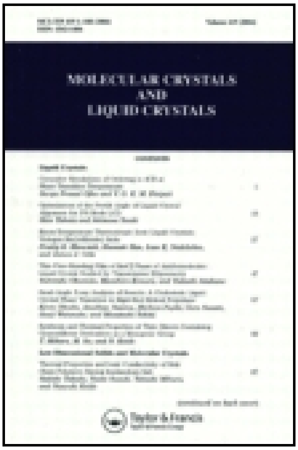

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Alignment Characteristics of Nematic Liquid Crystal on UV Curable Resin Film with Periodical Groove Structure

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Periodical groove structure was formed on the substrate surface by copying the structure on the grating film on the market to the photo curable resin coated on the substrate surface. And then, the substrate surface with groove structure was rubbed along the direction perpendicular to the groove. Alignment of LC on such substrate surface was experimentally investigated. And the occurring of pre-tilt was confirmed. In a cell constructed using such substrate and, for the other side, the substrate treated by a vertical alignment material, distinctive domains with different orientation direction were observed. This suggests us that the bistable alignment property can be adapted on the substrate surfaces by the method above mentioned.

Keywords: bistable LCD; groove structure; nematic liquid crystal

1. INTRODUCTION

With the surge of the environmental awareness, the electronic (E-) paper has attracted attention since they have both superior properties of paper and an electronic display device. A thin thickness, a light weight, a low power consumption and a rewrite-ability etc. are required for the E-paper. For the E-paper in which a LCD is used,

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the adaptation of memory effect on the LC alignment results on the low power consumption.

So far, some types of the E-paper have been proposed. Foe example, the electro-phoretic display and some new types of LCD such as the Bi-Nem (Bistable Nematic) LCD [1] and the ZBD (Zenithal Bistable Display) [2,3] were proposed with the intention of applying to the E-paper. Among them, in the ZBD proposed by Bryan-Brown and others in 1997, the groove (grating) structure is constructed on the one side substrate surface and a vertical alignment treatment is conducted on the groove surface to adapt the bi-stable anchoring properties. On the other substrate surface, a vertical alignment treatment or a parallel alignment treatment is conducted.

When a dc field perpendicular to the substrate surface is applied, either one of a homeotropic alignment or a parallel alignment perpendicular to the grooves is obtained at the interface on the substrate with a groove structure, according to the polarity of the applied dc voltage.

In this study, we report it about a method to adapt the bistable anchoring properties on the surface with a groove structure. In this method, a new method to adapt the bistable anchoring properties on the surface with a groove structure is proposed. In our method, a periodical groove structure was formed on the substrate surface by copying the structure on the grating film on the market to the photo curable resin coated on the substrate surface. And then, the substrate surface with groove structure was rubbed along the direction perpendicular to the groove. Alignment of LC on such substrate surface was experimentally investigated.

2. EXPERIMENTALS

2.1. Sample Preparation

As a UV curable resin, the Technovit 2000LC (Heraeus Kulzer Gmb H&Co. KG) was coated on the substrate on which an inter-digit in-plane electrode (the pectinate electrode) has been constructed as shown in Figure 1. The diffraction grating film was stacked on the resin under an appropriate uniform pressure. Then, a UV light was irradiated on the UV curable resin through the diffraction grating film (straight line type, code : 2563, dispersion : 36 degrees) by (Koyo) set on the resin film.

The UV light irradiation energy was $7\,J/cm^2$. The pitch of the diffraction grating film was $1\,\mu m$. After removing the diffraction grating film resin, which was not cured, the UV light was irradiated again for 30 min to be completely cured.

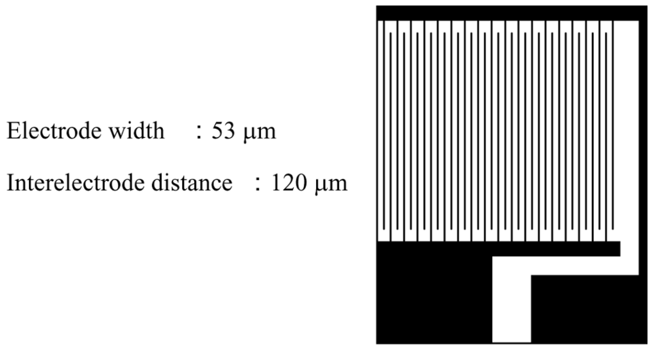

FIGURE 1 Electrode pattern.

Two types of cell were prepared. One of them was constructed using a substrate on which the groove structure was constructed and the substrate on which a kind of polyimide SE1211 (Nissan Chemical Ind.) was coated to obtain a vertical alignment. Hereafter, this type of cell is called as the cell-A.

For the other one of cells, the surface of groove structure was rubbed three times along the direction perpendicular to the groove direction using a rubbing roller. The cell was constructed using the substrate treated by the method mentioned above and the substrate on which a kind of polyimide SE1211 was coated to obtain a vertical alignment. Hereafter, this type of cell is called as the cell-B.

The sample cell was fabricated by using the substrate on which the groove structure was formed and the other substrate treated by the SE1211. As the LC material, a single compound nematic LC, 5CB (Merck) was used. The spacer material with a diameter of 6 μm was used.

3. EXPERIMENTAL RESULTS AND DISCUSSIONS

3.1. Observation of the Groove Structure Formed by UV Curable Resin Film

The diffraction grating film and the transferred groove structure on the substrate was observed by a laser beam microscope. The observed results are shown in Figures 2(a), (b). A laser micrograph after the rubbing treatment conducted along the direction perpendicular to the groove structure is shown in Figure 2(c). It can be confirmed that the groove structure of the diffraction grating film was copied neatly to the UV curable resin film from Figures 2(a) and (b). Comparing

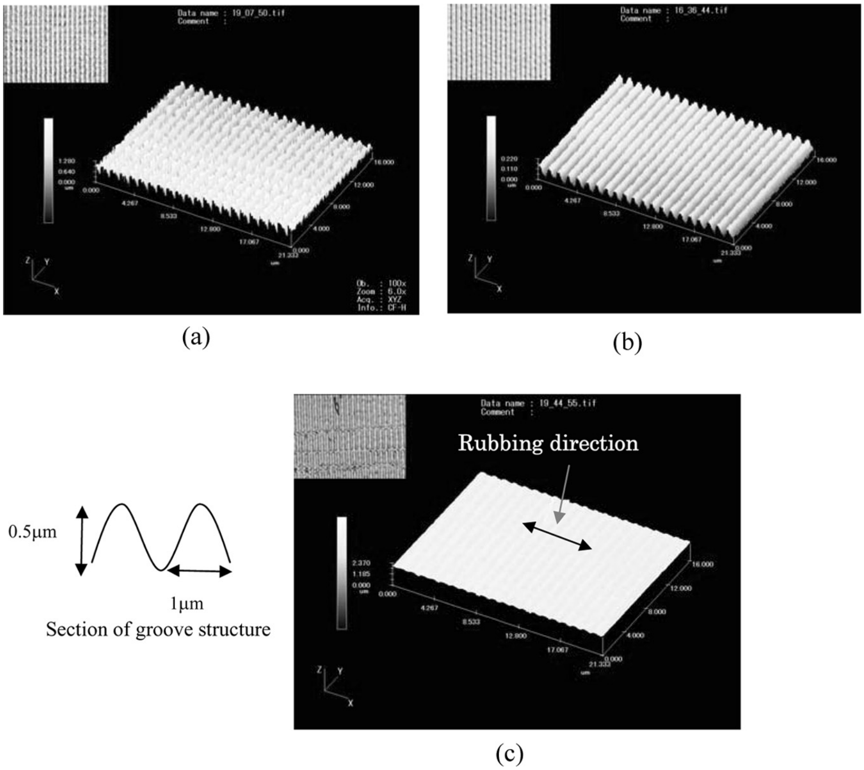

FIGURE 2 (a) Diffraction grating film original. (b) Copy-printing groove structure on the glass substrate. (c) After processing rubbing treatment.

Figure 2(c) with Figure 2(a) and Figure 2(b), it is known that the resin was shaved off by rubbing, and the height of the groove structure was lowered by rubbing processing.

3.2. The Alignment of the Liquid Crystal Molecule by the Groove Structure

The molecular alignment in the cell-A was investigated under the crossed Nichol condition in which the direction of the polarizer was set at an angle of 45 deg. with respect to the direction of the grooves. It was confirmed that the LC molecules in the cell-A is in the configuration of the hybrid alignment and they aligned along the grooves on the substrate with the groove structure. The direction of molecular orientation was determined by inserting a compensation plate

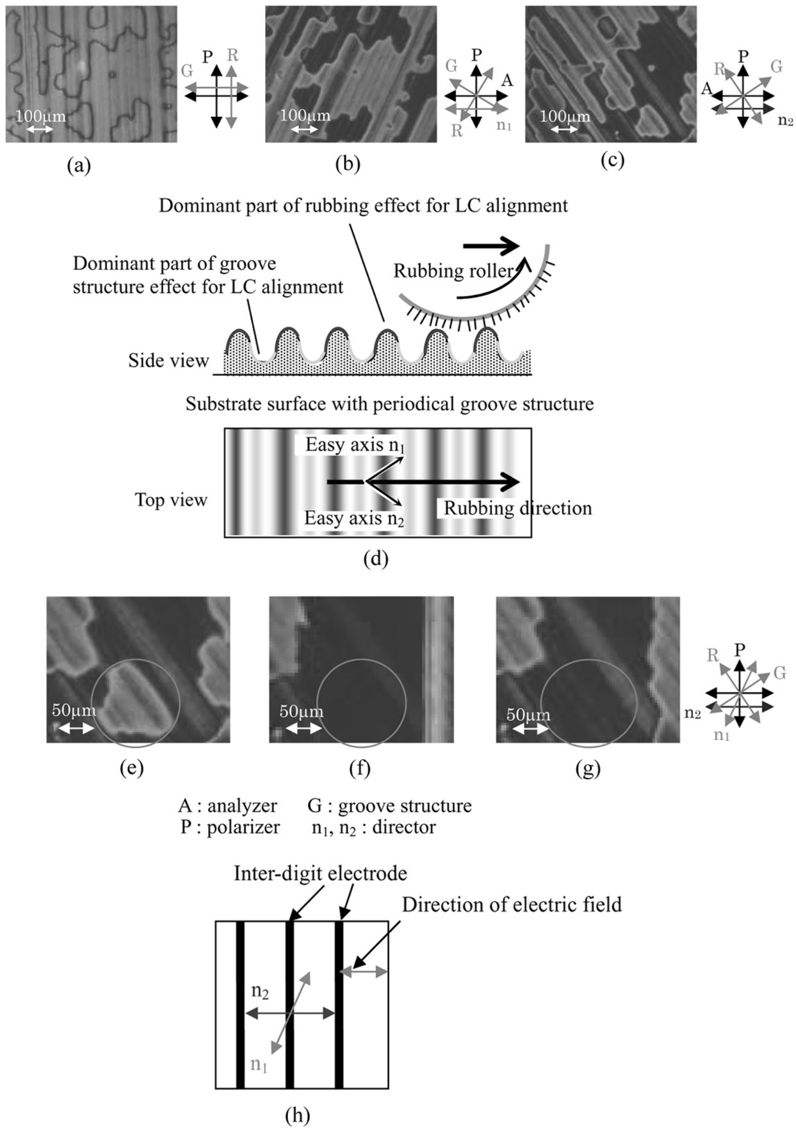

FIGURE 3 (a) P is parallel to the Rubbing direction (Initial state). (b) One of the optical extinction state: the cell was rotated by 31 deg. in the CW from the initial state. (c) Another of the optical extinction state: the cell was rotated by 34 deg. in the CCW from the initial state. (d) Two orientation easy axes with groove. (e) Before applying the voltage (0 V). (f) During the application of the voltage (1 Hz, ±20 V). (g) After removing the applied voltage (0 V). (h) Schematic of electrode pattern and directors n_1 and n_2.

together with the sample cell between the crossed Nichol and searching the optical extinction position by rotating the compensation plate.

3.3. Alignment of the Liquid Crystal Molecule in the Cell-B

The molecular alignment in the cell-B was investigated with a polarizing optical microscope under the crossed Nichol condition in which the direction of the polarizer was set at an angle of 45 deg. with respect to the direction of the grooves. Figures 3(a)–(c) show the photographs of the observed domains with distinctive alignments. It was confirmed that the angle of the directions of molecular alignment with respect to the rubbing direction were −59 degree and +56 degree in those two domains. Those angles were obtained by searching the optical extinction position by rotating the compensation plate as shown in Figures 3(b) and 3(c). In these textures, the reversed tilt domain was not observed, it was shown the pre-tilt angle was occurred. However, the pre-tilt angle was not confirmed on the rubbed flat-film with the UV curable resin using this experiment. The mechanism for the occurring of pre-tilt angle is shown in Figure 3(d). It seems that, the one side of the groove structure was rubbed strongly and deeply, when the buff the rubbing roller rubbed the groove structure as shown in Figure 3(h). Then pre-tilt angle was occurred.

Next, the change of molecular alignment with the application of an in-plane electric field was investigated. A rectangular wave voltage with the amplitude of 20 V and a frequency of 1 Hz was applied between the inter-digit electrodes. The observed results are shown in Figures 3(e) to Figure 3(g). Figure 3(e) is the initial state before applying the voltage. Figure 3(f) is the state during the voltage application. Figure 3(g) is the state after removing the applied voltage. It should be noted that the one domain marked by the circle changed to the extinction state by the voltage application. This change means that the transition of molecular orientation from the direction of one easy axis denoted as n_1 in Figure 3(h) to the direction of the other easy axis denoted as n_2 in Figure 3(h) occurred by the applied in-plane field.

4. CONCLUSIONS

On one of substrate surfaces, the periodical groove structure was formed by copying the structure on the diffraction grating film to the photo curable resin coated on the substrate surface. The surface of groove structure was rubbed three times along the direction perpendicular to the groove direction using a rubbing roller. The cell was constructed using the substrate treated by the method mentioned above and the substrate on which a kind of polyimide SE1211 was coated to obtain a vertical alignment. It was confirmed that the substrate treated by the method above mentioned have two orientation easy axes. Furthermore, the transition of the molecular orientation from the one easy axis to the other easy axis was confirmed by the application of in-plane field. However, in the present stage, only one directional switching was succeeded. It will be necessary to examine the method in the future for the bidirectional switching.

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