Formation of Polymer Walls with a High Aspect Ratio on a Plastic Substrate

Su-Min Do, Tae-Hoon Choi, Jae-Won Huh, Yeongyu Choi, and Tae-Hoon Yoon

Department of Electronics Engineering, Pusan National University, Busan 46241, Korea

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ABSTRACT

We formed polymer walls with a high aspect ratio on a plastic substrate. Polymer walls are formed without a photomask through the phase separation of liquid crystal/reactive mesogen mixture induced by a spatial difference of elastic energy and electric field intensity.

1. INTRODUCTION

Microstructures with a high aspect ratio can be formed by using ultraviolet (UV) lithography (aspect ratio ~ 5) and X-ray lithography (aspect ratio ~ 20). Microstructures require a high aspect ratio for various applications, such as bio-MEMS, micro fluidal device, and X-ray grating [1]. The conventional photolithography suffers from a serious issue in forming structures with a high aspect ratio because of the diffraction limit by a photomask [2]. The diffraction limit can be overcome by using a short wavelength light source (EUV ~ 14 nm). However, it requires a high-fabrication cost due to the expensive lithography equipment and narrow process window by the light source. For practical application, fabrication of a microstructure with low cost and wide process window is required.

Liquid crystal (LC), one of the materials whose optical characteristics can be controlled by applying an electric field, has been widely used in various optical and photonic devices as well as display devices. By mixing reactive mesogen (RM) with LCs, polymer structures can be formed in an LC cell by phase separation. The physical mechanism on the phase separation of an LC/RM mixture has been investigated through several theoretical and experimental approaches [3-8]. One is the phase separation of an LC/RM mixture by the spatial difference in the intensity of the electric field [3-5]. Another mechanism on the phase separation of an LC/RM mixture is based on a spatial elastic energy difference [6-8].

In this presentation, we demonstrate a polymer wall with a high aspect ratio using LC/RM mixture. A polymer wall was fabricated without a photomask through phase separation of an LC/RM mixture induced by a spatial difference of elastic energy and electric field intensity. When an in-plane electric field is applied to vertical alignment (VA) cell containing an LC/RM mixture, a large spatial elastic energy is induced along the direction perpendicular to the interdigitated electrodes. RMs move to the center of interdigitated electrodes and the middle of the gaps between them where the elastic energy is very high and the in-plane component of the applied electric field is weak. We found that the proposed fabrication method can be used to form polymer walls with a high aspect ratio. Moreover, the fabrication method does not require high-cost equipment and specific process window because it does not require photomask. The proposed method uses simple UV irradiation in the air. Thanks to its simple and cost-effective fabrication process, we believe that polymer walls formed on a plastic substrate could be a potential candidate for various applications.

2. FABRICAION PROCESS

The effect of two-dimensional (2-D) confinement by an in-plane electric field is reported in [9-13]. When an in-plane field is applied, LC molecules with positive dielectric anisotropy are symmetrically reoriented at the boundaries A and B, as shown in Fig. 1(a). Virtual walls at the boundaries A are formed at the center of the interdigitated electrodes and the middle of the gaps between them. Virtual walls at the boundaries B are formed at the edge of the interdigitated electrodes. At the domain boundaries, LC molecules are not rotated in the azimuth or polar angle. Deformation of 2-D confined LCs induces physical phenomena in the LC cell. While an in-plane electric field is applied, a large spatial elastic energy difference is induced along the direction perpendicular to the interdigitated electrodes. Relatively high elastic energy is built at boundaries A and B, as shown in Fig. 1(b). However, the relatively strong in-plane electric field is built at boundaries B, as shown in Fig. 1(a). According to the previously reported mechanisms on the phase separation [3-8], RMs are moved to boundaries A.

The cell consists of top and bottom substrates and LC/RM mixture injected between them, as shown in Fig. 2(a). The gap of cell is maintained at 11 μm. The top substrate is a plastic coated with indium tin oxide layer. The bottom substrate consists of glass and electrodes. The interdigitated electrodes are separated from the common electrode by an insulating layer. While an in-plane electric field is applied for three hours, phase separation of the LC/RM mixture is induced, and RMs are polymerized by exposing UV light, as shown in Fig. 2(b). After polymerization, LCs are removed with a solvent of isopropyl alcohol, as shown in Fig. 2(c). After removing LCs, the cell is separated to the top and bottom substrate, as shown in Fig. 2(d). Polymer walls remain on the plastic substrate.

3. EXPERIMENTAL RESULTS

To confirm the formation of polymer walls, we fabricated the cell on the interdigitated electrodes. The width of the interdigitated electrodes was 2.8 μm, and the distance between them was 4 μm. The fabricated structure was observed by using the scanning electron microscopy (SEM), and light scanning interferometer (LSI), as shown in Fig. 3. The top view of polymer structures was observed by using SEM. Polymer walls were formed on a plastic substrate, as shown in Fig. 3(a). The pitch of a polymer wall was about 3.4 μm, which is half of the pitch of interdigitated electrodes. The polymer structures were formed in parallel straight lines, and the width was 0.55 μm. On the other hand, any polymer structures were not found on the glass substrate except for interdigitated electrodes, as shown in Fig. 3(b). Polymer structures were separated from the glass substrate because polymer structures were more strongly attached on the plastic substrate than the glass substrate. The height of the polymer structures could not be observed in the top view image by using SEM. To confirm the height and width of polymer walls, the cross-sectional image was observed by using LSI. Fig. 3(c) shows that the height, width, and aspect ratio of polymer walls were 10.33 μm, 0.55 μm, and 19, respectively.

4. CONCLUSION

In summary, we demonstrated to form polymer walls with a high aspect ratio without a photomask on a plastic substrate using LC/RM mixture. The polymer walls were formed by phase separation of an LC/RM mixture induced by a spatial difference of the elastic energy and electric field intensity. When an in-plane electric field is applied to a VA cell, a large spatial elastic energy is induced along the direction perpendicular to the interdigitated electrodes. By exposing UV light to the cell, polymer walls are formed at the boundaries where the elastic energy is relatively high and electric field intensity is relatively low. We fabricated polymer walls and confirmed them through the SEM and LSI images.

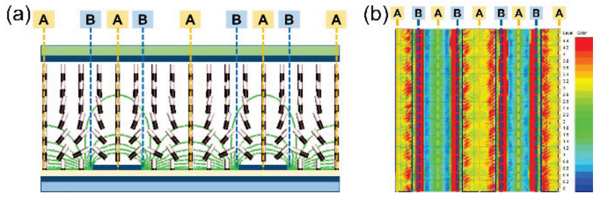

Figure 1 (a) LC director orientation and equipotential lines in a VA cell driven by an in-plane electric field, (b) total elastic energy profile in a VA cell driven by an in-plane electric field.

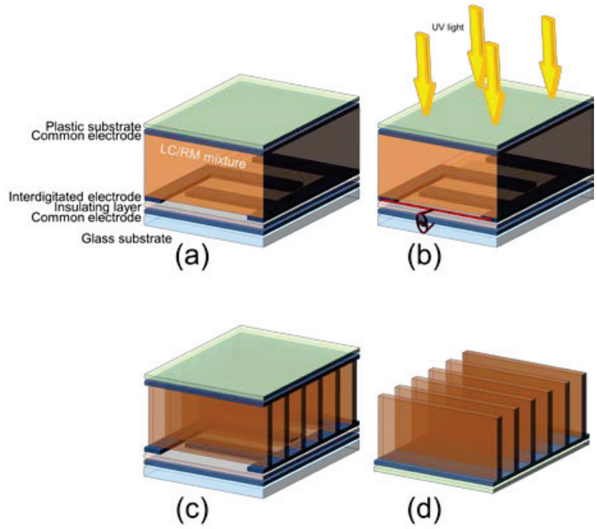

Figure 2 Fabrication process, (a) the cell, (b) UV curing of LC/RM cell while an in-plane field is applied, (c) LC-removed cell, (d) polymer walls on the plastic substrate.

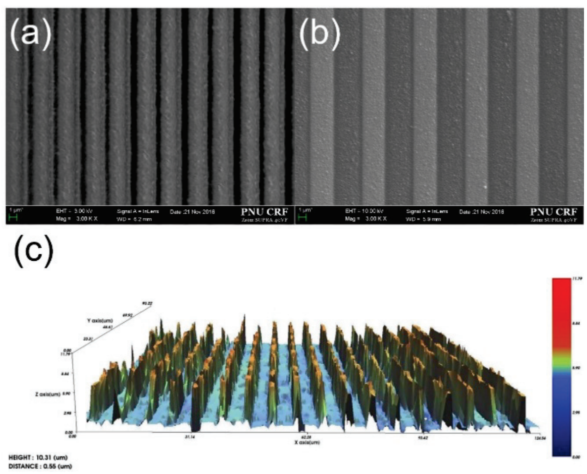

Figure 3 SEM images of polymer walls formed on (a) the plastic substrate and (b) glass substrate, (c) LSI image of polymer walls formed on the plastic substrate.

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