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Alignment of Liquid Crystal Using a Replication Method of Directional Polymerization of Reactive Mesogen

Piao Meixuan and Chang-Jae Yu

Department of Electronic Engineering, Hanyang University, Seoul, Korea
cjyu@hanyang.ac.kr

We proposed a simple method to control liquid crystal (LC) alignments by stamping method of the nano-groove structures generated by ultraviolet exposure to the RM mixed alignment layer in a LC cell. Then the RM polymer structures were transferred to a polyimide by stamping method, which directly replicated the LC alignments of the LC cell. This method can generated the stable alignments of the LC without any aligning processes nor any electrode patterns.

1. Introduction

For a liquid crystal (LC) display application ,its uniform alignment decides the fundamental phenomena such as the molecular ordering and the phase transition. To obtain an uniform alignment, there are many alignment techniques for use such as rubbing, Langmuir-Blodgett films, ultra-violet (UV),and ion-beam exposure[1-3]. Though the rubbing method is widely used because of its low cost and strong anchoring characteristics [4,5], the direct contact of the rubbing roller to the substrate may induce electrostatic charge. And other methods also have some unsatisfactory characteristics such as weak anchoring properties.

In the Berreman theory[6],a periodic grooves structure was introduced to align the LC molecules. So fabricating the nano/micro grooves became another method of alignment. Recently Kim et al. reported the fabrication method of nano-filament structure using the reactive mesogen (RM) in the LC cell [7]. The polymerized RM filaments was fabricated by utilizing the LC molecules on the RM mixed alignment layer which is controlled by an external electric field during the UV exposure process. In this process, the LC directions were directly replicated by the polymerized RM filaments [7].

In this work, we proposed an easy way to fabricate the nano-grooves by replicating the directional polymerization of the RM. This process is expected to propose a simple method to generate the complicated alignment in the large area.

2. Experimental

As shown in Figure 1, we prepared the master mold by utilizing a vertically aligned (VA) LC cell. Spin-coated the mixed alignment material AL60702 (JSR) and RM257 (E.Merck) on the ITO glass. After baking process, the substrate was rubbed by cotton roller and assembled in anti-parallel direction. Using the glass spacers maintains the cell gap about 3μm thickness. The cell was injected the negative dielectric anisotropy ($\Delta\varepsilon = -3.2$) of the nematic LCs (MLC-6608, E.Merck) at the isotropic temperature and cooled down to the room temperature. The RM monomers align parallel to the LC molecules due to its properties. Then the next thirty minutes, the LC cell was exposed to the UV light under an external electric field (10V, 1 kHz with square waveform). The LC molecules aligned paralleled to the substrate with the RM monomers following. After disassembling the LC cell and washing out the LC molecules with hexane, we got the directional polymerized RM filaments.

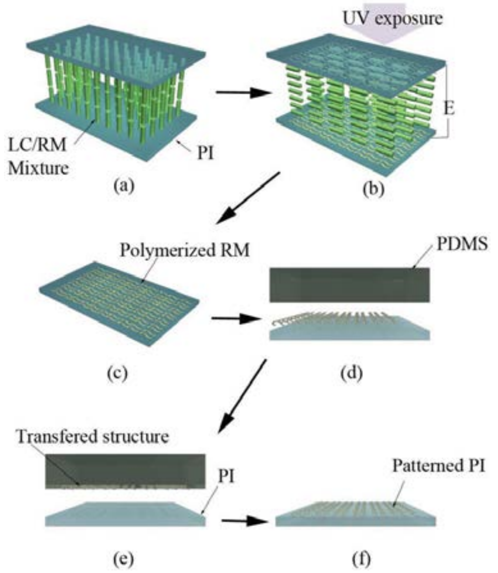

Figure1. The fabrication process of the nanostructure alignment layer.

Now, the RM morphology structure was replicated by polydimethylsiloxane (PDMS). The PI layers were imprinted using the PDMS replica as a stamp during the imidization process. Then we transferred the nanostructure to the VA alignment layer of AL60702 and the planar alignment layer of SE7492 (Nissan) with the negative dielectric anisotropy MLC-6608 and positive dielectric anisotropy ($\Delta\varepsilon$ = 3.8, ZKC-5085, JNC). By using AFM and microscope, we characterized the transferred alignments.

3. Results

In Figure 2, (a) is the AFM image of the fabricated RM morphology and (b) is transferred morphology to the AL60702. By using an equation of the surface anchoring energy shown as followed,

$$W = \frac{2\pi^3 A^2 K}{\lambda^3}$$

We can obtain the azimuthal anchoring strength 0.7 x 10^{-5} N/m, which is sufficient anchoring strength to get the uniform alignment of LCs.

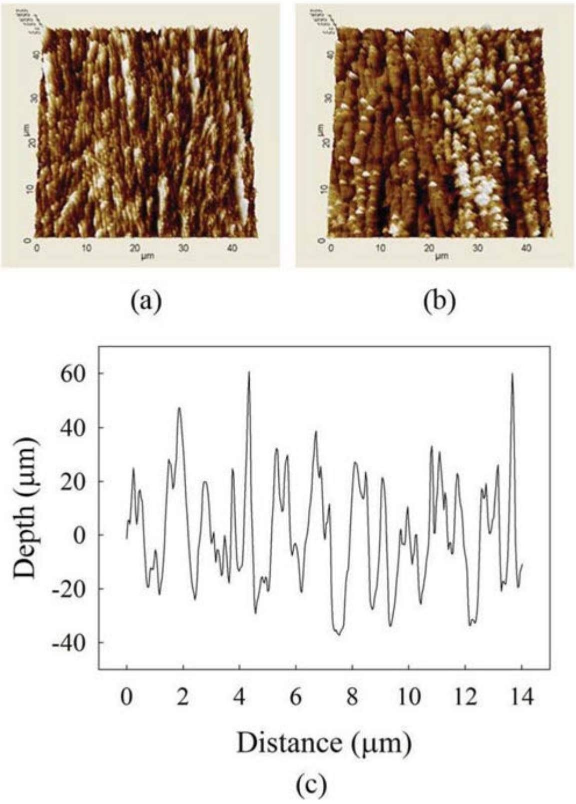

Figure 2. AFM images of (a) the PDMS mold surface and (b) the transferred PI surface. (c) cross-sectional distribution of the transferred PI surface.

Then we fabricated the LC cell with the transferred nanostructure substrate to confirm the characteristics of the transferred alignments. The transferred AL60702 layer used the negative dielectric anisotropy MLC-6608 as an injected LC and the cell gap maintained at about 3μm. The transferred SE7492 layer used the positive dielectric anisotropy ZKC-5085 as an injected LC and the cell gap is also about 3μm.

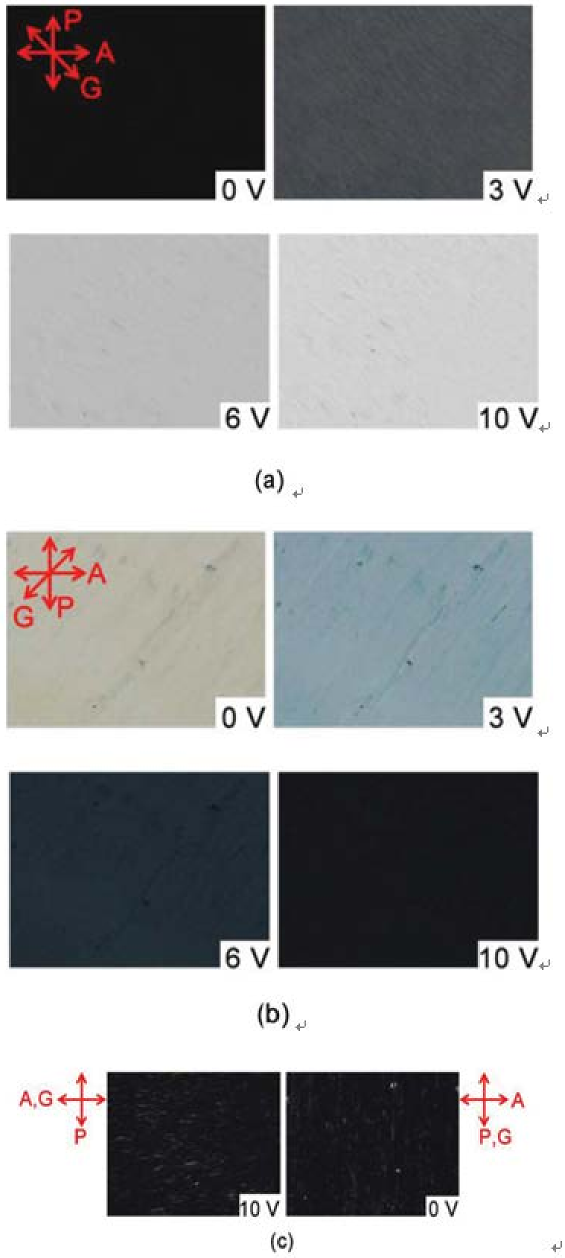

Figure 3. Polarized microscopic textures of (a) the vertical alignment, (b) the planar alignment samples, where the groove direction is rotated by 45◦ with respect to one of crossed polarizers. (c) Microscopic textures in the planar states in both samples, where the groove direction is parallel to one of crossed polarizers. The arrows depicted the optic axes of polarizers (P, A) and direction of the groove (G).

Under the crossed polarizers, we observed the transmittance of the two samples with different alignments by applying the electric field. Figure 3(a) shows the polarized microscopic textures for the MLC-6608 sample. The incident light was blocked at first, because the LC molecules were perpendicular to the substrate at initial state. By the increasing voltage the transmittance was increased due to the birefringence of the LC cell. Similarly, the ZKC-5085 sample shown as the Figure 3(b) under planar alignment was bright state at first and the transmittance gradually decreased with increasing voltage. In Figure 3 (c), we can confirm the uniform alignment of the transferred nanostructure substrates by observing the dark state of the samples. The MLC-6608 sample is under high applied voltage and the ZKC-5085 sample is under no applied voltage. The groove direction is parallel to the polarizer in both two samples. Through the polarized microscopic texture, we obtain the good dark state textures in both samples.

4. Conclusions

We proposed a simple method to control liquid crystal (LC) alignments by stamping method of the nano-groove structures generated by ultraviolet exposure to the RM mixed alignment layer in a LC cell. Then the RM polymer structures were transferred to a polyimide by stamping method, which directly replicated the LC alignments of the LC cell. This method can generated the stable alignments of the LC without any aligning processes nor any electrode patterns.

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