Ultra Thin Reflective Flexible Liquid Crystal Display

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Abstract

An ultra-thin reflective flexible LCD film has been demonstrated. The 30% thickness of the display can be reduced by applying a quarter-wave-plate film as upper substrate. A low temperature alignment material and special designed photo spacer were applied in this new display. The bending behavior was improved by reduced thickness.

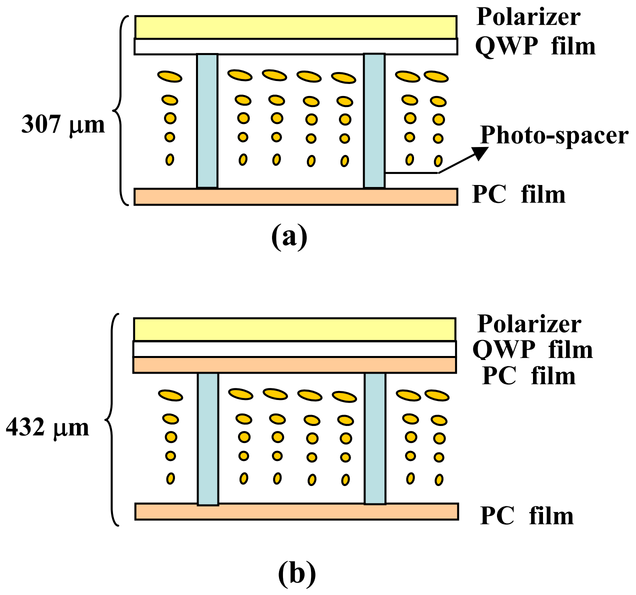
1. Introduction

Flexible displays with bendable frames could become popular in the next generation of flat panel displays[1,2]. Flexible display techniques are applied in many applications, such as smart cards, e-papers, and e-books. For paper-like display applications, the performance of reflective display is close to that of traditional paper. Besides, the reflective displays also have two advantages over transmissive ones : low power consumption, and sunlight readability.

In this paper, we fabricated reflective mixed-mode twisted nematic (MTN) LC film with ultra-thin quarter-wave-plate (QWP) films as substrates. A single-polarizer MTN mode has been demonstrated in 1980[3]. In our ultra-thin LC film, we directly used 45μm-thickness QWP films with conductive electrode to replace 120μm-thickness polycarbonate (PC) substrates. To keep the optical properties of QWP and support the ultra-thin QWP film, a low temperature alignment material and special designed photo-spacers were applied in this new display.

2. Experimental

The main purpose of our experiment is to examine the feasibility of ultra-thin QWP films assubstrates for flexible LC cells. Figure 1 shows the cell structural configurations of this experiment. As shown in Figure 1, two cells were assembled. One was an ultra-thin reflective MTN cell and the other was a traditional MTN cell. For traditional one, the two substrates were made by PC/IZO plastic substrates and the QWP film was attached outside the cell. Besides, the QWP film was directly used in the ultra-thin reflective MTN cell as its upper substrate. Before starting the manufacturing process of the ultra-thin MTN cell, the glass transition temperature (Tg) of QWP film was measured by differential scanning calorimeter (DSC) and shown in Fgure 2. From the measured result, the Tg of the QWP film was at 136℃. Hence, to avoid the deformation of QWP film at high temperature, we tried to lower the manufacturing process including the growth of conductive layer and polyimide (PI). The 45μm-thickness QWP film was sputtered with indium zinc oxide (IZO) below 120℃ as electrode before cell assembly. Liquid crystal molecules inside the thin cell were aligned by pre-imidized PI layers between IZO/PC and IZO/QWP substrates. Pre-imidized PI was selected here because that the imidization process has been finished before spin-coated on QWP hence the baking temperature of PI could be reduced. The pre-imidized PI layers was cured at 120℃/1hr to evaporate organic solvent on the IZO/QWP substrate and provided a solution to avoid structural deformation of QWP when baking. Finally, to get the optimum optical performances of reflective MTN cells and maintain the uniformity of cell gap, 2.5 μm-thickness photo-spacers with cross type were made by photolithography on the IZO/PC substrates.



(a)

(b)

Fig. 1. Cell structures of (a) ultra-thin reflective LC film and (b) traditional reflective LC film.

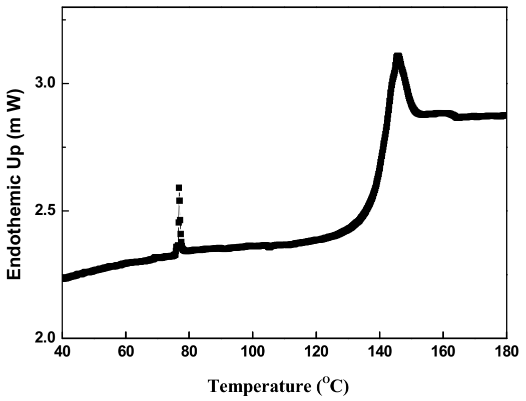


Fig. 2. Phase transition of the QWP film.

3. Results and discussion

The photo-spacers provided a cell gap uniformity of our reflective MTN cells. The pitch size of our photo-spacers was chosen as 100μm. To examine the deformation of cell gap which was maintained by photo-spacers, the test sample with two PC substrates was bent at various curvatures. Figure 3 shows the cell gap variations at different bending curvatures. Although the cell gap is changed when bending, the cell gap variation is still kept constant about 4% whatever the bending curvature is. Figure 4 shows the measured voltage (V)-dependent reflectance (R) of the ultra-thin reflective LC film and traditional reflective LC film. The reflection of LC cells was measured by Otsuka LCD5100 system. The incident light was normally onto the samples and the reflection was detected by photo-detector. The angle between the light source and detector was set as 30°. From Figure 4, the two LC films showed almost the same optical characteristics. The threshold voltages for the two samples were 1.4 V. Although the dΔn parameter of our cells was set about 230 nm which was close to the optimum parameter of MTN mode[4], the outside metal reflector still slightly reduced the reflectance of our ultra-thin MTN cells. However, the elimination of one PC layer of ultra-thin reflective MTN still reduced the interface scattering and enhanced the brightness about 4%. Table 1 shows the measured response time of our cells with reflective type. We set 5.5 V and 0 V as turn-on and turn-off voltages. The driving frequency was 1 KHz. The ultra-thin reflective LC film showed a normal behavior similar to the traditional one. The total response time ($\tau_{on} + \tau_{off}$) for the ultra-thin reflective LC film was about 6.6 ms which was close to the theoretically calculation.

TABLE 1. Dynamic properties of ultra-thin MTN cell and traditional MTN cell.

sample	τ_{on} (ms)	τ_{off} (ms)	τ_{total} (ms)
Ultra-thin cell	2.77	3.90	6.67
Traditional cell	2.32	3.91	6.23

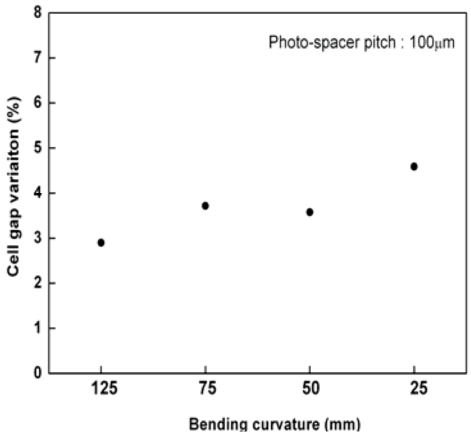


Fig. 3. Cell gap variations under different bending curvatures.

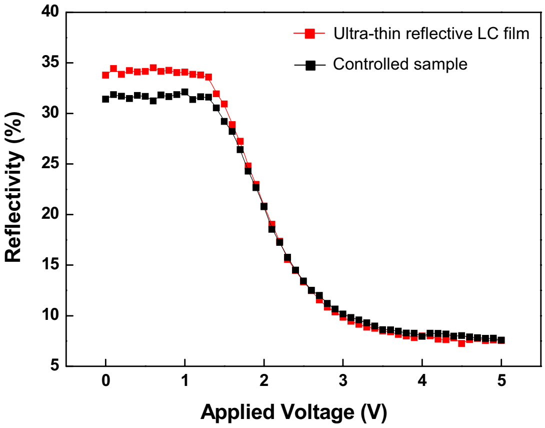


Fig. 4. Measured voltage (V)-dependent reflectance (R) of the ultra-thin reflective LC film and traditional reflective LC film.

4. Summary

We have fabricated the ultra-thin MTN films by using low temperature process. The QWP films have the potential for replacing traditional plastic substrates and can be applied on light-weight or low-cost flexible electronic applications.

5. Acknowledgements

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6. References

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