Surface Controlling Method for a Fast Response Time in a Dynamic Microlens Array

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We proposed a surface controlling method for a fast response time in a dynamic microlens array (DMLA) which is vertically aligned. Mixed alignment layer can form pretilt of LC director at each position due to omnidirectionally polymerized reactive mesogen (RM), as completely reoriented LC director. Through this method, the response time can be remarkably enhanced.

1. Introduction

The dynamic microlens array (DMLA) based on liquid crystal (LC), which can control the focal length without mechanical movement, has been researched by many research groups [1-4]. MLA based on nematic LC (NLC), however, has a slow response time because of the intrinsic property of that. So, MLA based on NLC is inappropriate in specific application of DMLA requiring a fast response time. Especially, MLA based on vertically aligned LC with negative dielectric anisotropy has a slow response time and unstable textures of LC director because the transition time from splay to twist leads to a slow response time when applying voltage above the threshold voltage.

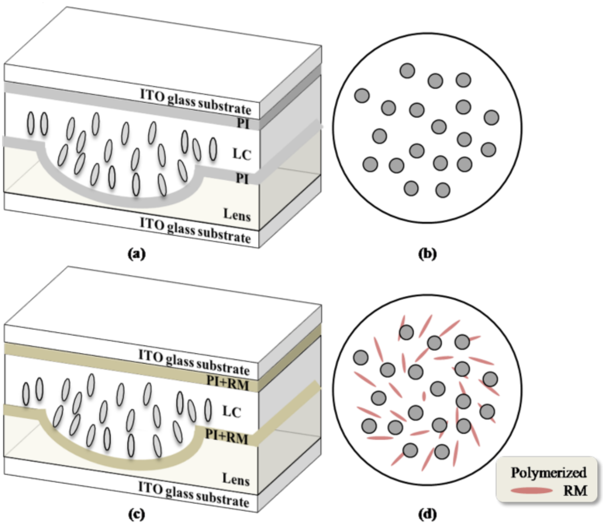

Figure 1 The schematic diagrams of (a) the conventional DMLA and (c) the proposed DMLA, top view of (b) the conventional DMLA (d) the proposed DMLA with polymerized RM

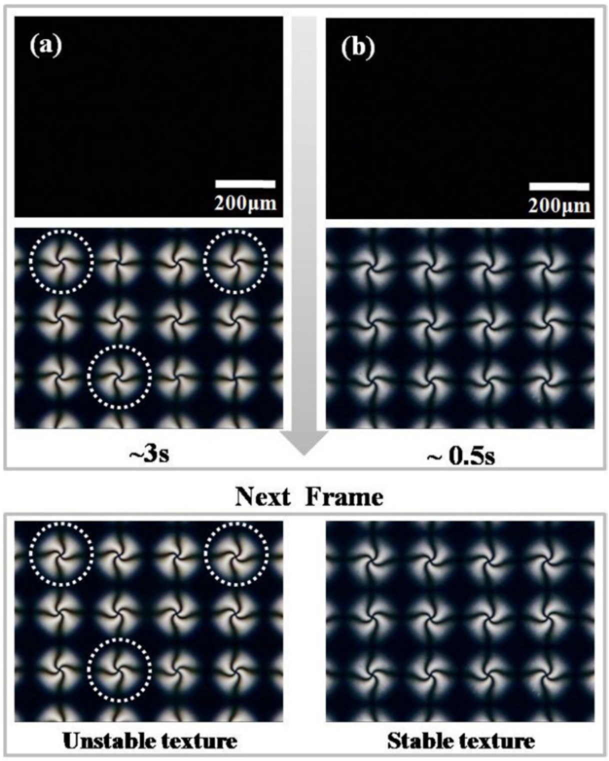

Figure 2 The time-resolved switching textures of (a) the conventional DMLA and (b) the proposed DMLA at 8V under crossed polarizers

In this paper, we proposed a surface controlling method to approach a fast response time of a DMLA with mixed alignment layer which is composed of the vertical alignment layer and reactive mesogen (RM). By polymerizing RM on the surface, the reoriented directions of LC molecules on the both of the substrates are predefined. In order to determine reoriented directions of LC molecules at each position of both substrates, the RM was polymerized by irradiation of UV light with an electric field to reorient LC director completely. Through this process, RM was omnidirectionally polymerized on the surface. Therefore, omnidirectionally formed pretilt at each position of surface relief structure (SRS) affects a fast response time. By forming pretilt effect, the proposed DMLA can remarkably reduce the reorientation time of the LC director, regardless of applied voltages.

2. Experimental

At first, we coated the indium-tin-oxide (ITO) substrate with UV curable polymer (NOA60, Norland). Subsequently, the spin-coated substrate with UV curable polymer was irradiated by UV lamp (λ=365nm) under the photo-mask for some minutes until the required depth was obtained to fabricate the appropriated lens surface. During irradiation, to preserve relative density of the monomers, they are diffused from the UV non-exposed regions to UV exposed regions. In order to completely polymerized UV curable polymer, the spin-coated substrate with UV curable polymer was irradiated by UV lamp for some minutes without the photo-mask, and then, the SRS was fabricated for the proposed DMLA structure. The pitch and diameter of the used photo-mask for DMLA structure are 200μm and 100μm, respectively.

We mixed properly AL1H659 (from JSR), used for vertical alignment layer, and RM for the surface controlling method. Both of the substrates were spin coated with the mixed material and prebaked at 100°C for 10 minutes. For a perfect polyimide, a full curing process at 180°C for an hour proceeded. Without a rubbing process, the LC was dropped on the SRS, and then both substrates are assembled by using 3μm spacer. Finally, for a applying the surface controlling method, the proposed DMLA was irradiated by UV lamp with an applied voltage for some minutes.

3. Result and Discussion

The DMLA using mixed alignment material, which is constituted by reactive mesogen (RM) and homeotropic alignment solution, has been proposed. In the conventional MLA, LC director reoriented by an applied voltage is changed randomly to minimize the deformation energy of LC as 2-step operation. Figure 1 shows the schematic diagrams of the conventional DMLA and the proposed DMLA, and shows LC molecules at zero voltage in the top view, also. In the initial state, an applied zero voltage, alignment state of LC director is same between two DMLAs. However, these DMLAs, in the top view as shown in Fig. 1 (b) and (d), is different each other because of polymerized RM in the proposed DMLA. The RM mixed with vertical alignment layer was omnidirectionally polymerized. As the omnidirectional RM, the pretilt of LC in the SRS was differently formed each position. In the event, polymerized RM in the SRS, which has an anchoring effect, reoriented direction of LC molecules are predetermined. When an applied voltage is 8V, time-resolved LC textures in the SRS are showed in Fig. 2. The conventional DMLA is unstable texture due to the different direction even at the same positions, and has a very slow response time, about 3 seconds. On the contrary, the proposed DMLA has a faster response time than that, and has a stable texture because of the same direction at the same position. And the conventional DMLA has a 2-step operation to minimize the deformation energy of LC. However, in the proposed DMLA using mixed alignment material, LC director reoriented by electric field is not changed as 1-step operation, because polymerized RM on the surface memorized texture of LC through UV exposure during applying voltage. In the presence of electric field, LC director is directly reoriented by directional polymerized RM as shown in Fig. 1 (b). Finally, response time of the proposed MLA is improved because of 1-step operation of LC director induced polymerized RM.

Applying 20V to the conventional MLA, the LC molecules were tilted down and randomly rotated with having high elastic deformation as shown in Fig. 3. After the above process completed, LC molecules started being reoriented to reduce the elastic deformation thus it has 2 steps to reach the stable state. This phenomenon indicates that the response time is inevitably slow. LC molecules in the proposed DMLA, prepared with the mixture of vertical alignment layer and RM, were fixed even applying a high voltage because memorizing effect by polymerized RMs on the surface [5, 6] affects LC molecules to be directly a spiral state with 1-step operation. In the event, the response time of the proposed DMLA is improved about 2 times faster than the conventional DMLA. The response time, measured by oscilloscope, of the conventional DMLA and the proposed DMLA, are 200ms and 90ms, respectively.

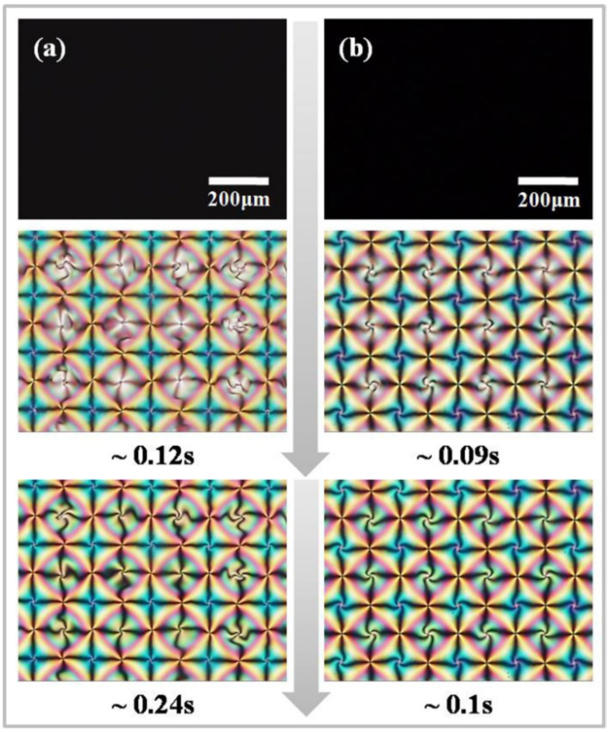

Figure 3 The time-resolved switching textures of (a) the conventional DMLA and (b) the proposed DMLA at 20V under crossed polarizers

4. Conclusion

We demonstrate the DMLA, vertically aligned using alignment layer mixed with RM to enhance the response time. Polymerized RMs on the surface memorized texture of LC, thus LC molecules in the proposed structure directly reoriented as the spiral configuration regardless of the applied voltage. As the result, our DMLA can be enhanced remarkably the response time, compared to the conventional DMLA.

5. Acknowledgement

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6. Reference

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