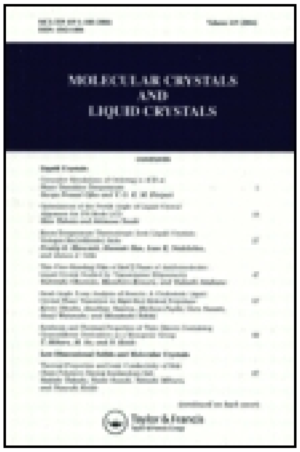

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Evaluation of the Tilted Homeotropic Alignment of Liquid-Crystal Molecules Using the Rubbing Method

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EVALUATION OF THE TILTED HOMEOTROPIC ALIGNMENT OF LIQUID-CRYSTAL MOLECULES USING THE RUBBING METHOD

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Abstract A new alignment technique of small tilted homeotropic alignment using rubbing method (THR method) has advantage in obtaining large area uniformity and productivity because of non-requirement of large vacuum equipment. In this paper, the applicability of this method for display device is discussed.

INTRODUCTION

Tilted homeotropic alignment becomes important recently because it is necessary for the positive type guest–host LCDs and highly multiplexed ECB type LCDs. Small tilted homeotropic alignment of liquid-crystal molecules is obtained by evaporation followed by homeotropic treatment, but the method needs a vacuum equipment. The authors have proposed a new alignment technique of small tilted homeotropic alignment using rubbing method (THR method) without evaporation process as shown in Figure 1.[1] The experimental results indicated that the mechanism of the tilted alignment closely related to the rubbed surface structure of the substrate. In this paper, the geometrical structure of the alignment surface is observed and its applicability for display device is discussed.

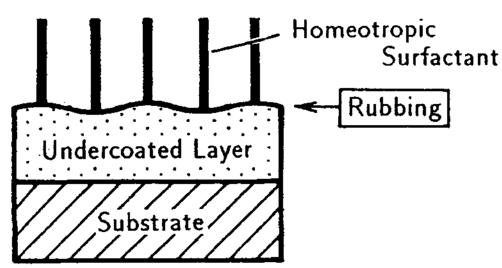


FIGURE 1 The examined method to obtain tilted homeotropic alignment.[1]

EXPERIMENTAL

In order to investigate the effect of rubbing, the cell consisting of the combination of three layers, homeotropic surfactant, undercoated layer and glass substrate, was examined as shown in Figure 1. The surface coupling agent for homeotropic alignment is N,N-dimetyl-N-octadecyl-3-aminopropyltrimethoxysilyl chloride (DMOAP)[2] on sale under the name of SRX-679 from Toray Silicone Co., Ltd. The glasses with indium tin oxide (In_2O_3) layer produced by Matsuzaki Shinku Co., Ltd. were used as the substrates. OCD Si-80000 (Ohka Coat Diffusion Source) supplied from Tokyo Ohka Kogyo Co., Ltd. was used as the undercoated layer. OCD is a silicon chemical compound dissolved in organic solvent. In the experiments, OCD was spincoated on the glass substrate at 2840 rpm and heated at 200°C for 30 minutes. The liquid crystal was a nematic liquid-crystal mixture EN-38 with a large negative dielectric anisotropy. The surface of the substrate was examined by a scanning electron micrograph (JSM-25SIII, JEOL Ltd.).

The liquid-crystal orientation is defined by tilt angle θ as shown in Figure 2, where the x-y plane corresponds to the surface of the substrate. The tilt angle θ is the angle between the normal to the substrate (z-axis) and the director of liquid-crystal molecule. Rubbing was done in the direction of y-axis. The tilt angle θ was measured by the conoscopic method.

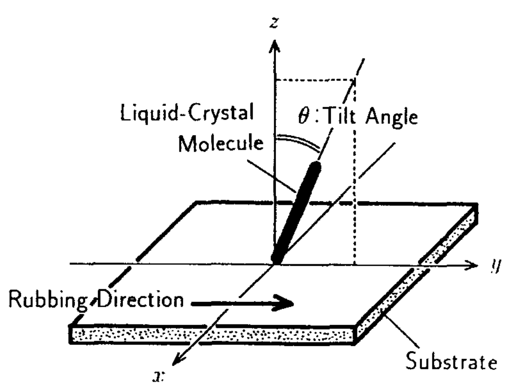


FIGURE 2 Definition of coordinate system.

RESULTS AND DISCUSSIONS

Figure 3 shows the weight of rubbing load dependence of the tilt angle θ from the normal to the surfaces of the rubbed In_2O_3 and OCD layers.[3] The cumulative number of rubbing was one. It can be seen that the value θ can be adjusted to arbitrary value between 0 and 10 degrees. This is because that the anisotropic surface structure induced by the rubbing process inclines the director of the liquid crystal from normal of the substrate.

The SEM images of the rubbed surfaces showed that the micro-grooves were formed

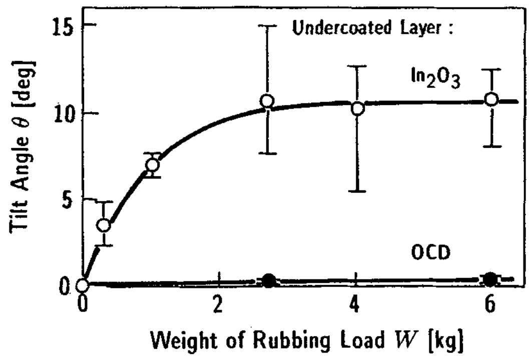


FIGURE 3 The weight dependence of the tilt angle θ on the In_2O_3 and OCD surfaces.[3]

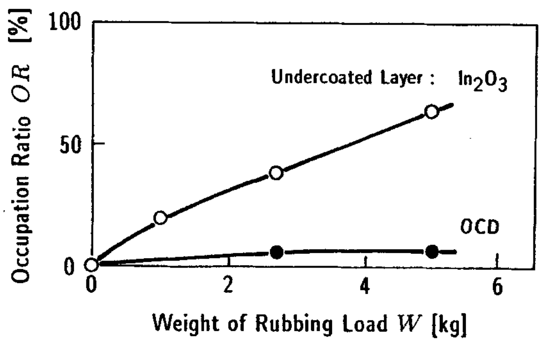


FIGURE 4 The weight dependence of the occupation-area ratio of the grooves caused by the rubbing process.

along the rubbing direction with separation of some 5 μm to 30 μm on the surface. It was confirmed that the rubbed surface is deformed strongly. In order to evaluate the deformation of the surface structure by the rubbing qualitatively, the parameter OR is defined. The parameter OR is an occupation-area ratio of the micro-grooves on the observed area. Figure 4 shows the weight of rubbing load dependence of the occupation-area ratio OR of the groove structure on the rubbed In_2O_3 and OCD surfaces. The weight dependence of OR is resemble to that of the tilt angle as shown in Figure 3. The occupation-area ratio OR relates to the tilt angle strongly. It is expected that the surface in fine region also changes and it affects the alignment of the liquid crystals. Then, it is predicted in Figure 1 that the surface without rubbing process produces homeotropic alignment and that with rubbing induces pretilt alignment. Therefore, the mechanical interactions related to the surface topology and anisotropic elasticity works an important role in the molecular alignment of the THR method.

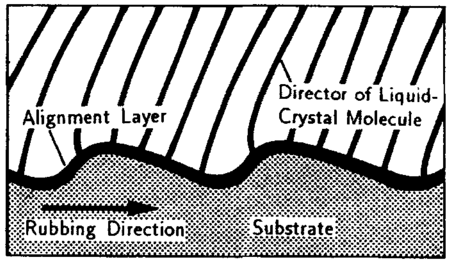
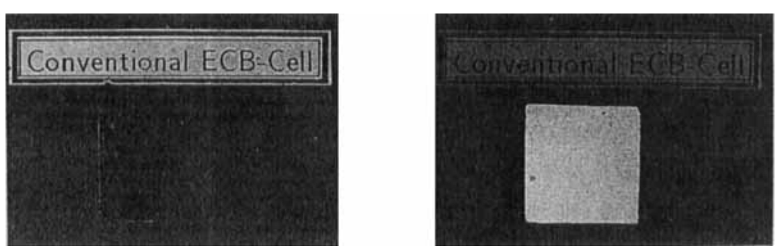


FIGURE 5 Alignment model of liquid-crystal molecule on rubbed surface followed by homeotropic treatment.

Nakamura[4] explained the existence of the pretilt angle by assuming a "phonograph record" model. Assuming this model, the homeotropic alignment agents makes liquid-crystal molecules align perpendicular to the surface. As the results, the director inclines according to the surface of substrate and uniform tilt alignment from normal of the microscopic surface of the substrate is generated in the bulk of the liquid crystal as shown in Figure 5.

In the production, the reproducibility of the molecular alignment controls the yield of the LCDs. In order to check the properties of the THR cells, the electrically controlled birefringence (ECB) mode was adopted for the display.[5] Because the electro-optical property of the ECB mode is very sensitive to the physical parameters such as tilt angle, cell thickness and so on. One example of applications of THR method is shown in Figure 6, which is a ECB type display device. At off state, black state can be seen and uniform alignment is recognized. At on state, the display changes to bright state. So that, the uniformly of the THR method is confirmed. Figure 7 shows the voltage dependence of the transmittance of the THR cell with the rubbed OCD surfaces. Each



(a) Off State (b) On State

FIGURE 6 One example of THR cells applied to ECB mode display. In on-state, applied voltage is 1.6V.

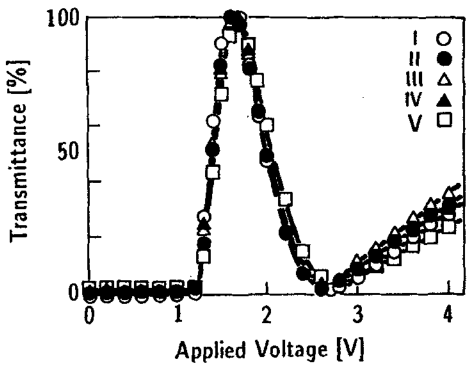


FIGURE 7 The voltage dependence of the transmittance of the THR cell with the rubbed OCD surfaces. The cells were constructed by the ECB mode.

of five THR cells I-V had an active area of one square centimeter. The transmittances at the five points in each cell were measured and averaged.

Figure 8 shows the variation of the tilt angle obtained by the THR method. In each cell, the tilt angles of five points in the active area were measured. It is shown that the tilt angle can be controlled within the variation of 0.16 degrees. Considering the practical use, the value of the THR method is sufficient for the display application, especially in the ECB display. It is considered that the variation of the tilt angle originates inhomogeneity of the rubbing pressure and so on.

In the oblique evaporation method, the tilt angle variation of 0.16 degree corresponds to the evaporation angle from 61 to 62 degrees as shown in Figure 9.[6] If the distance from the evaporation source to the substrate is 0.5 meter, the tilt angle variation of 0.16 degree in the oblique evaporation is successful within only one square centime-

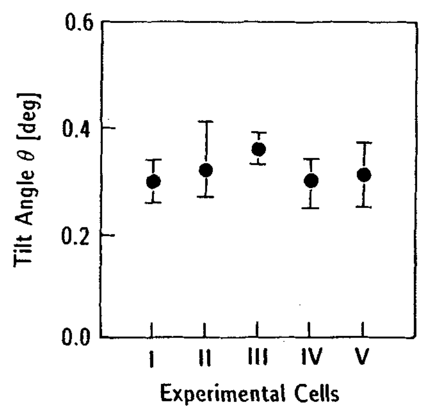


FIGURE 8 The variation of tilt angle θ in the experimental cells.

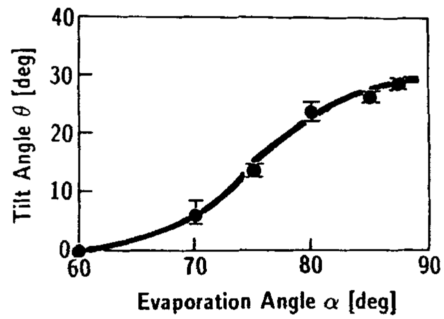


FIGURE 9 The evaporation angle α dependence of the tilt angle θ in the oblique evaporation method.[6]

ter of the substrate. This is because that, if the oblique evaporation method is applied to large area displays, the evaporation angle changes accordingly to the position of the substrate which affects the tilt angle. Hence, the contrast of the display with the oblique evaporation strongly changes according to the position.

CONCLUSION

As the results, the followings are clarified. The oblique evaporation method have disadvantage in obtaining large area uniformity and producibility because of requirement of large vacuum equipment. The THR method, however, does not need the oblique evaporation and is able to be applied to the display with infinite area. Hence, it is suitable for large area display and mass-production.

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