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Fast Switchable Microlens Array Using a Surface-Stabilized Ferroelectric Liquid Crystal

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We study on the fast switchable microlens array using a surface-stabilized ferroelectric liquid crystal (SSFLC). Due to the existence of the spontaneous polarization, the fabricated microlens array has a fast switching property. Also, due to the separated each part, the relatively lower driving voltage and simple fabrication process are obtained. Eventually, this system can be applied to the optical components requiring fast tuning of focal length.

1. Introduction

Recently, a microlens array (MLA) has showed superior promise in a variety of the optical system, such as optical interconnect, optical communication, integral imaging system, and data storage device [1-3]. Various structures and fabrication methods of the MLA have steadily researched [4, 5]. Among them, the MLA based on liquid crystals (LCs) has a variable focal length, which is controlled by applied electric field. The MLA with variable focal length opens new fields in the optical applications. Although the MLA based on LCs, especially using a nematic phase, has a good focusing property, the response time is not enough in the some optical components requiring the real-time tuning focusing property. To satisfy fast response time, the MLA based on smectic C* (SmC*) phase of LCs is researched [6]. Using the ferroelectric liquid crystal (FLC), the fast response time is obtained easily.

We have researched the MLA of the refractive type using surface-stabilized ferroelectric liquid crystal (SSFLC) and each part (focusing part and switching part) was separated each other. Switching part was composed of SSFLC cell and the focusing part was composed of the concave type of UV curable polymer lens and liquid crystalline polymer (LCP). Compare to the previous MLA using the same SSFLC [7], our proposed MLA has an advantage in terms of driving voltage. Additionally, the rubbing direction of SSFLC is half of cone angle of the FLC with respect to the rubbing direction of the LCP. So, the increased focusing property is shown.

2. Experimental

To fabricate the proposed MLA, we first fabricated the switching part. We prepared two ITO (Indium-Tin-Oxide) glass substrates that were cleaned. Then, for homogeneous alignment state of the FLC molecules, the RN1199 (Nissan Chemical, Japan) was spin-coated on the cleaned ITO glass. Two ITO glass substrates were rubbed anti-parallel. To suppress the helical pitch of the FLC material,

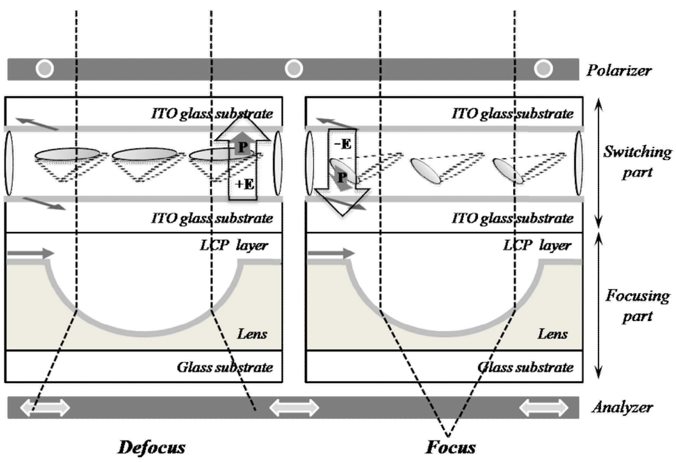

Figure 1. Proposed structure of the MLA

the cell gap of the assembled two ITO glass substrates was maintained under 2μm, which can obtain the maximum transmittance of the SSFLC. The injection of the FLC material (Felix-015/100, Clariant) was carried out in the isotropic phase (86°C) of the FLC material. We carried out detailed temperature control in the phase transition with low-frequency AC electric field to avoid zigzag defect.

For the focusing part, we prepared the cleaned glass substrate and spin-coated the UV curable polymer (NOA60, Norland Products Inc.). And then, coated glass substrate was exposed to the UV lamp for 100 sec under circularly patterned mask. For full-curing, that was exposed to the UV lamp without the mask. Then, the concave lens was formed. Next step was to form LCP (RMS03-001, Merck) layer. The RN1199 was spin-coated and rubbed on the lens surface to align homogeneous LCP molecules. Then, the LCP was spin-coated on the alignment layer twice. The solvent in the LCP compound was reduced at 60°C for 1 min. Last step was UV exposure for 25 min under nitrogen circumstance to polymerize the LCP material.

For the best focusing property, two parts were attached, keeping a half the cone angle of the FLC material. Fig. 1 shows the fabricated MLA structure.

3. Result and Discussion

The proposed MLA operated under crossed polarizer. In the positive DC voltage (+20V), because the optic axis of the polarizer is perpendicular to the FLC molecules, the incident beam passes through the slow axes of the FLC molecules and the LCP molecules. In accordance

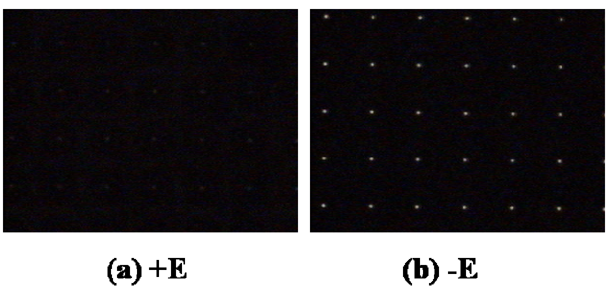

Figure 2. Polarizing microscope images at the focal plane under the crossed polarizer: (a) at the positive DC voltage, (b) at the negative DC voltage

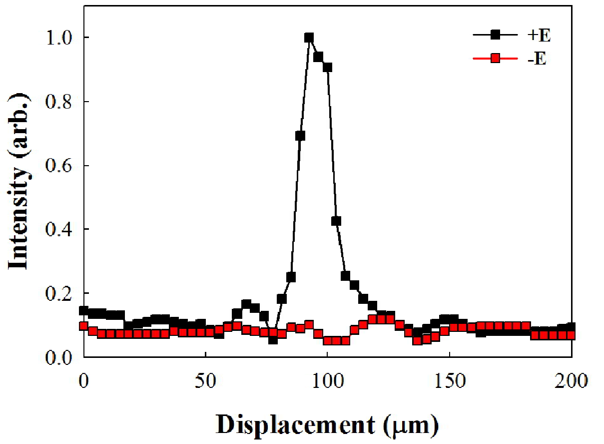

Figure 3. Beam intensity profiles at the applied voltage.

with the incident beam diverged due to the lower refractive index of the LCP (n_o=1.525) than that of the UV curable polymer (n_p=1.56) and defocused beam was blocked by the analyzer. In the negative DC voltage (-20V), the FLC molecules were tilted by 45 degrees with respect to polarizer and analyzer. Then, polarization of the incident beam was rotated by 90 degrees. As a result of changed polarization state, the incident beam is focused due to the higher refractive index (n_e=1.68) than n_p. Also, the focused beam passes through the analyzer.

The proposed MLA shows an excellent focusing and defocusing characteristics as shown in Fig. 2 and beam intensity profiles was shown Fig. 3. The measured focal length was about 3mm. The response time of the proposed MLA was very fast at the lower DC voltage due to existence of the spontaneous polarization and the separated each part. The measured falling time and rising time were 26μs and 44μs, respectively.

4. Conclusion

We study on the fast switchable MLA using SSFLC. The fabricated MLA has the good focusing property and the fast response time property at the lower DC voltage. Consequently, the proposed MLA can be suitable to the optical component requiring fast tuning of focal length.

5. Acknowledgement

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6. Reference

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