P-21: Patterning of Alignment Layers for Multi-Domain Liquid Crystal Structures

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Abstract: *We propose a simple patterning method for patterning of liquid crystal (LC) alignment layers. With soft-lithographic techniques such as a micro-contact printing method and a capillary force lithographic method, LC anchoring properties including surface pretilt and easy axis distribution can be spatially modified, producing multi-domain LC structures. It is expected that our pattering method would be a very useful tool for designing or enhancing electro-optic properties of LC devices with multi-domain LC structures.*

Keywords: liquid crystal alignment; multi-domain alignment, soft-lithography, micro-contact printing; capillary force lithography.

Introduction

The electro-optical (EO) properties of liquid crystal (LC) devices highly depend on a LC geometry determined by surface alignment conditions. Recently, patterning methods of a LC alignment layer for producing a multi-domain structure have attracted much attention for enhancing the EO properties in many LC applications including a wide viewing LC display [1, 2], a transflective display [3], and diffractive LC devices [4].

There are several approaches for patterning a LC alignment surface including a selective rubbing method with photolithographic protecting layers, a photoalignment with masks, holographic methods, a dip pen nanolithography using an atomic force microscope (AFM) tip [5], a microrubbing method with a metallic sphere [6, 7], and chemical nanoimprint method [8]. However, conventional multi-domain alignment methods are unattractive because of cumbersome multiple processing techniques and/or long processing time in real display applications. In order to apply chemical nanoimprint methods to practical applications, the thermal stability and durability of LC alignments have to be further examined.

In this work, we propose a simple patterning method for multi-domain LC alignment. First, we proposed a micro-contact printing method with conventional polyimide (PI) materials by facilitating surface wetting properties of patterning PIs and controlling baking conditions during the micro-contact printing procedures. Second, a pressure-assisted capillary force lithographic (PA-CFL) method [9] is proposed for patterning a thermoplastic LC alignment layer on a thermally stable LC alignment layer. By using a polystyrene (PS) and a PI, an orthogonal LC alignment on the patterned PS/PI surface can be easily achieved only by unidirectional rubbing process.

Micro-contact printed PI layers

In our fabrication process, the patterning of an LC alignment layer was executed by single step of contact printing without any etching process and any photo-mask process, as shown in Fig. 1. First, a patterning material (alignment agent I) was spin-coated on a patterned mold structure. Before transferring the patterning material with micro-contact printing, the base substrate to be patterned was preheated to pre-baking temperature of the patterning materials, which enhances the adhesion of the patterning material to the bottom substrate. After placing the mold structure coated with alignment layer onto the base substrate, the patterning material was wholly transferred to the base substrate by keeping the contact at pre-baking temperature of the patterning material. Then, the mold substrate was removed and the substrate with the patterned layer was cured at a polymerization temperature of the patterning material. With the proposed method, the LC anchoring at the surface can be spatially modified in easy axis orientation, pretilt, and surface anchoring energy by varying patterning materials and the base surface condition. We note that the method can be applied to the substrate with bare ITO or coated polymers.

With the proposed micro-contact printing method, we tested the precision of the patterned alignment layers on an ITO surface or a different alignment layer surface. From the obtained results, it was observed that a complete pattern transfer from the mold surface to the base surface to be patterned was obtained only when the patterning material's wettability on a base surface is much higher than that on a mold surface. Comparing with the homogeneous alignment PIs, RN1199 (Nissan Chemical Ind.) and JALS1371 (JSR Co.), the contact angles of both alignment agents on the ITO substrate were similar with the value of about 20°.

However, the wettability of JALS1371 on a mold surface used in our experiment was about two times larger than that of RN1199 and thus we could obtain a superior pattern transfer only when JALS1371 was used as a patterning material between them.

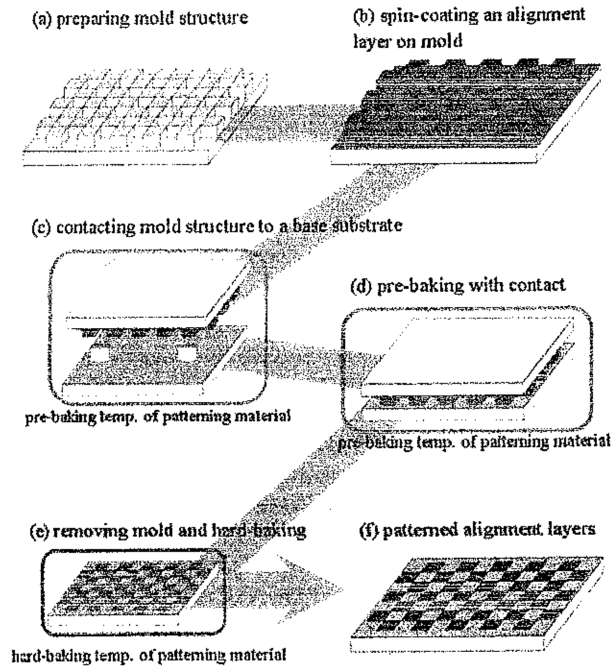

Figure 1. The schematic illustrations of micro-contact printing procedures for patterning LC alignment layers.

Figure 2 shows the polarizing microscopic images of LC textures as a function of an applied voltage, where the LCs were aligned between an unpatterned homeotropic alignment layer and a patterned homeotropic alignment layer on ITO substrates. As an alignment agent for patterning a homeotropic LC anchoring on the ITO surface, commercially available PI, AL1H659 (JSR CO.) was used. Between the prepared substrates, a nematic LC (NLC) with a negative dielectric anisotropy, MLC6610 (E. Merck) was filled in the cavity in isotropic phase of the NLC to remove the flow-induced LC anchoring effect. Figure 2 shows that the LCs on the unpatterned regions were aligned with a hybrid geometry between the homeotropic PI and the bare ITO surface. On our unrubbed ITO surface, there is no preferred azimuthal planar anchoring direction and thus the images between the patterned regions showed schlieren textures. As shown in Fig. 2(a), the LCs on the patterned regions were homeotropically aligned in the field off state, which showed that AL1H659 were successfully transferred from the mold surface to the ITO surface. From the measurement of the wetting behavior of AL1H659, the contact angle on the mold surface (29.6°) was higher than that on ITO (10.7°). In the field on state, the LCs on the unpatterned regions were reoriented in response to a lower applied voltage than those on the homeotropically patterned regions, as shown in Fig. 2 (b). In general, the NLCs, which are homeotropically aligned, exhibit the Schlieren textures above the Freedericksz transition voltage. However, for the cell configuration with our patterned surfaces, the NLCs in the pixel regions created axially symmetric multi-domain patterns with a field-induced reorientation, as shown in Figs. 2 (c) and (d). Such shapes of the multi-domain patterns were determined by the schieren textures around each pixel since the preferred switching directions of the NLC molecules inside the pixel were induced by the hybrid-aligned NLC molecules at the pixel walls.

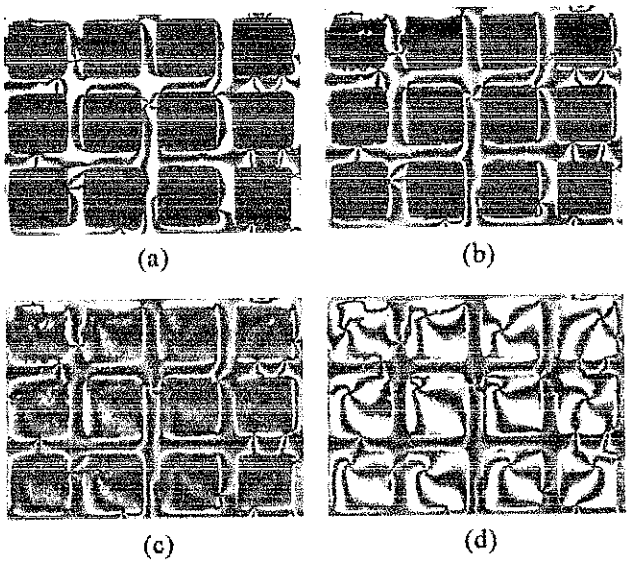

Figure 2. The polarizing microscopic images of LC textures as a function of an applied voltage, where the LCs are aligned between a homeotropic LC alignment PI (AL1H659) layer and a patterned homeotropic LC alignment PI (AL1H659) layer on ITO substrates.

Such axially symmetric multi-domain LC alignments can be obtained by facilitating surface-induced anisotropic phase separation with LC/polymer mixtures. For spatially modifying the surface wetting condition to the LC/polymer mixtures with a mixing ratio of 50:50, a homeotropic alignment layer (JALS684, JSR Co.) was patterned on one of the bare ITO-substrate by a micro-contact printing method. On the other substrate, JALS684 was uniformly coated. The mixture of negative NLC (MLC-6610, Merck) and photocurable prepolymer (NOA65, Norland) was introduced into the cell by capillary action at an isotropic temperature condition. After filling the mixture, the cell was cooled down slowly to room temperature. Because the wettability of the LC is higher than that of the prepolymer on the patterned alignment layer, phase separation between the LC and the prepolymer are spontaneously promoted an isotropic phase of the NLC. But, the temperature should be lower than T_g of i-PS to avoid thermal fluctuation of the chain ordering and resultant erasing of the rubbing effect on the patterned i-PS surface. The nematic to isotropic transition temperature of E7 (E. Merck), used in our experiment as a NLC, was about 60°C, which were sufficiently lower than T_g of i-PS. Figures 6 (c) and (d) show the polarizing microscopic images of the LC textures under the crossed polarizers and the parallel polarizers, respectively. In Fig. 6 (c), the dark and the bright regions corresponded to the LC textures on the patterned PS and PI layers, respectively. When we changed the optical instruments from the crossed polarizers to the parallel polarizers, the bright and the dark regions changed to each other, which meant that the LCs on the patterned PS layer had a homogeneous planar structure and those on the patterned PI layer had a TN structure.

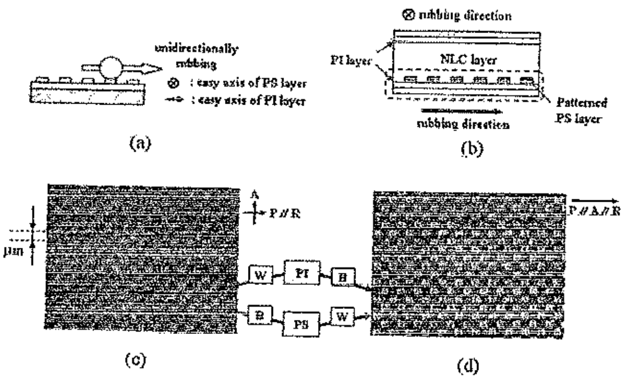

Figure 6. (a) Schematic illustration showing the easy axis direction on the patterned PS/PI layer after unidirectional rubbing. (b) The multi-domain LC cell structure fabricated by a patterned PS/PI surface and unpatterned PI surface. (c) and (d) are the polarizing microscopic images of LC textures observed under the crossed polarizers and the parallel polarizers, respectively.

Figure 7 shows the viewing angle improvement of the hybrid-aligned NLC cell fabricated by our patterned PI/PS surface. In the cases of the hybrid NLC cell, fabricated by uniformly aligned PI or PS alignment layers, the viewing angle properties showed highly asymmetric patterns due to the tilting of the NLCs along one direction, determined by the rubbing direction, as shown in Figs. 7 (a) and (b). However, in case of the hybrid –NLC cell aligned by the patterned PS/PI surface, the viewing angle was effectively improved by the effect of the multi-directional easy axis distributions, as shown in Fig. 7 (c).

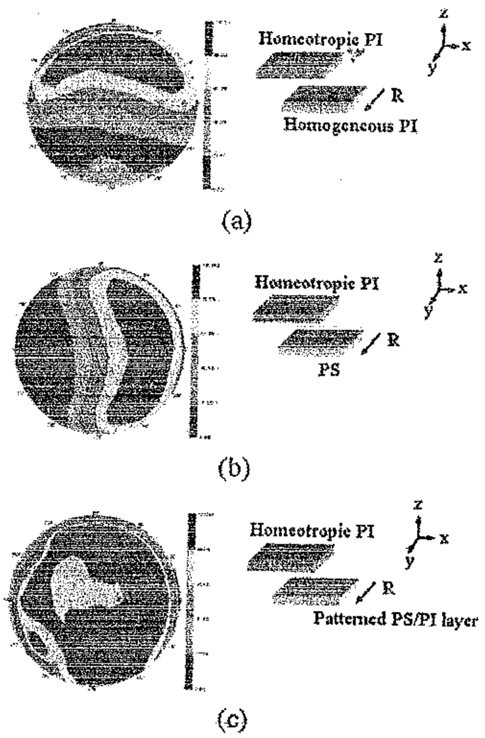

Figure 7. The viewing angle properties of the hybrid-aligned NLC cells and their surface anchoring conditions. As a planar anchoring surface, (a), (b), and (c) used PI, PS, and patterned PS/PI surfaces, respectively, where the planar anchoring surfaces were unidirectionally rubbing with the same direction.

Conclusion

We proposed soft-lithographic patterning methods of a micro-contact printing method and a PA CFL method for preparation of multi-domain LC cell. On the patterned surfaces, the LC anchoring could be spatially modified and several types of multi-domain LC cell could be fabricated. The precision and resolution of the patterning available by the micro-contact printing method was relatively lower than those fabricated by the PA-CFL method. However, in applying the CFL method, the LC alignment layer to be patterned should have thermoplastic behaviors. Depending on the purposes of the spatially modified LC anchoring, the patterning materials and relevant patterning methods should be chosen. Our simple patterning methods are expected to be very useful tools in enhancing or designing EO properties of LC-based devices requiring multi-domain LC structures.

Acknowledgements

This research was supported in part by a grant (F0004052) from Information Display R&D Center, one of the 21st Century Frontier R&D Program funded by the Ministry of Commerce, Industry and Energy of Korean government

References

1. van Aerle, N. A. J. M., "A Novel Multi-Domain Wide-Viewing Angle Liquid Crystal Display," *Jpn. J. Appl. Phys.*, Vol. 34, no. 11A, pp. L1472-L1474, 1995.
2. Liang, B.-J., S.-H. Chen, and Y. F. Wang, "Liquid crystal display with wide viewing angle," *Appl. Phys. Lett.*, Vol. 72, no. 11, pp. 1290-1292, 1998.
3. Yu, C.-J., D.-W. Kim, and S.-D. Lee, "Multimode transflective liquid crystal display with a single cell gap using a self-masking process of photoalignment," *Appl. Phys. Lett.*, Vol. 85, no. 22, pp. 5146-5148, 2004.
4. Choi, H., J. W. Wu, H. J. Chang, and B. Park, "Holographically generated twisted nematic liquid crystal gratings," *Appl. Phys. Lett.*, Vol. 88, pp. 021905, 2006.
5. Kim, J.-H., M. Yoneya, and H. Yokoyama, "Tristable nematic liquid-crystal device using micropatterned surface alignment," *Nature*, Vol. 420, pp. 159-162, 2002.
6. Varghese, S., Varghese, G. P. Crawford, C. W. M. Bastiaansen, D. K. G. de Boer, and D. J. Broer, "Four-domain twisted vertically aligned liquid crystal pixels using microrubbing," *Appl. Phys. Lett.*, Vol. 86, pp. 181914, 2005.
7. Varghese, S., S. Narayanankutty, C. W. M. Bastiaansen, G. P. Crawford, and D. J. Broer, "Patterned Alignment of Liquid Crystals by μ-Rubbing," *Adv. Mater.*, Vol. 16, no. 18, pp. 1600-1605, 2004.
8. Park, S., C. Padeste, H. Shift, J. Gobrecht, and T. Scharf, "Chemical Nanopatterns via Nanoimprint Lithography for Simultaneous Control over Azimuthal and Polar Alignment of Liquid Crystals," *Adv. Mater.*, Vol. 17, no. 11, pp. 1398-1401, 2005.
9. Khang, D.-Y., and H. H. Lee, "Pressure-Assisted Capillary Force Lithography," *Adv. Mater.*, Vol. 16, no. 2, pp. 176-179, 2004.

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