KLCC 2007, Vol. 10 ,
Reprints available directly from the publisher
Photocopying permitted by license only

Tunable-focus LC lens using a birefringence bilayer and a Ferroelectric Liquid Crystal

Kwang-Ho Lee, Yeonseuk Choi, Yongmin Lee, Kyung-Bae Kim and Jae-Hoon Kim*

Dept. of Electronics and Computer Engineering, Hanyang University, 17 Haenddand-Dong, Seongdong-Gu, Seoul, 133-791, South Korea
Phone: +82-2-2220-0343, E-mail: jhoon@hanyang.ac.kr

We fabricated LC lens which has variable focusing intensity by using UV curable polymer, Liquid Crystalline Polymer(LCP) and FLC layer. The LC lens has stable focusing characteristics and fast response time. It can be used for 3D displays, optical storage device and optical communications.

1. Introduction

Recently, the need of low operation voltage and fast response and stable focusing characteristics of LC lens has been increased optical communication and optical storage device and etc[1-3]. Thus, a variety of LC lenses has been reserached using a surface relief structure and graded refractive index and dielectric modulation[4-6]. However such LC lenses suffer from high operation voltage and delicate fabrication method and unstable focusing characteristics.

In this paper, we suggested a novel structured LC lens which has UV curable polymer, Liquid Crystalline Polymer (LCP) and Ferroelectric Liquid Crystal(FLC) layer. The LC lens is composed of two parts (tuning unit and focusing unit). The focusing unit consists of a concave microlens and LCP. When polarization direction status of incident light is changed, the intensity of the focusing unit is varied. The tuning unit includes a FLC layer which controls the light polarization with a fast response time and bistability. With this proposed LC lens, good focal properties and simple fabrication process can be achieved.

2. Experiment

Device configuration of our LC microlens is illustrated in Figure. 1. Focusing unit is a concave microlens array, fabricated by a UV curable polymer (NOA61, Norland). The UV curable polymer was spin-coated on the ITO substrates at the rate of first step 1000rpm for 10s and second step 4000rpm for 30s. After making a thin polymer film on the ITO glass, the UV (λ =365nm) light was irradiated on the thin polymer film through a patterned photo mask. Monomers in polymer compound were diffused by the irradiation process from the low-intensity resign to the high-intensity resign[7]. Then the surface relief structure was cured by UV irradiation. We prepared a homogeneous alignment layer of RN-1199A (Nissan Chemical, Japan) to align LC molecules. The alignment layer was spin coated onto the UV curable polymer layer, followed by unidirectional rubbing process. Then the liquid crystalline polymer was spin-coated on the concave structure at the rate of 3000rpm for 30s and cured by weak UV irradiation. To achieve a flat boundary of LCP layer, another spin-coating and curing process is required. Using a alpha-step, we measured the depth of microlens array and double LCP layer which were 3.92 μm and 0.006 μm, respectively. The fabrication process of the focusing unit is shown in Figure. 2. The other substrate was spin-coated with the homogeneous alignment material. In our configuration, no additional alignment layer is required. LCP acts as a homogeneous LC alignment layer due to the polymer chain ordering effect. The cell thickness was maintained by glass spacers of 3.0 μm. The FLC layer (Felix-016, Clariant) was inserted to the device by dropping method. Microscopic textures of the LC lens were acquired by a polarizing optical microscope (ECLIPSE E600 NIKON). All the focal images were captured by the CCD and computer-controlled image grabbing system at the focal plane of the microlens array.

KLCC 2007, Vol. 10 ,

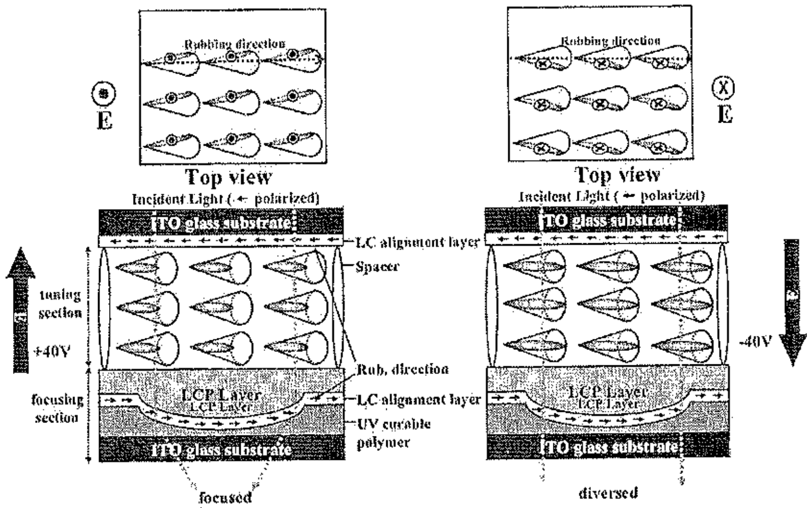


Figure 1. Suggested structure of novel LC lens

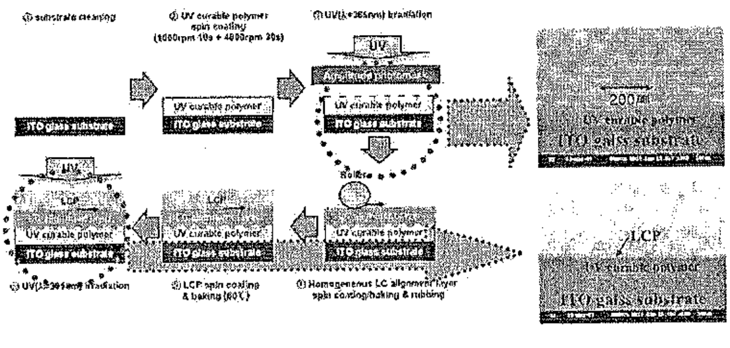


Figure 2. Fabrication process of focusing unit

3. Results and Conclusion

We examined the focusing intensity by applying an electric field as shown in Figure 3.

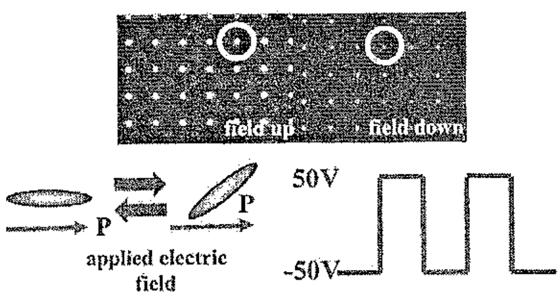


Figure 3. The focusing characteristics of the FLC microlens device with applied voltages.

In Figure 3, the switching characteristics of our FLC microlens device were shown as a function of the electric field. When the applied electric field is +50V, the incident linear polarization is parallel to the rubbing direction and the polarization direction is unchanged after passing through the FLC layer. Then, we can achieve the maximum focusing intensity of LC lens. The light is focused since the effective refractive index of the LCP is greater than that of the UV curable polymer. When -50V is applied to the tuning unit, we can confirm the minimum focusing intensity of the LC lens as shown in Figure 3. Therefore, focusing intensity is changed by the applied electric field. From the beam profile measurement as shown is Figure 4, it is confirmed that the maximum focusing intensity is about 3.3 times than the minimum focusing intensity.

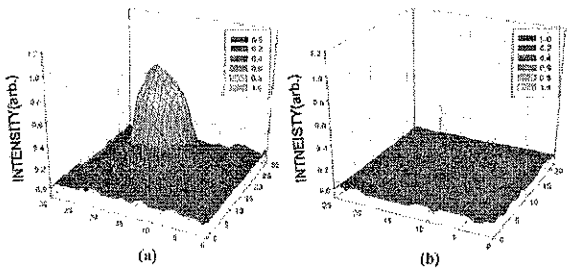


Figure 4. Focusing intensity by applied. (a) +50V, (b) -50V

We measured the response time of the suggested LC lens, using a He-Ne laser (λ =632.8nm). The measured rising and falling time are 74 μs and 69 μs, respectively. We measured the switching time using an oscilloscope, measuring the time with intensity variation between 10% and 90% of the maximum intensity. We noted that the switching time of our novel structure LC lens is about 1000 times faster than that of the NLC microlenses[1].

In summary, we have demonstrated the novel LC lens which has property of electrically controllable focusing intensity microlens array by using LCP, UV curable polymer and Ferroelectric Liquid Crystal. The device has the stable and fine focusing properties by controlling incidence polarization direction with applied electric field. The device consists of the tuning unit and the focusing unit. The proposed LC lens has static focal length, polarization dependent tunable focus and fast response time. This device is expected to be applicable for various optical communications, 3D display, and optical storage device.

4. Acknowledgements

This work was supported by Samsung Electronics co. Ltd.

5. References

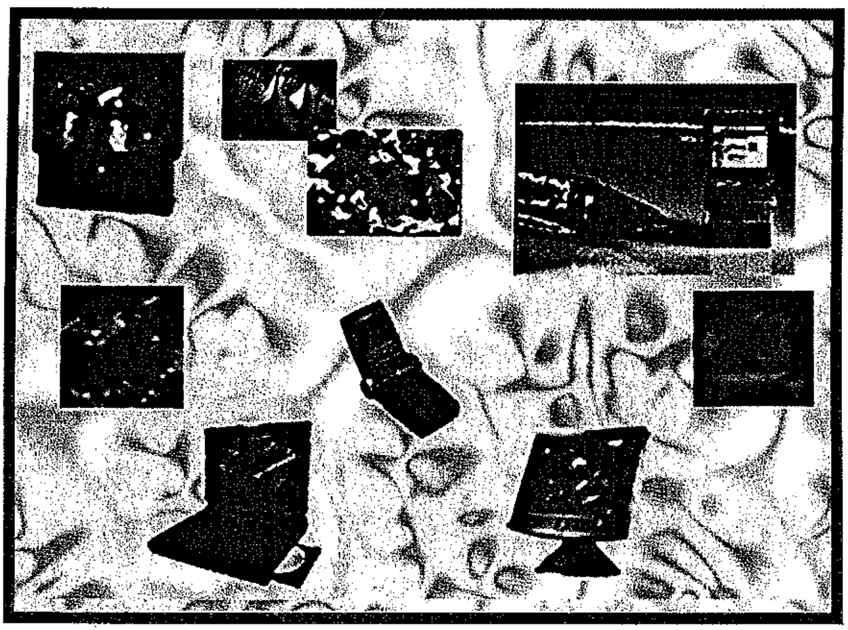
[1] J.-H. Kim and S. Kumar, J. Lightw. Technol., 23, 628 (2005).
[2] Y. Choi, J.-H. Park, J.-H. Kim and S.-D. Lee, Opt. Mater., 21, 643 (2002).
[3] H. Niino and A.Yabe, Appl. Phys.Lett. 70, 11,(1997).
[4] S. Masuda, T. Nose, and S. Sato Appl. Opt, 37, 11 (2004).
[5] H. Ren, Y.-H. Fan, and S-T Wu Opt. Lett, 29, 14 (2004).
[6] T. Nose, S. Masuda and S. Sato, Jpn. J. Appl . Phys, 31, 1643 (1992).
[7] Y. Choi, Y-W. Lim , J.-H. Kim , and S-D. Lee, proc. of KLCC 2004 , 7, 133, (2004).

KIΔΣ The KOREAN INFORMATION DISPLAY SOCIETY

Proceedings of the 10th

Korea Liquid Crystal Conference

Pusan National University
July 12 - 13, 2007



Korea Liquid Crystal Society (KLCS)
Display Division, Optical Society of Korea (OSK)
Research Institute of Computer, Information, and Communication, PNU

10:20 06. Optical memory in dye-doped liquid crystals for binary grating application
Eunje Jang, Hak-Rin Kim, and Sin-Doo Lee*,
Seoul National University

10:40 07. Tunable-focus LC lens using a birefringence bilayer and a Ferroelectric Liquid Crystal
Kwang-Ho Lee, Yeonseuk Choi, Yongmin Lee, Kyung-Bae Kim and Jae-Hoon Kim*,
Hanyang University

11:00 08. Thermal and UV Stabilities for TN and IPS modes with new Cellulose-Based Photopolymer
Han-Dong Cho[1], Seo-Kyu Park[2], Chul Gyu Jhun[1], Soon-Bum Kwon[1], Yu.Kurioz[3], Yu.Reznikov[3], I.Gerus[4*],
[1]Hoseo University, [2]NDIS Corporation,
[3]Institute of Physics, National Academy of Science, Ukraine,
[4]Institute of Bioorganic Chemistry and Petrochemistry, National Academy of Science, Ukraine

COFFEE BREAK (11:20 ~ 11:30)

SESSION 3 (11:30 ~ 12:50)
Chair : J. H. Kim (Hanyang Univ.)

11:30 09 듀얼 모드 스위칭을 이용한 액정 표시 소자의 시야각 조절
Jong-In Baek*, Yong-Hoan Kwon, Jae Chang Kim, and Tae-Hoon Yoon,
Pusan National University

11:50 010. Soft-Lithographic Patterning Method of LC Alignment Layers for Axially Symmetric Domain
June-Yong Song[1], Min-Soo Shin[2], Kwang-Soo Bae[2], Hak-Rin Kim[3] and Jae-Hoon Kim[*1,2],
[1]Department of Electronics and Computer Engineering, Hanyang University,
[2]Department of Information Display Engineering, Hanyang University,
[3]Kyungpook National University

12:10 011. New Electrode Structure for color-shift free Fringe-Field Switching Mode
Gak Seok Lee, Jae Chang Kim and Tae-Hoon Yoon,
Pusan National University

12:30 012. Close-packed colloidal assembly fixed on a polymer thin film
Sang-Wook Lee, Yoonseuk choi, and Sin-Doo Lee*,
Seoul National University