Liquid crystal alignment on the multiply photo-treated layers by the interfered laser light

Eun-Kyu Lee*, Jong-Hyun Kim
Physics, Chungnam National University, Daejeon, Korea
E-mail : eunkyu_lee@hanmail.net

Abstract

Orientational alignment patterns proved that they are very useful for realizing diverse properties of liquid crystals. Here we tried to produce the patterns combining interfered laser light and double irradiations.
A photo-isomerizable polymer doped with azo dye, which induce uniform liquid crystal alignment to the uniform laser irradiation, was used as the alignment layer. Double irradiations into two orthogonal directions brought the orientation patterns similar to the checkerboard. It indicates the possibility of bistability on those patterns.

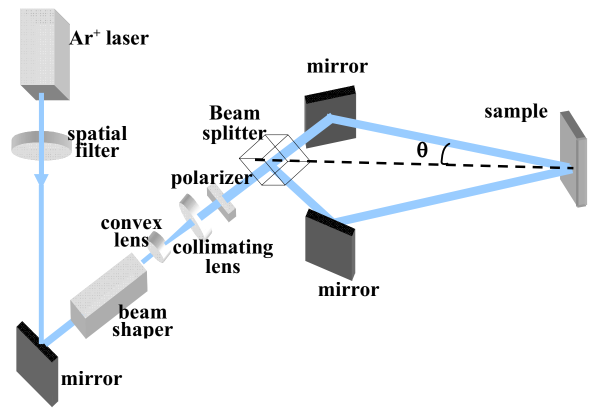

Figure 1. Schematic diagram for experiment. Coherent laser beams make interference on the sample surface.

1. Introduction

In a display which is commonly used at cellular phone or electric dictionary, there is just occasional change of images, once it displays some information on it. Therefore, it is appropriate to use low electric power bistatble liquid crystal devices (LCD) that keep on the image without continuous refreshing the image.

There are several techniques for liquid crystal (LC) bistability[1)-4)]. One technique took advantage of orientational patterns, which satisfy 4-fold rotational symmetry and, as a result, brings LC bistability on the patterns for its symmetry[1)]. Even its bistability is robust, it has several disadvantages like small pattern size, long process time and necessity for expensive machine. To overcome some of these issues, here we tried to realized orientational patterns with laser light and using its coherence. And we would like to show the primitive results of those effects.

2. Experiment

We tried to realize orientation patterns by applying the conventional optical method[5)] which makes grating in photo-sensitive material using interference of two coherent beams as in Fig. 1. The gaussian beam of linearly polarized Ar^+ laser at 488nm of 8mW/cm^2 was modified by shaper and expander to be large uniform beam. P-polarized two beams through the beam splitter at the same power were irradiated on the substrate, which was coated with photo-sensitive alignment layer. For orientation pattern, we irradiated into two orthogonal orientations by rotating the sample.

For the single irradiation, the interference pattern

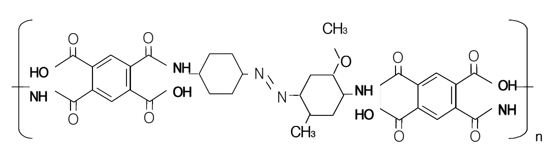

Figure 2. Chemical structure of main-chain-substituted PAA with azobenzene units

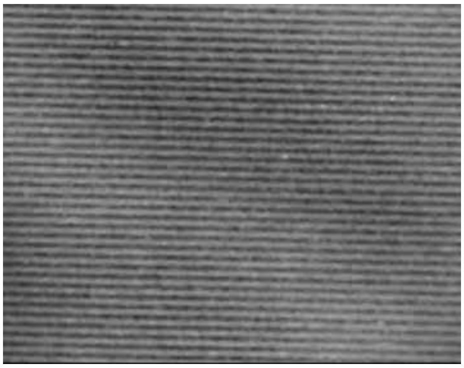

Figure 3. LC texture from single interfered laser light. The line pitch is about 1.5um.

of lines is expected. Double irradiations, in which the orientation of the second irradiation is rotated by 90degree to the first, will bring checkerboard like orientation pattern.

As an alignment layer, we used a main-chain-substituted polyamic acid (PAA) with azobenzene unit that occurs trans-cis transition by appropriate light[6)-8)]. The chemical structure of alignment material is shown in Fig. 2. It is known that this material has excellent thermal and optical stabilities[9),10)]. PAA was spin coated on the ITO glasses and dried at 70°C for 30min, in order to evaporate any solvent left over and to make isotropic surface.

The photo-aligned substrates were assembled with conventionally rubbed substrate with certain cell gap. 5CB was injected into cell in its isotropic phase via capillary effect. The cell was observed with polarizing optical microscope at room temperature.

3. Result and Discussion

Generally, LC is known to be aligned by the direction of main chain in main-chain-substituted PAA with azo units. It is perpendicular to the polarization of the irradiating light.

Before realizing the double irradiation, we confirmed the alignment by single interfered beam. Fig. 3 shows the LC alignment reflecting the interference pattern. The alignment on weaker light intensity regions follows the conventionally rubbed orientation. However, the alignment on higher light

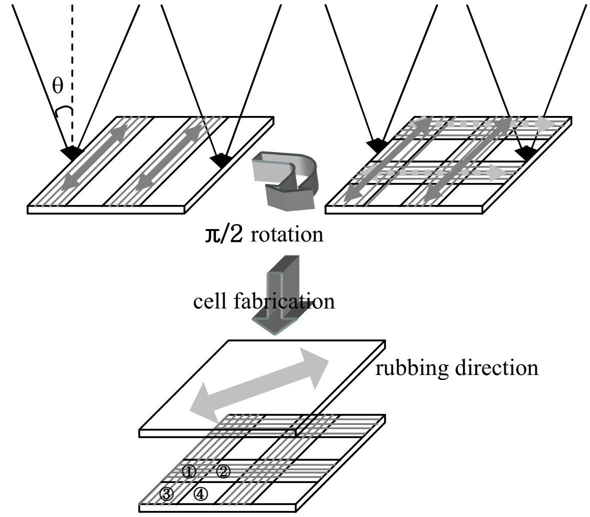

Figure 4. Schematic diagram for interfered laser light irradiation into two orthogonal directions and cell structure for observing the texture

intensity regions made twist following the photo-aligned orientation. Line pattern appeared with regular pitch. The pitch is expressed by $\lambda/(2\sin\theta)$, (λ : wavelength of light, θ : incident angle). The pitch can be controlled by adjusting the incident beam angles. The beam incident angle was 10° and the pitch between each alignment line was about 1.5μm.

As shown in Fig. 4, we made double irradiations on the PAA-coated substrate. Fig. 5 is the optical microscope image of the LC injected cell. The rubbing direction of counter substrate and the polarizer direction of optical microscope were adjusted for contrast of each domain.

In Fig. 4, we can see 4 different kinds of domains in a pixel : two single, but orthogonally irradiated domains (2,3), double irradiated domain

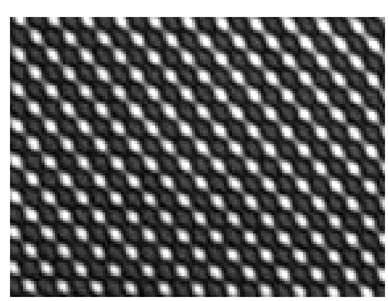

Figure 5. LC alignment texture on the double irradiations.

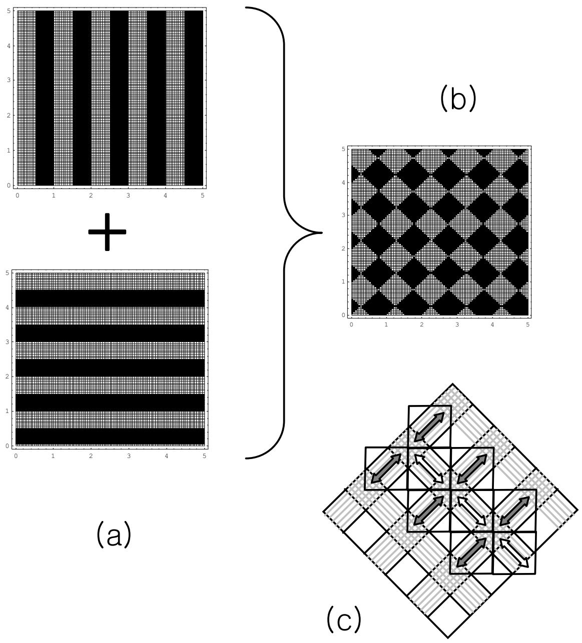

Figure 6. (a) Simple model assumed the same energy of light is irradiated with 90degree rotation. (b) Resultant alignment from the overlapping of (a). We assumed that the alignment follows the orientation of higher light energy. (c) Schematic diagram showing the influence of anchoring to the size of domain in each domain.

(1), no-irradiated domain (4). Here we assumed negligible influence of double or non-irradiated domains, but we focused on the behavior of two single irradiated domains. In the event, the experimental result indicated the assumption was not wrong.

The pitch of patterns is wider than that of single irradiation alignment. Moreover, we have expected that the patterns would be collection of rhombus, but it is collection of square. The result which is different from our expectation seems to be caused by the weak anchoring of domain 2 and 3 and strong anchoring of domain 1 and 4. A simple modeling like Fig. 6(a)(b)(c), under our assumption written above, made such result more understandable. In other words, the domains of weak anchoring shrink its size and, in the contrast, those of strong anchoring extend theirs. In such process the texture looks like collection of squares.

Next, we changed the ratio of irradiated energy between the first and second steps. We adjusted the ratio of 1:1.1 in experiment and the texture is shown in Fig. 7(a). It brings the image of a long cruller. Such patterns originated from the asymmetric anchoring effect between two orthogonal orientations. When performing a simple modeling with assumption that the irradiation energy of the second step is higher, the result is like in Fig. 7(b). That corresponds well with our experimental result. And we ascertained that it is also true in the case which is assumed that the irradiation energy of the first step is higher.

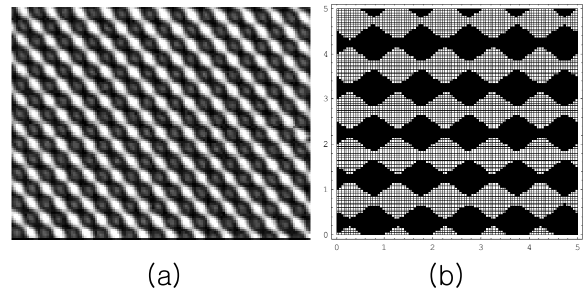

Figure 7. The texture and simple model calculation. Light energy of one direction was assumed to be higher by 10% than the other. (a) LC texture (b) model calculation

4. Conclusion

In this experiment, we made orientation patterns using interference of laser light. We repeated the irradiations twice with changing the direction. As a result, we obtained the patterns consisted of orthogonal orientations. And the detail shape of the domains was decided according to the ratio of light energy when it is irradiated twice. We think it originated from the asymmetric anchoring between each domain.

This report is the first step for realizing bistable state by multi domain. We think that more experiments and researches should be done.

4. Acknowledgements

This work was supported by Korea Energy Management Corporation.

4. Reference

[1] J. H. Kim, M. Yoneya, J. Yamamoto, and H. Yokoyama, Appl. Phys. Lett. **78**, 3055-3057(2001).

[2] R. Barberi, J. J. Bonvent, M. Giocondo, and M. Iovane, J. Appl. Phys. **84,** 1321-1324(1998).

[3] I. Dozov, M. Nobili, and G. Durand, Appl. Phys. Lett. **70**, 1179(1997).

[4] S. P. Palto, S. G. Yudin, C. Germain, and G. Durand, J. Physique Ⅱ **5**, 133(1995).

[5] M. H. Kim, and J. D. Kim, Liquid Crystal **27**, 1634(2000).

[6] M. Schadt, K. Schmitt, V. Kozinkov, and V. Chigrinov, Jpn. J. Appl. Phys. **31**, 2155 (1992).

[7] K. Nirmal et. al., J. Mater. Chem, **9**, 1941(1999).

[8] G. Y. Kevin, J. B. Christopher, Curr. Opin. Solid State Mater. Sci. **5**, 487(2001).

[9] B. J. Park, et. al., Jpn. J. Appl. Phys. **37**, 5664(1998).

[10] D. H. Chung, et. al., Jpn. J. Appl. Phys. **39**, 1252(2000).