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Micro-Contact Printing Method for Patterning of Liquid Crystal Alignment Layers

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We proposed a micro-contact printing method for producing multi-domain liquid crystal (LC) alignment with patterned alignment layers. Our results showed that conventional LC alignment materials could be selectively transferred to an ITO substrate or a different polymer layer by controlling surface wetting properties of a patterning material during the micro-contact printing procedures. The proposed patterning method is particularly simple and thus easily applicable to several LC devices such as wide-viewing LC displays (LCDs), transflective LCDs, and diffractive LC devices requiring spatially patterned LC orientations.

1. 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 LC structure have attracted much attention for enhancing EO properties in many LC applications including a wide viewing LC display, a transflective LC display [1], and diffractive LC devices. As patterning methods of single LC alignment surface, mechanical micro-rubbing methods by direct scribing with an atomic force microscope tip [2] or a metallic ball sphere [3], [4] and optical holographic methods [5] using photo-sensitive LC alignment materials have been proposed. As methods for producing multi-domain LC structures with patterned multi-layers, photo-lithographic etching methods [6] were proposed. However, conventional multi-domain alignment methods were unattractive in that cumbersome several processing steps and/or long processing time were required. Recent research result using soft-lithographic method [7] using specific molecular binding on a chemically modified surface showed relatively simple fabrication procedures. However, it seemed that stability and durability of LC anchoring had to be further examined.

In this paper, we propose a micro-contact printing method of LC alignment layers for producing multi-domain LC structures. By controlling pattern-transfer conditions such as baking procedures of solvented polymers and facilitating wetting properties of patterning materials on a mold surface and a base surface during micro-contact printing procedures, patterned LC alignment surfaces were easily produced on an ITO surface or other polymer surfaces with commercially available, conventional LC alignment agents such as polyimides (PIs).

2. Experimental

In our fabrication process, the patterning of an alignment layer was executed by single step of micro-contact printing without any etching process and any photo-mask process, as shown in Fig. 1. Fig. 1 shows the schematic illustrations of our micro-contact printing procedures for patterning LC alignment layers. First, a patterning material (PI I) was spin-coated on a mold structure which was

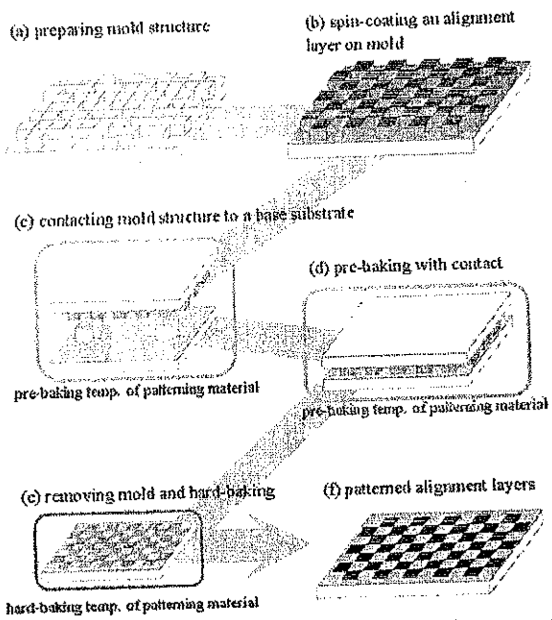

Figure 1. Schematic illustrations of micro-contact printing procedures for patterning LC alignment layers

Table 1. Contact angles of solvented PIs on base substrates.

		Base substrate			
		SU-8	ITO	RN1199	AL1H659
Solvented PI	JALS1371	42.4°	18.9°		
	RN1199	21.3°	18.0°		34.2°
	AL1H659	29.6°	10.7°	16.0°	

fabricated by a photo-lithographic method using a negative photoresist of SU-8 (MicroChem). As patterning materials, commercially available PIs, AL1H659 (JSR Co.), RN1199 (Nissan Chemical Ind.), and JALS1371 (JSR Co.) were tested in our experiment, where AL1H659 was a homeotropic LC alignment agent and RN1199 and JALS1371 were planar LC alignment agents. When the curing process for imidization of PIs was executed during the micro-contact printing, a uniform pattern transfer from the mold surface to the base substrate could not be obtained and much of the patterning materials were remained on the mold surface. Such problems were solved by executing the imidization process of the PIs after removing the contact. In our procedures, transfer of PI pattern took place in the first pre-baking process above the boiling temperature of solvents in the PIs. Before transferring the patterning material to the base substrate with micro-contact printing, the base substrate was pre-heated to the pre-baking temperature of the patterning material, which enhanced adhesion of the patterning material

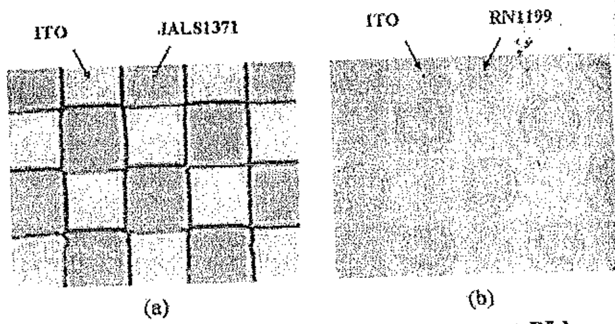

Figure 2. Patterning of planar LC alignment PI layers on the ITO surface. (a) and (b) are the microscopic images of patterned JALS1371 layer and patterned RN1199 layer, respectively, on the ITO surfaces.

to the base substrate. As the surface to be patterned, a bare ITO or a coated polymer (PI II) with a different LC-anchoring could be used. After placing the PI-coated mold structure on the base substrate, the contacted structures were kept in the oven above the pre-baking temperature of PI I. During the first thermal treatment with contact, the patterning material on the patterned mold substrate was transferred to the base substrate. Then, the mold structure was removed and the patterned alignment layer was cured for the PI imidization. Since the solvents in PIs were vaporized during the pre-baking treatment, the mold structure could be easily removed without degrading the precision of the patterning. With the proposed patterning method, the LC anchoring at the surface can be spatially modified in easy axis orientation, pretilt, and surface anchoring energy by selecting different alignment materials and base surfaces.

3. Result and Discussion

Figs. 2 (a) and (b) show the microscopic images of the patterned homogeneous alignment PIs on an ITO surface, where Figs. 2 (a) and (b) are obtained with JALS1371 and RN1199, respectively. When JALS1371 was used for a patterning material in the proposed micro-contact printing procedures, uniform PI pattern was obtained. Whereas, patterned result of RN1199 was highly nonuniform ones, where the thickness of the patterned PI layer showed much variation within each patterned area. These results originated in surface wetting difference of patterning materials between on the mold surface and on the base surface. In Table 1, the contact angles of JALS1371 and RN1199, in solvented state, on the SU-8 mold surface and the ITO base surface are presented. The contact angles on the ITO surface showed similar values in both

4. Conclusion

We proposed a patterning method for generating multi-domain LC structure, which could be realized with conventional LC alignment materials. By controlling 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 in enhancing or designing EO properties of LC-based devices requiring multi-domain LC structures.

Acknowledgement

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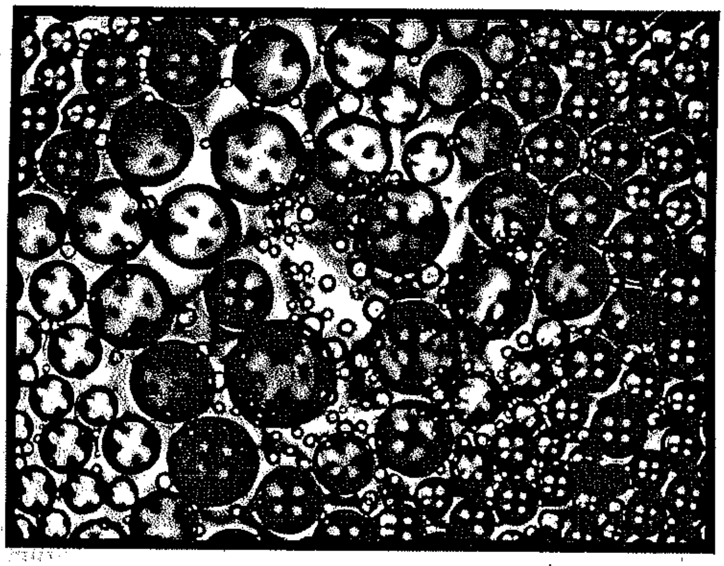

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O7. **Micro-Contact Printing Method for Patterning of Liquid Crystal Alignment Layers**

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O8. **Novel Transflective LCD with a Inner-Patterned Retarder**

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