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Nanotribological Properties of Hydrophobic Surfaces Using an Atomic Force Microscope

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Nanotribological characteristics of hydrophobic surfaces were studied experimentally using an atomic force microscope (AFM). Two kinds of thiolic self-assembled monolayers (SAM) having different spacer chains and their mixture were deposited onto gold-coated mica, where the deposited SAM resulted in the hydrophobic nature. Results showed that the mixed thiolic SAMs resulted in low adhesion and friction in nano-scale contact. It was argued that the water wetting characteristics played a central role on nano-scale adhesion and friction. Also the effect of mixing the thiolic SAMs were discussed on the basis of real area on contact and the stiffness of the SAM layers.

Key Words: *Nanotribology, nanoadhesion, nanofriction, AFM, SAM.*

1. INTRODUCTION

Self-assembled monolayer (SAM) is one of great concerns to many researchers those who are interested in nano-scale characteristics. The SAM can alter the characteristics of the surfaces to be hydrophobic, so they were focused recently in order to eliminate the adhesion problems in MEMS elements [1].

The characteristics of the SAMs have been known to be dependent upon the types of molecular chains, the types of end groups and the types of intermolecular bridges. In the viewpoint of nanotribology, not only those chemical characteristics but also the vertical and lateral stiffness of the SAMs are important. The hydrophobic nature of the SAM-coated surfaces is also important [2].

In order to attain low adhesion and low friction, most of the nanotribologists focused on the types of chemical chains of SAMs. Recently, using the ion beam modified PTFE, the authors showed that the nano surface morphology itself also affects greatly the water wetting characteristics, nanoadhesion and nanofriction.

In this work, the nanotribological effect of the spacer chain of SAMs was focused. Thiolic self-assembled monolayers of different spacer chains, and their mixture were deposited onto gold-coated silicon wafers. Nanoadhesion and nanofriction characteristics of the SAM-coated samples were studied with an atomic force microscope (AFM).

2. EXPERIMENTAL DETAILS

Thin gold film was coated on a cleaved mica surface by a thermal evaporation method and the film was annealed at 500°C in a furnace for 4 hrs to obtain a large flat single-crystal surface. After the annealing, the substrates were rinsed with the N_2 bubbles, DI water and the isopropylalchohol. SAMs were prepared by dipping the gold-coated samples into 1 mM Octylthiol ($C_8H_{17}SH$) and 1 mM Hexadecylthiol ($C_{16}H_{31}SH$) solution for 2 hrs. The mixture solutions (1:1 and 2:1) of the above two SAM solutions were also used to prepare mixed SAM-coated samples.

After the SAM coating process, nanosurface topography, nanoadhesion and nanofriction of the samples were measured with a commercial AFM system (Multimode, NanoScope IIIa, Digital Instruments), which is shown in Fig. 1.

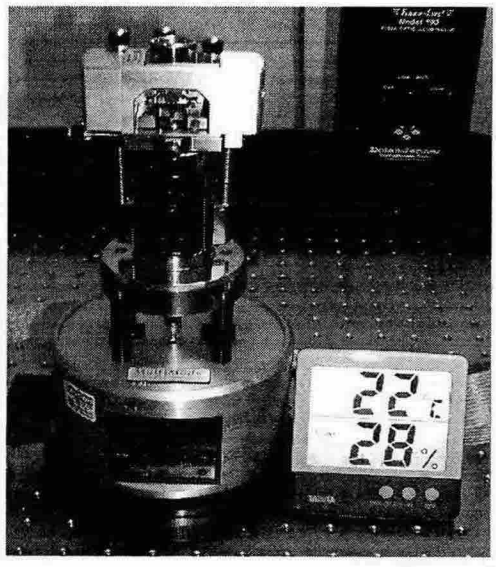
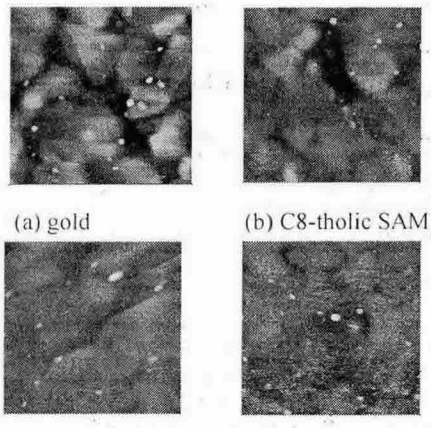


Fig. 1 A close-up view of the atomic force microscope (AFM) system.

3. RESULTS AND DISCUSSION

In order to study the effect of spacer chain on the nanotribological characteristics, four different SAMs (C8, C16 and their mixtures(1:1 and 2:1)) were prepared. The 2D-topographies of the samples were shown in Fig. 2.

Nanoahesion and nanofriction characteristics of the SAM-coated samples were evaluated with the AFM (Fig 3). The measured nanoadhesion forces of the thiolic SAMs, C8 and C16 were relatively higher than those of gold coated surfaces. But when the mixed SAM was coated on the gold surfaces, it showed a very low adhesion force. In this work, the tips having the radius of 15 nm were used to measure the adhesion force under the load of 40 nN.



(a) gold (b) C8-tholic SAM

(c) C16-thiolic SAM (d) Mixed (1:1)-thiolic SAM

Fig. 2 Two dimensional nanosurface morphologies of gold and thiolic SAMs.

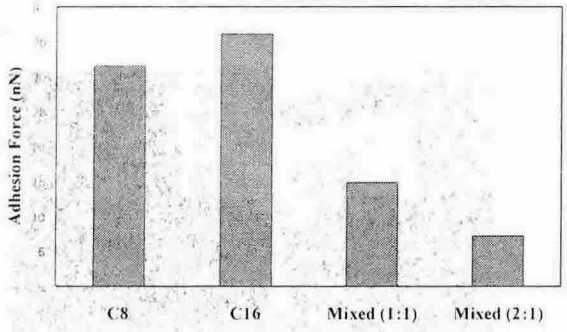


Fig. 3 Nanodhesion forces of the samples measured with the atomic force microscope.

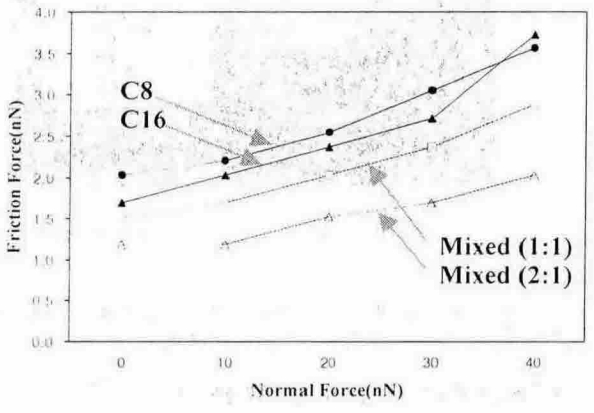
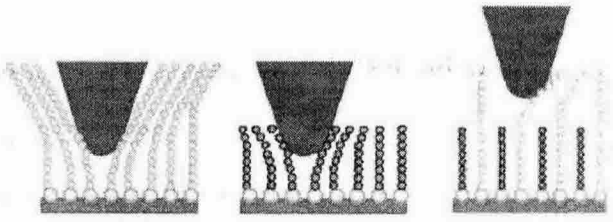


Fig. 4 Nanofriction forces of the samples measured with the atomic force microscope.

Previous works on the thiolic SAMs [3] argued that the tip can not penetrate the thiolic SAMs in this operating condition. It was thought that the mixing of the SAMs may result in the decrease of the real contact area. So it was found that the mixed SAMs resulted in low adhesion forces.

The results of nanofriction measurement were presented in Fig. 4. The nanofriction force decreased when the C8 and the C16 SAMs were mixed.



(a) C16 SAM (b) C8 SAM (c) Mixed SAM

Fig. 5 A schematic illustration of the effect of nano surface morphology on nano friction.

According to Fig. 4, the increase in the mixture ratio also resulted in the decrease in the nanoadhesion force. The effect of mixing can be illustrated not only by the decrease in the real area of contact but the relatively low lateral stiffness at the top of the mixed SAMs. Bhushan [4] also suggested that nanofriction force can increase with the lateral stiffness of the SAMs, so the low friction force of the mixed SAM can be illustrated by the decrease in the lateral stiffness of the SAM layer.

The effect of mixing the C8 and C16 thiolic SAMs on nanofriction is also illustrated graphically in Fig. 5.

4. CONCLUSIONS

The experimental results can be summarized as follows:

1. The thiolic SAM-coated samples were converted to be hydrophobic. The mixed thiolic SAMs showed higher water wetting angles than those on non-mixed SAMs..
2. Nanoadhesion and nanofriction decreased with the mixing of the C8 and C16 SAMs.
3. Nanofriction forces also decreased with the mixing of the SAMs.
4. The spacer chain of SAMs affected the nanotribological characteristics.

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REFERENCES

[1] Maboudian, R., Ashurst, W. and Carraro, C., "Self-assembled Monolayers as Anti-stiction Coatings for MEMS : Characteristics and Recent Developments", Sensors and Actuators A : Physical, Vol.82, pp.219-223, 2000.

[2] Spencer, N.D., Lee, S., Perry, S.S. and Lim, M.S., "Approaches to biological and biomimetic lubrication", Proceedings of the 2nd International Workshop on Microtribology, Ishigaki Island, Japan, April 16-19, pp.12, 2002.

[3] Carpick, R. and Salmeron, M. "Scratching the Surface: Fundamental Investigations of Tribology with Atomic Force Microscopy", Chem. Rev., Vol.97, pp. 1163-1194, 1997.

[4] Liu H. and Bhushan, B.," Investigation of nanotribological properties of self-assembled monolayers with alkyl and biphenyl spacer chains", Ultramicroscopy, Vol.91, Issues 1-4, May, pp.185-202, 2002.