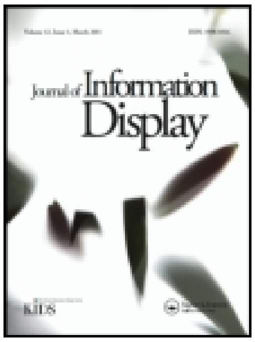

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Micro-contact printing method for patterning liquid crystal alignment layers

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Micro-Contact Printing Method for Patterning Liquid Crystal Alignment Layers

Jong-Wook Jung[**], Hak-Rin Kim[**], You-Jin Lee[**], and Jae-Hoon Kim[*]

Abstract

We propose a patterning method of liquid crystal (LC) alignment layer for producing multi-domain LC structures. By controlling thermal conditions during micro-contact printing procedures and facilitating wetting properties of patterning materials, patterned LC orientation can be easily obtained on a bare ITO surface or other polymer films. The newly proposed patterning method is expected to be a very useful tool for fabricating multi-domain LC structures to enhance or design electro-optic properties of LC-based devices.

Keywords : liquid crystal alignment, micro-contact printing, patterned alignment layer, surface wetting

1. Introduction

Recently, several types of multi-domain liquid crystal (LC) structures have been proposed to enhance or modify electro-optic (EO) properties of LC-based devices. In LC displays (LCDs), conventional viewing angle problems can be solved by azimuthally distributed LC orientations [1,2]. In transflective LCDs, the amounts of retardation in transmissive and reflective parts can be tuned by controlling surface pretilt of LCs differently in each part [3]. Electrically controllable, diffractive LC devices are achieved by periodically modified LC orientations [4].

Since the LC structure in bulk is determined by the surface alignment condition, patterned LC alignment layer is essentially required in obtaining multi-domain LC structures. Mechanical scribing methods with atomic force microscope tip [5] or metallic ball sphere [6,7] and optical alignment methods with photosensitive materials [8,9] have been proposed. As patterning methods to modify LC anchoring spatially. However, these conventional approaches are not suitable for that real applications due to their complex procedures requires long processing time and that low stability in LC anchoring.

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In this paper, we will demonstrate that commercially available, conventional LC alignment agent such as polyimides (PIs) can be easily patterned by micro-contact printing method. Patterned LC alignment PI layers were produced on a bare ITO surface or other polymer surfaces by facilitating wetting properties of the patterning PIs on the base surface to be patterned and the mold surface during micro-contact procedures.

2. Experiments

Fig. 1 shows the proposed alignment layer patterning procedures with micro-contact printing method. First, a patterning material (PI I in Fig. 1) was spin-coated on a patterned mold structure. To a pattern base substrate, a bare ITO substrate or other PI-coated substrate was prepared. The base substrate was pre-heated to a pre-baking temperature of the patterning material, PI I. Then, the PI-coated mold substrate was placed on the heated base substrate. When the wettability of the patterning material on the base substrate is higher than that on the mold surface, the PI I on the mold surface was transferred to the base substrate with the patterns of the mold structure during this first baking process. The imidization of the PI was executed after removing the mold structure from the base substrate. Finally, the patterning of alignment layers was completed. When the second baking process for imidization of the PI was executed with preserving the contact, we could not obtain uniform pattern transfer of PIs from the mold

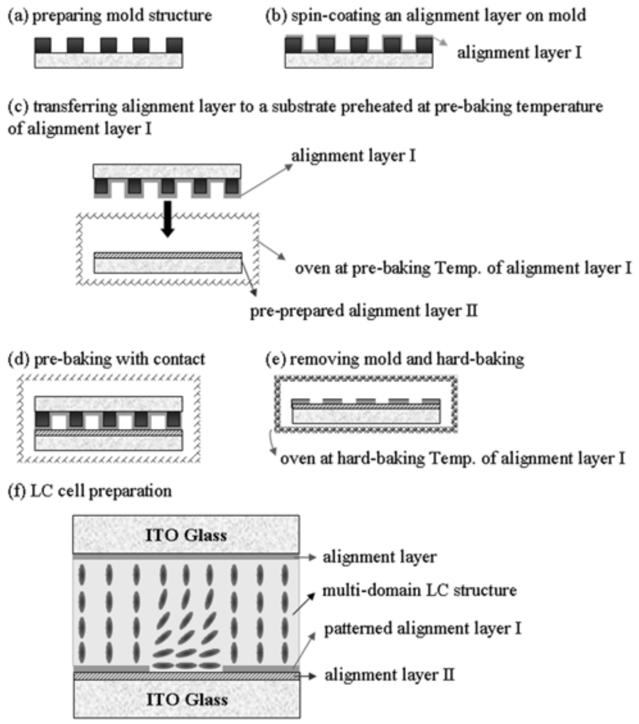

Fig. 1. Schematic illustrations of LC alignment layer patterning procedures with micro-contact printing method.

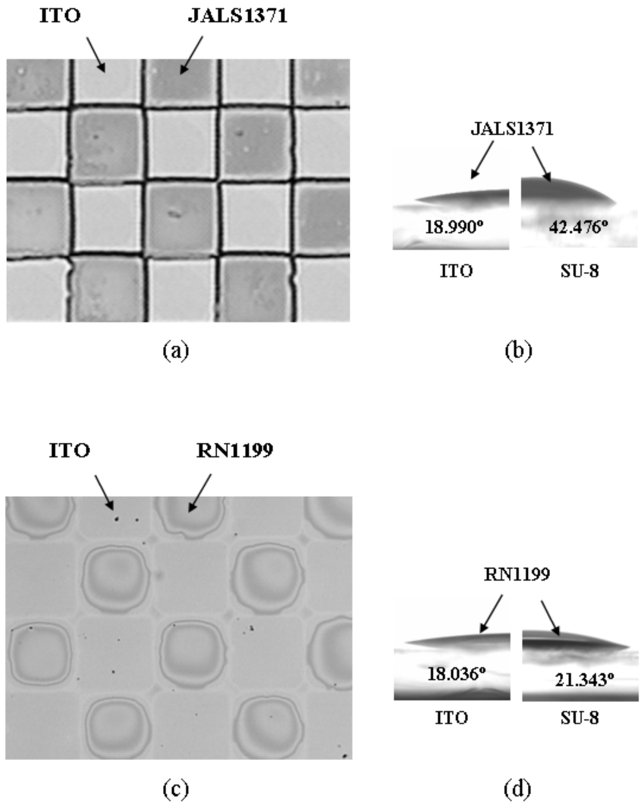

Fig. 2. Patterning of a planar LC alignment PI layer on ITO surface. (a) and (c) are the microscopic images of JALS1371 and RN1199 patterns, respectively, on an ITO surface. (b) and (d) show the wetting properties of JALS1371 and RN1199, respectively, on the ITO base surface and the SU-8 mold surface.

surface to the base film surface due to increased adhesion of imidized PI on the mold surface. Therefore, the pattern transfer of PIs should be executed in solvent state as shown in Fig. 1.

A patterned mold substrate was fabricated by a photo-lithographic method using negative photoresist of SU-8 (MicroChem). For patterning materials, commercially available PIs, such as AL1H659 (JSR Co.), RN1199 (Nissan Chemical Ind.), and JALS1371 (JSR Co.) were tested, where AL1H659 was a homeotropic LC alignment agent and both RN1199 and JALS1371 were planar LC alignment agents. The PIs were patterned on a bare ITO surface or other PI surfaces.

3. Results and discussion

The patterned planar LC alignment PI (JALS1371 and RN1199) layers on an ITO surface are presented in Fig. 2. The patterned substrates were prepared by micro-contact printing with identical SU-8 mold substrates in 100 μm period of check patterns. The microscopic images of the patterned surfaces showed that the JALS1371 pattern on the ITO surface was obtained with good uniformity in a check pattern, whereas the RN1199 pattern on the ITO surface was highly irregular. When we used RN1199 as a patterning material, much of RN1199 were still remain on the mold surface. These results can be explained by the relative wettability of patterning materials between the mold surface and the base surface. Figs. 2 (b) and (d) show the contact angles of JALS1371 and RN1199 in solvented state, respectively, on the ITO and SU-8 surfaces. In both PIs, the contact angles on the ITO substrate had similar values. However, the wettability on the mold surface showed significe difference. The contact angle of RN1199 on the SU-8 surface was slightly larger than that on the ITO surface, whereas the contact angle of JALS1371 on the SU-8 surface was more than two times that on the ITO surface. This relative surface wettability of the patterning PIs resulted in the different pattern uniformity between JALS1371 and RN1199 as shown in Figs. 2 (a) and (c).

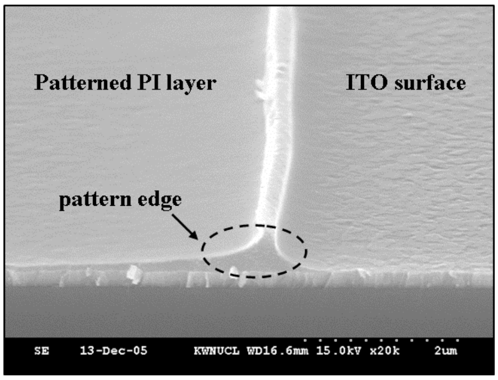

Fig. 3. Cross-sectional SEM image of the patterned PI (JALS1371) layer on the ITO surface.

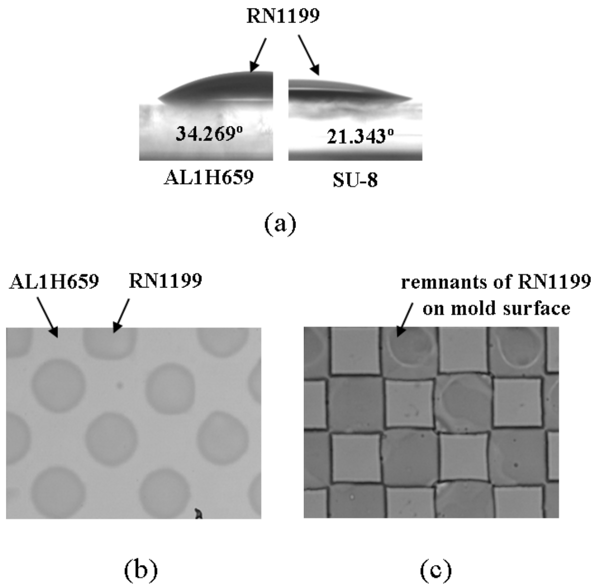

Fig. 4. (a) shows the wetting properties of RN1199 (a planar LC alignment PI) on AL1H659 (a base surface) and on SU-8 (a mold surface). (b) is the microscopic image of the RN1199 pattern on the AL1H659 surface. (c) is the microscopic image of the mold surface after the micro-contact printing procedures.

Fig. 3 shows the cross-sectional SEM image of the patterned PI (JALS1371) layer on the ITO surface, where we could observe the selectively patterned PI layer only in the micro-contact printed area by the mold structure. The boundaries of the PI patterns were relatively thicker than the inner area of the patterns since some of solvented PIs were squeezed out from the patterning area during the micro-contact procedures. Such phenomena can be reduced by making the patterned layer thinner and selecting Pis with higher viscosity in a solvented state.

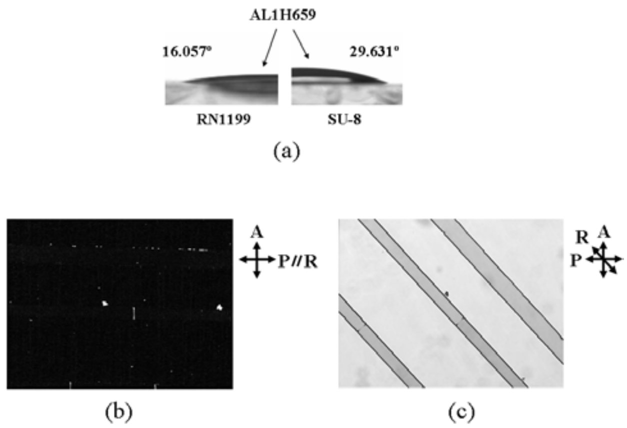

Fig. 5. Patterning of a homeotropic LC alignment PI (AL1H659) on a planar LC alignment PI (RN1199) layer. (a) shows the wetting properties of AL1H659 on the RN1199 and SU-8 surfaces. (b) and (c) are the polarizing microscopic images of the LC texture, where the LC is aligned between the patterned PI layers and a unpatterned planar LC alignment PI (RN1199) layer.

With the micro-contact printing method, we fabricated a homeotropic (AL1H659)/planar (RN1199) LC alignment pattern. When we used RN1199 as a patterning PI and AL1H659 as a base PI layer, the patterning material was more wettable on the mold surface than on the base surface as shown in Fig. 4 (a). Therefore, the RN1199 on the SU- 8 mold was partially transferred to the AL1H659 surface as shown in Fig. 4 (b). Fig. 4 (c) shows the remains of RN1199 on the mold surface, which were not transferred to the base surface.

However, when we used AL1H659 and RN1199 as a patterning material and a base surface, respectively, the patterning material was more wettable on the base surface than on the mold surface as shown in Fig. 5 (a). Therefore, the patterning material could be easily transferred to the base film and a homeotropic/planar LC alignment pattern was successfully obtained. With the patterned LC alignment substrate and an unpatterned planar LC alignment substrate, we made a LC cell by anti-parallel rubbing on both surfaces. Under these surface conditions, the LC could be aligned with multi-domain LC structures of homogeneously planar geometry on the RN1199 base surface and hybrid geometry on the patterned AL1H659 surface. Fig. 5 (a) shows the polarizing microscopic image of the LC texture obtained when the rubbing direction was parallel with one of polarizers. In this dark state, some of light leakage was observed at the pattern edges, which might originate from in the abrupt thickness variation at the pattern edge as shown in Fig. 3. However, within the homeotropic PI patterns, hybrid LC alignment could be obtained uniformly. In Fig. 5 (c), the LC texture on the homeotropically patterned PI layer showed relatively dark areas due to reduced effective optical birefringence in the hybrid geometry. The above results show that LC anchoring properties such as pretilt, anchoring strength, and azimuthal easy axis can be formed differently in space by patterning PI layers with proper surface wettability.

4. Conclusions

We proposed a patterning method for generating multi-domain LC structure, which could be realized with conventional LC alignment materials. By controlling the baking conditions during our micro-contact printing procedures and facilitating relative wetting difference of a patterning material between on the mold surface and on the base surface, we could obtain uniformly and precisely patterned alignment layers on a bare ITO surface or other polymer surfaces. Our simple micro-contact printing method is expected to be a very useful tool for enhancing or designing EO properties of LC-based devices requiring multi-domain LC structures.

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