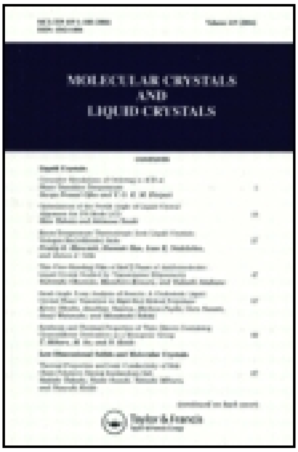

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Etching Effects of Blended Polyimide Layers for Liquid Crystals

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Etching Effects of Blended Polyimide Layers for Liquid Crystals

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This paper introduces a novel alignment method for control of pretilt angles in liquid crystals (LCs) using an etchant dipping effect on a mixed polyimide layer as an alternative alignment layer for liquid crystal display applications. A rubbing process was used to induce LC alignment and induce the measured LC pretilt angle on the etchant dipped mixture layer. The resulting thermal stabilities were good, however thermal stresses decreased as the etchant dipping time increased, indicating that the LC anchoring energy became weaker as a function of etchant dipping time after treatment. Excellent voltage-transmittance characteristics for vertically aligned cells were observed for all conditions.

Keywords alignment method; etchant dipping effect; mixed polyimide; rubbing process

Introduction

Thin film transistor (TFT) liquid crystal displays (LCDs) are widely utilized in information displays such as notebook computers, monitors, and televisions because they offer excellent resolution quality, low power consumption, and high performance. However, the performance and the fabrication processes of TFT-LCDs are still being developed.

Various techniques are available to improve the viewing angle, response time, and fabrication process of TFT-LCDs. The viewing angle and response time characteristics may be improved by, the addition of birefringence films [1], domain divided twisted nematics [2], in-plane-switching (IPS) mode [3, 4], and multidomain vertical alignment (MVA) mode [5]. MVA-LCDs offer wide viewing angles, fast response times, and high contrast ratios. However, methods for dividing each pixel into multidomains and a fringe field are required. The optically compensated bend (OCB) mode has been introduced to improve the narrow viewing angle and response time [6, 7]. However, this mode has some deficiencies

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with regard to controlling the LC conformation and pretilt angle. Recently, no-bias-bend pi mode is once in the spotlight because various techniques to control pretilt angle have been researched [8, 9]. Improvements to the fabrication process are important to reduce the unit cost of production [10], and increase profits. Therefore, researchers have studied various techniques to improve LCD performance and the fabrication process.

In this study, we report a novel alignment method for control of the pretilt angle by using an etchant dipping effect on a mixed PI surface.

Experimental

Mixed PI films were coated on indium tin oxide (ITO) coated glass substrates by spin-coating, and were imidized at 230°C for 1 h. Mixed PIs (JSR Co. Ltd., Japan) for the homogeneous and homeotropic alignment layers were prepared at a ratio of 50:50. The thickness of the mixed PI layers was 50 nm. The mixed PI films were dipped in etchant for 0–5 min before the rubbing process. The mixed PI films were rubbed using a machine equipped with a nylon roller (Y_o-15-N, Yoshikawa Chemical Industries Co., Ltd.). The rubbing strength (RS) is defined by the following equation [11].

$$RS = NM(2prn/V - 1)$$

where, *N* is the cumulative number of rubbings, *M* is the depth of the fibers (mm), *r* is the radius of the drum (cm), *n* is the rotational rate of the drum (rpm), and *V* is the velocity of the substrate stage (cm/s). For this experiment, all of the blended PI layers were rubbed with a RS of 300 for LC alignment. LC cells were assembled with antiparallel rubbing directions. The LC layer thickness was set at 60 μm. Commercially negative ($\Delta\varepsilon = -4$, MJ98468, Merck) LCs were injected into the cell in the isotropic state to minimize the influence of flow alignment by capillary action. The LC alignment was observed using a photomicroscope (Olympus BXP51) with a cross polarizer. The pretilt angles of the LCs were measured by the crystal rotation method (Autronic TBA107). The surface roughness of the mixed PI film was observed by atomic force microscopy (AFM). To measure electro-optical properties, VA cells were assembled with a cell gap of 4.25 μm. Voltage-transmittance (V-T) performances of VA cells were measured using an LCD evaluation system.

Results and Discussion

In order to assess the properties of the LC alignment as a function of etchant dipping time, the polarizing microscope images of the LC cells are observed. Figure 1 is a photomicroscope image showing LC molecules alignment in cells made of etchant dipped mixture layers treated by the rubbing process. The mixed PIs treated with the rubbing process exhibited good LC alignment. LC molecules on the mixture layer treated by rubbing completely blocked the polarized light regardless of the etchant dipping time. Therefore, rubbing treatment efficiently aligned LC molecules on the mixed PI layer with various states.

Figure 2 shows the pretilt angle of LC molecules on the mixed PI surface after the rubbing process as a function of etchant dipping time. LC molecules were aligned vertically in all LC cells, even though the pretilt angle of LC molecules increased slightly depending on the etchant dipping time. The same tendency was observed in the LC cell with annealing at 100°C for 10 min, indicating that the LC molecules were strongly aligned and blocked from thermal stress.

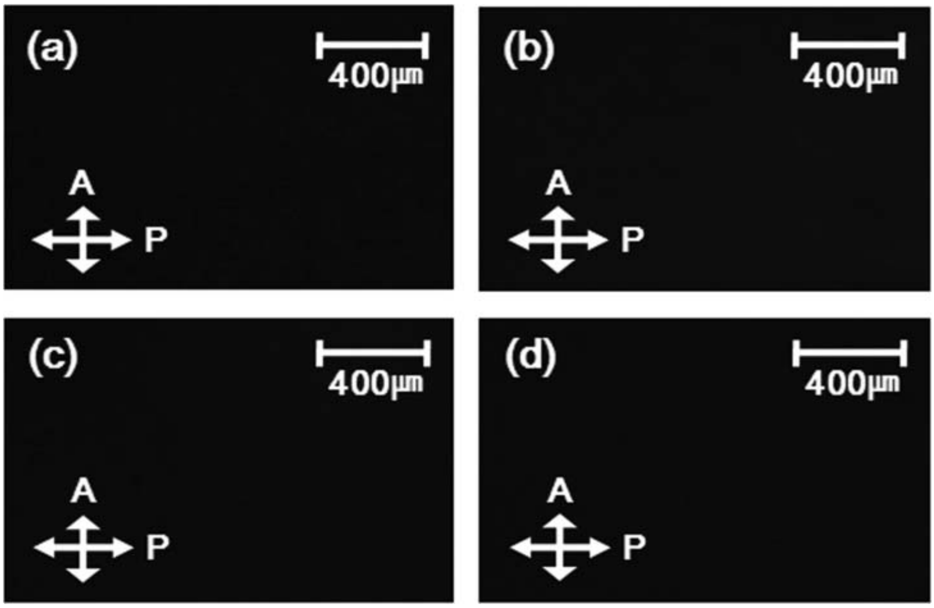

Figure 1. Photomicroscope images of LC cells with an etchant dipped mixture layer produced using the rubbing process as a function of etchant dipping time: (a) 0, (b) 1, (c) 3, and (d) 5 min.

A thermal stability experiment was performed to measure LC anchoring energy between the LC molecules and the mixed PI layer. After each LC cell was heated and slowly cooled, the LC alignment state was observed by photomicroscope images. Figure 3 shows photomicroscope images of LC cells fabricated by the etchant dipped mixture layer cooled gradually after heating for 10 min at 100, 150, 200, and 240°C. For an LC cell produced

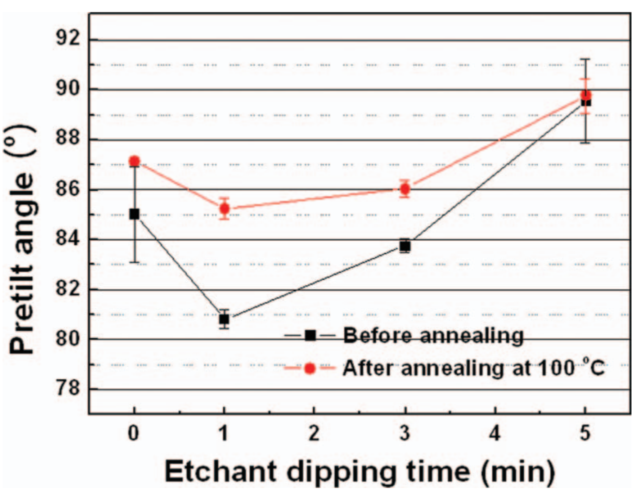

Figure 2. Pretilt angles of LCs on an etchant dipped mixture layer as a function of etchant dipping time before and after annealing of 100°C.

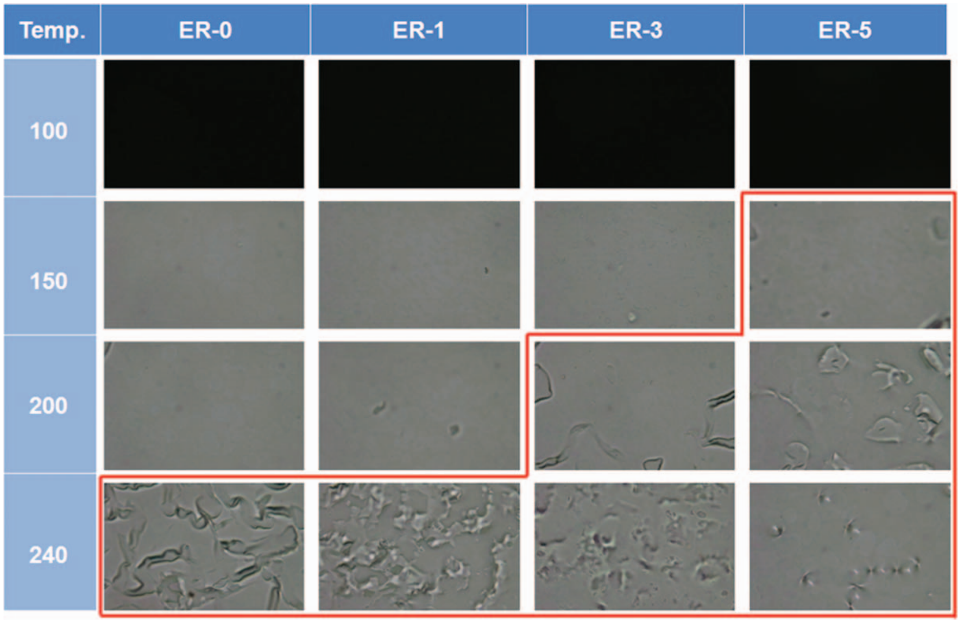

Figure 3. Thermal stabilities of LC cells with an etchant dipped mixture layer as a function of etchant dipping time. Annealing temperatures were 100, 150, 200, and 240°C.

with an etchant dipping time of 0 and 1 min, the LC alignments were good when the heating temperature was 100°C was 200°C. However, for an LC cell produced with an etchant dipping time of 3 and 5 min, the LC alignments became worse as the etchant dipping time increased. Enduring a high thermal stress for LC cell means the LC molecules could anchor the mixed PI layer more strongly [12]. Specifically, the LC anchoring energy between LC molecules and the mixed PI layer was weakened as a function of the etchant dipping time due to the randomly etched ITO substrate which decreased the dipole field on the PI layer.

To observe the surface roughness of the mixed PI surface after the rubbing process, AFM images were obtained and are shown in Fig. 4. Smaller surface roughness values of 3.79 Å and 14.4 Å were observed for a rubbed mixture surface with etchant dipping times of 0 and 1 min, while a greater surface roughness of 117 Å and 33.9 Å were observed for a rubbed mixture surface with an etchant dipping time of 3 and 5 min. The root-mean-square (RMS) of the surface roughness increased up to an etchant dipping time of 3 min due to non-uniform ITO etching while the surface roughness decreased because the ITO substrate under the mixed PI layer was more planar. However, as shown in Fig. 1., variation of the surface roughness cannot affect LC alignment. We assume that selective ITO etching can distribute the electric field, resulting in the influence on the electro-optical properties of the VA cell.

In addition, the V-T characteristics were used to confirm practical applications. Light transmission as a function of the voltage applied in the VA cell was confirmed using the etchant dipped mixture layer in Fig. 5. The light transmission was completely inhibited for an applied voltage of 0 V (off-state) and visible light generated from backlight units was clearly transmitted through the cell for an applied voltage of 5 V (on-state). The threshold voltages of VA cells with an etchant dipped mixture layer were increased as the etchant

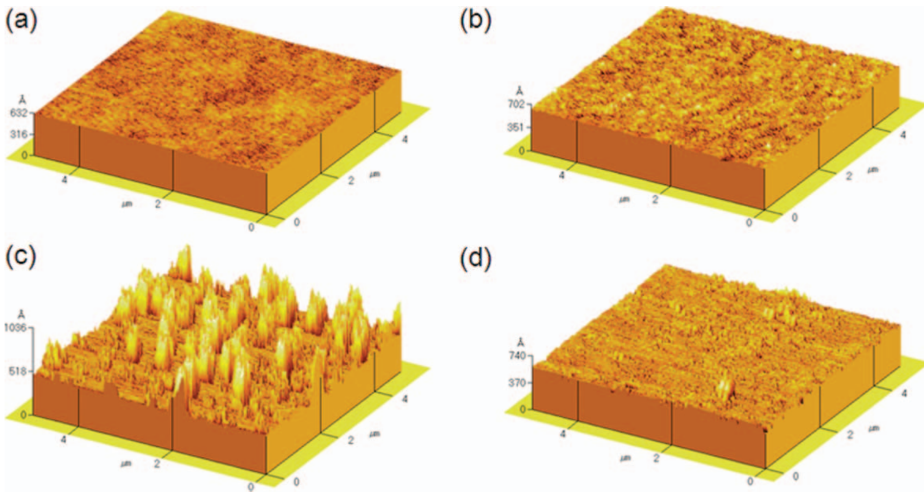

Figure 4. AFM images of the mixed PI surface for surface roughness as a function of the etchant dipping time: (a) 0, (b) 1, (c) 3, and (d) 5 min.

dipping time increased. Interestingly, backflow bounce effects for VA cells decreased as the etchant dipping time increased, resulting in uniform switching as a function of the voltage applied to the VA cell. This phenomenon might be attributed to variation in surface roughness of the mixed PI surface.

Conclusions

In summary, a novel alignment method that controlled LC pretilt angles by etchant dipping was successfully investigated on mixed PI layers. The LC molecules were aligned vertically

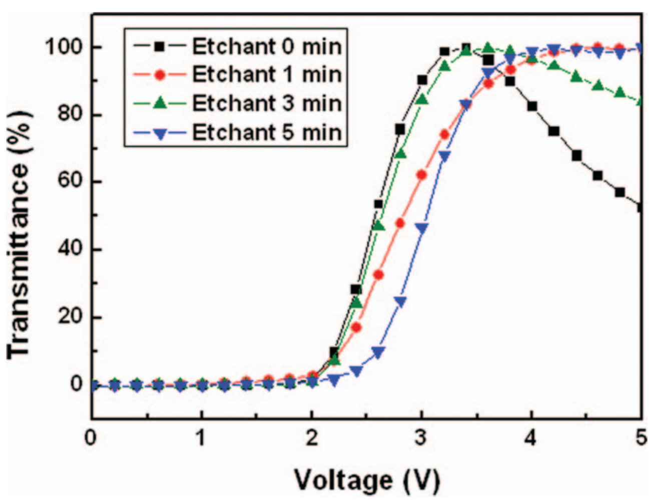

Figure 5. Light transmission as a function of the voltage applied to the VA cell using an etchant dipped mixture layer.

and uniformly on all cells. The pretilt angles of LCs increased as the etchant dipping time was increased. Tests of thermal stability revealed that the LC anchoring energy between LC molecules and the mixed PI layer became weaker as a function of etchant dipping time due to randomly etched ITO substrates. Excellent V-T characteristics were observed for VA cells under all conditions. Threshold voltage increased as the etchant dipping time increased. However, backflow bounce effects for VA cells decreased as the etchant dipping time increased.

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References

[1] H. Yoshida, K. Nakamura, M. Ohashi, I. Tomita, and M. Okabe, *J. SID*, **1**, 63 (1993).
[2] K. H. Yang, *Jpn. J. appl. Phys.*, **31**, L1603 (1992).
[3] M. Oh-e and K. Kondo, *Appl. Phys. Lett.*, **67**, 3895 (1995).
[4] S. Y. Jeon, S. H. Shin, S. J. Jeong, S. H. Lee, S. H. Jeong, Y. H. Lee, H. C. Choi, and K. J. Kim, *Appl. Phys. Lett.*, **90**, 121901 (2007).
[5] Y. Koike and K. Okamoto, *Fujitsu Sci. Tech. J.*, **35**, 221 (1999).
[6] P. J. Bos, P. A. Johnson, Jr., and K. R. Koeler-Beron, *SID Symp. Dig.*, 1983, **30** (1983).
[7] S. Y. Lu and L. C. Chien, *Opt. Express.*, **16**, 12777 (2008).
[8] F. S. Yeung, J. Y. Ho, Y. W. Li, F. C. Xie, O. K. Tsui, P. Sheng, and H. S. Kwok, *Appl. Phys. Lett.*, **88**, 051910 (2006).
[9] H. G. Park, B. Y. Oh, Y. H. Kim, B. Y. Kim, J. M. Han, J. Y. Hwang, and D. S. Seo, *Electrochem. Solid State Lett.*, **12**, J37 (2009).
[10] C. Kim, Y. B. Park, H. S. Kong, D. G. Kim, S. J. Kang, J. W. Jang, and S. S. Kim, *SID Symp. Dig.*, **31**, 1006 (2000).
[11] D. S. Seo, S. Kobayashi, and M. Nishikawa, *Appl. Phys. Lett.*, **61**, 2392 (1992).
[12] J. W. Lee, B. M. Moon, K. M. Lee, Y. H. Kim, H. G. Park, J. H. Lim, B. Y. Oh, B. Y. Kim, J. Y. Hwang, C. H. Ok, D. S. Seo, and J. M. Han, *Liq. Cryst.*, **37**, 279 (2010).