3D Liquid Crystal Display with Single Polarizer and Patterned Retarder Structure

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ABSTRACT

We present a three dimensional (3D) Liquid crystal display (LCD) in a stereoscopic type using the single-polarizer LCD and in-cell patterned retarder. To construct 3D images in single-polarizer LCD with the microlens array, the micro-patterned retarder embedded the LCD generates two orthogonal polarizations.

1. INTRODUCTION

Recently, three dimensional (3D) display which can satisfy the requirements of consumers for more realistic picture is considering a prospective candidate for next generation display [1]. Many technologies for realizing the 3D display have been researched in various fields. The various efforts for 3D displays are classified into two major types. One is a group of the non-glasses (auto-stereoscopic) display such as a lenticular imaging display and a parallax-barrier display. The other is the stereoscopic display to construct the 3D images by using shutter glasses or polarized glasses [2-4]. The auto-stereoscopic display as the direct-watching 3D type does not demand functional glasses because right and left images are spatially separated by two orthogonal polarizations through geometric devices [5-7]. However, this type has tight limitations, which the image quality absolutely relies on the certain position of the viewer's head. Contrarily, in the stereoscopic type, the decoupled right and left images are sent into right and left eyes of viewers through the glasses with particular functionality such as shutter glasses, anaglyph glasses, and polarized glasses. This type has been the most attractive method due to the lower cost and simpler manufacture than other methods. Among the diverse technologies for 3D display in the stereoscopic type, LC device equipped with a micro-patterned polarizing element and used the polarized glasses is considered as the most advantageous technology in binocular disparity stereoscopic display systems.

In this work, we proposed a stereoscopic single-polarizer LCD equipped with micro-patterned polarizing elements. In the structure of our device, the patterned liquid crystalline polymer (LCP) acts as the selective λ/2 phase retarder in the single-polarizer LC cell [6]. We could obtain 3D stereoscopic images by two orthogonal polarization states. Moreover, using by a single-polarizer LC cell without the analyzer as the optical switching device, we could fabricated the 3D display reducing the parallex-problem through embedding the patterned retarder.

2. EXPERIMENT

Figure 1 shows the schematic diagram of the fabrication process for our 3D LCD device. First of all, we fabricated two complementary black matrices (BMs) by a lift-off method using the photo-resistor (AZ5214, AZ Electronic Materials) on the indium-tin-oxide (ITO) glass substrate. The first BM array with the circular type was patterned with aluminum (AL) using a conventional photo-lithography process. It has the diameter of 50 μm and the pitch of 200 μm. The second BM array has the 70 μm diameter and the same pitch of the first BM array. After then, on the first BM array, we spin-coated the homogeneous alignment layer (RN1199, Nissan Chemical) and rubbed 45° on the substrate with the first BM array. Liquid crystalline polymer (LCP) with 45 wt.% concentration (RMM141C added in 30 wt.% of RMS03-013C) was spin-coated on the rubbed substrate and baked at 60 °C for 1min to evaporate the solvent. Next, through the patterned photo-mask with the line shaped and UV irradiation (365 nm, 3 mW/cm^2) for partial polymerization, line-type patterned retarder is fabricated along the forming direction of 1st BM structure. The partially polymerized LCP is soaked in propylene glycol methyl ether acetate (PGMEA) for 40 s to remove the non-polymerized RMs.

To generate the lens surface, UV curable polymer (NOA 60, Norland) was spin-coated on the patterned retarder layer. Using a photo-mask with the pitch of 200 um and diameter of 100 um, UV light was irradiated for 55s to diffuse monomers of UV curable polymer by the difference of the

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intensity of UV light. For the complete polymerization of lens surface, it is irradiated by UV light without a photo-mask. Next, we spin-coated the planar alignment (RN1199, Nissan Chemical) on the lens surface and rubbed 0°, unidirectionally. Finally, we dropped LC (MDA-01-2901, Merck) on the lens surface and then, the upper glass was assembled at the room temperature.

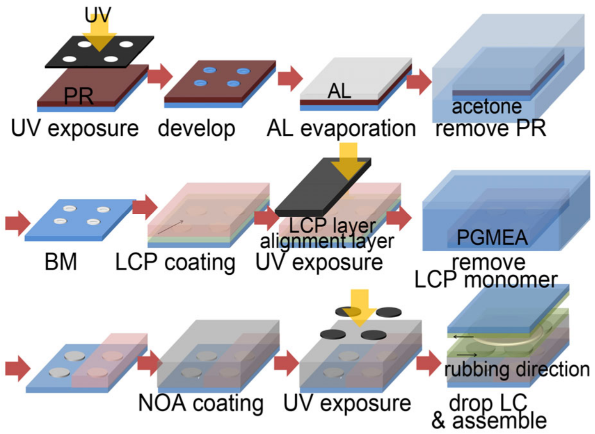

Fig. 1 Schematic diagram of the fabrication process of the 3D liquid crystal display with single polarizer and the patterned retarder structure

3. RESULT

Figure 2 shows a schematic diagram and the operating principle of the stereoscopic 3D LCD device proposed in this work. Our device consists of a polarization switching part in LC layer and a polarization-dependent focusing component. In the off-state, the incident polarized light is focused by the difference of refractive index between slow axis of LC and UV polymer. Then, the polarization state of focused light in the B pixels line is rotated by the patterned retarder as the half-wave plate (HWP). At the same time, the polarization state of focused light in the A pixels line is not rotated because of zero retardation. Consequently, we can recognize binocular parallax by using a polarizer glasses. When the driving voltage is applied into LC layer, LC molecules are reoriented along the electric field direction. In this case, we can observe a complete black state because the whole light is defocused and blocked by the second BM array.

Figure 3 is the monochromatic images of the difference of the polarization state passing through a single-polarizer LCD with in-cell retarder. Figs. 3(a) and (b) are two partial CCD images of the 3D images which are decoded by the different polarized glasses. Under the crossed polarization, the patterned region shows a bright state due to the polarization conversion to the 90° linear polarization by the half-wave retarder. On the other hand, under the parallel polarization state, the bright and dark states are inversed. and bright states are inversed. Whereas, when the polarized glasses are taken off, 2D image could be obtained as shown in Fig. 3(c).

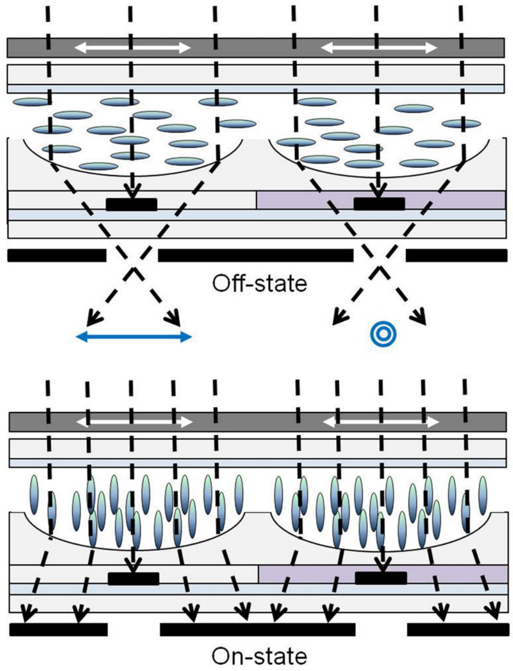

Fig. 2 Schematic diagram and operating principle of the proposed stereoscopic 3D display

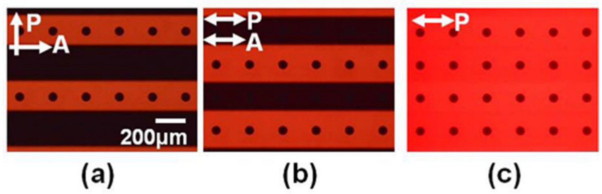

Fig. 3 Monochromatic images of the difference of the each polarization state (a) using the crossed polarizer, (b) using the parallel polarizer, and (c) using the single polarizer. All of images are observed without 2nd BM array for the clear identification of the patterned retarders

Figure 4 shows the driving characteristic by the applied voltage on the (a) 3D and (b) 2D modes, respectively. By increasing the voltage above the threshold voltage, the LC molecules gradually is rearranged perpendicular to the substrates, thus reducing the transmittance. In both modes, our device has the low operating voltage under 10 V. We could see that the transmittance of 2D mode is two times higher than the transmittance of 3D mode. Although the light passes all regions in the 2D mode, it passes through the divided regions by the patterned retarder which can change the polarization. Thus, its transmittance is lower than the 2D mode.

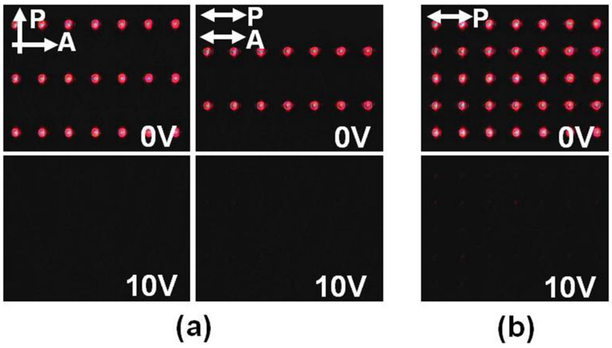

Fig. 4 The texture of each polarization state according to applied voltage: (a) the polarized inversion image according to the polarized direction in stereoscopic 3D display and (b) 2D image using single polarizer

4. CONCLUSION

In this paper, we suggested the 3D LCD device with the single-polarizer and inner patterned retarder. Our device could be obtained 3D stereoscopic images by the orthogonal polarization generated from the in-cell patterned retarder reducing the parallex-problem in the conventional stereoscopic 3D display using the outer patterned retarder. Moreover, it can be expected that a novel 3D device with lower cost and higher optical efficiency is achieved.

5. ACKNOWLEDGEMENT

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