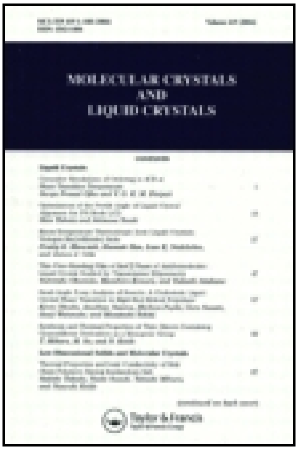

Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl19

Lateral Force Microscopy Investigation of Bacteriorhodopsin Adsorption onto Mixed Self-Assembled Monolayers

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Version of record first published: 24 Sep 2006

Mol. Cryst. and Liq. Cryst., 2000, Vol. 349, pp. 307-310
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Lateral Force Microscopy Investigation of Bacteriorhodopsin Adsorption onto Mixed Self-Assembled Monolayers

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The chemically distinctive domains of mixed self-assembled monolayers (SAMs) were investigated by lateral force microscopy (LFM). Mixed SAMs were formed onto the silver coated Si-wafers by soaking them into the ethanolic solution of 11-aminoundecanoic acid ($H_2N(CH_2)_{10}COOH$) and undecanoic acid ($CH_3(CH_2)_9COOH$). Based on the LFM images, it was found that the distinctive domains were formed due to the different functional groups. The prepared mixed SAMs were used as a template for the adsorpton of bacteriorhodopsin (bR). It is concluded that site-directed adsorption of the protein molecules would be possible by using the mixed SAMs containing different functional groups.

Keywords: lateral force microscopy (LFM); bacteriorhodopsin; self-assembled monolayers (SAMs)

INTRODUCTION

In recent years, thin films such as polymer films, Langmuir-Blodgett (LB) films, and self-assembled monolayers (SAMs) have been the subject of numerous scanning probe microscopy (SPM) studies [1-3]. Lateral force microscopy (LFM) has been used for measuring friction, shear, and adhesion properties of monolayers, which are important factors in many fields of applications including lubrication, tribology, and recognition in biological systems.

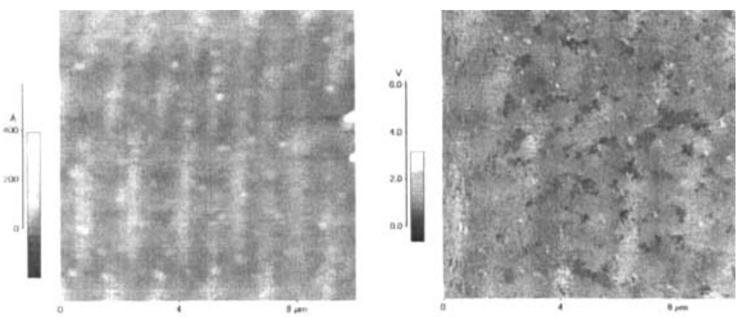
In the present paper, the friction images of different domains of mixed SAMs prepared on a silver coated Si-wafers were investigated by LFM. The possible application of the mixed SAMs as a template for protein adsorption was also suggested.

EXPERIMENTALS

Bacteriorhodopsin (bR), undecanoic acid ($CH_3(CH_2)_9COOH$), and 11-aminoundecanoic acid ($H_2N(CH_2)_{10}COOH$) were purchased from Aldrich Chemical Co. (Milwaukee, USA). Silver films (thickness, ~1000 Å) were prepared onto the pretreated Si-wafers by vacuum evaporation. The mixed SAMs of undecanoic acid and 11-aminoundecanoic acid were formed onto the silver coated Si-wafers by soaking them into the ethanolic solution of equimolar mixture (5 mmol : 5 mmol) for 2hrs, and then dried under the nitrogen atmosphere. bR-embedded purple membrane patches were then adsorbed onto the prepared mixed SAMs by soking them into the bR suspensions (5mg/mL, pH 8) for 2 hrs. The topographies and the friction images were obtained with a commercially available instrument (AutoProbe CP, PSIA Instrument Co.). All measurements were made in an ambient condition.

RESULTS AND DISCUSSION

Figure 1 shows the AFM and LFM images of the mixed SAMs composed of undecanoic acid and 11-aminoundecanoic acid onto silver. It can be considered that the formation of distinctive regions is due to the different surface properties primarily determined by the different terminal groups of two molecules (CH_3 and NH_2). The changes of friction between the tip and the surface result in the changes of the cantilever torsion. Since the tip experiences lower friction in the regions terminated by CH_3 than in the regions terminated by NH_2, the dark regions in the LFM image are corresponding to the surface composed of molecular assembly of undecanoic acid. On the other hand, the bright regions in the LFM image are assigned to the molecular assembly of 11-aminoundecanoic acid that has NH_2 group as a terminal functional group. It can be considered that the layers of undecanoic acid were formed onto the SAMs of 11-aminoundecanoic acid which are predominantly formed.



(a) (b)

FIGURE 1. AFM and LFM images of mixed SAMs composed of undecanoic acid and 11-aminoundecanoic acid on silver (scan size : $10 \times 10\ \mu m^2$); (a) topography, (b) LFM image.

Figure 2 shows the AFM and LFM images of bR thin films formed onto the mixed SAMs. It could be found that the bR-embedded purple membrane patches were selectively adsorbed onto the mixed SAMs. Since the amine groups of the SAMs of 11-aminoundecanoic acid can act as a positively charged surface and the isoelectric point of bR is about 4.85, the bR molecules can be spontaneously adsorbed onto the SAMs of 11-

aminoundecanoic acid under the condition of the higher pH than 5. As shown in Figure 2, bR molecules were selectively adsorbed onto the mixed SAMs. The dark regions in the LFM image are assigned to the surface of undecanoic acid on which bR molecules were not adsorbed due to the weaker interaction between the methyl groups and bR molecules. It is concluded that the site-directed adsorption of the protein molecules would be possible by using the mixed SAMs containing different functional groups as a template.

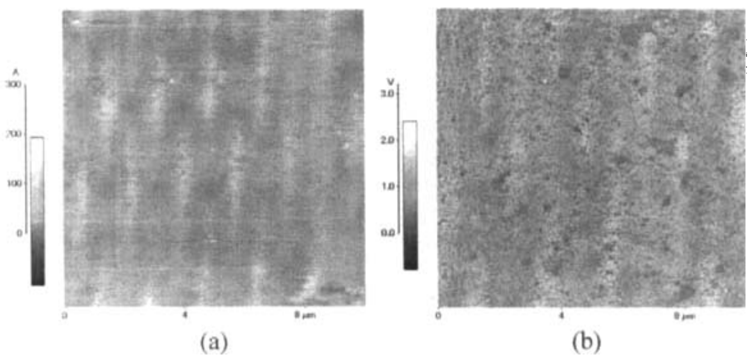


FIGURE 2. AFM and LFM images of bR thin films adsorbed onto the mixed SAMs (scan size : 10 × 10 μm^2); (a) topography; (b) LFM image.

Acknowledgement

This work was supported by the Korean Ministry of Science and technology under the Brain Science Research Program (99-J04-02-04-A-03).

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