and then saturates at 10 min. However, the NLC pretilt angle with NMP dipping before rubbing treatment decreases with increased dipping time above 2 min.

The NLC pretilt angles using various dipping solvents on rubbed PI-2 surfaces are shown in figure 3. The generated pretilt angle for all solvents used before rubbing is increased by the dipping. However, dipping after the rubbing treatment decreases the pretilt angle. Figures 1 and 2, show that the decrease in pretilt angle after rubbing treatment on a PI-2 surface is smaller than for a PI-1 surface. It is considered that the NLC pretilt angle with dipping after rubbing treatment on a PI-1 surface strongly depends on the long alkyl chain of the polymer. Therefore, the generated NLC pretilt angle on a PI-1 surface is attributed to depolymerization of the alkyl chain of the polymer.

Figure 4 shows the pretilt angle for two kinds of NLC on rubbed PI-3 surfaces as a function of dipping time. Homeotropic alignment of the NLCs on the PI-3 surface is observed. The pretilt angle of the positive type NLC ($\Delta\varepsilon > 0$) before rubbing treatment gradually decreases with increased dipping time. The large pretilt angle of 60° is observed at a dipping time of 30 min. The pretilt angle of the negative type NLC ($\Delta\varepsilon < 0$) before rubbing treatment slowly decreases with increased dipping time

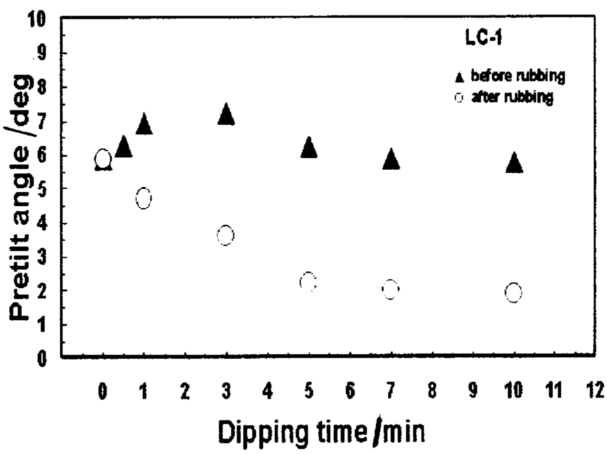

Figure 1. Pretilt angles in a NLC with ITO etchant dipping on a PI-1 surface, as a function of dipping time.

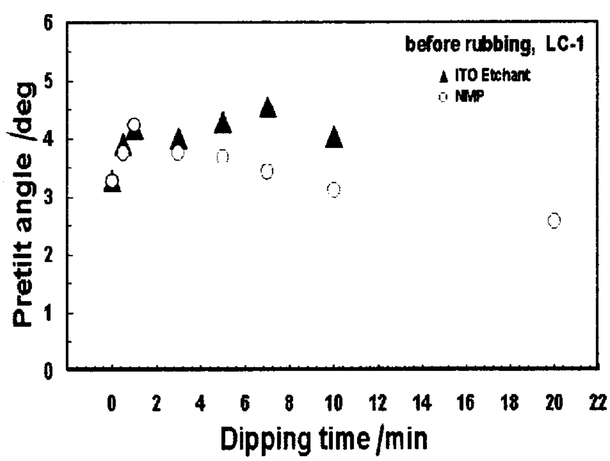

Figure 2. Dependence of pretilt angle on dipping time in cells using two kinds of dipping solvent on a rubbed PI-2 surface.

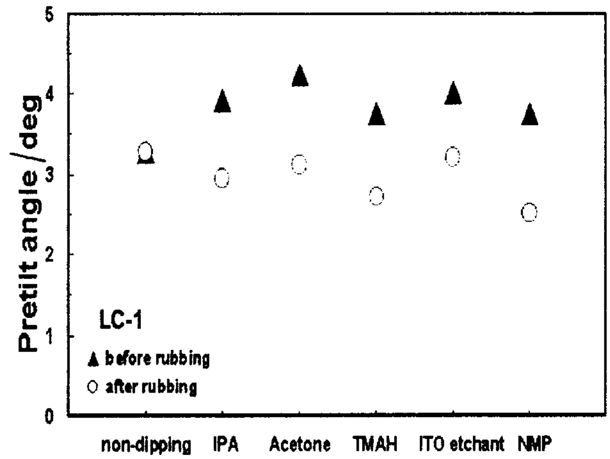

Figure 3. Generation of pretilt angles in a NLC using various dipping solvents on a rubbed PI-2 surface.

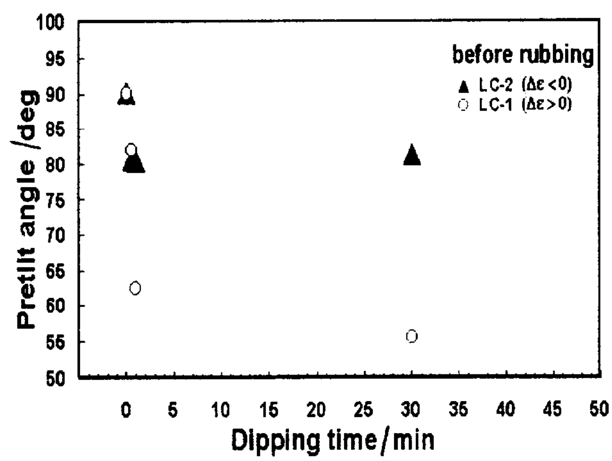

Figure 4. Pretilt angles for two kinds of NLC on a rubbed PI-3 surface, as a function of dipping time.

and saturates above 2 min at a higher value than for the positive type NLC. It is considered that the generated NLC pretilt angle is attributable to a perpendicular component of the NLC permittivity, $\varepsilon_{\perp}$.

In summary, a novel alignment method for control of high NLC pretilt angle by dipping was successfully investigated on various alignment layers. The pretilt angle is increased by solvent dipping before the rubbing treatment on two kinds of PI surfaces. The pretilt generated by dipping after rubbing a PI surface with short side chain is high compared with a PI surface with long side chain. The pretilt angle generated for a positive type NLC ($\Delta\varepsilon > 0$) is lower than that of a negative type NLC ($\Delta\varepsilon < 0$) when dipping before rubbing a homeotropic layer. The generated NLC pretilt angle is attributed to the perpendicular component of permittivity $\varepsilon_{\perp}$ of the NLC. Consequently, we suggest that the control of high pretilt angle by using the effect of solvent dipping on a PI surface is a new promising alignment technique.

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