# Liquid Crystal Display Mode with a Single Polarizer by Controlling the Optical Path

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We demonstrated a LCD mode based on single polarizer by controlling the optical path using a microlens array (MLA). To remove an analyzer, we controlled the optical path of incident light by using MLA and mutually complementary black matrix (BM). Consequently, we presented a novel LCD mode, which is lower cost and higher optical efficiency than the conventional LCD mode under crossed polarizers.

## 1. Introduction

Generally, the liquid crystal display (LCD) is realized by modified retardation of the liquid crystal layer (LCL) with applied electric field between two orthogonal polarizers due to the birefringence effect. In the recent LCD, in addition to, the various optical components such as retardation plate film and polarizer are indispensable for excellent device characteristics. However, these optical components induce not only considerably high process cost but also low optical efficiency. Although the polarizer in these optical components has many demerits, almost transmissive LCD modes cannot operate without two orthogonal polarizers due to the realization of the black state.

In this paper, we demonstrated a novel LCD mode with a single polarizer by controlling the optical path using a switchable MLA [1-5]. In order to operate with only one polarizer, the optical path controlling method is applied with black matrix layer (BML). In the proposed configuration, as shown in Fig. 1, initially homogenous aligned LCL is parallel to transmissive axis of incident polarizer, so the effective refractive index of a LCL is controlled by an applied electric field. Through the changed optical path by using MLA, incident light is penetrated and obstructed by the BML. Finally, we can remove an analyzer by introducing LCL and BML. Due to the only one polarizer, the proposed LCD mode has many merits, such as high optical efficiency and low process cost.

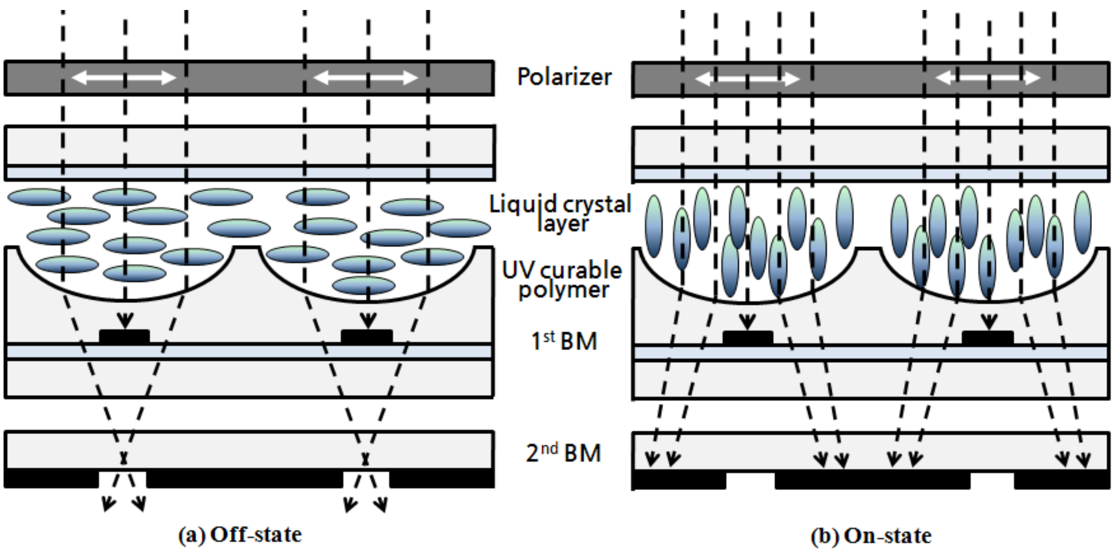


**Figure 1 Operating principle and schematic diagram of the proposed LCD mode with only one polarizer**

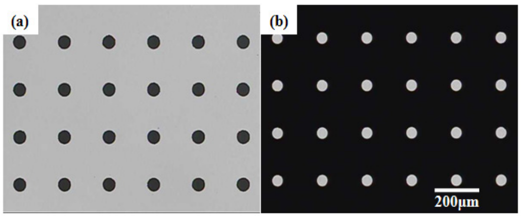


**Figure 1 Fabricated (a) the first BML and (b) the second BML by lift-off method**

## 2. Experimental

The proposed LCD mode includes just one polarizer, LCL, MLA on the first BML, and second BML as shown in Fig. 1. At first, mutually complementary BMLs are fabricated by lift-off method. The pitch and diameter of first BML and second BML are 200μm, 50μm, and 40μm, respectively.

The MLA was formed by using the first BML as a photomask, called self-align method. UV curable polymer (NOA60, Norland) was spin-coated on the first BML, and then the opposite side of spin-coated substrate was irradiated by UV light. Due to the UV curable property, the monomers diffused from unexposed regions to exposed regions to preserve relative density. After forming lens shape, we irradiated UV light on the spin-coated side for the completely polymerized lens surface. The measured depth and curvature of each lens were 10μm and about 340μm, respectively.

The planar alignment (RN1199, Nissan chemical) was spin-coated on the MLA substrate and top substrate which is formed indium-tin-oxide (ITO) on the surface, and then two spin-coated substrates were prebaked at 100°C for 10 minutes to evaporate solvent in the planar alignment and main-cured at 210°C for 1 hour. After curing process, the two substrates were rubbed by using a rubbing machine with anti-parallel direction each other. We used the nematic LC which has the large Δn (Δn = 0.2361 at 589nm, Merck) for the short focal length. By using one-drop filling (ODF) method, the complete sample, maintained a cell gap of 3μm at the edge of MLA, is assembled.

## 3. Result and Discussion

The proposed LCD mode is operated by mechanism of controlling optical path in a MLA with the electric field. The bright and black states of the proposed LCD mode are depending on the refraction of the boundary between the MLA and LCL. Figure 3 shows the microscopic images of the focused and defocused light at the focal plane (~2.5mm) under one polarizer without the second BML. LC director of LCL is homogeneously aligned parallel to transmission axis of incident polarizer, so according to electric field the refractive index of LCL is changed from extraordinary refractive index to ordinary refractive index, while the refractive index of MLA is fixed. In accordance with, incident light is focused and defocused by difference of refractive index between different materials. When applied voltage is 0V, maximum transmittance value can be obtained by our measuring system because the focused light penetrated through the second BML. The transmittance value is gradually decreased and disappeared as increasing voltage. Figure 3 (c) shows electro-optic characteristic which is measured, changing the applied voltage from 0V to 7V. Figure 4 shows the captured images of the propose LCD mode by using He-Ne (632.8nm) laser. We confirmed that the proposed LCD mode is well operated with a single polarizer.

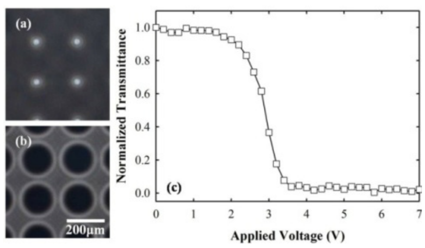


**Figure 3 Microscopic images with one polarizer (a) 0V, (b) 7V, and (c) measured EO characteristic**

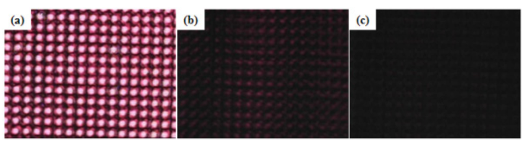


**Figure 4 The captured images of the proposed LCD at the focal plane with a second BML, (a) 0V, (b) 3V, (c) 7V**

## 4. Conclusion

We proposed a novel LCD mode controlling the optical path of the incident light by using MLA to be operated with only one the polarizer. Because of the focused and defocused light by electrically modulating the refractive index of LCL with two BML, this mode can be realized with only one polarizer. Consequently, the proposed LCD mode has some merits, such as a low process cost and high optical efficiency.

## Acknowledgement

This research was supported by a grant (F0004120-2008-31) from Information Display R&D Center, one of the 21st Century Frontier R&D Program funded by the Ministry of Knowledge Economy of Korean government.

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