P-138: Electrohydrodynamic Patterning Method of Liquid Crystalline Polymer for Patterned Retarder

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Abstract

We proposed a patterning method of liquid crystalline polymer by using electrohydrodynamics. Using this method, the patterned retarder films, applicable to 3-dimensional displays and transflective liquid crystal displays, were simply fabricated without complicated processes.

1. Introduction

The liquid crystalline polymers (LCPs) have attracted great interests for various optical devices due to their large optical anisotropy and excellent processibility [1-6]. In general, the LCP is uniformly aligned by conventional alignment layers used for aligning the liquid crystals (LCs) and thus the optic axis of the LCP is easily controlled by a rubbing process. In addition, the phase retardation is directly governed by the thickness of the LCP film which is easily controlled by spinning speed and/or amount of solvent. Due to these fascinated advantages, the LCPs have been applied to the variety of the optical devices such as a patterned retarder film, LC lens, gratings, and polarization rotators [1-6]. Especially, the patterned retarders have attracted much attention in the three-dimensional (3D) displays and the transflective LC displays.

The patterned retarders were fabricated with spatially selective polymerization of the anisotropic materials such as the LCPs. To pattern the LCPs, various methods such as a thermal patterning method and a solvent washing method were proposed [1]. Here, the key issue is a method forming the isotropic regions without phase retardation. In the thermal annealing method, the isotropic regions are obtained by polymerizing the LCPs at isotropic phase. On the other hand, in the solvent washing method, the LCPs in the isotropic regions are washed off by solvent and the dummy regions are formed. In these methods, however, it is difficult to obtain the clear pattern-shapes and/or control the phase retardation.

In this work, we propose a patterned retarder fabricated by the electrohydrodynamic (EHD) patterning method [7-11]. When the external voltage is applied to the patterned electrode matched to the patterned retarder, the LCPs between a sandwiched cell move to the electrode regions. Turning off the applied voltage, the ultra-violet (UV) light solidifies the LCPs and thus the patterned retarder is obtained. The properties of the patterned retarder such as the phase retardation and the optic axis are easily controlled in our method. The method for the patterned retarder is applicable to the 3D displays and the transflective LCDs.

2. Electrohydrodynamic Patterning

Figure 1 shows a schematic diagram for fabricating a patterned retarder using the EHD patterning. To produce the spatially selective phase retardation, the LCP was used. The LCP patterns are directly governed by the electrode patterns of a commanding substrate. After patterning the indium-tin-oxide (ITO) electrode, the homogeneous alignment layer was coated onto the electrode-patterned substrate to promote uniform alignment of the LCP. Before rubbing the alignment layer, the O_2 plasma treatment was carried out to reduce the interaction between the LCP and the commanding substrate. Finally, the LCP was coated on the surface-treated alignment layer.

The target substrate for a patterned retarder was prepared by coating and rubbing the homogeneous alignment layer without any electrode patterns. Both commanding and target substrates were assembled maintaining a certain gap corresponding to the phase retardation. When an electric field was applied to the assembled cell, the LCP was aggregated onto the patterned electrode regions due to the EHD force induced by a mismatch in the dielectric constants between the LCP and the air environment within the assembled cell [8]. Finally, the LCP layer begin to form stripe structure because of the electrostatic stress exceeded the surface tension [9]. In general, to form the rectangular stripe, the height of the aggregated LCP was high enough to reach to the target substrate and the ratio of the initial LCP thickness to the cell gap of the assembled substrates is larger than 0.5 [11] because the LCP should be produced sufficiently to fill an inter space for

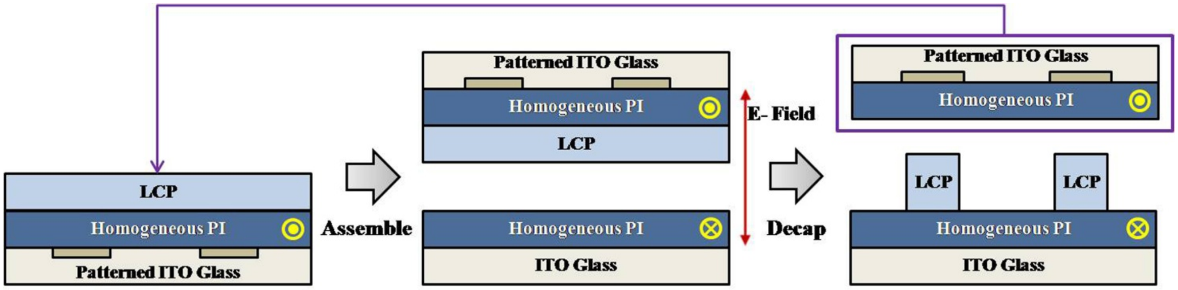

Figure 1. Schematic diagram for fabricating a patterned retarder using the electrohydrodynamic patterning method of liquid crystalline polymer.

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the patterned retarder. Applying the electric field for sufficient time to obtain the rectangular stripe structure, the applied electric field was eliminated. At this time, the rectangular stripe of the LCP still remains since the LCP is well wetted onto both target and commanding substrates. The ultra-violet (UV) light was exposed to the assembled cell to solidify the LCP. Finally, the patterned retarder was obtained after detaching the assembled cell. Here, the solidified stripes on the commanding substrate were completely transferred to the target substrate and the commanding substrate could be reused for fabricated a new patterned retarder.

3. Fabrication of a Patterned Retarder

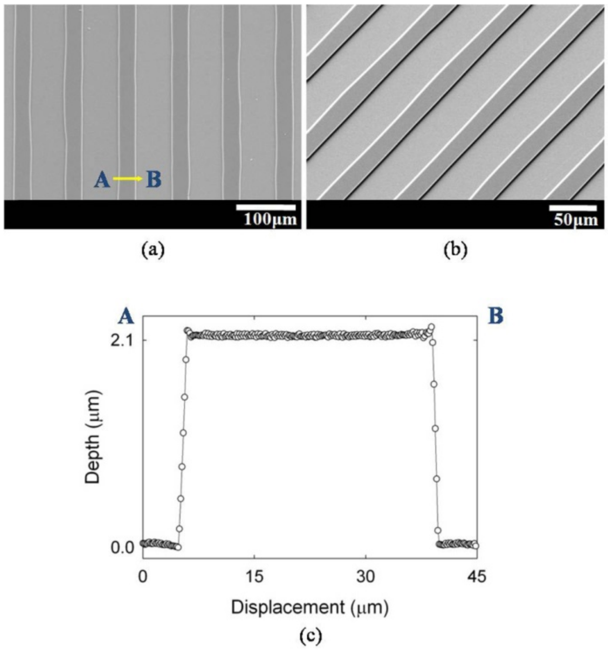
The patterned electrode for the commanding substrate was prepared with a conventional photolithography of the ITO glass. The alignment layer of RN1199 (Nissan Chemical Industries) was spin-coated on the patterned ITO glass for a commanding substrate and a common ITO glass for a target substrate. The prebaking process at 100 °C for 10 min was followed by the post-baking process at 210 °C for 1 hr to polyimidize the alignment layer completely. To reduce the surface interaction between the LCP and the alignment layer, the O_2 plasma treatment was introduced to the commanding substrate with the patterned electrode. After the O_2 plasma treatment, the contact angle of the LCP on the treated surface was increased from 0 to 4°. The reduction of the surface interaction gives rise to transfer the LCP stripe structure to the target substrate. Both commanding and target substrates were anti-parallelly rubbed.

The LCP of RMS03-001C (n_e = 1.680, n_o = 1.525, Merck) was spin-coated on the electrode-patterned substrate with a thickness of 1.3 μm and baked at 60 °C for 1 min. The cell thickness of the assembled substrates was maintained with 2.1 μm glass spacers to sustain air gap between the LCP film and the target substrate. The cell thickness corresponds to a half-wave plate in the patterned LCP region. The external voltage (80 V) was applied and the UV light (16.5 mW/cm^2) was illuminated under nitrogen environment to the assembled cell for detaching the cell and obtaining the patterned retarder with the rectangular stripes.

4. Results and Discussion

The morphologies of the patterned retarder were observed by using a field emission scanning electron microscope (FESEM) and a surface profiler as shown in Fig. 2. No residual LCP was observed in the dummy (isotropic) regions without the ITO electrode as shown in Figs. 2(a) and 2(b). The height of the rectangular stripe was measured to be 2.1 μm with a surface profiler as shown in Fig. 2(c). The clear pattern-shapes were obtained. The width and interval of the rectangular stripes were measured to be 35 and 100 μm, respectively. Considering the refractive indices of the LCP (n_e = 1.680 and n_o = 1.525), the height of the rectangular stripes approximately matches to the half-wave condition. The phase retardation and the width of the patterned LCP are easily controlled by varying the cell gap between the assembled substrates and the electrode pattern of the commanding substrate, respectively.

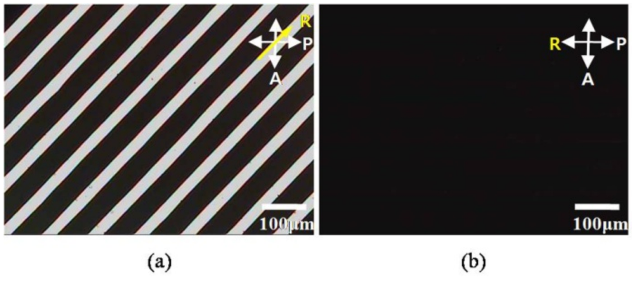
Figure 3 shows the microscopic textures of the patterned retarder with a stripe pattern under crossed polarizers. In the patterned LCP, the optic axis determined by the rubbing direction of the alignment layer is parallel to the direction of the stripes. As shown in Fig. 3(a), the bright state was obtained in the patterned LCP regions when the optic axis of the LCP was rotated by 45° with respect to one of crossed polarizers. Passing through a HWP, the linearly polarized incident light rotated by 45° with respect to the optic axis of the HWP is rotated by 90° from the incident polarization and thus the exiting light passes through the crossed analyzer. On the other hand, the linearly polarized light passing through the dummy region without the LCP is blocked by the crossed analyzer as shown in dark regions in Fig. 3(a). When the optic axis of the patterned retarder was placed parallel to one of crossed polarizers, not only the dummy regions but also the LCP regions show dark states, as shown in Fig. 3(b), since no phase retardation is produced in the optic axis of the HWP parallel or perpendicular to the incident polarization.



(a) (b)

(c)

Figure 2. FESEM images of the patterned retarder from (a) top view and (b) tilted angle view at 30°, and (c) the cross-sectional profile along "A-B" in (a).



(a) (b)

Figure 3. Microscopic images of the patterned retarder under crossed polarizers. Here, "R", "P", and "A" represent rubbing, polarizer, and analyzer directions, respectively.

When the optic axis of the LCP was rotated by 45° with respect to one of crossed polarizers, the linearly polarized incident light can be divided into two orthogonal polarized lights in the LCP and dummy regions. As a result, the patterned retarder can be applicable to 2D/3D switchable displays based on stereography with the orthogonally polarized glasses. Also, the patterned retarder acting as a quarter-wave plate for the transflective liquid crystal displays (LCDs) could be easily fabricated just controlling the LCP thickness governed by the cell gap between the assembled substrates.

5. Conclusion

We proposed a fabrication method for the patterned retarder by using the EHD patterning of the LCP producing the phase retardation. The patterned retarder was fabricated by transferring the patterned and solidified LCP, uniformly aligned by the rubbed alignment layer, from the commanding substrate with a patterned electrode. To transfer the patterned LCP to the target substrate, the surface treatment of the commanding substrate was involved before coating the LCP layer. The LCP pattern directly matched to the electrode pattern. In addition, the phase retardation in the patterned LCP region was easily governed by controlling the cell gap between the commanding substrate and the target one. Also, the optic axis of the patterned retarder was controllable with the rubbing direction of the alignment layer. This EHD patterning method of the anisotropic liquid crystalline materials is expected to be a viable technology for various patterned retarders applying the 3D displays and the transflective LCDs.

6. Acknowledgements

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