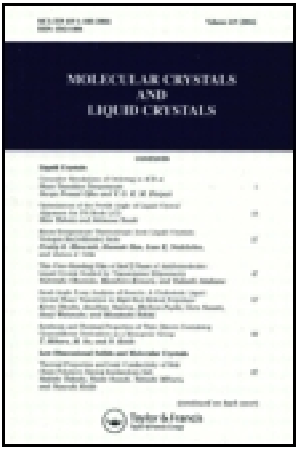

Molecular Crystals and Liquid Crystals
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl20

Novel Photo Alignment Method with Rotating Substrate

Taiju Takahashi [a], Naoyuki Tanabe [a], Takanori Ando [a] & Susumu Saito [a]

[a] Department of Electronic Engineering, Kogakuin University, Hachioji-shi, Tokyo, Japan

Version of record first published: 31 Aug 2006

To cite this article: Taiju Takahashi, Naoyuki Tanabe, Takanori Ando & Susumu Saito (2005): Novel Photo Alignment Method with Rotating Substrate, Molecular Crystals and Liquid Crystals, 433:1, 309-315

To link to this article: http://dx.doi.org/10.1080/15421400590955082

Mol. Cryst. Liq. Cryst., Vol. 433, pp. 309–315, 2005

ISSN: 1542-1406 print/1563-5287 online
DOI: 10.1080/15421400590955082

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Taiju Takahashi
Naoyuki Tanabe
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Susumu Saito
Department of Electronic Engineering, Kogakuin University,
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In the photo-alignment treatment, the substrate is rotated at constant period during UV irradiation, through a sector slit photo mask fixed between the substrate and the light source. In our experiments, a kind of polyimide film was used as the photo-alignment material. The concentric circle of LC orientation, or the radial LC orientation was obtained in the cell over relatively large area, according to whether the direction of sector slit pattern in photo mask. Furthermore, the computer simulation program is developed from which one can easily predict the molecular orientation pattern obtained by the rotating photo alignment treatment.

Keywords: liquid crystals; photo alignment method; rotating photo alignment method

1. INTRODUCTION

To make uniformly align liquid crystal molecules to a certain direction on the substrate surfaces, the rubbing method has been widely used in a fabrication process of LCDs. In the rubbing process, the surface of the alignment film such as a kind of polyamide is rubbed by a rubbing roller rolled by a cloth rotating with high speed. The rubbing method is the most superior alignment technology with the high productivity. However, it has some disadvantage too, such as the generation of dust particles and static electric charges on the rubbed surface. Recently, the photo alignment method is attracted attention as an alternative promising alignment method [1]. In the photo alignment method, the generations of dusts and static charges which are serious problems

Address correspondence to Taiju Takahashi, Department of Electronic Engineering, Kogakuin University, 2665-1 Nakano-cho, Hachioji-shi, Tokyo, 192-0015, Japan. E-mail: ct12326@ns.kogakuin.ac.jp

in the rubbing method does not become problem. Furthermore, using a photo mask in the photo alignment process, one can easily realize to make a divided orientation in a pixel.

In the usual photo alignment treatment, the arrangement of substrate and UV light source is fixed during the UV light irradiation. However, J. Chen *et al*. attempted in 1996 to rotate the substrate at constant period during the polarized UV light irradiation and called this method as the rotating photo alignment method [2]. They irradiated the polarized UV light through a sector slit photo mask fixed between the substrate and the light source. In their experiments, they used PVCi as the alignment material and obtained the concentric circular or the radial molecular orientations according to the directions of the sector slit. After Chen's short report above mentioned, no paper reported concerning the rotating photo alignment method.

In this study, we focus again on the rotating photo alignment method, and investigate in more detail the configuration of molecular orientations obtained by the method and the influences on resultant molecular orientation of the various UV irradiation conditions [3]. Furthermore, we investigate the realization of novel photonic devices by using the rotating photo alignment method.

2. EXPERIMENTS

As the horizontal alignment material, SE-610 (Nissan Chemical Industry) was coated by a spinner on a pair of ITO coated substrates

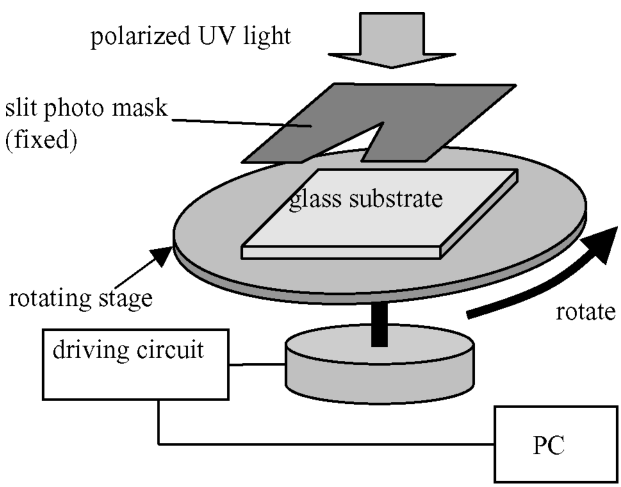


FIGURE 1 Formation of the rotating photo alignment method.

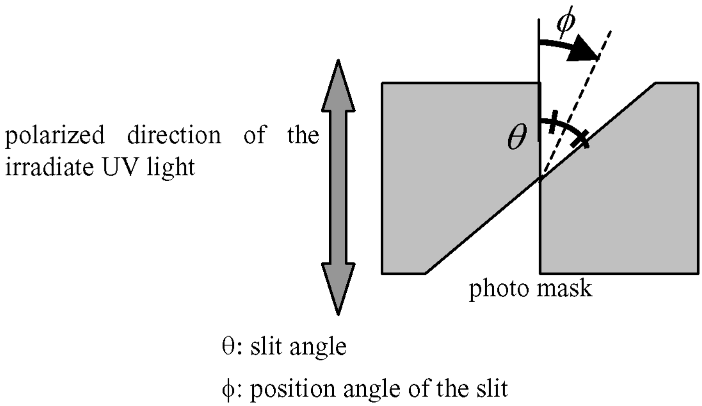


FIGURE 2 Slit mask pattern. (The angles θ and ϕ are defined as shown in the figure).

and baked at 250°C for 60 min. The polarized UV light was irradiated on one of those substrates. The other one of substrates did not be treated anymore. As the liquid crystal material, the nematic mixture ZLI-2293 (Merck) was used.

The formation of the system for our rotating photo alignment method shows in Figure 1. The irradiation energy of UV light was 54 J/cm^2, which is multiplication of the irradiation intensity and times, for the wavelength of 365 nm. During the UV irradiation, the substrate was rotated at a constant speed about 7°/s. One of the sector slits with sector angles 10, 20, 120, and 240° was used. In Figure 2, the apparatus for the rotating photo alignment is shown.

3. COMPUTER SIMULATION ON THE RELATIONSHIP BETWEEN THE OPTICAL PATTERNS OBSERVED WITH CROSSED POLARIZERS AND THE DISTRIBUTION OF AZIMUTHAL ANGLE OF DIRECTORS IN THE CELL

When one observes the cell treated by the rotating photo alignment method using the crossed polarizers, one can see the dark areas spreading to four directions from the rotated center. From such results, it is known that the molecules in the cell are oriented with the point symmetry whose center is the rotation center in the rotating photo alignment. However, one cannot distinguish whether it is the concentric circular or the radial orientations.

So, we developed the computer simulation program from which one can easily predict the molecular orientation pattern obtained by the rotating photo alignment treatment.

The algorisms of the simulation program is as followings. The total area to be treated by the photo alignment method was divided into 100×100 sub-areas. Average UV light polarization direction that each sub-area experiences in the rotation process of substrate during the irradiation of UV light through the sector slit mask is calculated for all of the sub-areas. Average UV light polarization directions are calculated for each 100×100 fine sub-areas by using the area interpolation method. Considering that the molecular orientation obtained by the photo alignment method is perpendicular to the direction of the polarization of UV light, the directions of molecular orientation $\{\phi_{ij};\, ij = 1 \sim 100\}$ are determined for all of fine sub-areas. Then the transmittance of each fine sub-area, T_{ij}, is calculated by the formula;

$$T_{ij} = \sin^2 2\phi_{ij} \sin^2 \frac{\pi}{\lambda} \langle \Delta n \cdot d \rangle;\ ij = 1 \sim 100,$$

where Δn is the birefringence, d the thickness of LC layer and λ the wavelength. By making the data of $\{T_{ij};\, i,j = 1 \sim 100\}$ the gray level presentation, we obtain the optical image corresponding the molecular orientation pattern.

In Figure 3, two examples of optical pattern obtained from the computer simulation are shown.

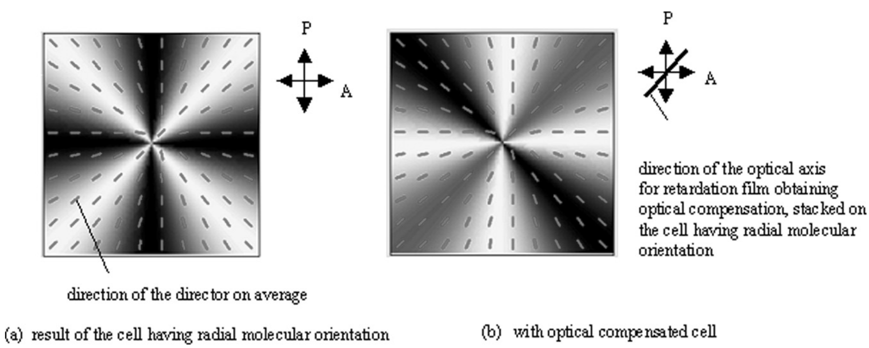


FIGURE 3 Optical pattern of cells in computer simulation. (The cell is located between crossed polarizers.)

4. EXPERIMENTAL RESULTS

Experimental result for the case when the directions of the sector slit and the polarization of UV light is parallel is shown in Figure 4(a). In this case, the sector slit with the sector angle 10° was used.

The places appearing the quenching site were invariant when only the cell is rotated under the fixed polarizers, as shown in Figure 5. This shows that the molecules are oriented with the point symmetry with respect to the rotation center. Figure 4(b) is the photograph of the cell compiled by the uni-axial birefringence film. The quenching sites appear in the direction parallel to the optical axis of the birefringent film. From these results, we can conclude that the configuration of molecular orientation in the cell is the concentric circular.

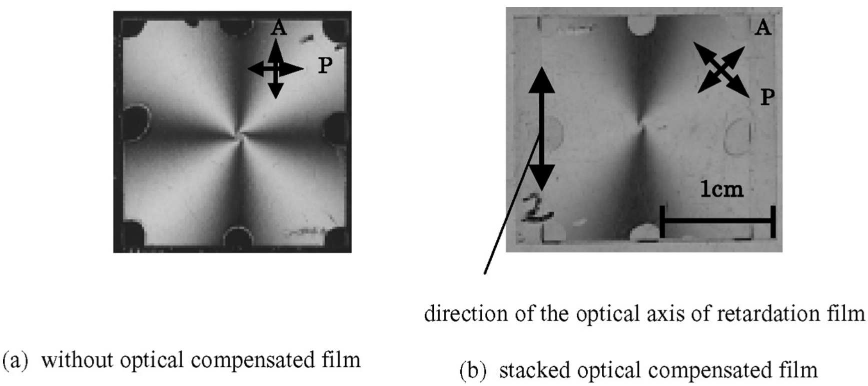


FIGURE 4 Optical pattern of cell, under located in the crossed polarizers, in experimental results. (The case of the direction of sector slit and polarization of UV light is parallel: $\phi = 0°$.)

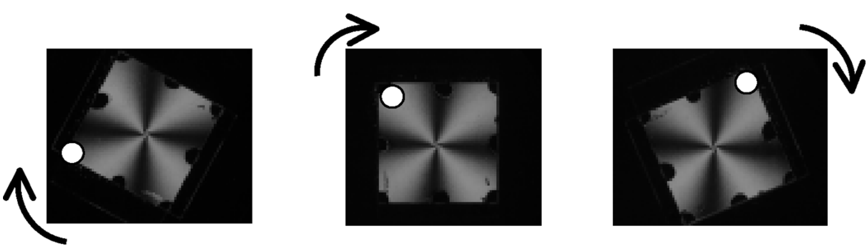
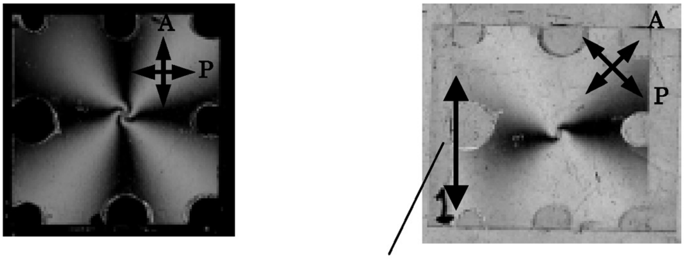


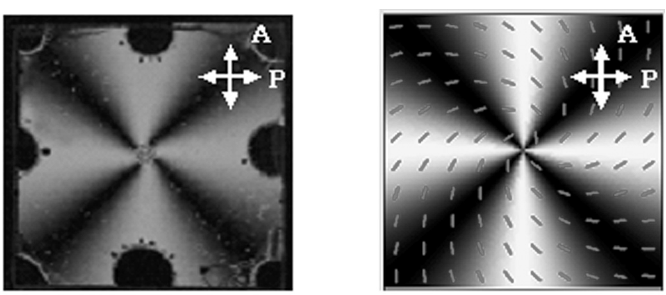
FIGURE 5 The places appearing the quenching site were invariant when only the cell is rotated under the fixed crossed polarizers.



(a) without optical compensated film (b) stacked optical compensated film

FIGURE 6 Optical pattern of cell, under located in the crossed polarizers, in experimental results. (The case of direction of the sector slit and polarization of UV light is perpendicular: $\phi = 90^{\circ}$.)

When the directions of the sector slit and the polarization of UV light is perpendicular, the results as shown in Figure 6(a) were obtained. In this case, the sector slit with the sector angle 10° was also used. Similarly to the case above mentioned, it can be known that the molecules are oriented with the point symmetry with respect to the rotation center since the quenching places were invariant for the rotation of the cell under the fixed polarizers. However, when the cell was compiled with the uni-axial birefringent film, the quenching sites appear in the direction perpendicular to the optical axis of the birefringent film. Thus, we could conclude that the configuration of molecular orientation in the cell is the radial one.



(a) Experimental results (b) Simulated results

FIGURE 7 Optical pattern of cell, under located in the crossed polarizers. (The case of the direction of sector slit and polarization of UV light ϕ is 45°.)

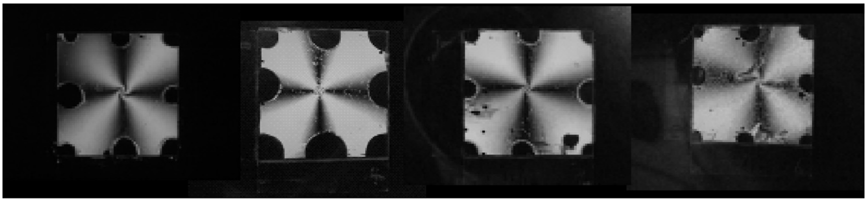


FIGURE 8 Defects patterns in cells treated by the rotating photo alignment method, changing the slit angle θ.

Figure 7 shows the result for the case when the directions of the sector slit and the polarization of UV light is 45°. In this case, the quenching place appeared in the direction deviating 45° from the axes of the polarizer and the analyzer. In this case, the molecules are oriented with an intermediate pattern between two cases above mentioned, as shown in Figure 7(b). Figure 7(b) was obtained due to our calculation program.

Figure 8 shows the results for the cases when the sector slits with different sector angles were used. In all of them, the direction of the sector slit and the polarization direction of UV light were perpendicular. As can be seen, it is confirmed that the LC orientation with less defects was obtained for the narrower sector slit angle.

5. CONCLUSION

We developed the computer simulation program from which one can easily predict the molecular orientation pattern obtained by the rotating photo alignment treatment. Good agreement was obtained between the orientation pattern predicted by the simulation program and the experimental results.

It was confirmed that the LC orientation with less defects was obtained for the narrower slit pattern.

The LC orientation pattern with this rotating photo alignment method is though to be useful for the fabrication of photonic devices using liquid crystals.

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