Fabrication of Flexible Liquid Crystal Display Using the Surface Grooves for LC alignment and Tight Adhesion

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We present a fabrication of flexible liquid crystal displays (LCDs) with the UV curable polymer layer patterned grooves on the top substrate. Thin polymer layer with the groove structure induced in the uniform LC alignment and tight adhesion characteristics between two flexible substrates. By simplified processes for our multi-functional polymer film, we could obtain the flexible LC cell with the satisfied functionalities to apply to the optical devices.

1. Introduction

Flexible display is one of the most promised future displays due to their light weight, portability, fabrication cost, etc. From the cathode ray tube (CRT) to flat panel display (FPD), display devices have been developed by adopting the advanced technologies. Especially, liquid crystal displays (LCDs) are very cost-effective and have powerful performance characteristics for display device. Due to their good characteristics, recently, LCDs are applied to many kinds of the display application such as the portable multimedia player (PMP), mobile laptop computer and mobile phone.

Now, LCDs technologies prepare for the flexible future display. To achieve the flexible LCDs, we have to overcome the limitation following the successful challenge of the problems. One is the maintenance of the cell gap uniformity in LC layer between flexible substrates. And the other is mechanical stability for the external forces such as bending stress, point pressure and so on. Many solutions have been suggested to solve these problems. First solution was the pixel isolated liquid crystal (PILC) mode using the phase separation method by the ultra violet (UV) light gradient. After mixing with UV curable polymer and LCs, the UV light is irradiated selectively using the photo mask. By the gradient effect, the polymer moves under the mask and form the structure for cell gap [4-5]. Second, the wall structure using the photo-resist (PR) was also proposed. By the photolithography method, pixel area onto the flexible substrate has residual spacers formed with the PR. These photo-resist walls can be maintained the cell gap and assured the mechanical stability [6]. However, these conventional methods are not fully satisfies with problems and these adhesion methods have low efficiency for fabrication yields.

In this paper, we present a fabrication of flexible LCDs using the groove structure by the UV curable polymer. The grooves made onto the UV polymer layer have good LC alignment and tight bonding characteristics, simultaneously.

2. Experiment

Through our process, the top plastic substrate has groove pattern which is 4um pitch and 1um depth. The groove pattern was made by PDMS mold which is hydrophobic. The direction of grooves was perpendicular to the rubbing direction of bottom substrate for realizing twisted nematic (TN) LC mode. And then, the stabilized condition of the patterned grooves could be obtained by the 1st UV irradiation (60mW/cm^2 for 2 minutes).

The bottom plastic substrate has the rigid spacer. These were made by negative photo-resist SU-8 (MicroChem.). The height of the rigid spacers was about 5μm. Cell gap is maintained uniformly by rigid spacers. These structures can prevent the distortion from the external force such as pressing and bending deformation. After that, bottom substrate was coated by the alignment layer over the rigid spacers and rubbed uniformly. The top and bottom substrates were assembled into the condition of which rubbing direction is perpendicular to the groove direction. We irradiated the 2nd UV light for tight adhesion between the grooves and rigid spacers on the bottom substrate. The 2nd irradiating time and intensity were 30 minutes and 60 mW/cm^2, respectively.

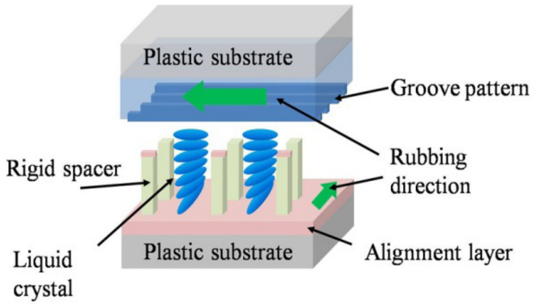

Figure 1 The schematic diagram of our proposed structure

3 Result and Discussion

Figure 2 shows the AFM image of NOA polymer layer with the patterned grooves. We could obtain the morphological structure of 3μm pitch by stamping method with PDMS mold on the top substrate and confirm that the patterned grooves induced the good alignment were fully transferred. We describe the azimuthal anchoring energy by the formulated function as

$$W_a = 2K\pi^3 \frac{A^2}{\lambda^3}$$

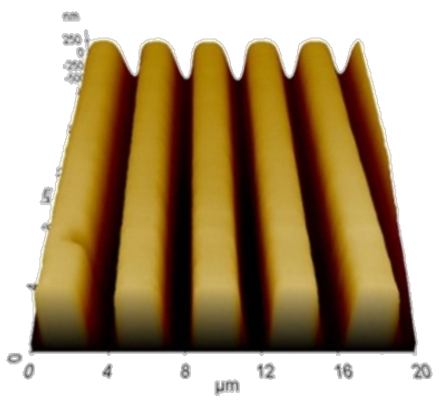

Figure 2 AFM image of patterned grooves of the top substrate

where the K denotes the mean value of elastic constants of LC material. D is the depth of the groove and λ is the pitch of the groove. In our case, the elastic constant is 12.85 pN and the size of the patterned groove is same to the size of PDMS mold.

Using the Berreman equation, we could obtain the azimuthal anchoring energy of 1.25 x10^{-5} J/m^2, which is sufficiently enough to align the LC molecules on the groove surface uniformly [4].

Figure 3 shows the microscopic images under the crossed polarizer by varying the applied voltage. In the field off state, we could achieve the bright state due to the wave guiding effect of TN structure. As applying to the perpendicular electric field, LC molecules are aligned parallel to the field direction due to the positive anisotropy of dielectric constant. The microscopic textures of fig. 3(a)-(d) show the change of the transmittance in our sample at 5 V, 10 V, and 15 V, respectively. Proposed TN Cell does not have the light leakages on the rigid wall for apply voltage because both rigid wall and top substrate were adhered tightly by UV adhesion.

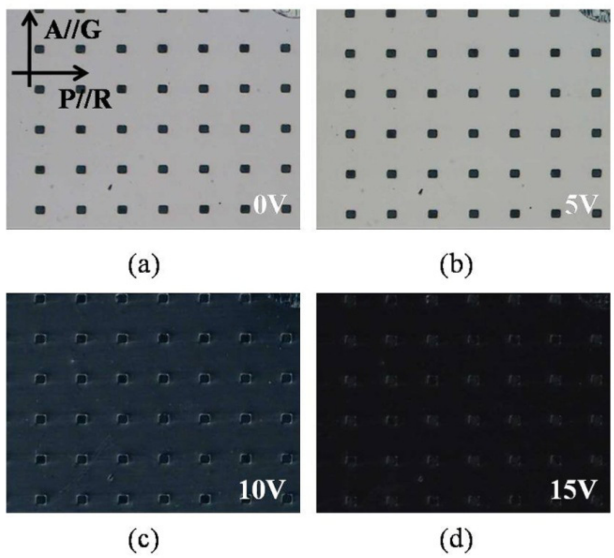

Figure 3 The microscopic images of the TN mode fabricated our cell at (a) 0 V, (b) 5 V, (c) 10 V, and (d) 15V. Here, R, A, P, and G are a rubbing direction of bottom substrate, a direction of the upper analyzer, a direction of the lower polarizer, and a grove pattern direction of top substrate, respectively

4. Conclusion

We proposed a fabrication of flexible liquid crystal display (LCD) using micro-sized grooves formed on UV curable polymer layer. The stable LC alignment and tight adhesion could be achieved by the groove pattern. We could attach the flexible top and bottom substrates with UV adhesion layer. The fabrication proposed in this work is very simple and applicable for the cost effective roll-to-roll process for the printable display. The presented fabrication of Flexible LCD is expected to play a role in the flexible display technology in ubiquitous environment.

5. Acknowledgement

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