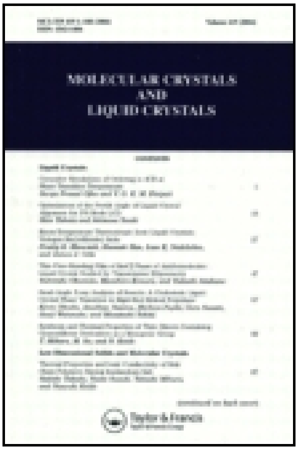

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Orientation on Periodical Micro Pattern with Vertical and Homogeneous Alignments Using Anodic Porous Alumina for Bi-Stable Surface

Keiji Imai [a], Atsushi Yokoyama [a], Susumu Saito [a] & Taiju Takahashi [a]
[a] Department of Electric Engineering and Electronics, Graduate School of Kogakuin University, Tokyo, Japan

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Keiji Imai, Atsushi Yokoyama, Susumu Saito, and Taiju Takahashi
Department of Electric Engineering and Electronics, Graduate School of Kogakuin University, Tokyo, Japan

In order to obtain the bistable surface, a new method is proposed to fabricate the micro-patterned substrate surface formed by stripes of alternating vertical and planer anchorings. In this method, aluminum film evaporated in vacuum on substrate surfaces was etched in stripe pattern using the photolithography techniques. And then, stripes of aluminum were anodized. Coexistence of the vertical alignment on stripes of porous alumina and the planer alignment along stripes due to grooves between stripes of alumina is experimentally confirmed. However, the bistable property has not been observed yet.

Keywords: anodization; bistable LCD; porous alumina; vertical alignment

1. INTRODUCTION

Recently, portable devices equipped with LCD have rapidly, spread and the demand for the low power consumption display has increased. The research and development for the bistable nematic LCD with permanent memory characteristics have actively proceeded from the aim of realizing low power consumption display.

In recent years, a variety of bi-stable LCDs have been proposed. The bi-stable LCDs are classified into two types according to whether the

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Address correspondence to Keiji Imai, Department of Electric Engineering and Electronics, Graduate School of Kogakuin University, 2665-1 Nakano-cho, Hachioji, Tokyo 192-0015, Japan. E-mail: cm07009@ns.kogakuin.ac.jp

bi-stability is based on bi-stable anchoring properties of the alignment layer, or only on the bi-stability of molecular orientation configurations [1,2]. Some techniques have been proposed for the adaptation of bi-stable anchoring properties within the alignment layer. Jerome *et al.* have demonstrated an in-plane bi-stability which uses approximately 20 nm thick SiO films obliquely evaporated in a narrow range of incidence angles between 60° and 72° [3,4]. Bryan-Brown *et al.* proposed the zenithal bi-stable device (ZBD) [5] in which a grating surface treated with a homeotropic surfactant was found to support two stable pre-tilt configurations when at an optimal groove depth pitch [6]. Kim *et al*. have demonstrated a robust LC alignment in-plane bistability based on tailored submicrometer-sized surface domains in a frustrated alignment [7,8]. An atomic force microscope (AFM) was used to prepare a checkerboard pattern orientation on a polyimide layer which consists of a square-unit domain in which the alignment is locally constrained to be planar yet orthogonal between the neighboring domains. Oo *et al.* have proposed a micro-patterned LC device in which the patterns are formed by alternating planar and homeotropic stripes [9,10]. A micro-patterned surface provides the bi-stable anchoring.

Additionally, as the alignment material, some inorganic materials with higher reliabilities than organic materials have been required for the use in a high temperature environment [11].

In this study, as a vertical alignment layer for the nematic LC, a porous alumina film obtained by anodizing aluminum are investigated. Furthermore, as a method for the adaptation of bi-stable anchoring properties within the alignment layer, the micro-striped porous alumina is investigated. It is thought that the bistable anchoring property is resulted from the combination of the parallel alignment due to the groove structure formed by the micro-striped alumina and the vertical alignment due to the porous alumina.

2. VERTICAL ALIGNMENT OF LC MOLECULES ON ANODIZED ALUMINUM FILM AND NEW METHOD TO OBTAIN A BISTABLE ANCHORING PROPERTY

The anodization develops the oxide film on the surface with engender the oxidation reaction coercively by oxygen of hydroxide ion in the electrolytic solution react with material of the anodic by flow the current as the target material is anodic in electrolytic solution. The oxide film has high corrosion resistance. Consequently, it is used as the high reliability material.

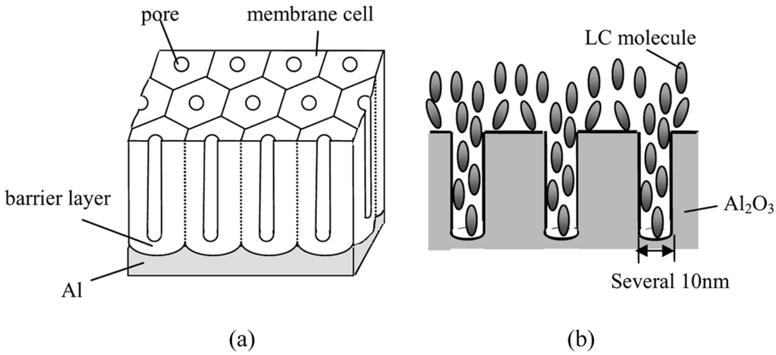

FIGURE 1 Anodization of the aluminum film. (a) Model of the porous film structure and (b) Principle of the vertical alignment for LC molecules

The oxide film is obtained by anodization of aluminum is porous structure as shown in Figure 1(a). It is honeycomb structure orderly arranged in hexagonal cylinder with porosity of columnar in center of the cell, and the diameter of porosity is about several 10 to several 100 nm, and the depth becomes deep while lengthening anodization time. The bottom of the porosity is in contact with aluminum substrate on both sides of the alumina layer with high purity called a hemispherical barrier layer. Additionally, the size of an LC molecule is small at about 5 to 10 nm compared with the size of this porosity. Thus, it is thought that the LC molecule goes into the porosity when liquid crystal is injected into this porous film.

The vertical alignment of the nematic LC using this porous film is shown in Figure 1(b). How the vertical alignment due to this mechanism above mentioned, and planer alignment due to the shape effect of

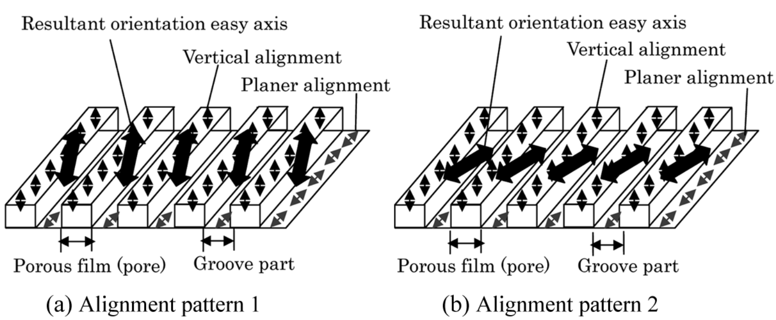

FIGURE 2 Schematic explanation for the LC molecules alignment on anodized Al film with groove structure.

the groove affect the occurrence of bistable alignment is shown in Figure 2(a) and (b).

3. PREPARATION OF THE SAMPLE CELL

Aluminum was evaporated on the metal Cr coated ITO glass substrate under 3×10^{-4} Pas. The thickness of evaporated Al was about 1 µm. A periodical micro stripe structure with 5 µm pitch was fabricated on the Al film by the photolithography technique. After that, the anodizing treatment was done under the constant current 12.5 µA/cm^2 in a 0.5 mol/l oxalic acid solution. A polyimide alignment material for vertical alignment was coated on another one of substrates. The sample cell with a 6 µm cell gap was fabricated by assembling these substrates. The nematic LC having negative dielectric constant was injected within isotropic phase into the cell, then cooled down to nematic phase.

4. RESULT AND DISCUSSION

The V-t curve in the process of constant current anodization is shown in Figure 3. The change in the V-t curve gives us the information about the situation of anodization. Anodization was done for about 100 second when the voltage saturates to about 1.6 V.

The situation of surface of the anodized aluminum film with groove structure observed by the laser beam microscope is shown in Figure 4. It can be confirmed that the groove structure has been constructed.

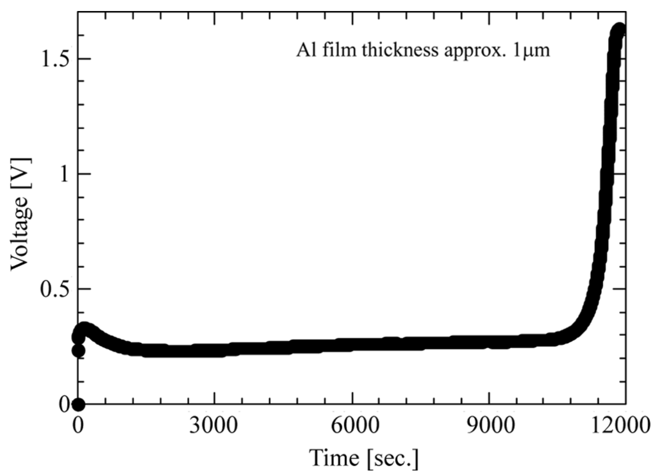

FIGURE 3 V-t curve in constant current anodization (example).

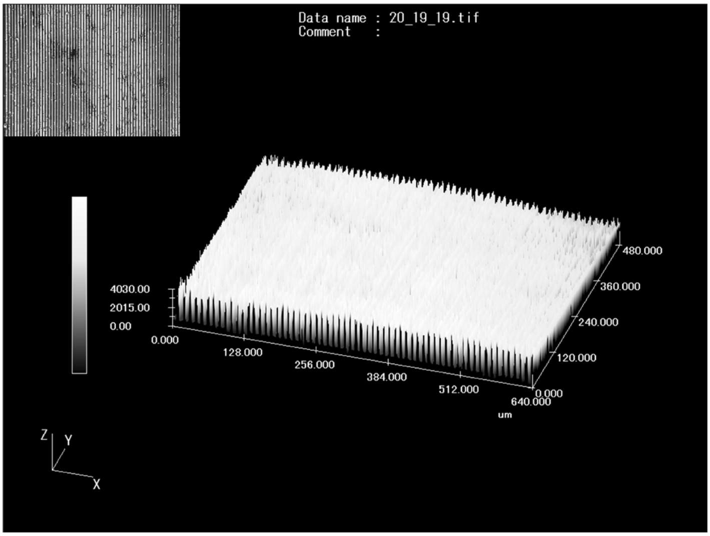

FIGURE 4 Surface structure after the anodization of the Al film by the laser microscope.

Next, the situation of LC molecular alignment in the cell was observed using the polarizing optical microscope. The result when a cell was rotated is shown in Figure 5.

Since in the part of the anodized aluminum, only the extinction state was observed even if the cell was rotated, it is confirmed that

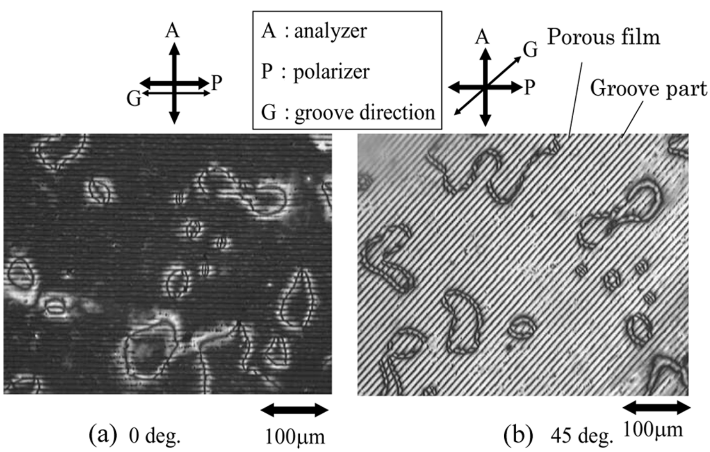

FIGURE 5 Al anodization film with the groove structure was used as an alignment film (cell gap 6.0 μm).

LC molecules are vertically aligned on the anodized aluminum. On the other hand, in the part of the groove, it can be confirmed that LC molecules align parallel along the grooves, since the extinction was observed when the direction of grooves coincided with the direction of transmission axis of polarizer and the brightest state was observed when the direction of groove becomes 45 deg with respect to the transmission axis of polarizer. Coexistence of the vertical alignment and the planer alignment is experimentally confirmed. However, the bistable property has not been observed yet. It is thought that the width of aluminum and the space of the groove were too large.

Furthemore, the defect was partially confirmed in the LC cell. This defect was not confirmed in cell using the aluminum anodization film without groove structure. Therefore, the groove structure made of the striped alumina is thought as one of the causes of the appearance of the defects.

5. CONCLUSIONS

In order to obtain the bistable surface, a new method is proposed to fabricate the micro-patterned substrate surface formed by stripes of alternating vertical and planer anchorings. In this method, aluminum film evaporated in vacuum on substrate surfaces was etched in stripe pattern using the photolithography techniques. And then, stripes of aluminum were anodized. Coexistence of the vertical alignment on stripes of porous alumina and the planer alignment along stripes due to grooves between stripes of alumina is experimentally confirmed. However, the bistable property has not been observed yet.

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