Stereoscopic 3D Display in Reflective Mode using Cholesteric Liquid Crystal

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ABSTRACT

We report a stereoscopic 3D liquid crystal display in a reflective type. Using the cholesteric liquid crystal with a patterned retarder, two orthogonal polarization states are obtained and thus the stereoscopic images are constructed.

1. INTRODUCTION

The 3D displays have attracted great interest in the entertainment and education due to their realistic images [1]. In general, two types of the 3D displays were reported based on a binocular disparity. One is an autostereoscopic 3D display without glasses including the lenticular lenses or the parallax-barriers [2, 3]. The other is a stereoscopic 3D display wearing shutter glasses or polarized glasses [4-6]. In the stereoscopic 3D display, the binocular disparity is constructed by the orthogonal polarizations. Therefore, the liquid crystal display (LCD) adopting a patterned retarder is a viable technology.

In this work, we propose a stereoscopic 3D display in a reflective type using the cholesteric liquid crystal (ChLC) and the micro-patterned retarder. The reflective 3D LCD presented here consists of a conventional ChLC display panel and a micro-patterned retarder. In the ChLC display, as you expected, the polarizers, color filter, and backlight unit are not required [7]. The incident light is selectively reflected with a certain circular polarization coinciding with the helical sense of the ChLC. To produce the orthogonal polarization in a panel, the patterned retarder with half-wave retardation is introduced.

2. EXPERIMENTS

The ChLC panel was prepared with the ChLC mixture consisting of a host nematic LC of MLC6875 (75.8 wt%, E. Merck) and a chiral dopant of R811 (24.2 wt%, E. Merck) which induced a right-handed helical structure. The polyimide of RN1199 (Nissan Chemical) was spin-coated on top of the indium-tin-oxide (ITO) evaporated substrates, followed by unidirectional rubbing to promote planar alignment. After assembling two ITO substrates, the ChLC mixture was injected by the capillary action in an isotropic phase. The cell thickness was maintained using ball spacers of 10 μm thick.

The patterned retarder was fabricated by the selective ultra-violet (UV) exposure to the aligned liquid crystalline polymer (LCP) of RMS03-013C (E. Merck). At first, the RN1199 was spin-coated on a glass substrate and soft-baked at 100 °C, followed by hard-baking at 220 °C. The LCP was coated on the rubbed polyimide substrate to produce a phase retardation of half-wave corresponding to the thickness of 2.3 μm. The patterned retarder was fabricated by UV irradiation through a photo-mask of a periodic line shape with 200 μm width and 200 μm interval.

3. RESULTS AND DISCUSSION

Figure 1 shows a schematic diagram of the cross-sectional structure and an operating principle of the stereoscopic 3D display in a reflective type. In the ChLC display panel, the ChLC molecules were rotated on a helical axis perpendicular to the substrate surface with a certain chiral pitch depending on the mixed chiral dopant [7]. In a dummy area without the LCP pattern, the right-handed circular polarization reflected from the ChLC layer passes through the patterned retarder keeping the polarization state, and thus is transmitted by a right-handed circular polarizer in glasses but blocked by a left-handed circular polarizer. On the other hand, in a LCP patterned area, the right-handed circular polarization reflected from the ChLC layer is orthogonally converted to the left-handed circular polarization, and thus the converted polarization is transmitted by a left-handed circular polarizer in glasses but blocked by a right-handed circular polarizer. Therefore, the stereoscopic 3D images were constructed in the reflective configuration. It should be noted that the conventional 2D images were shown through taking off the glasses.

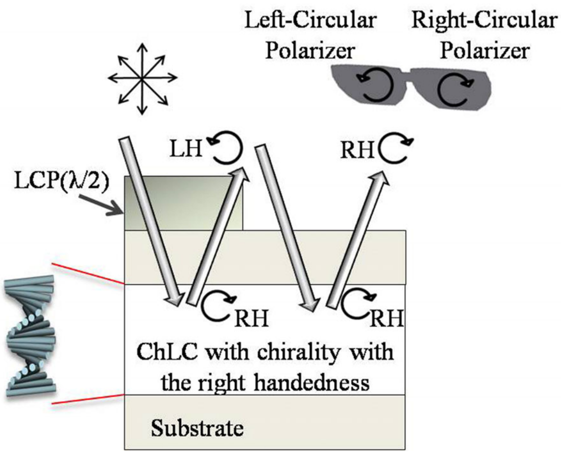


Fig. 1 Schematic diagram of our reflective 3D display. The right-handed circular polarization reflected from the ChLC panel is orthogonally converted by the patterned LCP retarder of half wave.

Figure 2 shows the microscopic textures observed in different polarization states in our reflective 3D display. Taking off the glasses, our 3D display works as a conventional 2D display. Fig. 2(a) shows the microscopic texture without any polarizer corresponding to the 2D image. In both patterned and unpatterned regions, the bright states were observed. The subtle difference of brightness between two regions is mainly originated from transparency of the LCP layer. Figs. 2(b) and 2(c) show the microscopic textures under two orthogonal circular polarizations working as the 3D display. Here, dark stripes represent the orthogonally polarized regions to the circular polarization in glasses. As shown in Fig. 2(b), the patterned region shows a dark state under the right-handed circular polarization due to the polarization conversion to the left-handed circular polarization by the half-wave retarder. On the other hand, under the left-handed circular polarization, the dark and bright states are inversed. Therefore, wearing the glasses with the orthogonal circular polarizers, the 3D images are constructed and the 2D images are shown taking off the glasses in the reflective type display.

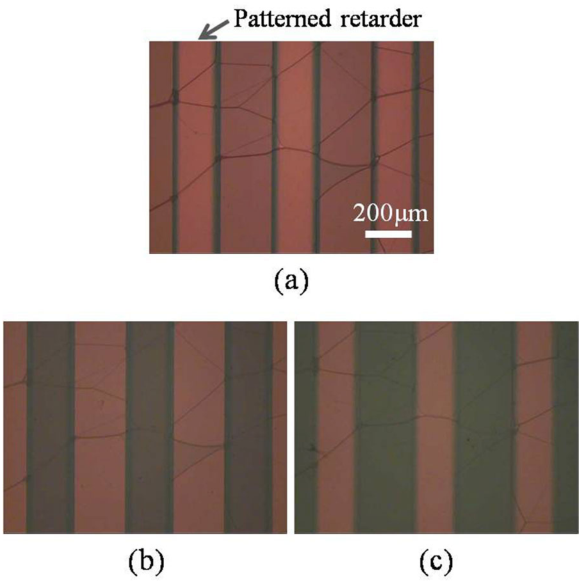
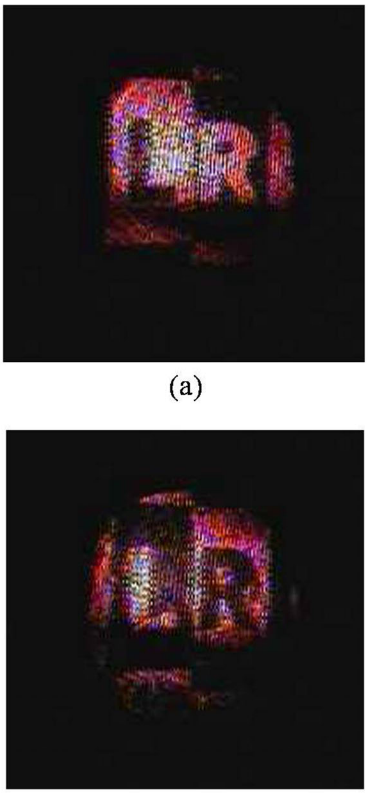


Fig. 2 Microscopic textures of our reflective 3D display (a) without a polarizer, with (b) a right-handed circular polarizer, and (c) a left-handed circular polarizer.

We demonstrate a 2 inches prototype of the reflective 3D display presented in this work. Figs. 3(a) and 3(b) show the charge-coupled device (CCD) images taken under the right- and left-handed circular polarizations, respectively. We simply patterned the LCP layer with a photo-mask of the characters “L” and “R” to show the left- and right-handed circular polarization. In this case, the LCP patterned regions are the character “L” and the background of the character “R”. Therefore, the character “R” and the background of the character “L” show the bright states as shown in Fig. 3(a). Similarly, under the left-handed circular polarizer, the same regions show the dark states but the other regions show the bright states as shown in Fig. 3(b).

4. CONCLUSION

We demonstrated the stereoscopic 3D display in a reflective mode using the ChLC panel and the patterned retarder with the half-wave retardation. The selectively reflected circular polarization from the ChLC panel was orthogonally converted by the half-wave retardation. The circular polarization, coinciding with the handedness of the ChLC, passing through the dummy regions in the patterned retarder and the orthogonal circular polarization passing through the half-wave region construct the 3D images based on the binocular disparity. Also, the 2D images were shown by taking off the glasses without any additional process.



(a)

(b)

Fig. 3 Images captured by a CCD camera of our 3D reflective display under (a) the right-handed circular polarizer and (b) the left-handed circular polarizer.

5. ACKNOWLEDGMENT

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