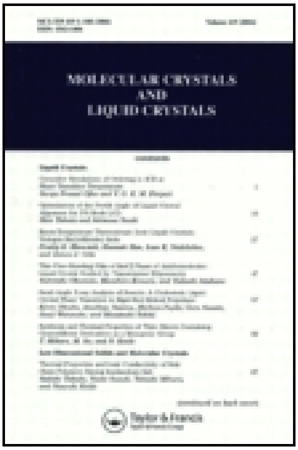

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Molecular Alignment of Liquid Crystal on Microgroove Surface

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Microgroove (MG) substrate using a ruling engine was evaluated geometrically and optically. As the result, it was confirmed that the MG substrate had periodic structure and uniform molecular alignment was observed partially. Precise control of the ruling engine promises uniform molecular alignment of LCDs.

Keywords: liquid crystal displays; reflective modes; ruling engine; molecular alignment; microgroove

INTRODUCTION

A reflective liquid crystal display is a key device for the information oriented society. In transmissive mode, the brightness can be easily controlled by backlight. However, it consumes large electric power. It is an answer for this problem that the reflective mode realizes as a display dignity like a printed papers by using natural light. We proposed a reflective CSH (Reflective-Color Super Homeotropic) mode which has high multiplexibility and a wide viewing angle cone [1]. In this case, it is needed to incline liquid crystal molecules with negative dielectric anisotropy to one direction slightly. In this report, we examined fundamental property for molecular alignment on microgroove surface using a ruling engine system.

RULING ENGINE SYSTEM

The ruling engine system gives a carved line on a thin aluminum film by a diamond cutter as shown in Figure 1. In this figure, the glass substrate moves toward to the normal direction in this paper surface.

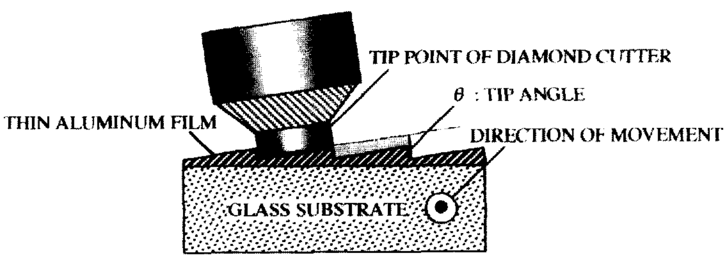

FIGURE 1 Diamond cutter of the ruling engine system.

Figure 2 shows a mechanism of the ruling engine system. The system is composed of a diamond cutter, a movable stage with a piezo-driving mechanism and a position detecting system by the Michelson interferometer[2]. The movable stage acts as a reciprocation of crank mechanism. The moving axis of diamond cutter crosses the movable stage. The location of carved line is controlled by a movable stage with a piezo-driving mechanism. The position detecting system is based on the Michelson interferometer.

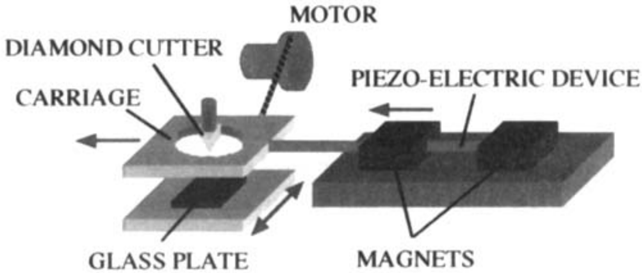

FIGURE 2 Mechanism of the ruling engine system.

Figure 3 shows the schematic diagram of Michelson interferometer. The carriage is installing a moving cube corner. Laser is separated the moving cube corner side and fixed cube corner by the beam splitter. The reflective lights in photo detector interfere each other by the moving cube corner side. The cutter position is decided by the intensity change of reflective light. The microgroove is carved on the thin aluminum film of the sample by the diamond cutter. Figure 4 shows an AFM image of the microgroove surface. The fine periodic structure with 2.43 μm pitch and 53.7 nm depth is observed. We optically evaluated of microgroove substrate. We measured light reflective intensity for optically evaluation of fabricated MG structure. We used EZContrast 160D manufactured by ELDIM in the measurement. Figure 5 shows a reflective light distribution

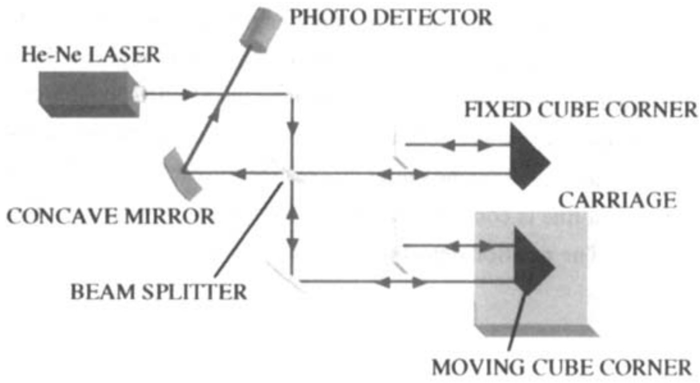

FIGURE 3 Schematic diagram of the Michelson interferometer.

on the microgroove substrate (abbreviated as the MG substrate). The radius direction is a polar angle and the circumference direction is a azimuthal angle. The light source filtered 125 W arc lamp had the spectra luminance efficiency. The incidence direction of the light is perpendicular to the MG substrate and the groove direction of MG substrate coin-

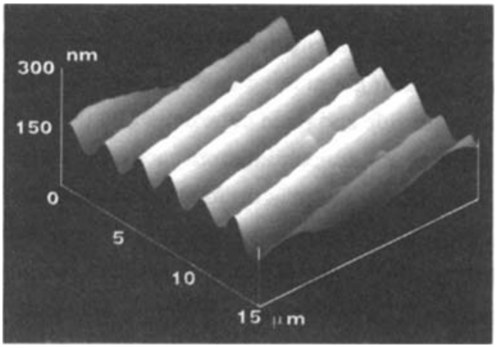

FIGURE 4 AFM image of the microgroove substrate.

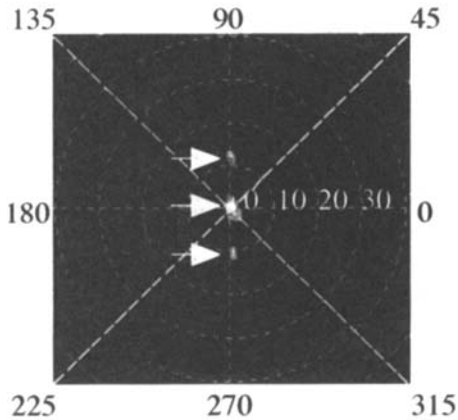

FIGURE 5 Reflective light distribution on the microgroove substrate.

cides with the horizontal direction. Three diffracted spots were observed in the center, top and bottom positions, and it is shown that periodic structure exists in the vertical direction. The pitch is estimated to be about 2.55 μm from this figure. It is confirmed that the pitch value almost corresponds to the AFM image.

MOLECULAR ALIGNMENT ON MICROGROOVE SURFACE

The molecular alignment on the microgroove surface was examined as follows. Considering the R-CSH mode, a cell structure as shown in Figure 6 was constructed. The lower substrate had microgrooves at the surface. The upper substrate was ITO flat surface. Each substrate was treated with a homeotropic surfactant JALS-2021-R2 (JSR Co., Ltd.). A dichroic dye G-165 (Nippon Kankoh Shikiso Lab.Co., Ltd.) was added 0.5 wt%

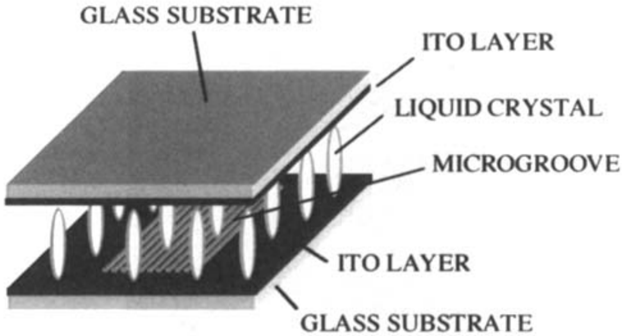

FIGURE 6 Cell structure for microgroove substrate.

to the liquid crystal MJ-HT (Merck Japan Co., Ltd.) with negative dielectric anisotropy. Thickness of the liquid crystal layer is about 10 μm. Using a polarizer, the molecular alignment on the microgroove surface was evaluated. Figure 7 or Figure 8 shows an absorption anisotropy parallel or perpendicular to microgroove with application of 7 voltages. The inside of the dotted line is the area of the carved line and the direction of MG structure is an up-down direction. The arrows show the direction of the incident lineally polarized light. The uniform alignment of the mol-

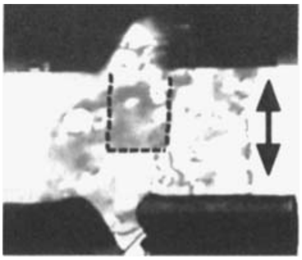

FIGURE 7 Absorption anisotropy of parallel to microgroove.

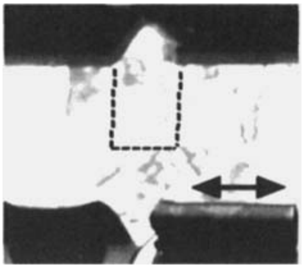

FIGURE 8 Absorption anisotropy of perpendicular to microgroove.

ecules on the microgrooves almost coincided with the groove direction. However, the schlieren texture was partially observed. As the result, it is clarified that precise control of the ruling engine promises the uniform molecular alignment.

GEOMETRIC EFFECT

Using the elastic energy of liquid crystal, we examined the surface geometrical effect on the liquid crystal alignment. In the estimation of the elastic energy, we used following physical parameters. The relative dielectric constant in the parallel and perpendicular direction toward the molecular axis were ε_{para}=4.0 and ε_{perp}=8.7. Then, relative dielectric anisotropy was $\Delta\varepsilon=\varepsilon_{para}-\varepsilon_{perp}$=-4.7. The spray and bend elastic constants were $K_{11}=3.76 \times 10^{-11}$[N] and $K_{33}=1.88 \times 10^{-11}$[N], respectively. Figure 9 shows geometry of the microgroove substrate. A is a depth of microgroove, q is a wave number, $1/q$ is a pith of microgroove. Figure 10 shows an elastic energy of the liquid crystal. $F_{\parallel}$ or $F_{\perp}$ is an elastic energy that liquid crystal molecules are parallel or perpendicular to the groove direction. In this case, the molecules prefer the alignment (a) which has least

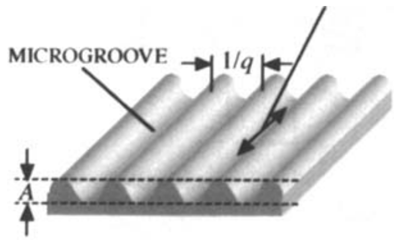

FIGURE 9 Geometry of the microgroove substrate.

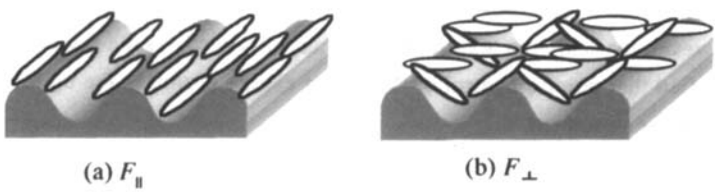

FIGURE 10 Elastic energy of the liquid crystal.

elastic energy. The following equation defines an elastic energy difference ΔF.

$$\Delta F = F_{\perp} - F_{\parallel} = \frac{K}{4} A^2 q^3 \qquad (1)$$

K is an average Frank elastic constant and A is a depth of microgroove[3]. The substrate has a energy difference ΔF=1.42 nJ/m^2. This value is very small in comparison with the rubbed surface. Figure 11 shows an effect of depth and pitch of microgroove surface on elastic energy difference. The black dot shows the experimental result. We need more precise control of

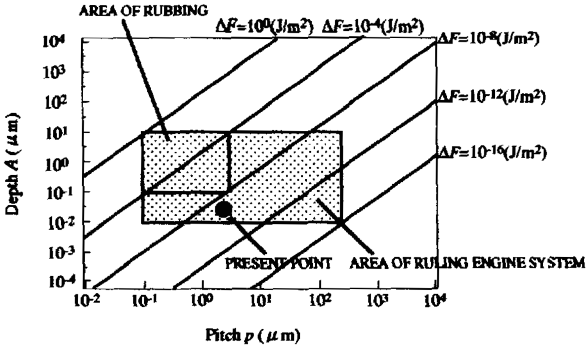

FIGURE 11 Effect of depth and pitch of microgroove surface on elastic energy difference.

the surface compared with the rubbing method.

CONCLUSION

We fabricated the microgroove surface using the ruling engine system, and examined a geometrical effect on liquid crystal alignment. As the result, it was clarified that precise control of the ruling engine promises the uniform molecular alignment.

Acknowledgments

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