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Liquid Crystal Alignment by Atomic Force Microscopic nanolithography

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We fabricate a twisted nematic (TN) cell with surface liquid crystal (LC) alignment layer scratched by scanning atomic force microscopy (AFM) tip. To check possibility of this technique for liquid crystal display (LCD) application, the electro-optic characteristics of the cell is examined broadly.

1. Introduction

Typically, rubbing and photo-alignment methods are widely used for liquid crystal (LC) alignment. However, they can control simply surface morphology which has influence greatly on LC behavior[1,2,3]. The atomic force microscopy (AFM) nanolithography has emerged as an important research area producing nanoscale-surface undulation for LC alignment[4,5]. And it is well known that directors of liquid crystal have a tendency to align parallel to the groove shape solid surface.[6] Recently, in order to make LC pixel with uniformly distributed submicron patterns, nanopatterning by AFM has been suggested [7]. However there has been little reported on the voltage-dependence-transmittance characteristic of the LC cells fabricated with such surface morphologies which produce nearly zero pre-tilt at homogeneous alignment that may cause disclination line when voltage is applied to LC cell.

So as to solve this pretilt problem, another nanolithography method was reported [8], but does not has unidirectional pre-tilt since there is no preferring direction between both alignments (x or –x directions) even though LCs is not planar state (zero pretilt).

In the paper, we demonstrate uniformly and unidirectionally distributed pre-tilted twist nematic (TN) cell using a slope nanosize-groove pattern driven by a continuously modulated force of AFM tip at a scanning line and observe the electro-optic characteristics to confirm the pretilt generation at this technique.

2. Experimental

ITO glass spin-coated with a layer of polyimide (SE7492, Nissan chemical) which currently used for homogeneous alignment and its pretilt angle is known as 5 degrees. And we used another homogeneous polyimide (RN1199, Nissan chemical), has zero pretilt angle, to inquire the pretilt angle created by AFM nanolithography. Each glass is spin-coated at 1000 rpm for 10 sec and 2500 rpm for 10 sec. And it is pre-baked at 100° C for 10min, hard-baked 210℃ for 1 hour on the hot plate to completely imidize the surface.

AFM nanolithography process was performed by commercial AFM (XE-100, Park system) using the contact mode with various load force. Diamond coated cantilever (905U-DT-NCHR) is used and its radius of the apex is almost 20-30 nm.

To produce nanoscaled surface morphology on the LC alignment layer, we create a scratch on the each polyimide layer by AFM nanolithography process. Differ from present method [4], we make a directional linear pattern with depth about 20 nm by the AFM contact mode with cantilever force of 4000 nN. And we make the scratch line with unidirectional way due to difference of the lithographed shape when the tip move forward and backward.

Fig.1. shows the topological AFM image of lithographed area. The pitch of the surface morphology were 1um, respectively. The protruded beside the

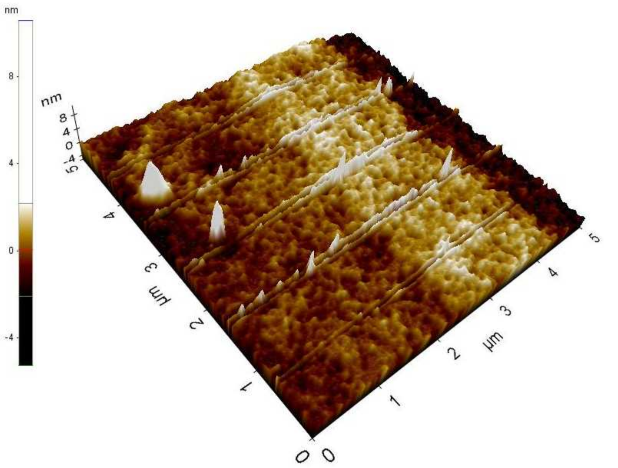

Fig. 1. Topological AFM image of lithographed area.

polyimide produced by lithography. And we add a cleaning process after lithography to remove this useless area.

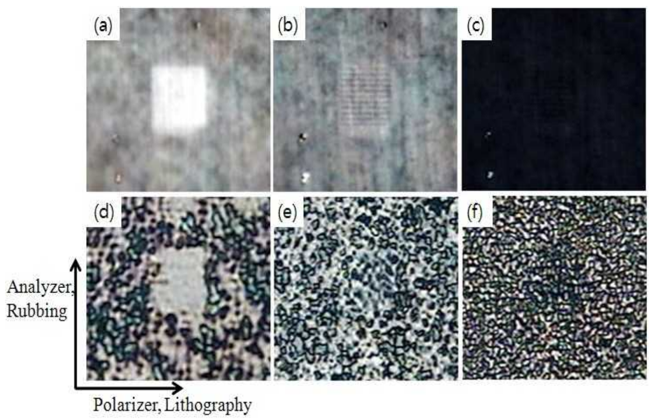

Fig. 2. Optical microscope images of TN cells according to field under crossed polarizers; at (a) 0V, (b) 3V, (c) 6V of TN cell with SE7492 at (d) 0V, (e) 3V, (f) 6V of TN cell with RN1199

The patterned polyimide substrate with indium tin oxide (ITO) electrode was assembled with counter ITO substrate coated by same polyimide rubbed perpendicular to nanolithography direction to fabricate TN cell. LCs (MAT-03-382) were injected in the sandwich cell along nanolithography direction and the cell was sealed by UV curable sealant.

Figure 2 is the microscopic images showing the electro-optical changes of the fabricated TN cells between crossed polarizers. Upper three images show microscopic images of TN cell fabricated with SE-7492 coated on the substrates, which has the pretilt angle of 5° . Due to the pretilt angle of rubbed substrate, we can not find any the disclination lines when the voltage is induced to the cell. On the other hand, lower three images show microscopic images of TN cell fabricated with RN-1199 coated on the substrates, which has almost zero pretilt angle. In this case, however, many declination lines occur with applied field as shown in Figs. 2 (e) and (f). With this result, we know that the surface relief by AFM nanolithography doesn't generate pretilt angle of LC.

In order to produce the pretilt angle by AFM lithography, we propose the improved line structure with inclination groove.

3. Results and Discussion

In previous experiment with RN1199, when the voltage across the two glass was induced, the director of the liquid crystal rotate randomly and it makes the disclination line texture. But, with our new method, liquid crystal director of the lithographed area arranged uniform direction when the voltage induced. This result indicates that the pretilt angle of LC can be controlled by the proposed AFM technique. In this work, we cannot measure the pretilt angle of this sample due to lithograpy of very small area. But we expect that this technique is useful to control surface LC behavior.

4. Conclusion

In contrast to current LC aligning methods, this research is about LC aligning method using AFM nanolithography. With this process, generating more elaborate and reliable nanoscale alignment is available for future LCD applications. For complementing the currently used AFM lithography which doesn't generate the pretilt angle, we propose the new AFM lithography that produces periodic inclination structure in a groove line and it can generate the pretilt angle. And we confirm this fact with observing the microscopic texture change in proportion to the voltage. Disclination line was disappeared, with this fact we can find out our inclination groove structure make the director of the liquid crystal arrange uniformly along the inclination surface.

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References

[1] J.A. Castellano, *Mol.Cryst. Liq. Cryst*. 94,33 (1983)

[2] C.-J. Yu, J. Kim, D.-W. Kim, and S.-D. Lee, *2004 SID International Symposium Digest of Technical Papers* (Society for Information Display, Seattle, 2004), p. 642.

[3] C.-J. Yu, D.-W. Kim, and S.-D. Lee, "Multimode transflective liquid crystal display with a single cell gapusing a self-masking process of photo alignment", *Appl.Phys. Lett 85, 22(2004)*

[4] J.H Kim, M.Yoneya, J. Yamamoto, H. Yokoyama, "Nano-Rubbing of a liquid crystal alignment layer by an atomic force microscope: a detailed characterization", *Nanotechnology,* 13, 133-137 (2002)

[5] A.J. Pidduck, G.P. Bryan-Brown, S.Haslam, R.Bannister, I.Kitely, T.J. McMaster, L.Boogaard, ''Atomic force mixroscopy studies of rubbed polyimide surfaces used for liquid crystal alignment", *J. Vac. Sci. Technol* A 14 (1996)

[6] D. Berreman, "Solid Surface Shape and the Alignment of an Adjacent Nematic Liquid Crystal", *Phys. Rev. Lett*. **28**, 1683 (1972).

[7] B.Zhang, F.K Lee, Ophelia K. C. Tsui, Ping Sheng, "Liquid Crystal Orientation Transition on Microtextured Substrated", *Phys. Rev. Lett*. 91, 215501 (2003).

[8] F.K Lee, B.Zhang, and Ping Sheng, H.S Kwok, Ophelia K. C. Tsui "Continuous liquid crystal pretilt control through textured substrates", *Appl.Phys. Lett 85, 23(2004)*

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