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Rubbing Effect on Geometrical Anisotropy of Alignment Surface of Liquid Crystals

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Rubbing Effect on Geometrical Anisotropy of Alignment Surface of Liquid Crystal

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Abstract

Molecular alignment of liquid-crystal affects on electro-optical characteristics in display device. Rubbing on the alignment surface is most reliable process for obtaining uniform molecular alignment in manufacturing. In this paper, fine structures of the surface of the alignment substrates were observed by atomic force microscope (AFM) and the mechanism of liquid-crystal molecular alignment was investigated. As the results, the rubbing process induces geometrical anisotropy on the substrate in specific condition and has not monotonous dependence of the rubbing condition.

Keywords ; liquid crystal, molecular alignment, rubbing method, AFM

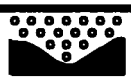
1. Introduction

The factors that affect the orientation of liquid-crystal molecules are the alignment effect of solid surfaces and the geometrical effect of alignment surfaces. The dominant factor

in nematic liquid crystals is clearly suggested by Kahn.[1] Typical alignments on the surface with parallel grooves in one direction are shown in TABLE 1. The energies *Fp* of the physicochemical interaction are zero when the liquid crystal aligns parallel and perpendicular to the homogeneous and homeotropic surfaces, respectively. On the other hand, the elastic energy *Fe* of liquid crystal is zero when the molecules align in one direction and deformed alignment of liquid crystal makes $Fe \fallingdotseq 0$. TABLE 1 shows the results of *Fp* and *Fe* on the four alignments. In these cases, $Fe(\perp) \fallingdotseq Fe(\parallel)$ can be considered. Liquid crystal is stabilized so that the free energy $F=Fp+Fe$ is minimized. On the homogeneous surface, the alignment (a) is dominant and the alignment (b) or (d) corresponds to the homeotropic surface. From the table, it is confirmed that whether the alignment in the bulk becomes homogeneous or homeotropic alignment depends on the physicochemical energy, on the geometrical structure of the surface. Therefore, the physicochemical interactions are the main factor that determines the molecular alignment, and the geometrical effect of the surface is the second factor that determines the direction of the homogeneous alignment as shown in TABLE 1 (a). In the case of oblique evaporation, as the surface structure is strongly deformed, the geometrical structure mainly affects the molecular alignment.

Molecular alignment of liquid-crystal affects on Electro-optical characteristics in display device. Rubbing on the alignment surface is most reliable process for obtaining uniform molecular alignment in manufacturing. This process, however, has some demerits such that dusts of cloth fibers contaminate the rubbing are and electrostatic

TABLE 1 Elastic free energy for nematic materials alignment by grooved substrates. Orientations of nematic directors (alignment directions of the long molecular axis) are shown. [1]

Surface Alignment		Homogeneous Surface		Homeotropic Surface	
		Fp	*Fe*	*Fp*	*Fe*
(a)		0	0	$F_{\perp}$	0
(b)		$F_{\parallel}\cos^2\theta$	0	$F_{\perp}\overline{\cos^2\theta}$	0
(c)		0	$Fe(\tilde{\parallel})$	$F_{\perp}$	$Fe(\tilde{\parallel})$
(d)		$F_{\parallel}$	$Fe(\tilde{\perp})$	0	$Fe(\tilde{\perp})$

charge damages thin film transistors. New process in place of rubbing is required in manufacturing the display panel. In this paper, fine structures of the surface of the alignment substrates are observed by atomic force microscope (AFM) and the mechanism of liquid-crystal molecular alignment is investigated.

2. Experimental

In order to investigate the effect of rubbing, a substrate coated with surface coupling agent for homogeneous alignment, was examined, as shown in FIGURE 1. The surface coupling agent was AL1051 made by Japan Rubber Synthesis Co. Ltd. The condition of a rubbing apparatus is shown in FIGURE 2. A polishing cloth was used for rubbing. The structure of the alignment surface was examined by an atomic force microscope NanoScope III by Digital Instrument.

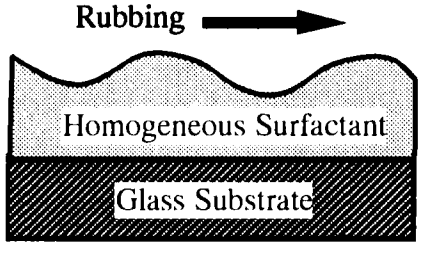


FIGURE 1 Structure of the experimental rubbed substrate.

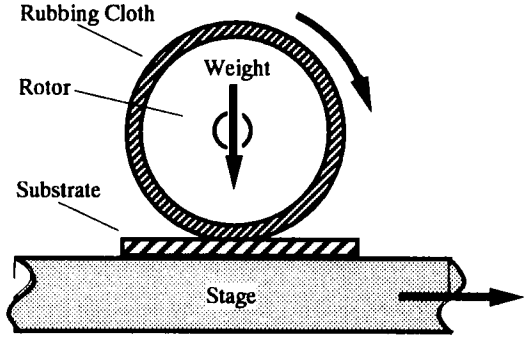
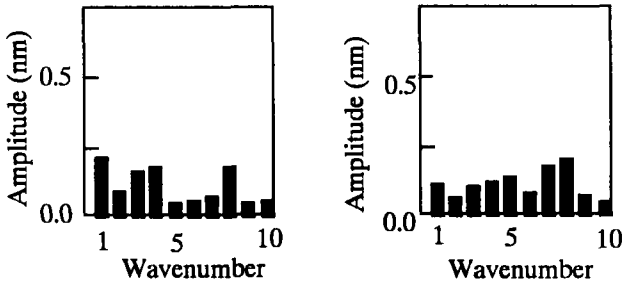


FIGURE 2 Arrangement of rubbing system.

3. Results

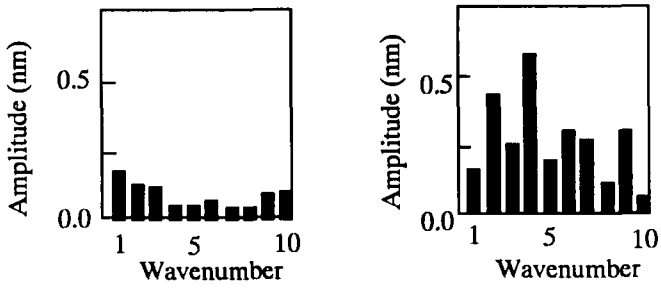
FIGUREs 3 and 4 show the power spectra of the alignment surface. The spectrum analysis allows filtering of images in the frequency domain through the fast Fourier transform (FFT). The analysis was carried out in the 2μm length in one direction. Wavenumber in the abscissa was obtained in the 2μm length. FIGURE 3 shows the results of the surface without rubbing (L=0[cm]), every sampling direction in (a) and (b) is crossed each other. These two directions are selected for representing the anisotropy of surface geometry. There is not remarkable difference between FIGUREs 3(a) and 3(b). So that, the geometrical anisotropy of the untreated surface can not be observed from these spectra.

FIGURE 4 shows the geometrical spectrum of the alignment surface with rubbing (L=10[cm]). FIGUREs 4(a) and (b) are data in the directions parallel and perpendicular to the rubbing direction, respectively. The spectrum of parallel direction have almost



(a)Arbitrary Direction (b) Normal to Direction(a)

FIGURE 3 Power spectrum of geometrical structure of non-rubbed substrate. (L=0[cm], Length 2μm)



(a) Parallel to Rubbing Direction (b) Normal to Rubbing Direction

FIGURE 4 Power spectrum of geometrical structure of rubbed substrate. (L=10[cm], Length 2μ m)

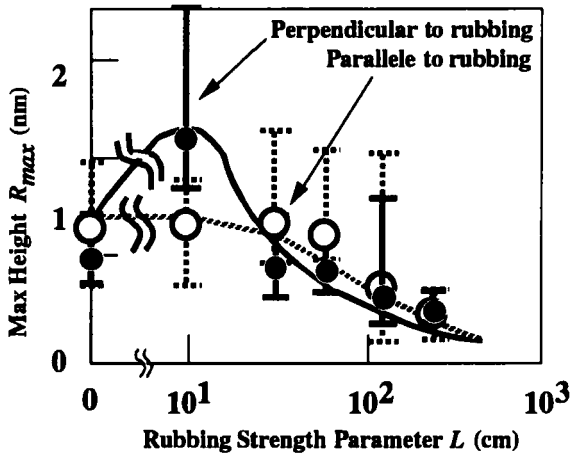


FIGURE 5 Rubbing strength parameter L dependence of max height *Rmax*. Max height is the difference between the highest and lowest points.

same tendency as FIGURE 3. On the other hand, the perpendicular direction has few times large amplitude. Wavenumber 4, which corresponds to 500nm wavelength, has relatively large amplitude. These data show that the surface geometry of alignment surface varies according to the rubbing conditions.

In order to evaluate the surface geometry, max height *Rmax* was introduced. The max height is the difference in height between the highest and lowest point on the surface relative to the mean plane. In this case, the mean plane of the surface has the meaning that the image data has a minimum variance about this flat plane. FIGURE 5 shows rubbing strength parameter L dependence of *Rmax* which is the difference between max and minimum height. *Rmax* decreases according to the increase of L. On the other hand, *Rmax* of the direction perpendicular to rubbing has peak value.

Next, the alignment surface was evaluated by mean roughness. Mean roughness *Ra* is the mean value of the surface relative to the center plane and is calculated using ;

$$R_a = \frac{1}{l}\int_0^l |f(x,y)|dx$$

where $f(x,y)$ is the surface to the center plane and l *is* the dimension of the surface. Two crossed directions *lx* and *ly* are selected to express the geometrical anisotropy of the surfaces shown in FIGURE 6. FIGURE 7 shows the rubbing strength dependence of mean roughness value *Ra* of the rubbed surface. The parameter L exhibits the strength of

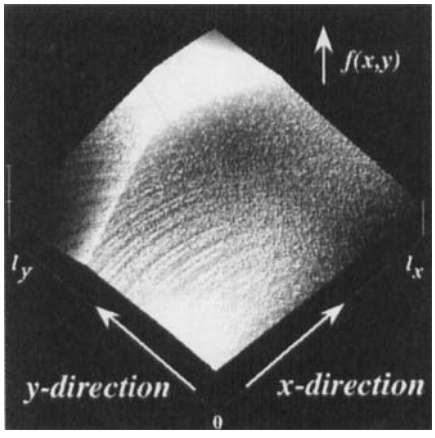


FIGURE 6 Expression of geometrical anisotropy of rubbed surface by mean roughness *Ra*. Mean roughness is the mean value of the surface relative to the center plane.

the rubbing quantitatively.[2] The values of *Ra* was calculated in the two directions that are parallel or perpendicular to the rubbing. The figure shows the average, max and minimum values of Ra on ten data in one direction of the surface. It can be seen that the increase of the rubbing strength parameter *L* reduces the mean roughness *Ra* of the rubbed surface. However, the surface of *L*=10(cm) gives remarkable difference between two directions. The perpendicular value is about two times as much as the parallel one. Therefore, the geometrical anisotropy is induced in this condition. The

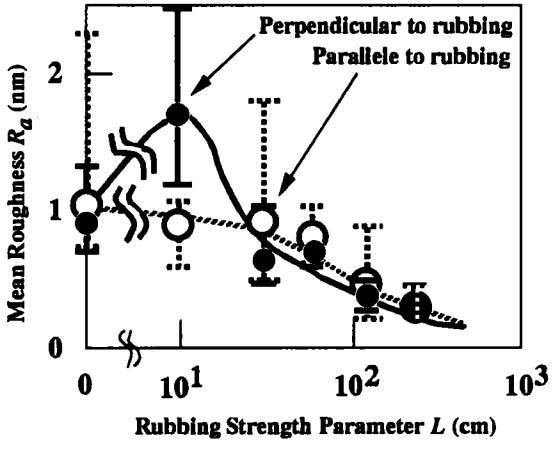
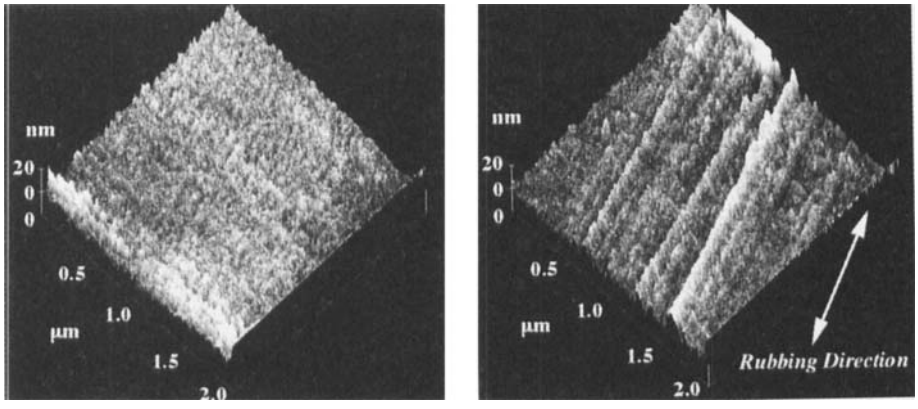


FIGURE 7 Rubbing strength parameter *L* dependence of mean roughness *Ra*.



(a) L=0[cm] (b) L=10[cm]

FIGURE 8 AFM images of geometrical anisotropy of rubbed surface.

spectra of fast Fourier transform in FIGURE 4 also support this result. The tendency of *Ra* is same as *Rmax* as shown in FIGURE 6. As the results, the rubbing process induces geometrical anisotropy in specific condition and has not monotonous dependence of the rubbing condition.

FIGURE 8 shows AFM images of alignment surface with and without rubbing process. Many grooves parallel to the rubbing are generated under the condition of L=10[cm] in FIGURE 8(b) and the direction perpendicular to the rubbing has rough structure. It is considered that these structures are originated in digging and smoothing effects of rubbing process.

4.Conclusion

Molecular alignment of liquid-crystal affects on electro-optical characteristics in display device. In this paper, fine structures of the surface of the alignment substrates are observed by atomic force microscope (AFM) and the mechanism of liquid-crystal molecular alignment investigated. As the results, the rubbing process induces geometrical anisotropy in specific condition and has not monotonous dependence of the rubbing condition.

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