Single substrate flexible LCD with enhanced stability using functional photopolymer structure

Kwang-Soo Bae[1], Yoonseuk Choi[2], Hak-Rin Kim[3], and Jae-Hoon Kim[1,2,4,*]

[1]Department of Information Display Engineering, Hanyang University, Seoul 133-791, Korea
[2]Rearch Institute of Information Display, Hanyang University, Seoul 133-791, Korea
[3]School of Electrical Engineering and Computer Science, Kyungpook National University, Daegu 702-701, Korea
[4]Department of Electronics and Computer Engineering, Hanyang University, Seoul 133-791, Korea

Abstract

We proposed a simple method for fabricating a single substrate flexible liquid crystal display (LCD) with mechanical stability. The plastic bottom substrate which has a patterned transparent electrode is covered with a functional photopolymer cover structure by laminating technique which has the LC aligning property and the bonding ability of two substrates, simultaneously. The cover structure of photopolymer was prepared by soft-lithography using pre-designed master mold of elastomer. The fabrication process and the electro-optical characteristic of device are described. Our flexible LCD would be highly useful for practical applications due to the simple process and the good mechanical stability.

1. Introduction

For the upcoming ubiquitous environment, the flexible display is one of the most attractive devices due to several advantages such as flexibility, durability and portability [1]. The application range of flexible display is very wide from mobile applications such as cell phone and personal digital assistant to new-concept devices like electronic paper and electronic book. Among the competing technologies, the flexible liquid crystal display (LCD) exhibits various merits compared to other approaches, for example, full-color realization, well-established fabrication, high contrast ratio and good electro-optic performance [2-4]. However, for the successful commercialization of flexible LCDs, the cumbersome fabrication and the mechanical instability in the extreme bent condition should be solved to exhibit the practical device performances. Also, if the cost-effective roll-to-roll process can be adopted during fabrication, it would be highly useful for the productivity of display.

In this work, we proposed a simple fabrication method of flexible LCD with enhanced mechanical stability by laminating photopolymer cover structure which has a high elongation property and strong adhesion ability simultaneously. The cover structure has the micro-groove structure to align the liquid crystals (LCs) and the micro-wall structure to maintain the constant cell gap under various external deformations. Also, the tight bonding between the cover structure and the bottom substrate can be obtained through the simple UV irradiation process from the self-adhesive property of photopolymer. The proposed method can realize the flexible LCD with high mechanical stability and is applicable of the roll-to-roll process because it uses a single plastic substrate.

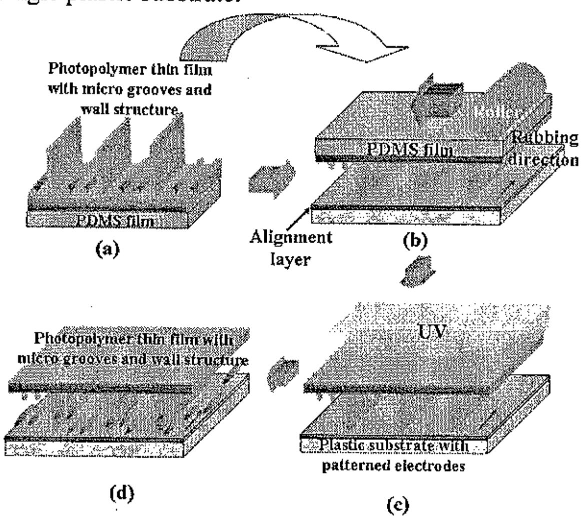

Figure 1. The schematic diagram of fabricating a single substrate flexible LCD with photopolymer cover structure. (a) The cover structure of photopolymer on the supporting film of PDMS. (b) Laminating process on the bottom plastic substrate. (c) Detachment of supporting film and UV irradiation for full curing of the photopolymer. (d) LC injection and the device configuration.

2. Experimental

Figure 1 shows the fabrication process of our flexible LCD schematically. The cover structure of photopolymer was prepared by stamping the pre-designed mast mold to the thin photopolymer layer on the supporting film of PDMS (poly-dimethylsiloxane) which is conventional stamp in the soft-lithography [6]. It has the periodic wall structure and the micro-grooves between the walls as shown in Fig. 1(a). The rigid walls maintain a uniform cell gap under bending condition and the micro-grooves align the LCs unidirectionally from the elastic energy relaxation [4,7]. Note that this photopolymer structure was partially cured by UV irradiation for sustaining the bonding ability to the bottom substrate. Using the soft-roller, we laminated the cover structure on the plastic substrate which has rubbed LC alignment layer on it (Fig. 1(b)). After UV irradiation, we can easily detach the supporting film and the cover structure was tightly bonded to the bottom substrate as depicted in Fig. 1(c). In the final step, we injected commercial nematic LC (ZKC5085, Chisso) by capillary action (Fig. 1(d)). The direction of micro-groove was parallel to the rubbing of LC alignment layer to induce the planar alignment of LCs. Commercial UV curable photopolymer (NOA 68, Norland) and PDMS (GE Silicon) were used in this experiment. The thickness of cover structure was measured as 30μm by observing the cross-section of sample using FESEM and the height of micro-wall (i.e., cell gap) was 6 μm. The width and periodicity of wall were 30 and 100 μm, respectively.

3. Results and Discussion

The transparent electrodes for in-plane switching are patterned to incline 45° with respect to the micro-groove direction. In figure 2, the wall structure and the patterned electrodes are easily observable from the microscopic images. In the absence of electric filed, completely dark images was observed under crossed polarizers as shown in Fig. 2(a) as the easy axis of LCs are parallel to the polarizer. When we applied in-plane field (Fig. 2(b)), the LCs reoriented to align parallel with the electric field due to its positive dielectric anisotropy and the bright state of texture was observed. This result shows the electro-optic characteristic of our device is very similar to the conventional IPS (in-plane-switching) mode [8]. Thus, we can conclude that various merits of conventional LCD technology can be successfully achieved on the flexible substrate by using our method. Also, from experimental results of the adhesion test, the mechanical stability of proposed structure was confirmed enough to tolerate the high bending distortions. The optimization for the device parameters is remained.

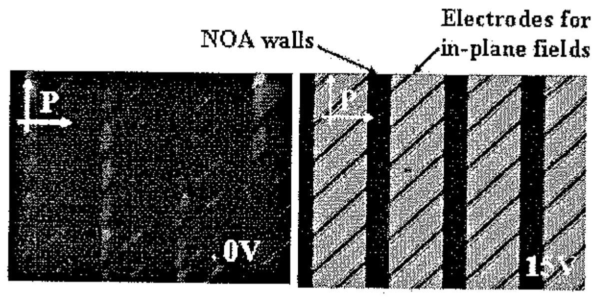

Figure 2. Microscopic images of a single substrate flexible LCD at applied voltage of (a) 0V and (b) 15V.

4. Conclusions

We have demonstrated a single substrate flexible LCD by lamination the functional cover structure of photopolymer. The good electro-optic characteristic and the high mechanical stability of proposed flexible LCD were experimentally confirmed. This display is expected to be highly applicable for the future mobile application in ubiquitous environment such as roll-up display.

Acknowledgements

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5. References

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PI-20. Temperature Stability of Electro-Optic Properties of Polymer Dispersed Liquid Crystal with Different Crosslinking Agent in PN393 Base Pre-Polymer

Young-Seok No*, Jae Hong Kim, Chan-Wook Jeon
School of Display and Chemical Engineering, Yeongnam University

PI-21. Single substrate flexible LCD with enhanced stability using functional photopolymer structure

Kwang-Soo Bae[1], Yoonseuk Choi[2], Hak-Rin Kim[3], and Jae-Hoon Kim[1,2,4,*]
[1]Department of Information Display Engineering, Hanyang University
[2]Rearch Institute of Information Display, Hanyang University
[3]School of Electrical Engineering and Computer Science, Kyungpook National University, [4]Department of Electronics and Computer Engineering, Hanyang University

PI-22. Substrates Fastening Technique for Pixel Isolated Liquid Crystal mode

Ji-Hong Bae[1], Se-Jin Jang[1], Hong Choi[2], Sang-Il Kim[4] and Jae-Hoon Kim[1,2,3,*]
[1]Department of Information Display Engineering, Hanyang University,
[2]Research Institute of Information Display, Hanyang University,
[3]Deartment of Electronics and Computer Engineering, Hanyang University
[4]Samsung Electronics, LCD R&D Center

PI-23. New Materials for Organic Interdielectric Layer Patterning of TFT Array

Hyo-Jung Lee[1], Hong-Qing Wang[1], Dong - Ju Kim[1], Soon -Hak Kim[1], Lee - Soon Park*, Yun Su Lee[2], Gab Deuk Song[2], Suk-kyung Kim[2]
[1]Department of Chemical Engineering, Daegu University, Gyeongbuk, 712-714, Korea
[2]Advanced Display Manufacturing Research Center, Kyung pook National University, Daegu, 702-701, Korea