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Liquid Crystal Alignment on the Multiple Photo-treated Layers by the Interfered Laser Light

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Abstract

Orientational alignment patterns have been proven to be that they are very useful for realizing diverse properties of liquid crystals. Here we produced the patterns combining interfered laser beams. A photo-isomerizable polymer including azo unit, which induces nematic liquid crystal alignment to the polarized laser light, was used as the alignment to layer. Double irradiations into two orthogonal directions brought the orientation patterns similar to the checkerboard. It indicates the possibility of bistability on those patterns.

Keywords : liquid crystal, alignment, photo-alignment, interference, multi-domain

1. Introduction

The display of cellular phone or electronic dictionary changes images only occasionally, once it displays some information on it. Therefore, it is appropriate to use bistatble liquid crystal devices (LCD) of low power consumption that keep up the image without continuous refreshing the image.

There are several techniques for nematic liquid crystal (NLC) bistability[1-4]. One technique takes advantage of orientational patterns, which satisfy four-fold rotational symmetry and, as a result, brings LC bistability on that pattern[5]. 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, we tried to realize orientation patterns using coherent laser light. Thus, in this paper, we will show the primitive results of those effects.

2. Experiment

We obtained orientational patterns by applying the the conventional optical method[6] 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 of $8 mW/cm^2$ was modified by shaper and expander to be large uniform beam. P-polarized two beams through the beam splitter were irradiated on the substrate,

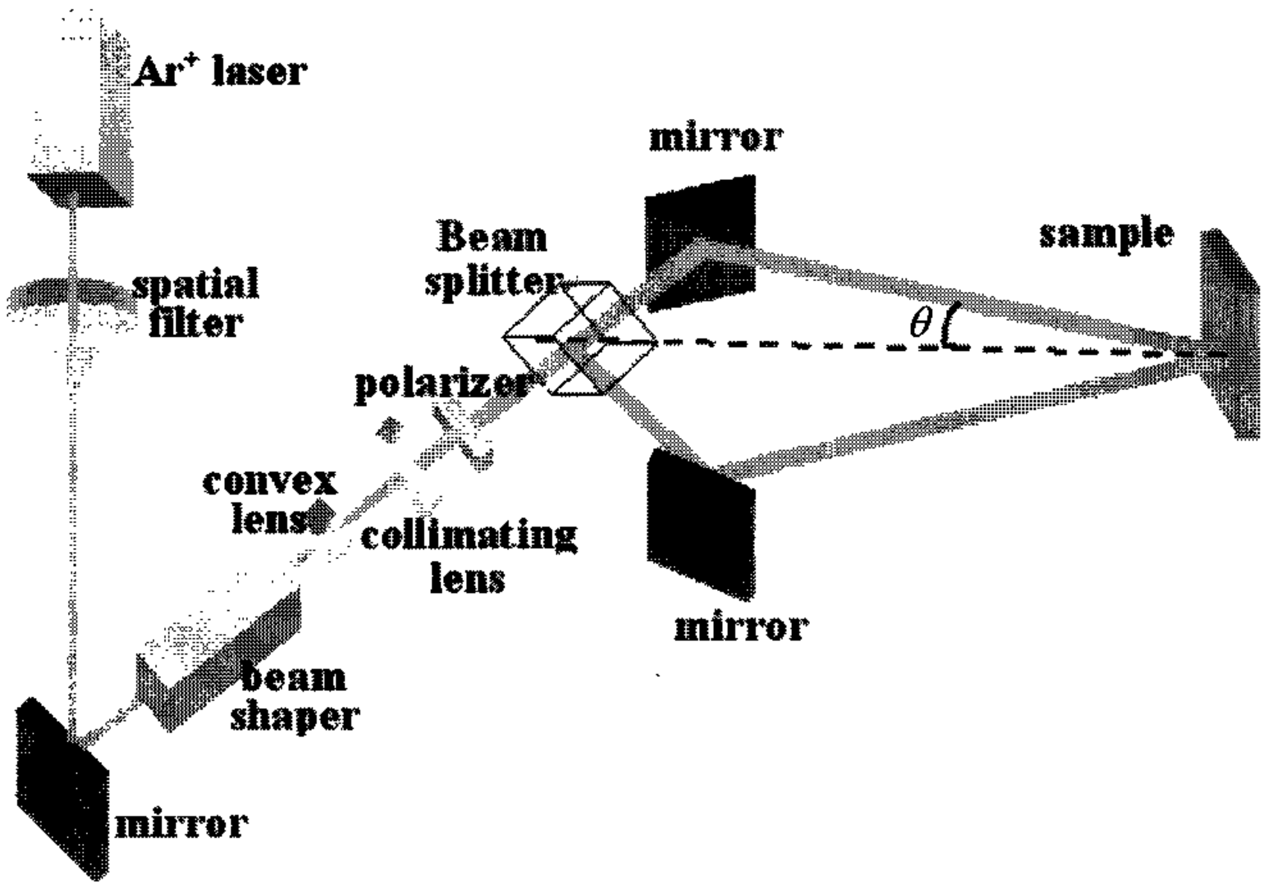

Fig. 1. Schematic diagram for experiment. Coherent laser beams make interference on the sample surface.

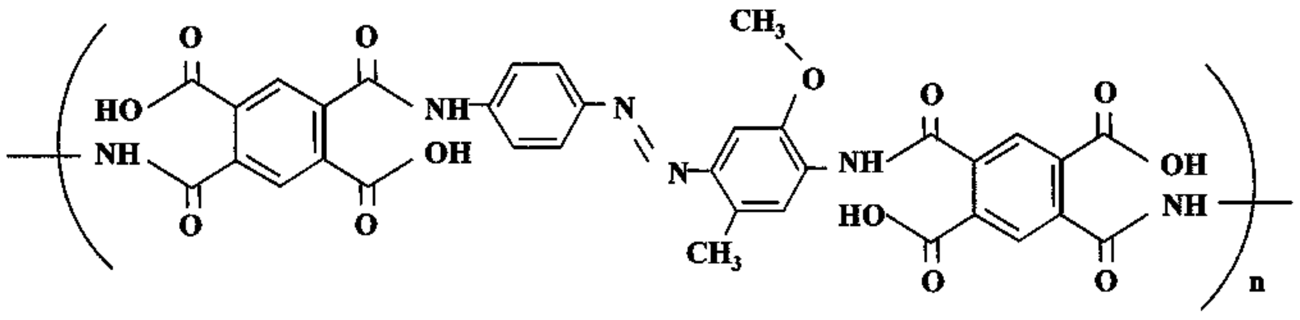

Fig. 2. Chemical structure of main-chain-substituted PAA with azobenzene units

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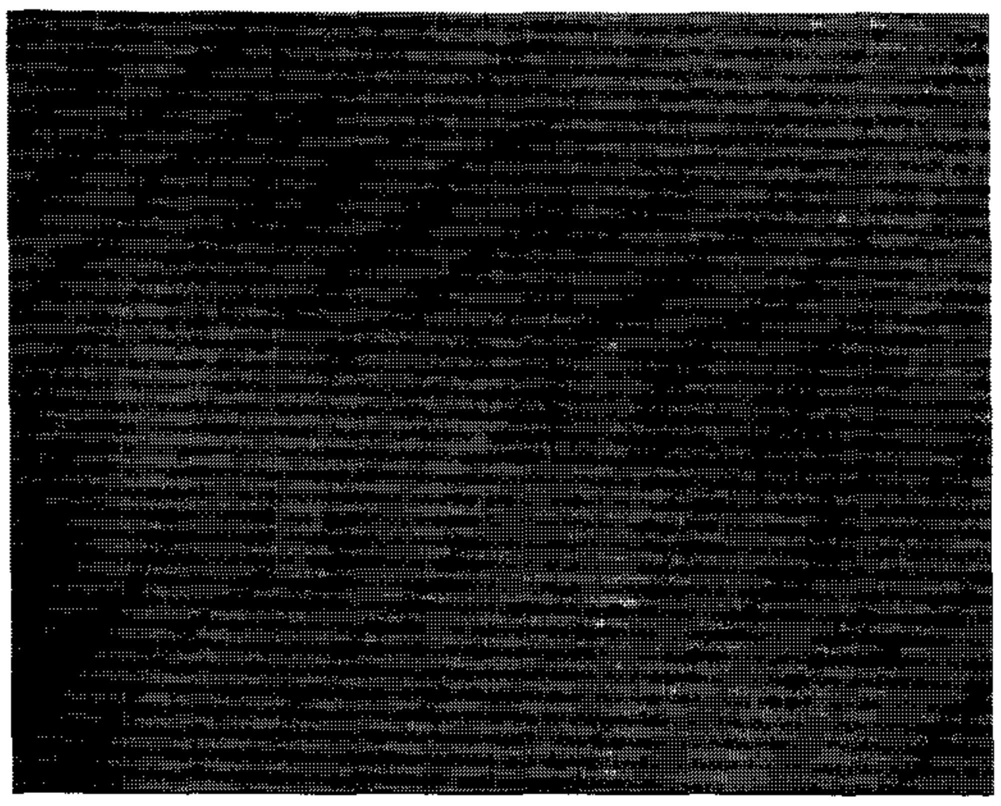

Fig. 3. LC texture on the substrate of single irradiation. The line pitch is about 1.5um.

which was coated with photo-sensitive alignment layers.

In the event of single irradiation, 1-dimensional interference pattern is expected. Double irradiations, in which the orientation of the second irradiation is rotated by 90degree to the first one, can anticipate originating orientational patterns like checkerboard.

As an alignment layer, we used a main-chain-substituted polyamic acid (PAA) with azo unit that reacts by trans-cis transition by appropriate light[7-9]. The chemical structure of alignment material is shown in Fig. 2. It is known that this material has excellent thermal and optical stabilities[10-11]. The 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 the commercial polymide coated and substrate was conventionally rubbed substrate with about 50μm cell gap. A nematic LC(5CB) was injected into the cell in its isotropic phase via capillary effect. The cell was observed with a polarizing optical micro-scope 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. We irradiated the interfered laser light on the conventionally rubbed surface with the polarization parallel to the rubbing. Fig. 3 shows the LC alignment reflecting the interference patterns. The directors on darker regions oriented along the conventionally rubbing. However, the alignment on brighter regions was rotated by the photo-alignment deviating from the rubbing direction. Line patterns have 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.

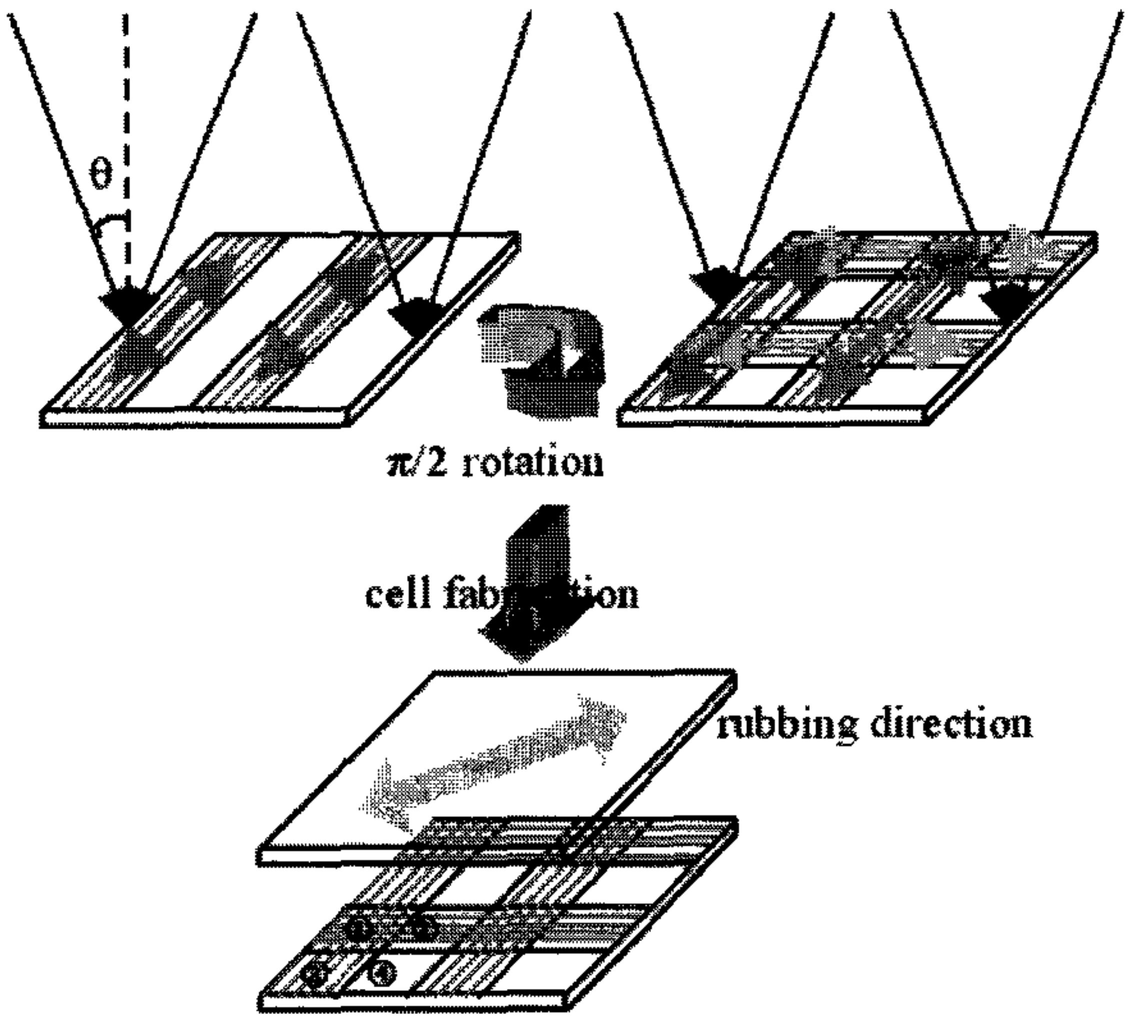

Fig. 4. Schematic diagram for interfered laser light irradiation into two orthogonal directions and cell structure for observing the texture

As shown in Fig. 4, we carried out 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. For the slightly different irradiation energy between the first and second irradiations and inhomogeneous energy point by point, the dark and bright regions show slight variation in size.

In Fig. 4, we can see four different kinds of domains in a texture two single, but orthogonally irradiated domains (2,3), double irradiated domain (1), no-irradiated domain (4). Here we assumed negligible influence of double or

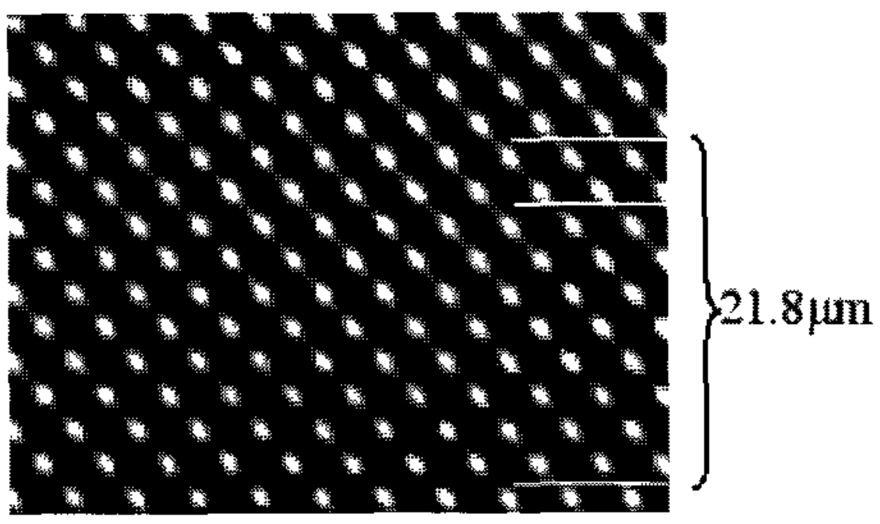

Fig. 5. LC alignment texture on the double irradiations.

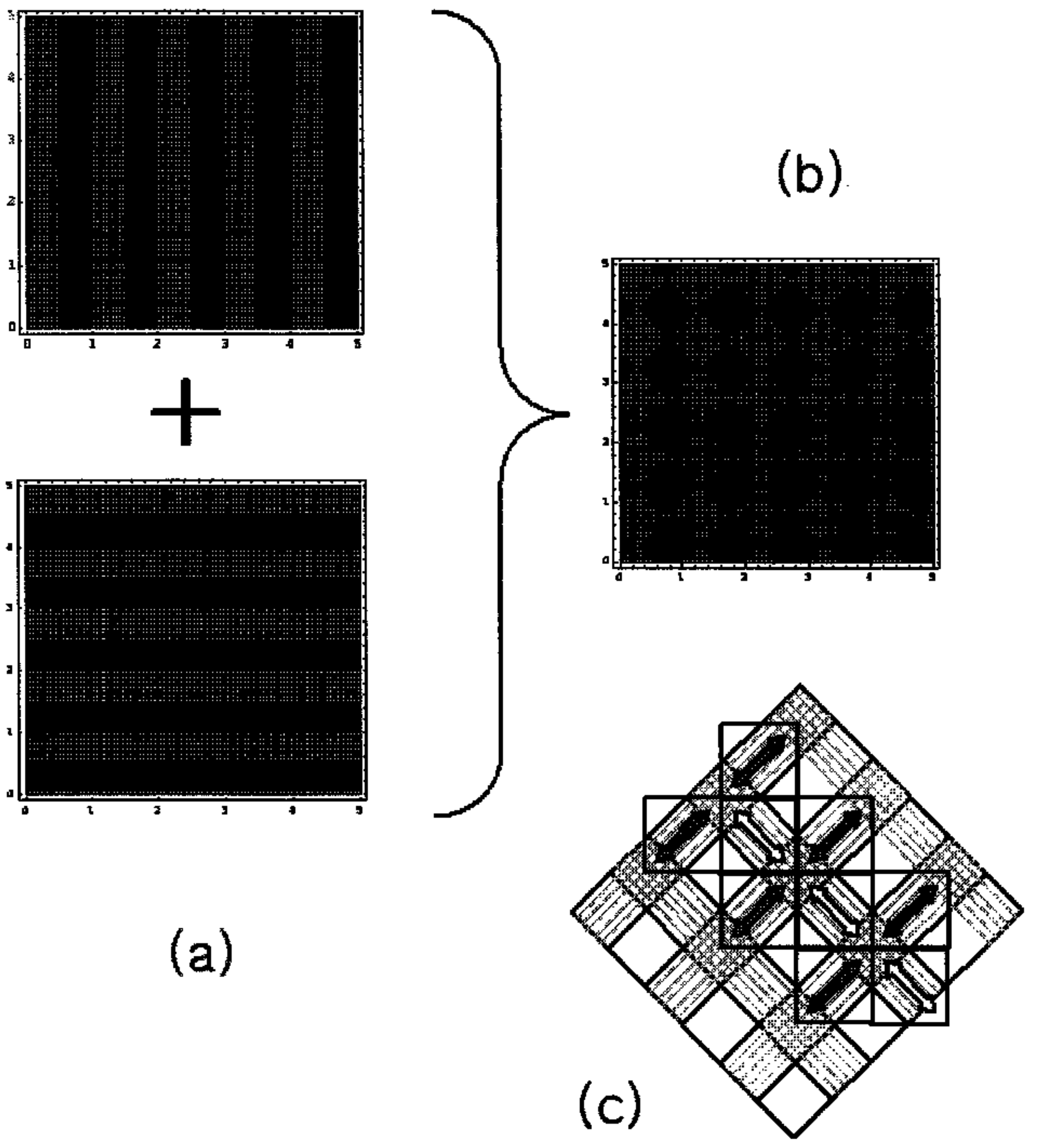

Fig. 6. (a) Simple model assumed the same energy of light is irradiated with 90degree rotation. (b) Resultant alignment from the overlapping of (a). We assumed that the alignment follows the orientation of higher light energy. (c) Schematic diagram showing the influence of anchoring to the size of domain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

non-irradiated domains. We focused on the behavior of two single irradiated domains. Experimental results indicate that the assumption was not wrong.

Even though optical setup of laser light irradiation was the same, the pitch of patterns was wider than that of single irradiation alignment. Moreover, we expected that the patterns would be collection of rhombus, but it turns out to be a collection of squares. The result which is different from our expectation seems to be caused by the competition between the weak anchoring of domains 2 and 3 and strong anchoring of domains 1 and 4. A simple modeling as shown in Fig. 6(a)(b)(c), which is based on our assumption described before, indicates the reasonability of the results. 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 a 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 the experiment and the texture is shown in Fig. 7(a). The texture image is changed into the array of long crullers. Such patterns are the result of 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 as shown in Fig. 7(b), which corresponds well with our experimental result. In addition, we ascertained that it is also true in the case where it is assumed that the irradiation energy of the first step is higher.

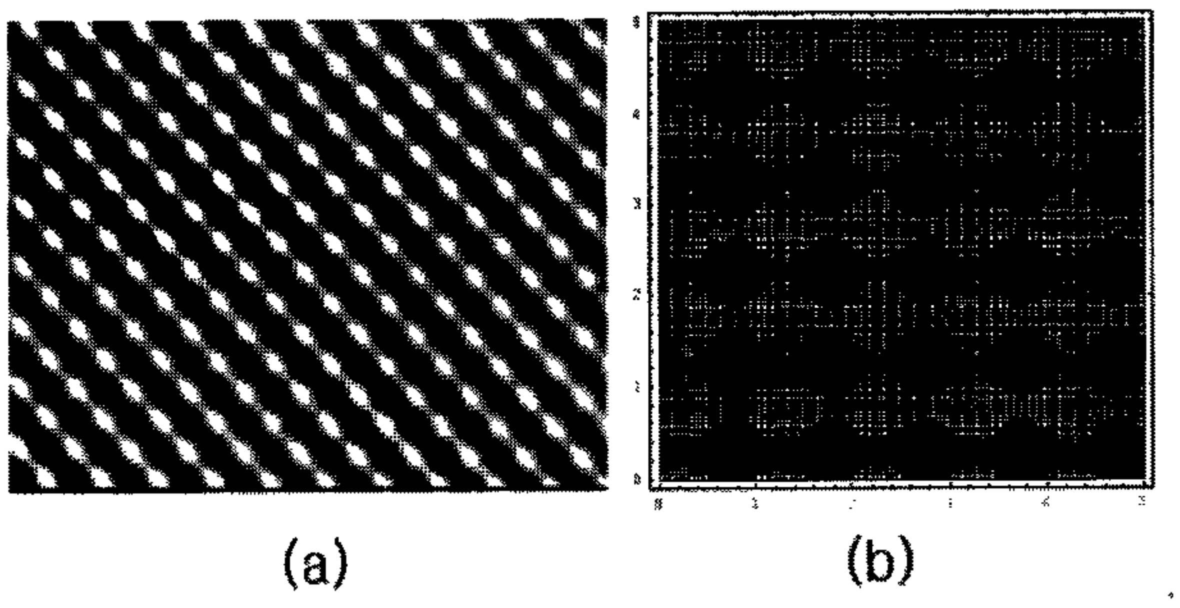

Fig. 7. The texture and simple model calculation. Light energy of one direction was assumed to be higher by 10% than the other. (a) LC texture (b) model calculation

From the symmetric pattern of LC texture, we expect the bulk directors, far away enough from the patterning surface, orient along an average direction of the two dominant domains[1]. As a consequence, we expect the bistability to be shown with bulk directors.

4. Conclusion

In this experiment, we made orientational patterns using interference of laser light. We repeated the irradiations twice by changing the direction. As a result, we obtained the patterns consisting of orthogonal orientations. The detailed shape of the domains was decided according to the ratio of light energy when it is irradiated twice. We think it may have originated from the asymmetric anchoring between each domain.

This report is the first step for realizing bistable state by multi domains.

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