The Advanced substrate-assembling technique using SU-8 for Flexible Liquid Crystal Displays

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We propose to expect the simple structure of flexible display with spacers not only as maintain the cell-gap but also assemble between two substrates. And the fabrication procedures of our suggested structure are analogous to the traditional manufacturing processes of LCDs. We also confirmed that this suggested structure has similar electro-optic properties under flat condition and better under bending conditions.

1. Introduction

The flexible display have been expected to have versatile applications such as a smart cards, a mobile phones, and writing tables because of their thin, lightweight, and roll able properties [1-3]. For flexible display applications, the variety of display modes such as the organic light emitting diodes (OLEDs) [4], the electrophoretic displays [5], and the flexible liquid crystal displays (LCDs) with plastic substrates [6-9]. Expect for the LCDs, the manufacturing process for these display techniques are not well established yet and the display performances are still insufficient. However, the flexible LCDs have an essential problem of non-uniform cell gaps under bending deformations because the radius of curvature of top substrate is different from that of bottom one. TO improve the mechanical stability of the flexible displays, several techniques such as the pixel isolation with UV curable polymer [4, 5] and the micro-contact printing (μCP) with thermal curable polymer [6, 7] have been reported.

In this paper, we expected the simple structure of flexible display with spacers not only as rigid spacers to maintain the cell gap but also as glues to assemble between top and bottom substrates. The fabrication procedures of our suggested structure are analogous to the conventional manufacturing processes of liquid crystal displays. We also confirmed that this suggested structure has similar EO properties under flat condition and better EO properties under bending conditions.

2. Experimental

The fabrication procedures of the flexible LCD with the adhesive patterned spacer structure are as follows figure 1.

At first, a pair of transparent substrates deposited with indium-tin-oxide (ITO) was

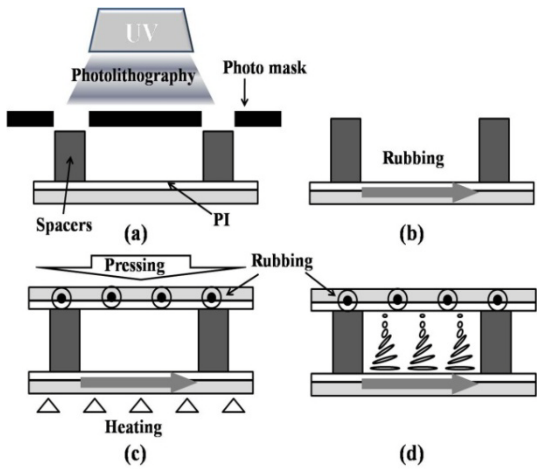

Figure 1 The schematic diagrams of our simple process: (a) coating SU-8 on PI layer by UV photolithography, (b) rubbing in definite directions, (c) assembling top and bottom with heating and pressing, and (d) filling the fabricated cell with TN LC

coated with polyimide (PI) of the AL22620 (Japan Synthetic Rubber Co.).

Next, the array of square spacers with a side of 35 μm was formed on the bottom substrate through the photolithography of the SU-8 (MicroChem Co.). And the patterned SU-8 spacers were just prebaked at 100°C for 10 minutes. The substrates with spacers on the PI layer and the others with the only PI layer were rubbed in the definite directions for TN LCDs using the rubbing machine. Two rubbed substrates were assembled orthogonally and post-baked at 180°C for 60 minutes under pressing. Finally, the TN liquid crystal (LC) of MAT-03-151 (Merck Co.) was injected into the assembled cell by capillary action above the clearing temperature of 79.4°C. LC material has the birefringence and the dielectric anisotropy are 0.104 and 5.5, respectively. The LC filled with this test cell was transited from isotropic phase to nematic phase when the temperature was cooling down and TN LC cell was completed in the result.

3. Results & Discussion

In our fabricating procedure, the alignment layer on the bottom substrate was prepared before forming the spacers through the photolithography and the rubbing process was introduced after forming the spacers which were not post-baked. In such situation, the alignment layer would be affected by photo-resister, developer, and solvents, which should have an effect on the alignment properties and the resultant EO properties.

Figure 2 shows the microscopic images of the TN cell fabricated with the adhesive patterned spacers under crossed polarizer. Here, *R*, *P*, and *A* depict the rubbing direction of the bottom substrate patterned SU-8 spacers, the polarizer direction faced to the bottom substrate, and the analyzer direction contacting with the top substrates. In the absence of an applied voltage, the bright state was obtained as shown in Fig. 2(a). Here, the dark squares represent the patterned spacers. When the applied voltage increases, the transmittance gradually decreases (Figs. 2(b)-(d)). These textures show the typical EO characteristics in a normally white mode. Near the spacers, the light leakage was observed due to the distortion of the LC directors by the boundary effects of the rigid spacers. The bending of the test cell was controlled by changing the distance between linear translations stages, where the value of R is represented by the radius of curvature of the cell and is decreasing when the amount of bending increase. When R is 30mm, drop of transmittance is about 92%.

Figure 3 shows the change of transmittances of the plastic based LCDs dependant on applied voltages under flat and bending conditions. This figure shows the decrease of transmittance with respect to the decrease of the radius of curvature. This phenomenon means that the cell gap of the TN sample with plastic substrate was varied depending on the bending force because the curvatures of top and bottom substrate are different each other.

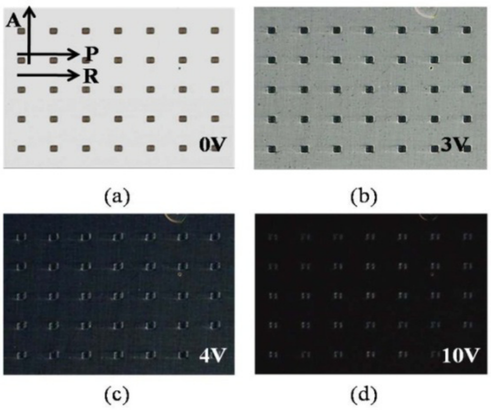

Figure 2 Microscopic photographs of the TN mode fabricated with the adhesive patterned spacers at (a) 0V, (b) 3V, (c) 4V, and (d) 10V. Here, R, A, and p are a rubbing direction of bottom substrate, a direction of the upper analyzer, and a direction of lower polarizer, respectively

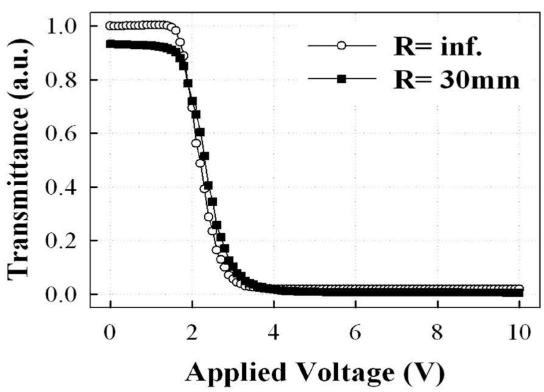

Figure 3 The EO characteristic of a suggested TN cell depends on degree of bending

4. Conclusion

We expected the simple structure of flexible display with spacers not only as maintain the cell-gap but also assemble between two substrates. And the EO stability of this suggested TN structure was enhanced in comparison with that of conventional TN cell with plastic substrates under bending distortions. Hence this assembling technique could be suitable to solve the serious problem such as low performance of plastic LCD under external deformations. The advanced substrate assembling technique is expected to be one of the excellent candidates for the flexile liquid crystal displays.

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