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Dual-Focusing Microlens Arrays Based on Electrohydrodynamic Pattering Method

Young Wook Kim[1], You-Jin Lee[1], Dae-Ho Jung[2], Jae-Hoon Kim[1, 2], and Chang-Jae Yu[1, 2*]

[1]*Dept. of Electronic Engineering, Hanynag University, Seoul, 133-791, Korea*
[2]*Dept. of Information Display Engineering, Hanyang University, Seoul, 133-791, Korea*
cjyu@hanyang.ac.kr

We proposed a dual-focusing microlens arrays (MLAs) based on the electrohydrodynamic (EHD) patterning method using a liquid crystalline polymer (LCP). The key mechanism of the EHD patterning method is an anisotropic flow of the LCP film induced by a fringe-field effect. By this method, we can fabricate a MLA having a polarization-dependence without complicated process. Therefore, it is suitable for a double-layer optical storage disc and other optical devices.

1. Introduction

In general, a microlens (MLA) is promising device for an optical pickup, optical communications, charge-coupled devices (CCDs), three-dimensional (3D) displays and so on [1-4]. Among them, the MLA in the optical storage having the single/dual-layer is an essential element to record and read data. Especially, in the dual-layer optical storage, two focal lengths are switched by a mechanical movement of the static lens and/or an electrically tunable focal length of the dynamic liquid crystal (LC) lens [5]. The former case, however, has some disadvantages, such as reliability and problem of an accurate position of the optic axis. And also, in the latter case, the response time is not enough for a focal length switching. Unlike them, the dual-focusing lens having a polarization-dependence is controlled by utilizing a polarization rotator such as a twisted nematic (TN) cell [6]. Thus, it has great dual-focusing properties without a mechanical movement. In general, the stamping process is a typical fabrication method for the dual-focusing lens [6, 7]. To get a dual-focusing characteristic, it used a mold having a surface relief structure included an alignment process. So, this method is very complicated. In this work, we proposed a novel method for the dual-focusing MLA, which is based on the electrohydrodynamic (EHD) patterning method using a liquid crystalline polymer (LCP) [8, 9]. The LCP is a proper material for a dual-focusing lens due to a large optical anisotropy, great durability and good alignment property. Besides the EHD patterning method is very simple, fast, and reliable. Eventually, this method is more suitable process than the conventional one.

2. Experiment

Figure 1 shows the fabrication procedure of the proposed dual-focusing MLA. At first, we prepared two substrate sputtered indium-tin oxide (ITO), then one is patterned by using conventional photo-lithography process with a designed photomask. To well-align the LCP molecules, a planar alignment material (AL22620, from JSR) was spin-coated onto the non-patterned substrate. It was pre-baked at 100^{o}C for 10 minutes to remove solvent in coated alignment layer and full-baked at 210^{o}C for 1 hour. It, in turn, was rubbed with one direction. Second,

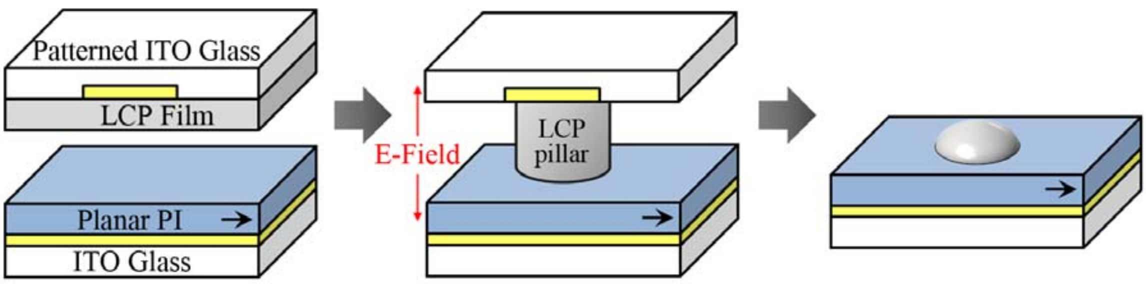

Figure 1. The fabrication procedure of the dual-focusing MLA.

the patterned substrate was spin-coated the LCP (RMS03-001C, from Merck) with a thickness of 1.45 μm and cured at 60°C for 1 min to evaporate solvent in the LCP solution. In order to maintain an air gap in the cell, we assembled two substrates with thickness of 5.5 μm using a glass spacer. Then, we applied voltage (~60V) to the cell to induce the EHD instability of the LCP film. When a net force, induced by the fringe-field effect and an air gap, exceeds the surface tension of the LCP film, cylindrical pillars was formed, linking between two substrates because an anisotropic flow of that toward high electric field regions [8, 9]. Lastly, we disassembled two substrates, then the separated LCP pillars on the non-patterned substrate change to the lens shape, well-aligned unidirectionally, due to the surface tension effect and surface roughness anisotropy. To solidify a lens shape, it was irradiated by UV light (λ=365nm) for 5 minutes in a nitrogen atmosphere.

3. Results

We introduced two capacitors in the cell to induce the EHD instability of the LCP film. The air gap in the cell has a key role in the EHD patterning method [8]. In the low field state, the LCP film is destabilized by the fringe-field effect, but it cannot form a flow because a net force is weaker than the surface tension. When a net force exceeds the surface tension by a high electric field, the LCP film forms an anisotropic flow from low field regions to high field regions, relatively. By this flow effect, the LCP film cannot maintain a stable state anymore. So, the pillar array is formed on the patterned electrode regions.

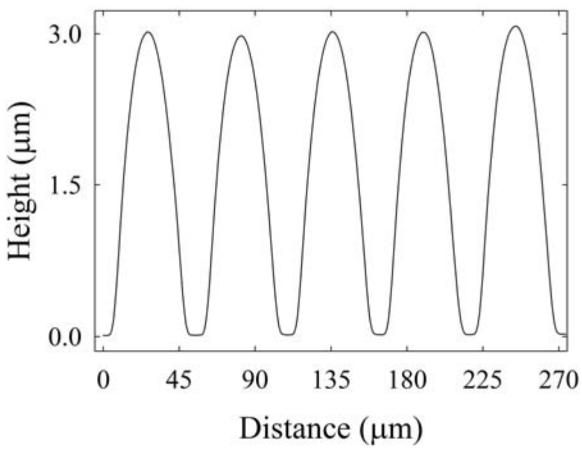

Figure 2. The surface profile of the fabricated dual-focusing MLA.

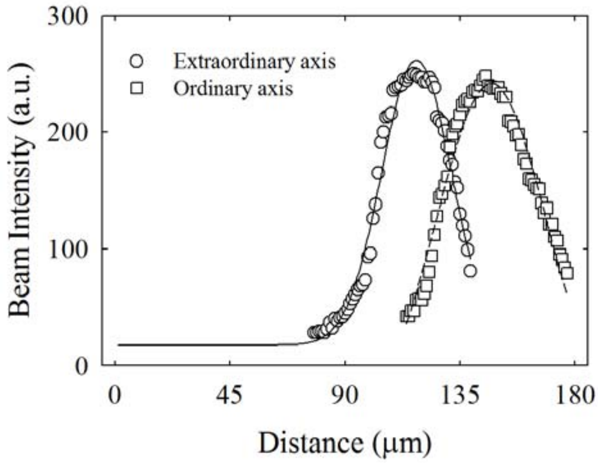

Figure 3. The dual-focusing property of the proposed MLA.

Figure 2 shows the surface profile of the proposed dual-focusing MLA. The measured height and diameter are 3.1 μm and 50 μm, respectively. To observe a dual-focusing property, we measured focal lengths according to the transmission axis of a polarizer using a He-Ne laser (λ=633nm). Due to the birefringence of well-aligned LCP, the measured two focal lengths are about 117 μm and 147 μm along the optic axis of the LCP molecules, respectively, as shown in Fig. 3, and the numerical apertures are 0.21 and 0.17, respectively. The extraordinary and ordinary refractive indices of the used LCP are 1.684 and 1.529, respectively.

4. Conclusion

We proposed the dual-focusing MLA based on the EHD patterning method. Using the LCP having a large birefringence and good durability, the dual-focusing MLA has excellent focusing properties according to the optic axis of the LCP. Besides, the EHD patterning method for the MLA processing is not only simple and fast, but also suitable for various applications such as the dual-layer optical storage disc and other optical devices.

5. Acknowledgements

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