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Advanced Liquid Crystal Display with Microlens Array for High Contrast Ratio

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We propose twisted nematic liquid crystal (TNLC) device with high contrast ratio (CR) using a new microlens array (MLA). It is composed largely of electrically controllable liquid crystal layer, a static liquid crystalline polymer (LCP) layer on the concave microlens structure and a circular black matrix (BM). For the dark state, the focused light is first blocked by the BM and light leaked in BM is blocked once more by the output polarizer. Such double blocking dramatically increases darkness. Consequently, we could get the high CR.

1. Introduction

Several types of liquid crystal displays (LCD) have been proposed under each individual merit [1-4]. One of the most popular operation modes in LCD is TN mode and TNLC device has been widely used at portable personal digital assistants and notebook computers because of its advantages, such as relatively high transmittance, low operation voltage, low electric power consumption and simple fabrication process. However, the asymmetric director alignment of it causes a narrow viewing angle and it has a limitation at LCD applications demanding high CR due to light leakage in the dark state. TN mode has advanced drastically viewing angle which has been regarded as a weak point of it, due to development of discotic film used as an optical compensation layer. But it has a limitation still for TV application demanding high CR.

In this paper, as a new approach, we present a high CR-TNLC device characterized by microlens array (MLA) configuration with a new concept. Several types of MLA with liquid crystal have been proposed for a tunable focal length and focus intensity which can be obtained by the electrically controlling birefringence of LC molecule such as Fresnel type [5] and a gradient refractive index (GRIN) type [6]. Fresnel type requires an extremely elaborate alignment and photolithographic

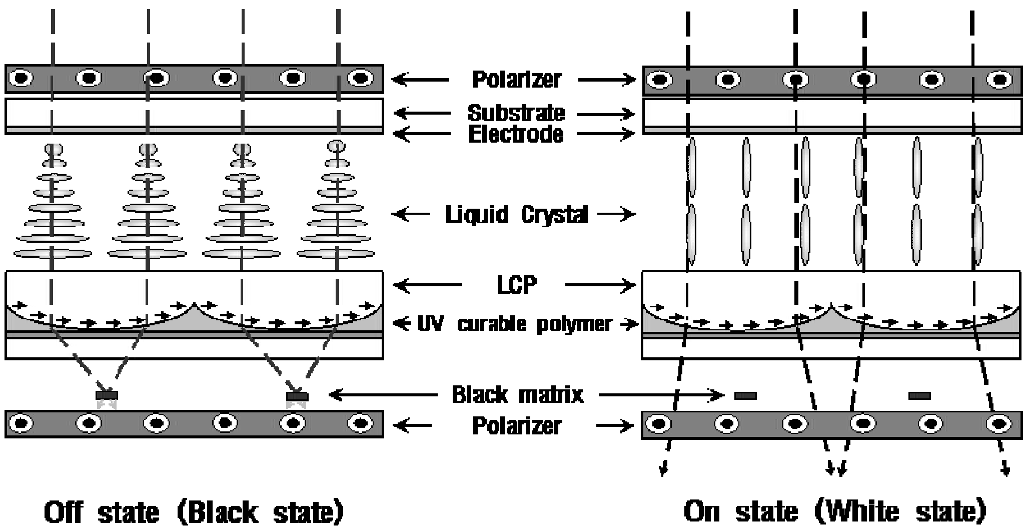

Figure 1. Schematic diagrams of the device configuration

technique and a multirubbing process for practical application. GRIN types usually requires a high driving voltage and complex fabrication which is hard to implement on microsized arrays and has a long focal length due to the limited modulation of the electric field gradient. In our previous work, we proposed a dynamic MLA using the combination of lens with the LCP and LC layer [7-8]. Such dynamic lens structure has stable and enhanced dynamic focusing characteristics. In this work, we adopt that system as an optical component to improve performance of LCD.

2. Experimental

Figure 1 shows schematic diagram of the proposed optical configuration. It is composed of parallel polarizer, largely electrically controllable liquid crystal layer (switching unit), a static LCD layer on the concave microlens structure of the UV curable polymer (focusing unit), and a small circular BM layer. The liquid crystal layer which has switching characteristics is adopted to control the polarization of incident light. The focal length of the focus unit is controlled by the polarization direction of light at the boundaries between LCP and the microlens due to the anisotropic refractive index of LCP. The black matrix is placed at focal point of microlens array.

When the direction of polarized light is perpendicular to the aligning direction of LCP, the incident light is defocused and the light comes out of output polarizer because the refractive index of LCP is smaller than it of UV curable polymer. In this case, transmittance decreases slightly due to black matrix. On the other hand, when the direction of polarized light is parallel to the alignment of LCP, the light is focused because the refractive index of LCP is bigger than it of UV curable index. The focused light is first blocked by the black matrix and light leaked in black matrix is blocked once more by the output polarizer. Such double blocking dramatically increases darkness.

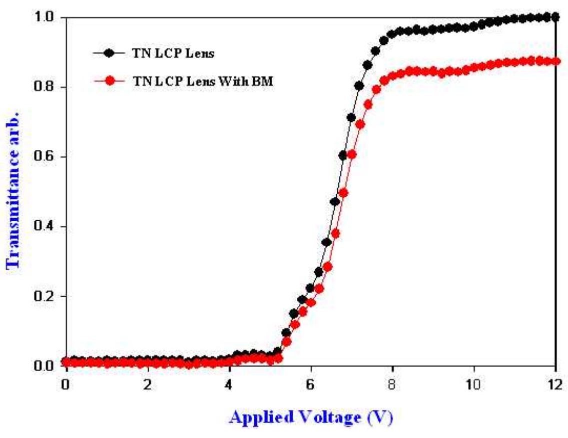

Figure 2. Voltage-transmittance of TN LCP lens using black matrix or not

Figure 2 shows the voltage-transmittance curve of TN LCP lens using black matrix or not. The threshold voltage was about 5V and the transmittance was saturated at 10V.

3. Conclusion

As TN LCP lens using the BM, the maximum transmittance is slightly decreased due to BM. However, the minimum transmittance is dramatically decreased due to double blocking method of BM and polarizer. In the event, we were confirmed dramatically increased contrast ratio. The contrast ratio of the TN LCP lens using the BM is about two times higher than the conventional TN LCP lens.

4. Acknowledgements

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5. Reference

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