A Replica Molding Technique for Fabricating Liquid Crystal Displays with Wide Viewing Characteristics

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Abstract

We demonstrated a replica molding technique for producing a self-formed multidomain structure displays (LCDs). The multidomain structure was naturally obtained on a replica mold film having periodic patterns which have two dimensional microgrooves. It was found that with the axially symmetric multidomain structure along the microgrooves exhibits excellent viewing characteristics.

Technical Summary

Recently, a liquid crystal display (LCD) is one of the most competitive flat panel displays (FPDs) due to its lightness, low power consumption and high image quality. The LCDs are widely used in various electronic equipments such as mobile displays, notebook computers, monitors, and televisions. Especially, large-size monitors and televisions show good performances in several configurations such as twist nematic (TN) with photo-alignment[1], in-plane switching (IPS)[2], multidomain vertical alignment (MVA)[3], patterned vertical alignment (PVA)[4], and fringe-field switching (FFS)[5].

Problems of manufacturing large-size LCDs based on the TN mode require a multi-rubbing process and an expensive compensation film for wide viewing characteristics. The IPS mode also needs the rubbing process which generates electrostatic charges causing a damage to thin film transistors (TFTs). Moreover, the IPS has a low aperture ratio since all of electrodes are formed on either the top or the bottom substrate. The MVA, PVA, and FFS modes require no rubbing process but need complex processes such as formation of protrusions, fine patterning of a transparent electrode and precise alignment of the top and the bottom substrates. Therefore, a new technology, which does not use complex patterning electrodes, rubbing process, and compensation films is required for advanced LCDs.

In this work, we propose spontaneously forming multidomains using a thin film with periodic microgrooves. The thin film can be fabricated by a replica molding technique[6,7,8] that has been used for biological applications. Our thin film provides the homeotropic alignment in addition to the capability of self-formed multidomains. Since LC directors have an axially symmetric distribution along microgrooves, the viewing characteristics of the LCD are greatly enhanced.

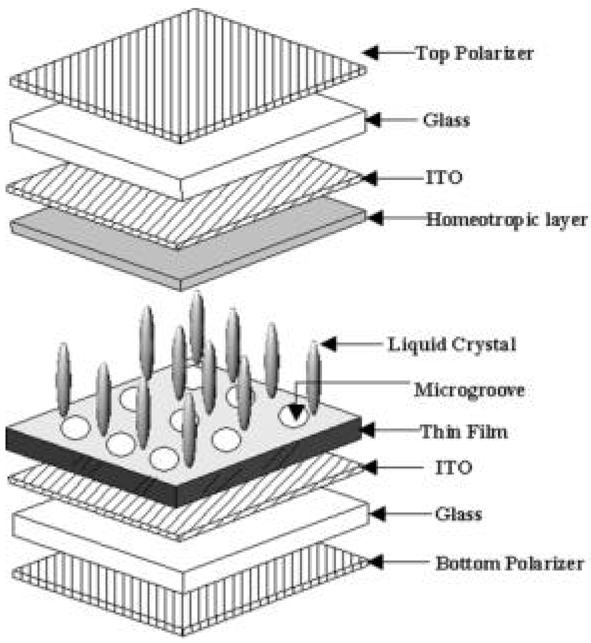

Figure 1. The schematic diagram of the LC cell with a thin film with periodic patterns.

Figure.1 shows the concept of our LCD. A thin film having periodical patterns is placed between the top and the bottom substrates. In the off-state, the LC director is aligned vertically to the thin film substrate, thus the cell appears black under crossed polarizers. A symmetric and small tilt around each microgroove is generated by the geometrical shape of the microgroove without a rubbing process. Therefore, the LC molecules at the center of the microgroove have homeotropic alignment at an initial state, and those in the rim of the microgroove are tilted toward the inclined plane of the microgroove.

In order to prepare the thin film with periodic patterns, we used a replica molding technique using polydimethylsilioxane (PDMS) from GE Silicones. The PDMS shows the homeotropic alignment of the LC and transparency down to 300 nm.

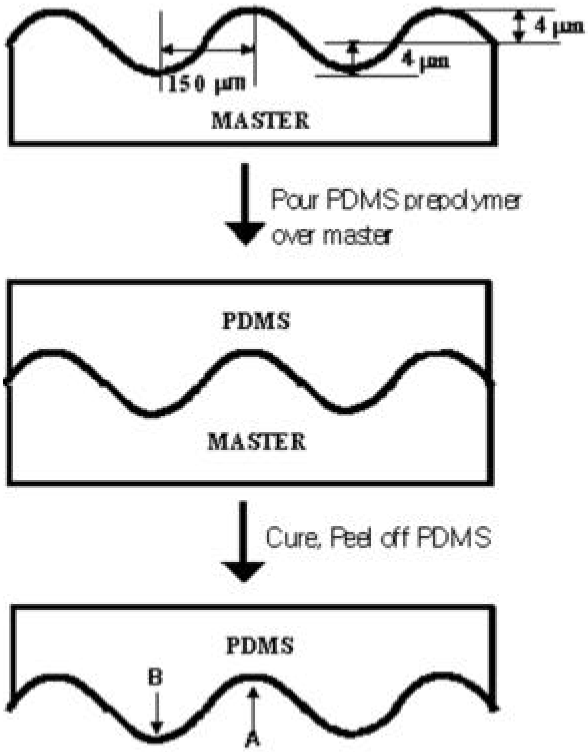

Figure 2. The preparation of a thin film with periodic patterns using the replica molding technique.

The replica molding technique is useful for duplicating the information, e.g., shape, morphology, and structure, present in a master. It is a procedure that accommodates a wider range of materials than the photolithography. It also allows for duplications of three-dimentional topologies in a single step, whereas the photolithography is not possible. As shown in Fig.2, the PDMS was poured onto a master and spin-coated under 800 rpm for 120 sec. After PDMS was cured at 100 ℃ for 1 hour, PDMS was peeled off from the master.

Figure. 3 shows the normalized electro-optic (EO) transmittance of our LCD. The EO transmittance begins to increase at 14 V and becomes a maximum at 20 V. The magnitude of the operation voltage required for our LCD is somewhat higher than that for a conventional LCD since a large voltage drop exist across the PDMS film. Thus, by reducing the thickness of the PDMS film with periodic patterns, the operation voltage can be much reduced.

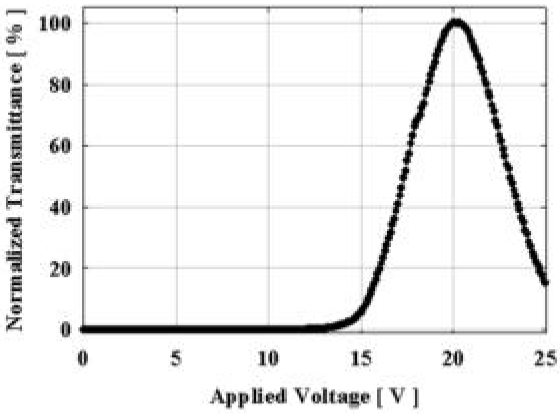

Figure 3. The normalized transmittance as a function of the applied voltage.

Figure. 4 shows the microscopic textures of our LCD under crossed polarizers. An excellent dark state was achieved in the off-state (0 V) because the LC was aligned homeotropically in the initial state. At the applied voltage of 14 V, region A experiences the Frederiksz transition, which first appears as four bright brushes around the center of the microgroove. This Frederikcsz transition results in the increase EO transmittance. As the applied voltage was increased, the bright brushes were expanded into the rim region of the microgroove, indicating the propagation of the Frederikcsz transition toward region. Consequently, a complicated but symmetric spatial modulation of the LC director was achieved near each microgroove. This phenomenon enhances the viewing characteristics of our LCD .

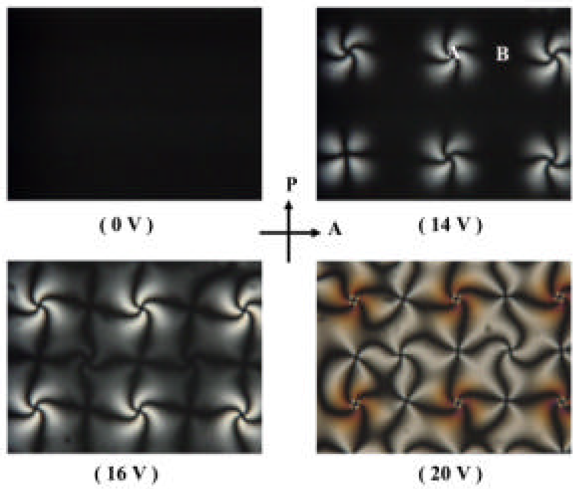

Figure 4. The microscope textures at different applied voltage under the crossed polarizers.

In summary, we have demonstrated a simple method of producing a multidomain structure on a thin film with periodic patterns for wide viewing LCDs. By using the replica molding technique, the LC director undergoes axially symmetric distortion on the replica film without using a complicated photolithography process or a multiple rubbing. Our technology should be useful for reducing the cost in manufacturing wide viewing LCDs in large size.

References

[1] M. Schdat, H. Seiberle, and A. Schuster, Nature (London).**381**, 212 (1996).

[2] M. Oh-e and K.Kondo, Appl. Phys. Lett. **67**, 3895 (1995).

[3] H. Yoshida, Y. Tasaka, Y. Tanaka, H. Sukenori, Y. Koike, and K. Okamoto, SID'04 Digest, 6 (2004)

[4] S. Kim, SID'04 Digest, 760 (2004)

[5] S. H. Lee, S. L. Lee, and H. Y. Kim, Appl. Phys. Lett. **73**, 2881 (1998).

[6] M. Geissler and Y. Xia, Adv. Mater.**16**,1249 (2004).

[7] Y. Xia and G. M. Whitesides, Angew. Chem. Int. Ed. **37,** 550 (1998).

[8] G. M. Whitesides, E. Ostuni, S. Takayama, X. Jiang and D. E. Ingber, Annu. Rev. Biomed. Eng. **3**, 335 (2001)