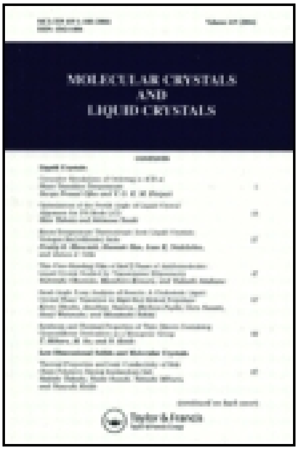

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Surface Morphology of the Rubbed Polyimide and Polystyrene Films and Their Liquid Crystal Aligning Capability

Dae-Shik Seo [a], Toshio Oh-ide [a b], Hideaki Matsuda [a], Toh-Ru Isogami [a], Koh-Ichi Muroi [a], Yoshikazu Yabes [a c] & Shunsuke Kobayashi [a]

[a] Division of Electronic and Information Engineering, Faculty of Technology, Tokyo University of Agriculture and Technology, 2-24-16 Nakamachi, Koganel, Tokyo, 184, Japan

[b] Production Technology Research Center, Ricoh Co. Ltd., Atsugi, Kanagawa, 243-02, Japan

[c] Fujitsu Kiden Co. Ltd., 1776 Yanokuchi, Inagi, Tokyo, 206, Japan

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Surface Morphology of the Rubbed Polyimide and Polystyrene Films and their Liquid Crystal Aligning Capability

DAE-SHIK SEO, TOSHIO OH-IDE,† HIDEAKI MATSUDA, TOH-RU ISOGAMI, KOH-ICHI MUROI, YOSHIKAZU YABE‡ and SHUNSUKE KOBAYASHI

Division of Electronic and Information Engineering, Faculty of Technology, Tokyo University of Agriculture and Technology, 2-24-16 Nakamachi, Koganel, Tokyo 184, Japan

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Atomic force microscope (AFM) observation has been made on rubbed polymer films for liquid crystal (LC) molecular orientation such as those of alkylbranched and branchless polyimide (PI) together with polystyrene (PS); other characterizations such as Fourier analysis and roughness evaluation have also been made. It has been investigated how these results of the characterization relate to the LC aligning capabilities such as microscopic texture and pretilt angle. It is shown that in a PI film with alkylbranches there exist grooves owing to strong rubbing, while the branchless does not reveal grooves at the AFM resolution. However, both of them are shown to be capable of aligning nematic (N) LCs very well. Regarding PS film, the grooves run parallel to the rubbing direction but LC alignment is perpendicular to that of rubbing, in accordance with the previous report (D.-S. Seo *et al.*, *Jpn. J. Appl. Phys.* **31**, 2165C 1992)).

Keywords: polyimide (PI) films, polystyrene (PS) films, rubbing strength (RS), optical retardation, pretilt angle, surface morphology, atomic force microscope (AFM), nematic liquid crystal (NLC)

1. INTRODUCTION

In previous studies, we investigated the relationship between the characterization of the polymer films for nematic liquid crystal (NLC) orientation and their LC aligning capabilities by conducting atomic force microscope (AFM) observation on rubbed spin-coated polyimide (PI) films and as stacked PI Langmuir-Blodgett (LB) films and by performing measurements of polar anchoring strength for NLC(5CB) and pretilt angles.[1–5] In the other studies, we conducted research on the LC alignment of polystyrene (PS)[6] and polypyrrole (PP) films.[7]

In this present paper, the results of study on the surface morphology observed

†On leave from the Production Technology Research Center, Ricoh Co. Ltd., Atsugi, Kanagawa 243-02, Japan.
‡Fujitsu Kiden Co. Ltd., 1776 Yanokuchi, Inagi, Tokyo 206, Japan.

with an AFM on rubbed spin-coated alkylbranched and branchless PI and polystyrene (PS) films are described and discussed. The results are compared with the aligning characteristic of NLC(5CB) on these films obtained by microscopic texture observations and pretilt angle measurements.

2. EXPERIMENTAL

2.1. Samples

We examined two kinds of polymer films: PI and PS. Among them PI(1), which has no alkylbranches, was supplied from Nissan Chem. Ind. Co. Ltd. (RN305), and PI(2), which has alkylbranches, was also from Nissan Chem. Ind. Co. Ltd. (SE-150); PS was supplied from Japan Synthetic Rubber Co. Ltd.

The PI and PS films were baked at 250°C and 100°C, respectively. All of these films were rubbed, in an antiparallel way, with a nylon buff.

The definition of rubbing strength is given in a previous paper.[1,4] The nematic liquid crystal (NLC) used in this investigation was 4-cyano-4′-*n*-pentylcyanobiphenyl (5CB). The sample cells were ordinary sandwich type whose thickness were 60 ± 0.5 μm.

2.2. Observation and Measurements

The AFM observations have been done with an AFM (Nanoscope model II) along with Fourier analysis and estimation of surface roughness. The LC orientation capability was evaluated by optical microscopic textures and the generation of pretilt angles. The surface roughness of the films is defined as the average bottom to top height of apparent surface structures.

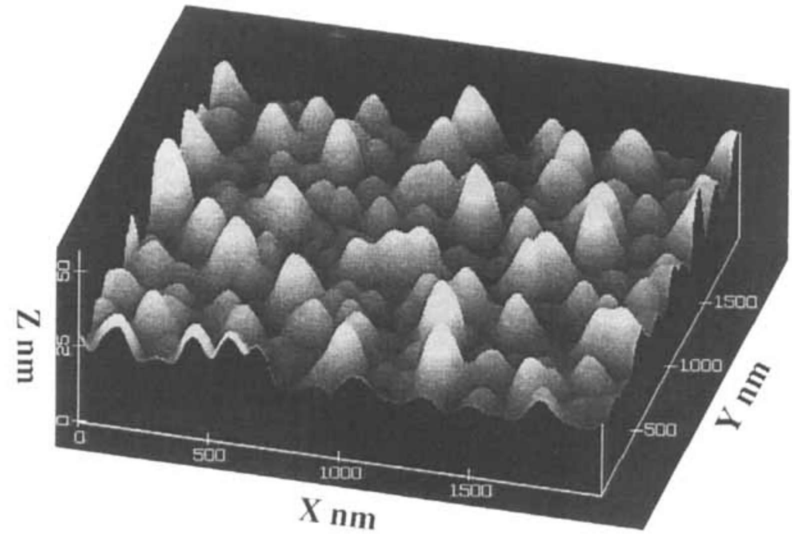
3. RESULTS AND DISCUSSION

3.1. Rubbed PI Films

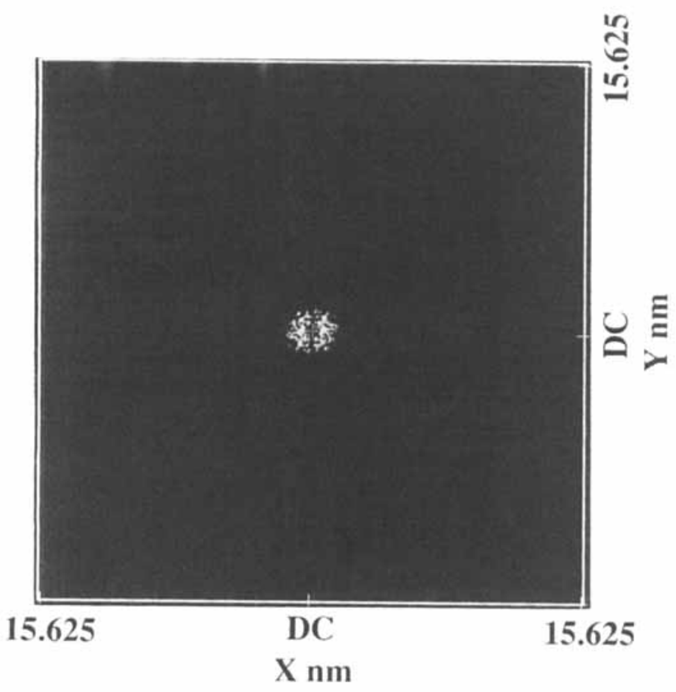
Figure 1(a) shows a surface morphology of an unrubbed PI(1) film obtained with the AFM. The surface is not flat but hillocks are observable. Figure 1(b) shows the 2D power spectrum of the Fourier analysis of the unrubbed PI(1) film. The pattern is naturally symmetric.

No grooves are observed on the surface of the rubbed PI(1) film even for a strong rubbing strength RS (RS = 406 mm) as shown in Figure 2(a). However, the texture of the aligned 5CB filled in a cell with these films is uniform, which credits the monodomain orientation. Figure 2(b) shows the 2D power spectrum of the Fourier analysis of the rubbed PI(1) film for strong RS (RS = 406 mm); a small amount of the anisotropy in this pattern is observed.

Figure 3(a) in a surface morphology of unrubbed PI(2) film obtained with the AFM. The surface structure is almost the same as that of unrubbed PI(1) film; Figure 3(b) shows a corresponding 2D power spectrum of the Fourier analysis. Again a symmetric pattern is obtained.



(A)



(B)

FIGURE 1 An AFM image of the unrubbed alkylbranchless PI(1) film with an atomic force microscope (AFM). (a) is surface morphology; (b) is 2D power spectrum of the Fourier analysis. See Color Plate I.

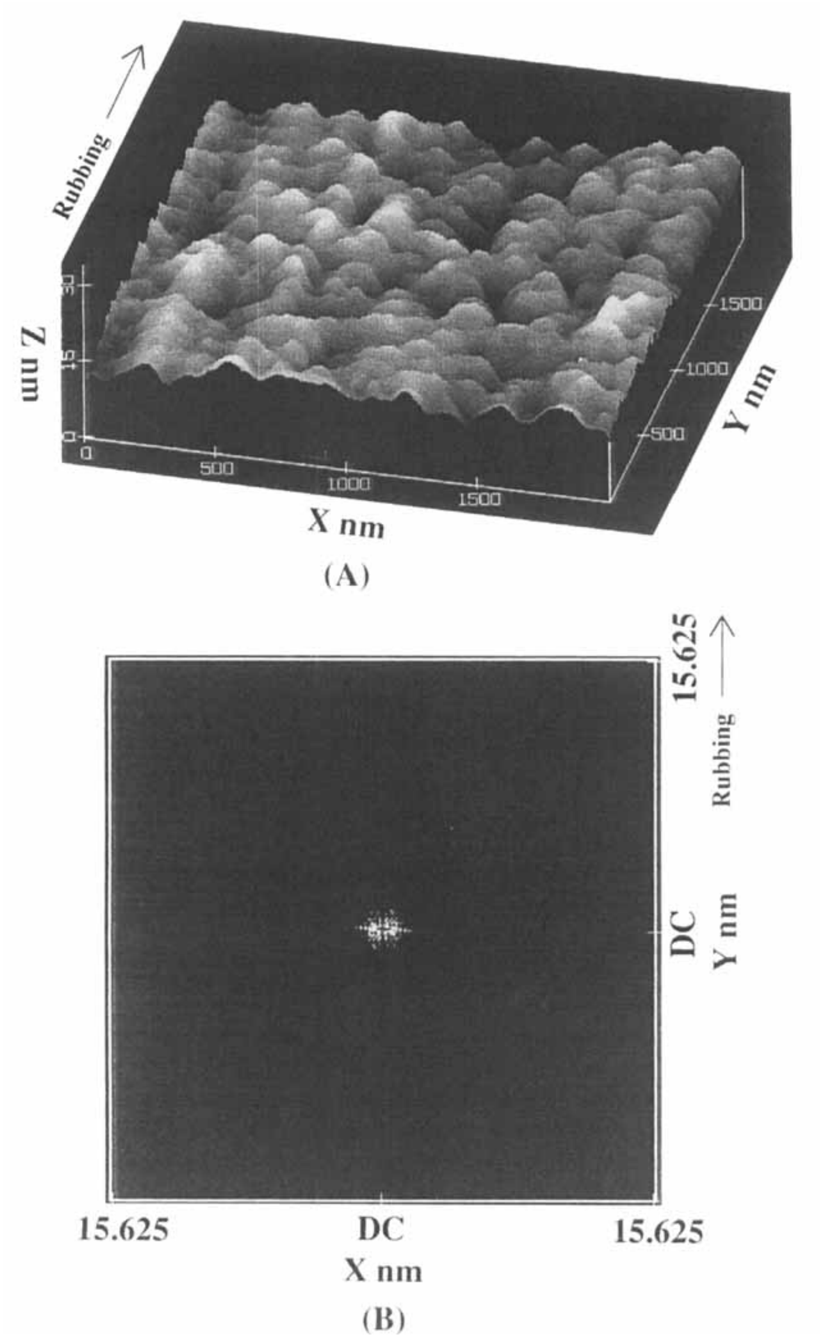
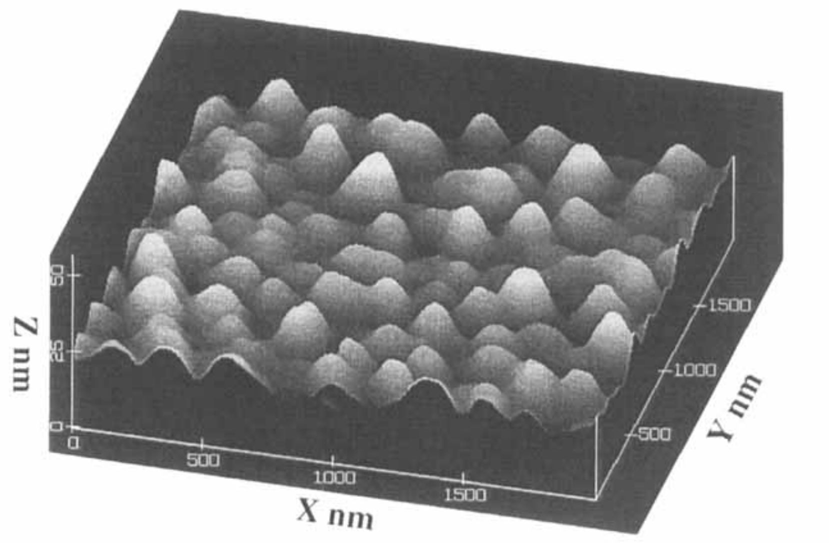


FIGURE 2 An AFM image of the rubbed alkylbranchless PI(1) film for strong RS (RS = 406 mm) with an atomic force microscope (AFM). (a) is surface morphology; (b) is 2D power spectrum of the Fourier analysis. See Color Plate II.



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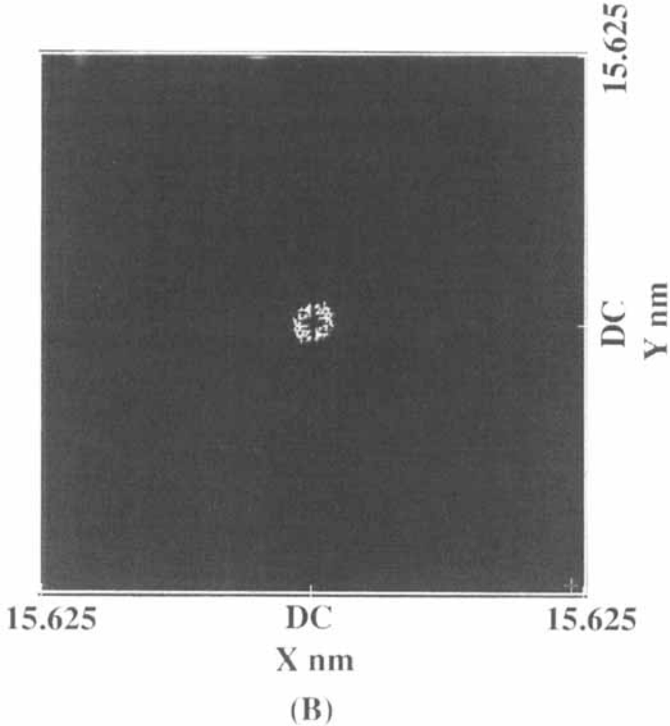
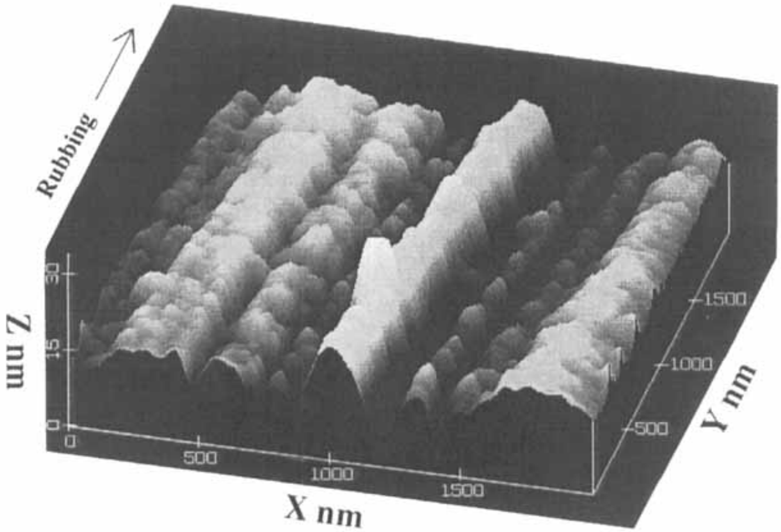
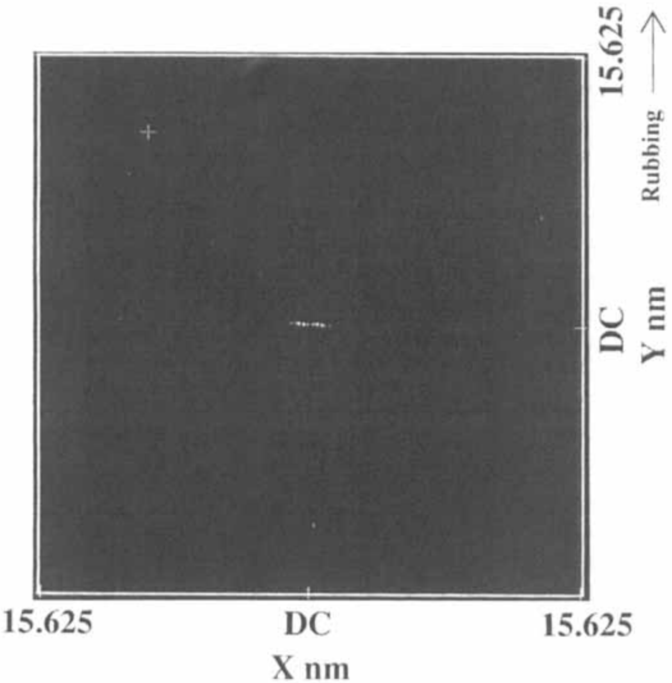


(B)

FIGURE 3 An AFM image of the unrubbed alkylbranched PI(2) film with an atomic force microscope (AFM). (a) is surface morphology; (b) is 2D power spectrum of the Fourier analysis. See Color Plate III.



(A)



(B)

FIGURE 4 An AFM image of the rubbed alkylbranched PI(2) film for strong RS (RS = 406 mm) with an atomic force microscope (AFM). (a) is surface morphology; (b) is 2D power spectrum of the Fourier analysis. See Color Plate IV.

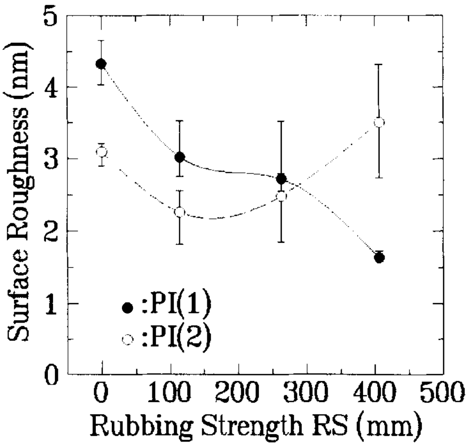


FIGURE 5 The dependence of the surface roughness aligned on rubbed PI(1) and PI(2) films as a function of RS.

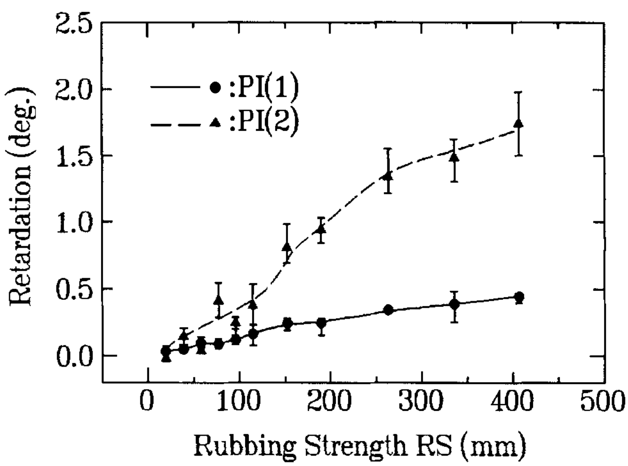


FIGURE 6 Observed optical retardation for samples with rubbed PI(1) and PI(2) films as a function of RS.

The grooves are clearly observed along the rubbing direction on the rubbed PI(2) film for a strong RS (RS = 406 mm) as shown in Figure 4(a). Figure 4(b) shows the 2D power spectrum of the Fourier analysis of the rubbed PI(2) film; a remarkable anisotropy in the pattern is observed along the perpendicular direction to the rubbing direction.

Figure 5 shows the dependence of surface roughness, which is the average amplitude of the surface undulation, on the RS for two kinds of rubbed PI films. The surface roughness of rubbed PI(1) decreases almost monotonically as the RS increases; on the other hand, the surface roughness of rubbed PI(2) shows a minimum.

Figure 6 shows the dependence of the optical retardation of two kinds of rubbed PI films on the RS. The optical retardation of the rubbed PI films increase monotonically with increasing the RS, where PI(2) results in large values compared to

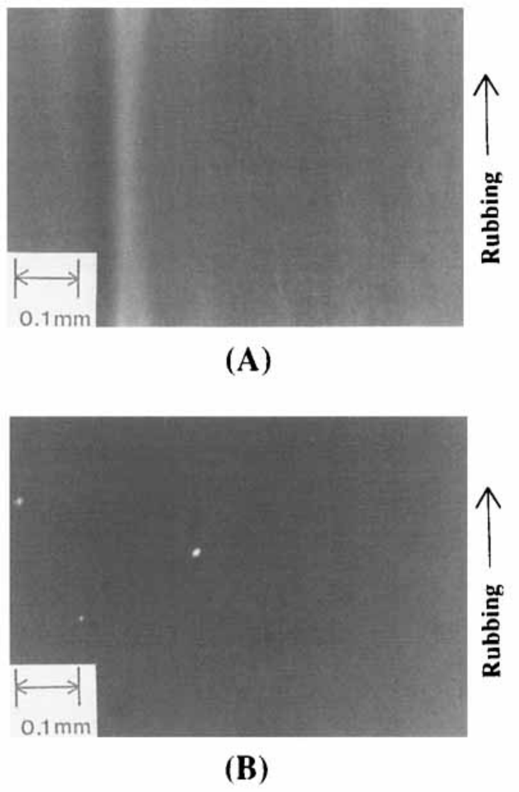


FIGURE 7 Microphotographs of the textures for NLC(5CB) for weak RS (RS = 118.9 mm). (a) is rubbed PI(1) films; (b) is rubbed PI(2) films. Under crossnicols. See Color Plate V.

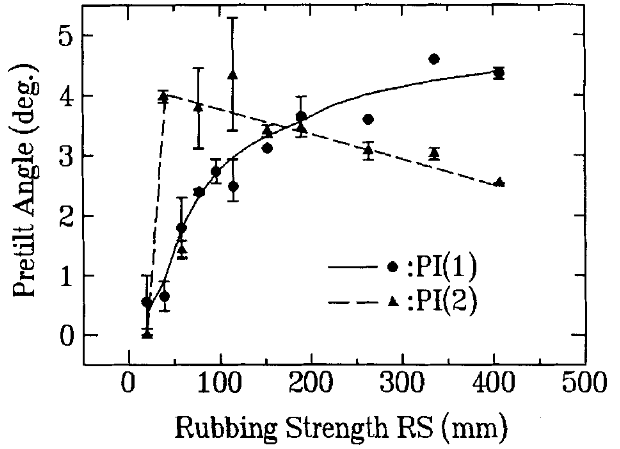
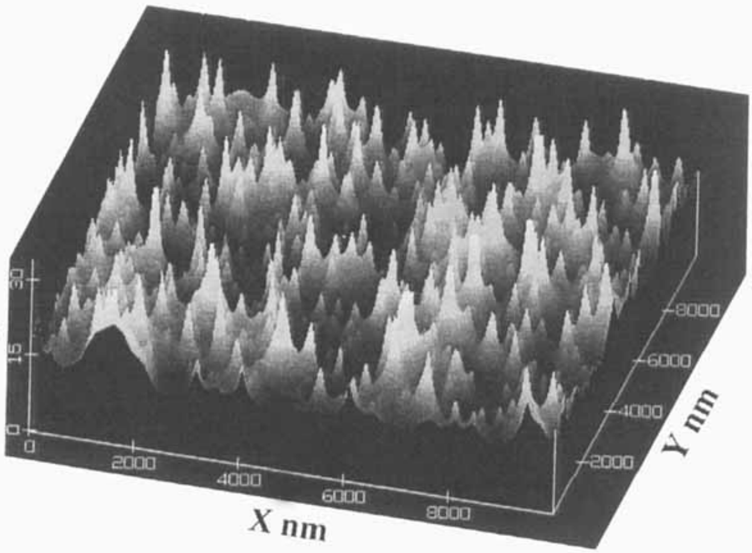
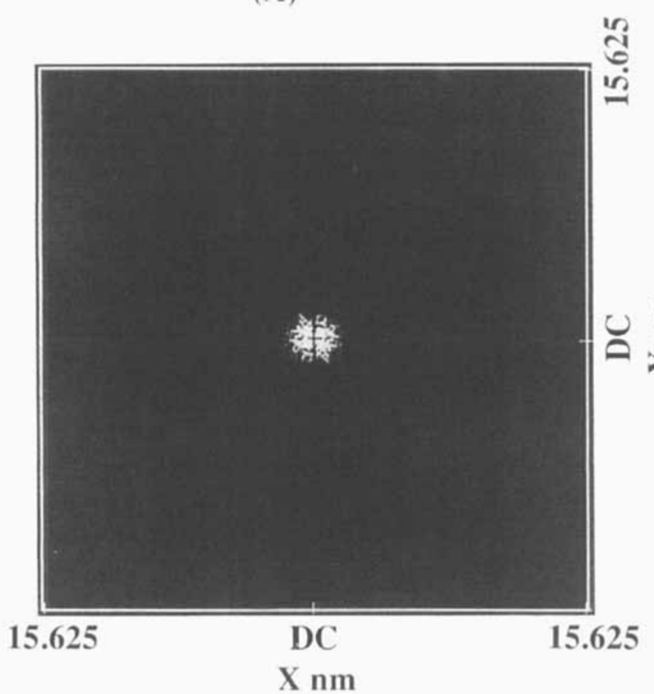


FIGURE 8 Generation of the pretilt angles for sample cells with rubbed PI(1) and PI(2) films as a function of RS.



(A)



(B)

FIGURE 9 An AFM image of the unrubbed PS film with an atomic force microscope (AFM). (a) is surface morphology; (b) is 2D power spectrum of the Fourier analysis. See Color Plate VI.

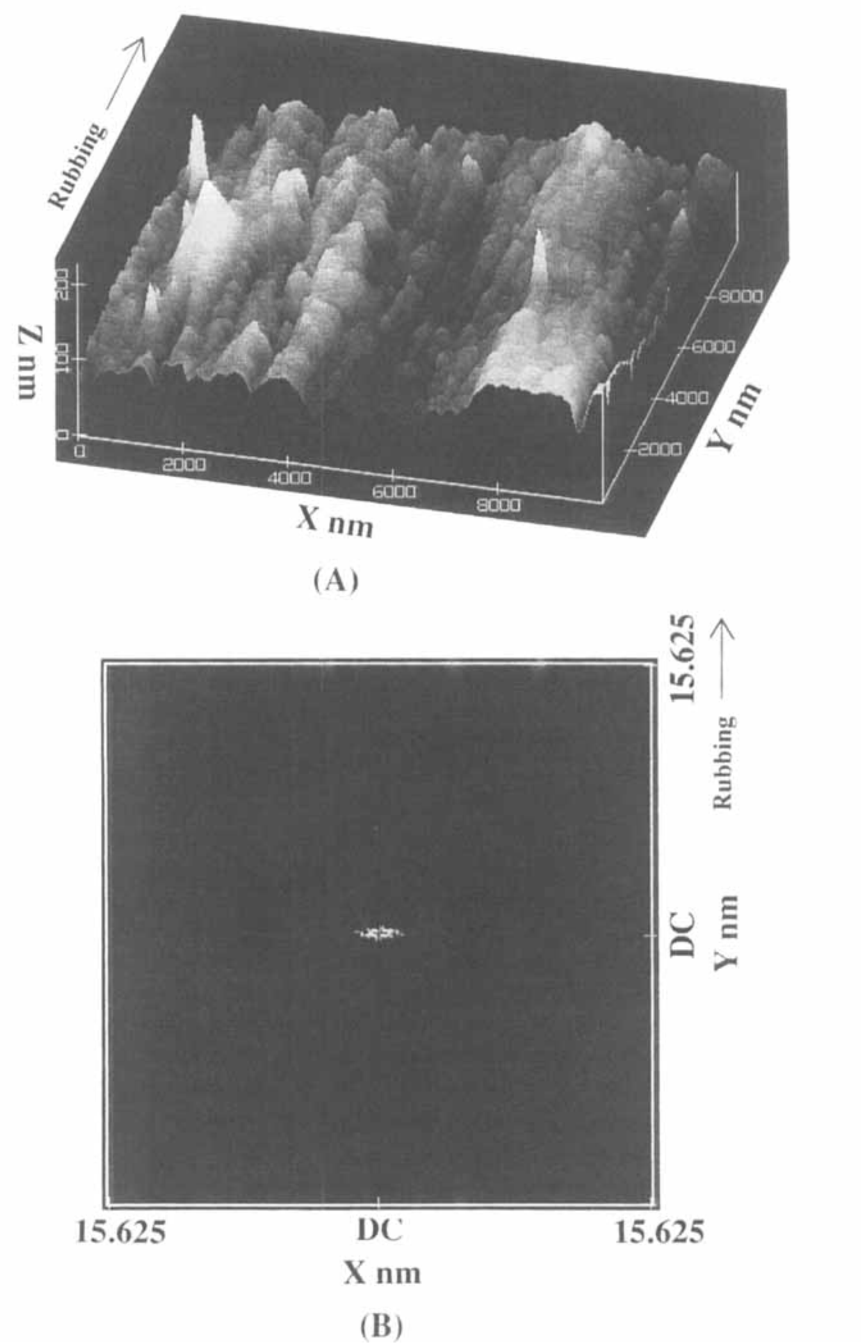


FIGURE 10 An AFM image of the rubbed PS film for strong RS (RS = 406 mm) with an atomic force microscope (AFM). (a) is surface morphology; (b) is 2D power spectrum of the Fourier analysis. See Color Plate VII.

PI(1). However, almost perfect alignment of NLC is obtained using these films (PI(1) and PI(2)), even though they are rubbed at low RS values, say RS = 100 mm.

Figure 7 shows the microphotographs of the textures for 5CB aligned on two kinds of rubbed PI films for a strong RS (RS = 406 mm); the textures of 5CB thus obtained are good monodomains.

The obtained pretilt angle occurring in 5CB filled in a cell with rubbed PI(1) films increases first monotonically with the RS and tends to saturate to about 4 degrees; while in another cell with rubbed PI(2) films the obtained pretilt angle is shown to reveal an abrupt increase at a low RS and then decreases gradually (Figure 8). These data suggest that surface topography that is suitable to create the pretilt angle may be formed by the rubbing due to the formation of asymmetric triangles even on the alkylbranchless PI when its molecular structure is appropriate.

The generation of the pretilt angles with branched PI may be caused by the steric interaction between NLC and inclined branches as discussed in the previous paper.[4,8]

3.2. Rubbed PS Films

Figure 9(a) shows the surface morphology of an unrubbed PS films obtained with the AFM; the surface is not flat but spear-like structures are seen. A symmetric 2D power spectrum is obtained for the unrubbed PS film as seen in Figure 9(b).

The surface morphology of rubbed PS films for strong RS (RS = 406 mm) observed with an AFM is shown in Figure 10(a). The grooves that run parallel to the rubbing direction are clearly observed. Also, an anisotropic 2D power spectrum that is stretched to the perpendicular direction to that of rubbing direction is observed.

In a previous paper, we report the characterization of rubbed PS films in terms of the optical retardation and study on the pretilt angle and polar anchoring strength.[6] We showed that the director of the aligned NLC is perpendicular to the rubbing direction; and further the optical retardation increases with increase of the RS whose principal axis is perpendicular to the rubbing direction. However, in the present research it is shown that the observed grooves formed by the rubbing along the parallel direction to that of the rubbing.

From these results, we suggested that the formed grooves are not responsible for the LC alignment but the anisotropic dispersion force originated from aligned phenyl rings of the rubbed PS is thought to be the dominant mechanism in this particular case.

4. CONCLUSION

Characterization of rubbed polymer films such as alkylbranched and branchless polyimide and polystyrene has been made in terms of AFM observation, 2D power spectrum, and roughness measurement. A clear relationship is shown between these results of the characterization and LC aligning capabilities such as aligning directions, microscopic textures, and pretilt angles.

Regarding the LC alignment on the rubbed polymer, the anisotropic dispersion force is thought to be the dominant mechanism; while in the generation of the pretilt with alkylbranched PI films the steric interaction seems to be dominant, but in other cases it is not as simple as pointed out by Barmentlo *et al.*[9]

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