Single-Polarizer Liquid Crystal Display Mode using a Passive Polarization-Dependent Microlens Arrays

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Abstract

We proposed the single-polarizer liquid crystal display (LCD) mode for enhanced response time using a passive polarization-dependent microlens arrays (MLA). Due to the flat-surface in liquid crystal layer (LCL), the response time can be enhanced at whole applied voltages. We expected that this LCD mode has a low process cost, and high optical efficiency.

1. Introduction

In general, liquid crystal display (LCD) is operated by modified retardation of the liquid crystal layer (LCL) with applied electric field between two orthogonal polarizers. However, the use of two polarizers caused a high process cost and low optical efficiency in the LCD.

In our previous research, we proposed the single-polarizer LCD mode using the microlens arrays (MLA), having a passive polarization-dependent property, and two orthogonal black matrices (BMs) [1]. In this mode, LC molecules on the non-flat surface caused by a surface relief structure of MLA are slowly operated by an applied voltage or not, so this mode has a slow response time, especially decay time.

In this research, we proposed an advanced structure of a single-polarizer LCD mode having an enhanced response time by using a polarization-dependent MLA. It consists of switching part and focusing part as shown in Fig. 1. Switching part is twisted nematic (TN) due to the wide process margin, and focusing part is composed by surface relief structure and liquid crystalline polymer (LCP), filled up that. Due to the birefringence property of LCP, focusing part has a polarization-dependent characteristic [2]. By altering the polarization of the incident light in switching part, and modulating optical path of incident light in focusing part, this mode can operate with only one polarizer with two orthogonal BMs as shown in Fig. 1. And also, response time is enhanced, due to flat-surface in the switching part. Consequently, proposed LCD mode with only one polarizer can decrease a process cost and increase optical efficiency, having an enhanced response time.

2. Experimental

For the focusing part, we first fabricated two BMs. In order to form BMs, we used a lift-off method using the photoresist on the opposite side of indium-tin-oxide (ITO) glass substrate. The diameters of first BM and second BM are 50μm, and 40μm, respectively, and same pitch is 200μm. For the surface relief structure, UV curable polymer (NOA 60, Norland) is spin-coated on the first BM layer and it is aligned with photomask having same pitch but diameter is 100μm. And then, surface relief structure is fabricated through UV exposure for 55sec, because monomers of UV curable polymer are diffused by difference of UV intensity, induced by photomask, to maintain their relative density. For complete polymerization of surface relief structure, it is irradiated by UV light without a photomask. The measured depth and the curvature of the fabricated surface relief structure were 8μm and about 498μm, respectively. Next, we spin-coated the planar alignment (RN1199, Nissan Chemical) on the surface relief structure and then, rubbed unidirectionally. Finally, LCP (RMS03-001C, Merck) is spin-coated on the surface relief structure in twice to stuff into there.

For the switching part, we rubbed both substrates in a cross-direction each other. Here, the slow axis of LCP is parallel to that of switching part. To maintain the cell thickness, we used glass spacers of 4.5μm. The nematic LC ($\Delta n = 0.104$, $\Delta\varepsilon = 5.5$) is injected into the cell by capillary effect at room temperature. The ordinary and extraordinary refractive indices of LCP, and the refractive index of the UV curable polymer are $n_o = 1.525$, $n_e = 1.68$, and $n_p = 1.56$, respectively.

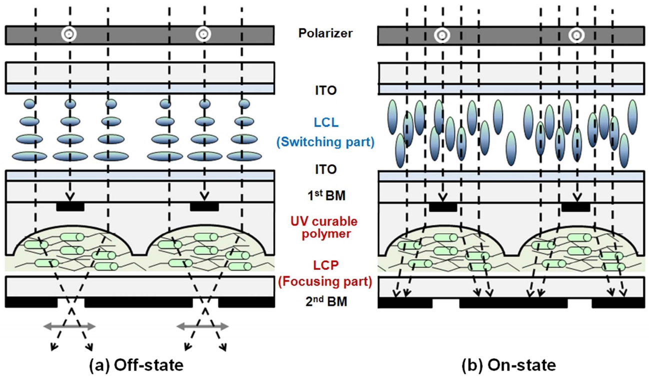

Fig. 1. Schematic diagram and operating principle of the proposed LCD mode in (a) off-state and (b) on-state

3. Results and discussion

The proposed structure and operating principle are shown in Fig. 1. Note that LC molecules of switching part are on the flat-surface, about the same conventional TN mode, in contrast to structure of Ref. 1. In the off-state, the polarization state of incident light can be rotated by 90° according to LC director, so incident light is focused by difference of refractive index between the slow axis of LCP and UV curable polymer in focusing part. And then, this state presents a white state because the focused light is passed through two orthogonal BMs. On the other hand, in the on-state, the polarization state of incident light is not changed by switching part. Then, the incident light is defocused by difference of refractive index, so this state is black state.

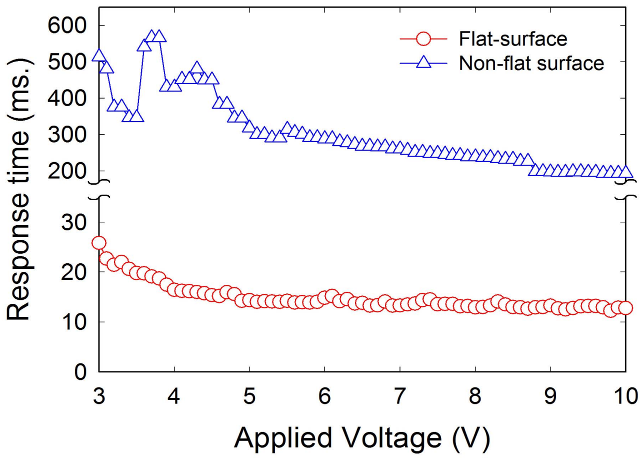

Fig. 2. Comparison of the measured response time as function of the applied voltage.

Figure 2 shows the measured response time of the structure having a non-flat surface and proposed one. Among them, the one has a very slow response time of about 200ms at even 10V. In contrast, the other having flat-surface has a much faster response time (~13ms) than the one relatively at all applied voltages. The measured contrast ratio (CR) is about the same between two structures, about 130.

4. Summary

We proposed a single polarizer LCD mode having a passive polarization-dependent MLA, filled up the surface relief structure by LCP and having a switching part, TN configuration. Because LC molecules of switching part are a flat-surface, response time of the proposed structure is considerably enhanced. Consequently, this LCD mode has some special characteristics, such as a fast response time, high optical efficiency and low process cost.

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5. References

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