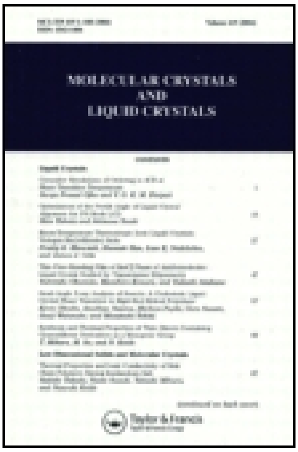

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Observation of the Surface Structure on As Stacked and Rubbed Polyimide(PI)-LB Films with an Atomic Force Microscope and Their Anchoring Capability for Nematic Liquid Crystal

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Observation of the Surface Structure on As Stacked and Rubbed Polyimide(PI)-LB Films with an Atomic Force Microscope and Their Anchoring Capability for Nematic Liquid Crystal

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We have observed the surface structure of stacked and rubbed polyimide(PI)-Langmuir-Blodgett(LB) films with an atomic force microscope.

It is shown that no grooves are formed on the PI-LB films stacked on ITO coated glass plates for a range of rubbing strengths; instead, the surfaces are rather flattened by the rubbing.

We have measured the polar anchoring energies for nematic liquid crystals (NLC), 5CB oriented on these films and it is shown that they increase with the rubbing strength.

Furthermore, textures of the aligned phase of the NLC have been examined. The textures are shown to become more uniform due to the rubbing.

1. INTRODUCTION

The surface alignment between the liquid crystal (LC) and the surface of the treated solid substrate is of scientific and technical importance in the understanding of the interfacial characteristics between the LC and the solid substrate surface.

For aligning LC molecules the rubbing technique has been widely utilized.[1–8] As a result of the rubbing it is expected that there occur the formation of microgrooves[9] and the creation of the induced birefringence on the rubbed surfaces.[6]

Ikeno et al. demonstrated the utility of polyimide(PI)-LB films for orienting LCs without performing rubbing.[10]

Recently, Suzuki et al. reported an observation of the surface structure of the spin coated and rubbed PI films with a scanning tunneling microscope (STM).[11]

However, no observation on the surface of PI-LB films has been made yet with an atomic force microscope.

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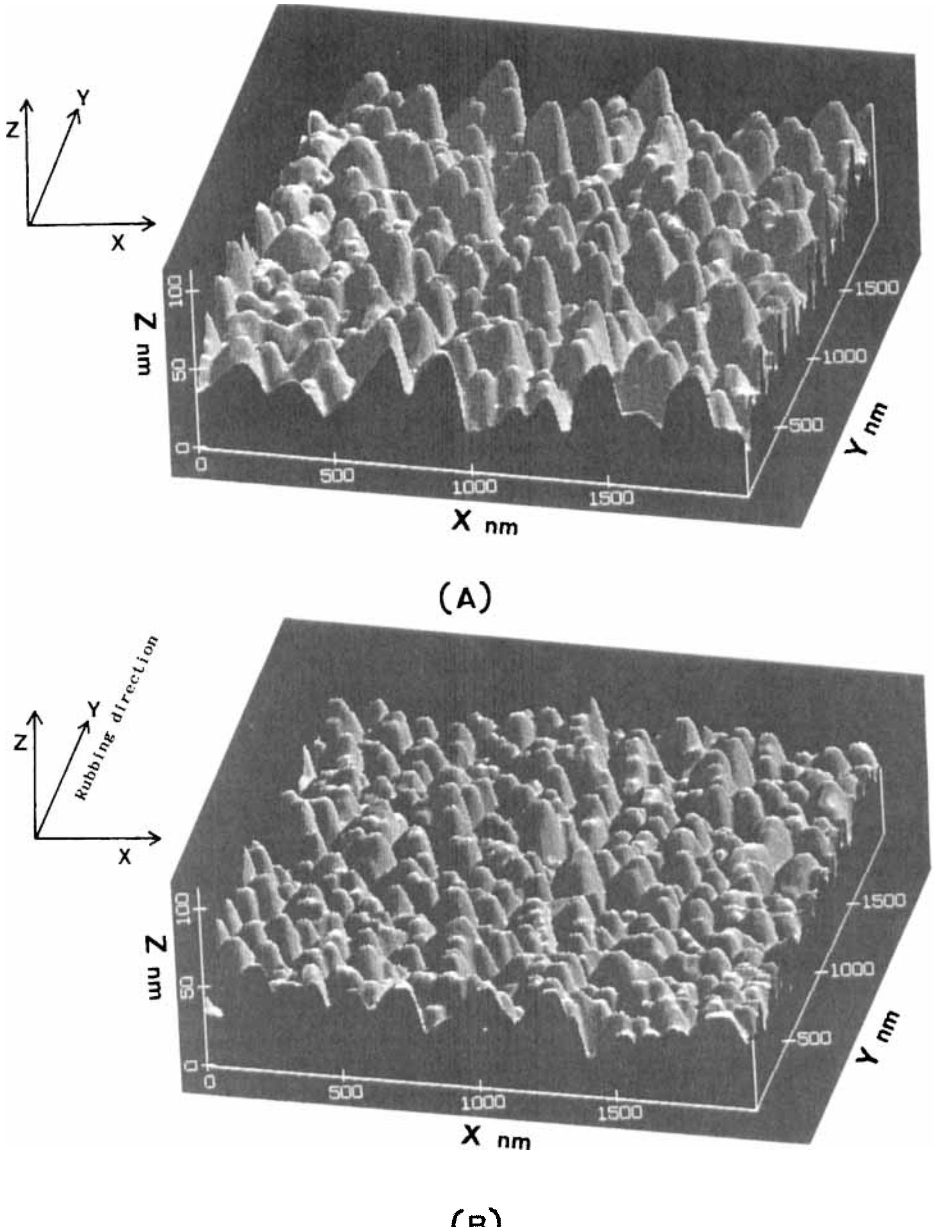


FIGURE 1 AFM images of the ITO films: (A) = bare ITO films; (B) = rubbed ITO films (RS = 189 (mm)). See Color Plate I.

In this research we made observation of both as stacked and rubbed PI-LB films with an atomic force microscope (AFM) by taking advantage of the fact that it is useful to observe an electrically insulating object with a several nm resolution.

In addition, we measured the polar anchoring energies of aligned 5CB on these films using a high-electric-field technique[12,13] and we investigated how the microscopic textures of the aligned 5CB show a better uniformity by performing rubbing.

2. EXPERIMENTAL

2.1 Polyimide(PI)-LB Films

Several kinds of polyimide(PI)-Langmuir-Blodgett(LB) films were prepared. Their code name and features are as follows:

PI(1), It consists of molecules without having alkyl-branches and containing a cyclopentane part; it is featured by medium electrical polarization.

PI(2), With alkyl-branch and with cyclobutane, lowest polarization.

PI(3), Also with alkyl-branch and with cyclobutane, medium polarization.

The precursors were stacked and polyimidized, using the method of chemical polyimidation in the same way as reported in a previous paper.[10]

The PI-LB films thus prepared were Y-type having 9 molecular layers.

Rubbing was done using a machine whose drum was wrapped with a nylon cloth. The rubbing strength can be controlled but medium strength was adopted throughout this research.

For measuring pretilt angles we used the method of crystal rotation.[14,15]

2.2 Sample Cells

We fabricated the sample cells with PI(1)-LB through PI(3)-LB films.

For comparison, non-rubbed and rubbed orientation films were used to prepare the sample cells.

Nematic liquid crystal (NLC) used was 4-cyano-4′-*n*-pentylbiphenyl (5CB) and it was aligned to form a monodomain medium in a sandwich cell by antiparallel alignment.

All the sample cells had LC layer thickness of 60 ± 0.3 μm.

2.3 Observation of the Surface Structure

Observation of the surface morphologies of both as stacked and rubbed PI-LB films was done with an atomic force microscope (model Nano Scope II).

All these PI-LB films were stacked on ITO coated glass substrates.

2.4 Measurement of Polar Anchoring Energy

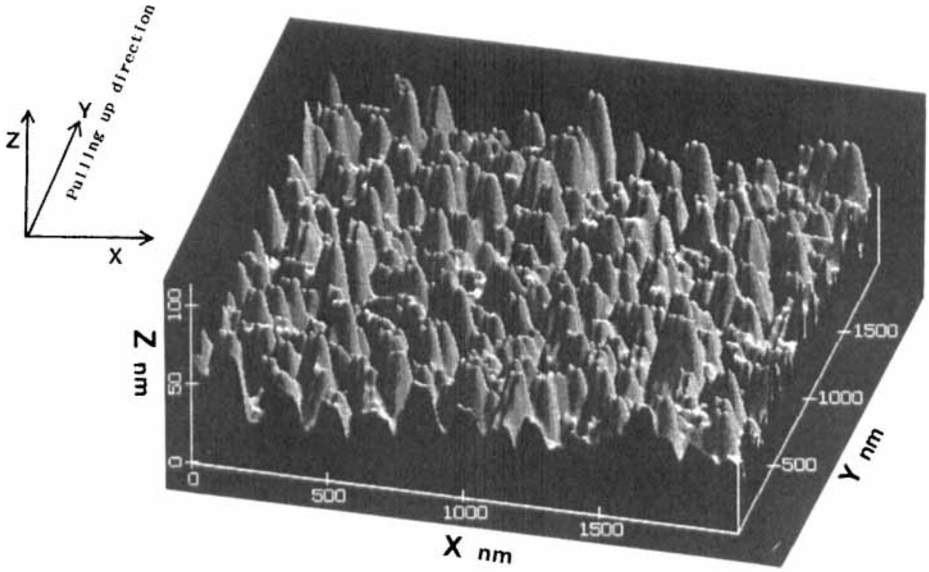
In order to measure the anchoring strength, we adopted the method developed by Yokoyama et al.[12,13]

Making use of this method, the extrapolation length d_e can be measured from a plot between the optical retardation R/R_0 $(V = 0)$ versus $1/CV$, where C and V stand for the capacitance of the sample and the applied voltage.

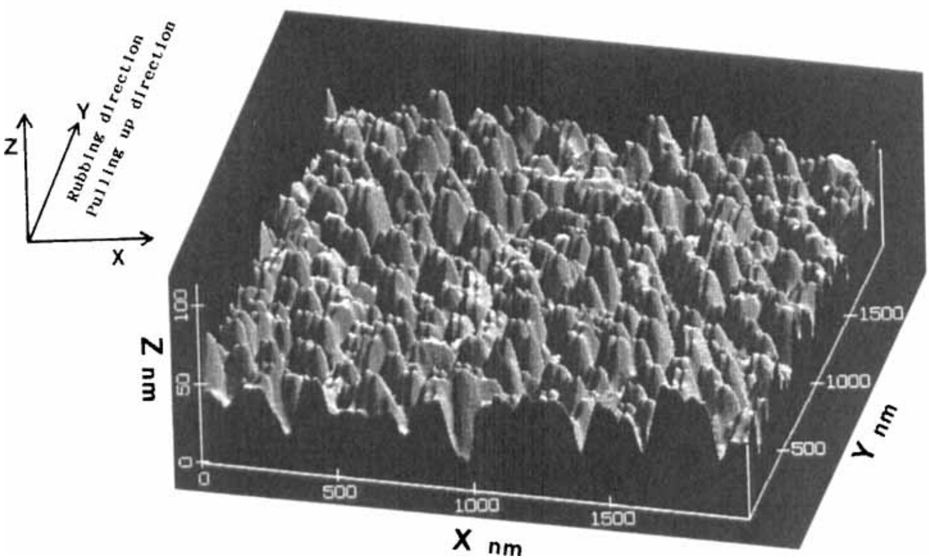
We determined the polar anchoring energy A_θ from the following relation:

$$A_\theta = K_1/d_e \tag{1}$$

where K_1 is the elastic constant for splay deformation.



(A)



(B)

FIGURE 2 AFM images of the PI(2)-LB films: (A) = stacked PI(2)-LB films; (B) = rubbed PI-LB films (RS = 189 (mm)). See Color Plate II.

TABLE I

The dependence of the pretilt angles on the rubbing strength RS (mm)

Samples	Pretilt Angle (deg.) Rubbing Strength RS (mm) 0	Pretilt Angle (deg.) Rubbing Strength RS (mm) 189
ITO		0
PI(1)-LB	0	0.5
PI(2)-LB	0.2	1.7
PI(3)-LB	0.2	2.5

TABLE II

The polar anchoring energies A_θ for PI-LB cells and rubbed PI-LB cells

Sample Cells	Anchoring Energy A_θ (J/m^2) T=30 °C, Rubbing Strength RS (mm) 0	Anchoring Energy A_θ (J/m^2) T=30 °C, Rubbing Strength RS (mm) 189
ITO		2.38×10^{-4}
PI(1)-LB	0.94×10^{-4}	4.75×10^{-4}
PI(2)-LB	1.69×10^{-4}	$> 1 \times 10^{-3}$
PI(3)-LB	9.32×10^{-4}	$> 1 \times 10^{-3}$

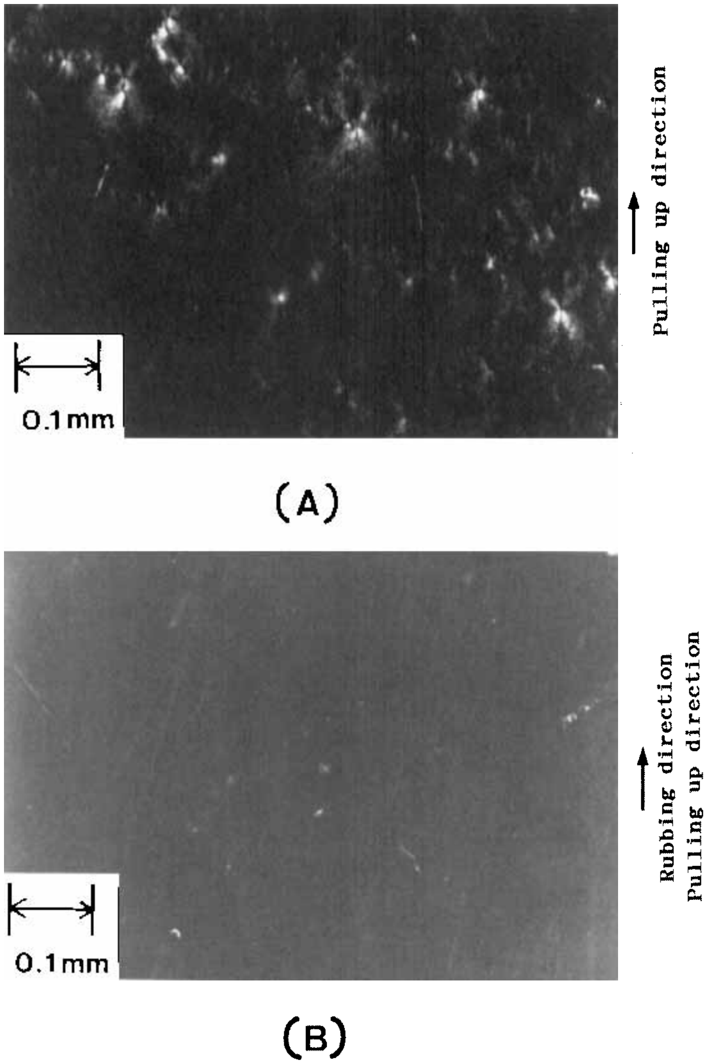


FIGURE 3 The textures of the aligned NLC,5CB: with (A) = stacked PI(2)-LB films; (B) = rubbed PI(2)-LB films (RS = 189 (mm)). See Color Plate III.

3. RESULTS AND DISCUSSION

Figure 1 shows AFM images of the ITO films in the field of view 2000 nm in X and Y directions, where Figure 1 (A) and (B) show the morphologies of the bare ITO surface before and after rubbing, respectively. These photographs were taken as references to the succeeding experiments.

Irregular structure having about 40 nm height are seen.

Figure 2 (A) and (B) are AFM micro photographs of the morphologies of stacked PI(2)-LB films deposited on ITO films and rubbed PI(2)-LB films, respectively.

The direction of the rubbing is the Y direction in Figure 2(B).

No distinct grooves are observed in the morphology of Figure 2(B).

Due to the thin thickness of the PI-LB film (it is about 4 nm) there can be seen the structure having almost the same height compared to those shown in Figure 1(B).

However, it is recognizable that the surfaces are flattened due to the rubbing as shown in Figure 1(B) and 2(B).

Table I shows the dependence of the pretilt angle on the rubbing strength RS (mm), whose definition was given in a previous paper.[16]

It is shown that the pretilt angles are generated by the rubbing in the cells with PI(2)-LB and PI(3)-LB films.

Table II shows the polar anchoring energies A_θ for non-rubbed PI-LB cells and rubbed PI-LB cells, respectively. Increases in the anchoring strengths are recognized due to the rubbing for all kinds of PI-LB films.

Figure 3 shows the textures of the aligned NLC,5CB, in the sample cells with non-rubbed and rubbed PI(2)-LB films, respectively.

The textures are shown to become more uniform due to the rubbing.

From these experiments it may be concluded that the polar anchoring strength increases in the same way of the surface order parameter which increases due to the rubbing while the materials combination is kept the same.

4. CONCLUSION

We have observed the surface structure of stacked and rubbed polyimide(PI)-Langmuir-Blodgett(LB) films with an atomic force microscope.

It is shown that no grooves are formed on the PI-LB films stacked on ITO coated glass plates for a range of rubbing strengths; instead, the surfaces are rather flattened by the rubbing.

We have measured the polar anchoring energies for NLC(5CB) oriented on these films and it is shown that they increase with the rubbing strength.

The textures of the aligned NLC(5CB) are shown to become more uniform due to the rubbing.

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