Novel film patterned retarder utilizing in-plane electric field

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Abstract: Conventional film patterned retarder (FPR) production requires a photo-alignment layer and a UV exposure process through a patterned wire-grid photo-mask, increasing the cost as well as limiting the resolution of FPR. We proposed a novel method for the fabrication of FPR without using the alignment layer and the photo-mask. Reactive mesogen (RM) was coated on a base film, and then the substrate with 2-domain interdigitated electrodes was contacted over the RM layer. The in-plane electric field reoriented the randomly orientated RM molecules to the field direction, generating the slow axes in each domain. Then, the UV light was exposed to the film, fixing the slow axes of the polymerized RM with orthogonal orientation between neighboring domains. Finally, an incident linearly polarized light gave rise to giving oppositely handed circular polarizations of light after passing the film.

OCIS codes: (230.2090) Electro-optical devices; (230.3720) Liquid-crystal devices.

References and links

1. K. Mashitani, G. Hamagishi, M. Higashino, T. Ando, and S. Takemoto, "Step barrier system multi-view glass-less 3-D display," Proc. SPIE **5291**, 265–272 (2004).
2. O. H. Willemsen, S. T. de Zwart, M. G. H. Hiddink, D. K. G. de Boer, and M. P. C. M. Krijin, "Multi-view 3D displays," SID Symposium Digest of Technical Papers, **38**, 1154–1157 (2007).
3. S. Yano, M. Emoto, and T. Mitsuhashi, "Two factors in visual fatigue caused by stereoscopic HDTV images," Displays **25**(4), 141–150 (2004).
4. T. Inoue and H. Ohzu, "Accommodative responses to stereoscopic three-dimensional display," Appl. Opt. **36**(19), 4509–4515 (1997).
5. S. S. Kim, B. H. You, H. J. Choi, B. H. Berkeley, D. G. Kim, and N. D. Kim, "World's first 240Hz TFT-LCD technology for full-HD LCD-TV and its application to 3D display," SID Symposium Digest of Technical Papers, **40**, 424–427 (2009).
6. J. C. Kuen Lee and F. Tseng, "Shutter glass stereo LCD with a dynamic backlight," Proc. SPIE **7237**, 72370X (2009).
7. Y. Yoshihara, H. Ujike, and T. Tanabe, "3D crosstalk of stereoscopic (3D) display using patterned retarder and corresponding glasses," Proc. IDW, **15**, 1135–1138 (2008).
8. H. Kang, S. Roh, I. Baik, H. Jung, W. Jeong, J. Shin, and I. Chung, "A novel polarizer glasses-type 3D displays with a patterned retarder," SID Symposium Digest of Technical Papers, **41**, 1–4 (2010)

1. Introduction

The 3D display devices have been rapidly flourishing in recent days and various kinds of 3D technologies are actively studied. In the small-sized portable display devices, glass-less type 3D technologies using parallax barriers are generally used [1,2]. In the large-sized displays

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such as a monitor and a television, glass-type 3D technologies are generally used [3,4]. The commercialized glass-type 3D displays can be classified into the active glass type and the passive glass type [5–8]. The active glass is also called as shutter glass and the shutter glasses transmit the time sequential left and right image by turns. The passive glass type is using a film patterned retarder (FPR) and polarized glasses. The left and right images are simultaneously generated from the neighboring pixel columns and different polarization is imposed to each image by FPR attached on the display panel. Then, the polarized glasses selectively pass the image which has the same polarization.

Conventional FPR is fabricated by coating reactive mesogen (RM) on the alignment layer and then exposing a UV light. To impose different orientation of the optic axis, patterned wire-grid photo-mask and photo-alignment layer are required, which raise the cost of FPR. In this paper, we suggested a novel method for the fabrication of FPR using RM oriented by in-plane electric field. The proposed method requires neither a photo-mask nor a photo-alignment layer, thus reducing the production cost and simplifying the fabrication process.

2. Experimental procedure

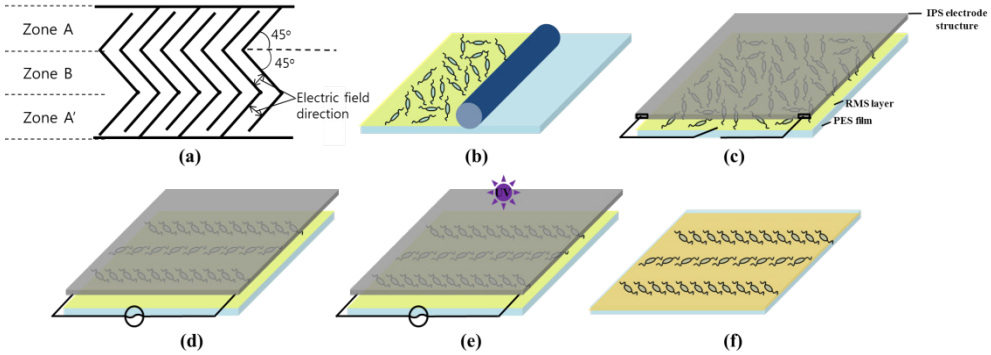

Fig. 1. Schematic illustration of the proposed fabrication process of FPR using in-plane electric field. (a) Structure of the in-plane electrode. The electrode direction in zone A and B is orthogonal and the electrode in zone A' is identical to zone A. (b) after RM coating on PES film, (c) RM coated PES film attached on in-plane electrode, (d) turning on electric field, (e) irradiating UV light, and (f) RM film detached from the electrode.

Figure 1 shows the suggested fabrication process of FPR using in-plane electric field. To apply in-plane electric field, the substrate with interdigitated indium-tin-oxide (ITO) electrodes was used [Fig. 1(a)]. The electrode substrate was obtained by a photo-lithography using a patterned photomask. The electrode has 2-domain structure, where the projected electric field directions on the substrate of the neighboring columns [zone A and B in Fig. 1(a)] were orthogonal. The width and separation of the electrodes were 3 and 7 μm, respectively. Commercial RM mixture RMS 03-013C (Merck) was slit-coated onto a poly-ether-sulfone (PES) film with a wire bar [Fig. 1(b)]. Then, the interdigitated electrode was contacted over the RM-coated substrate [Fig. 1(c)]. The separation between the PES substrate and the electrode corresponding to the thickness of the RM layer was maintained to be 5 μm using bead spacers. After applying 100 V in-plane electric field with a frequency of 60 Hz [Fig. 1(d)], a UV light of 25 mW/cm2 was irradiated to the RM-coated film for 120 sec [Fig. 1(e)]. Finally, the polymerized FPR film was separated from the electrodes [Fig. 1(f)]. Total area of the sample was 20 × 20 mm2.

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3. Results and discussion

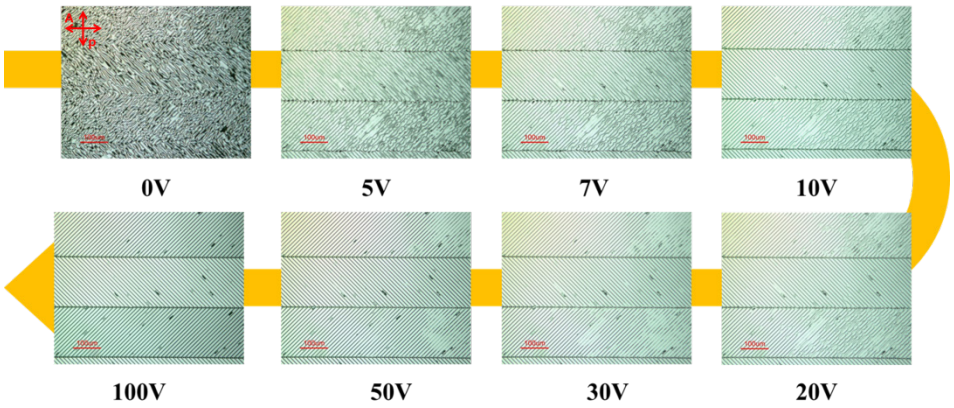

Fig. 2. POM image of the film coated with RM in the presence of the electric field before UV exposure.

Figure 2 shows the polarizing optical microscopy (POM) images of the RM-coated film attached on the electrode substrate before UV exposure. The sample was inserted between crossed polarizers. The in-plane field direction in neighboring domains was at ± 45° to the polarizer. In the absence of the electric field, the RM molecules were randomly oriented. With increasing electric field, the RM molecules were gradually switched to the electric field direction and disclinations lines disappeared. Under 100 V, most of the RM molecules were homogeneously aligned to the field direction.

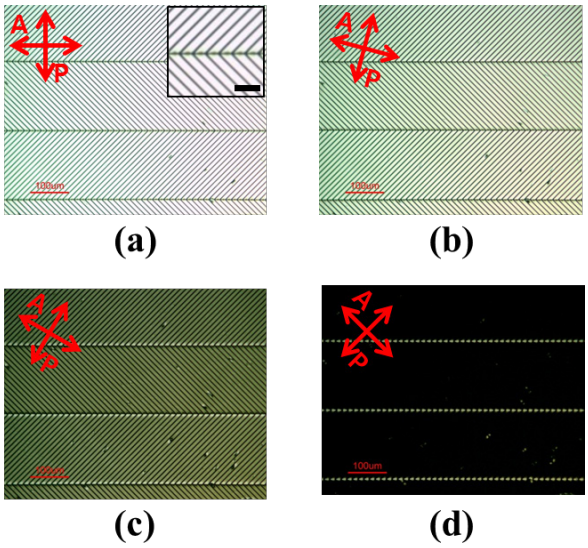

Fig. 3. POM image of the RM film attached onto the electrode substrate after UV exposure. The electrode direction of the top column was at (a) 45°, (b) 30° (c) 15°, and (d) 0° to the polarizer, respectively. Inset of (a) is the magnified image with the scale bar of 30 μm.

Figure 3 shows the POM images of the RM film at zero field state after UV polymerization. The polymerized RM film is still attached onto the electrode substrate, but the electric field was removed in Fig. 3. When the electrode direction of each domain was at ± 45° to the polarizer, the image showed the brightest state [Fig. 3(a)]. The brightness of the

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image decreased with rotating the sample between crossed polarizers [Fig. 3(b), 3(c)] and showed homogeneous dark state when the electrode direction was parallel to the polarizer [Fig. 3(d)]. Thus, it is confirmed that the polymerized RM molecules were homogeneously fixed parallel to the in-plane field direction.

We need to note the relatively dark stripes repeated in the domain in Fig. 3 with a period of ~10 μm. The position of this dark area is at the center of the in-plane electrodes [see the inset of Fig. 3(a)]. Because the in-plane electric field is not formed on the center of the in-plane electrode, the orientation of the RM molecules was not well defined. This periodic variance is also observed in Fig. 4 and Fig. 5. In order to remove the spatial variance, we think a time sequential application of the electric field can be a solution to remove the dark domains; During the first period, the electric field is applied between odd electrodes, e.g., the 1st and 3rd electrodes. During the 2nd period, the electric field is applied between even electrodes, e.g., the 2nd and 4th electrodes. With a sufficiently short period of the electric field, the RM molecules on the center of the electric field could be aligned to the field direction.

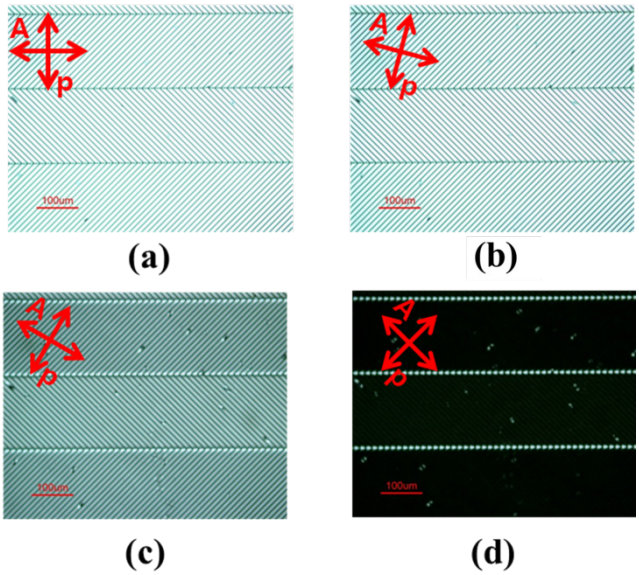

Fig. 4. POM image of the polymerized RM film after separation from the electrode substrate. The electrode direction was at (a) 45°, (b) 30°, (c) 15°, and (d) 0° to the polarizer, respectively.

We also checked the orientation of the polymerized RM film after separation from the electrode substrate [Fig. 4]. Similar to the images in Fig. 3, the detached film also showed bright and dark state when the optic axes of the neighboring domains were at ± 45° and 0° to the polarizer, respectively. Thus, the homogeneous orientation of the polymerized RM molecules was not destroyed in the course of detachment from the electrode substrate. We should note the lines of bright dots between the neighboring zones in Fig. 4(c) and 4(d). This like leakage is due to the misaligned RM molecules in the vicinity of adjacent zones. Because the in-plane electric field is not applied at the corners of the electrodes, the RM molecules are not perfectly aligned. However, the light leakage is blocked by the black matrix of the display panel, thus giving no crosstalk.

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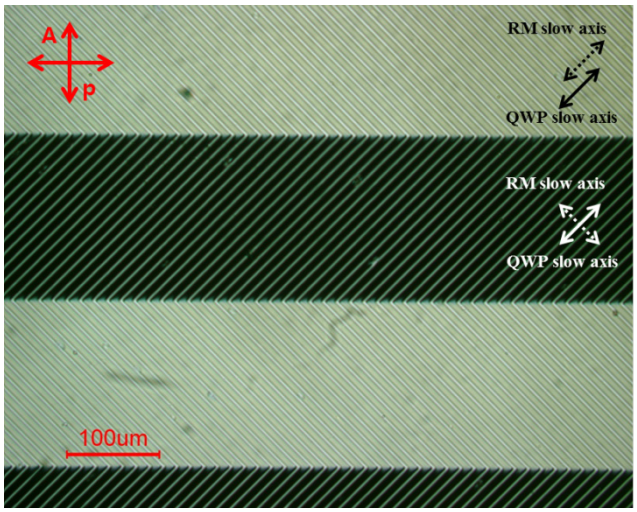

Fig. 5. POM image of the UV-polymerized RM film between crossed polarizers. A quarter wave plate film was inserted between the sample and the polarizer.

In order to check the polarization state of light passing through the FPR film, we inserted a quarter wave plate (QWP) between the sample and the polarizer, and observed the POM image between crossed polarizers. The slow axis of QWP was oriented parallel and perpendicular to the slow axis of the polymerized RM film in the neighboring domains in Fig. 5, respectively. The domain whose slow axis was parallel to that of QWP showed bright state, whereas the neighboring domain whose slow axis was perpendicular to that of QWP showed dark state. This result certainly indicates the neighboring domains give opposite retardation ± λ/4, hence the polarization of light passing through the neighboring domains were left- and right-circular polarized.

4. Conclusion

We proposed a novel method for the fabrication of FPR without a photo-mask and a photo-alignment layer. RM was coated onto the PES film, and then 2-domain interdigitated electrodes were contacted with the RM layer. UV light was exposed to the RM coated film in the presence of the in-plane electric field, and consequently homogeneous RM film where the slow axes of the neighboring domains were orthogonal was obtained. The suggested method could be used for the mass production of FPR film reducing the production cost.

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