Poster Session T6

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Quantitative Measurements of Friction Coefficient of Polymer Surface by Scanning Probe Microscopy.

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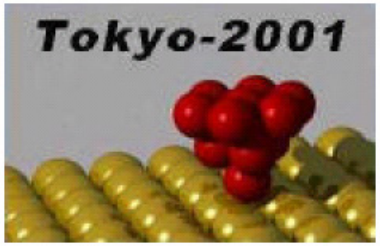

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Abstract

The frictional curve measurement in scanning probe microscopy (SPM) is useful tool for quantitative analysis of micro-scale surface friction. We studied the tribological properties of different silicone treated surface of polymer films. The macro-scale friction coefficient of the polymer film measured by ASTM (American Standard for Testing Material) is inversely proportional to the amount of silicone on the film surface. We measured the micro-scale friction coefficient of the polymer film by the frictional curve measurement and obtained the same correlation between micro-friction coefficient and the amount of silicone on the film surface. We propose that the frictional curve measurement is suitable for measuring micro-scale frictional properties in tribological application.

1. Introduction

Quantitative analysis of micro- tribological properties is very important in material research.

We propose micro-tribological tester with the frictional curve measurements in SPM.

1 Properties of friction (micro-friction coefficient)
2 Properties of wear and deform (scratch depth measurements)

1 Are there any correlation between macro-scale and micro-scale friction properties in relative small load? → Possibility of quantitative analysis of micro-scale friction properties

2 Is it possible to observe the structural factor of thin film in large load scratch test? → Possibility of quantitative analysis of properties of wear, scratch depth

2. Principle　Frictional curve measurement

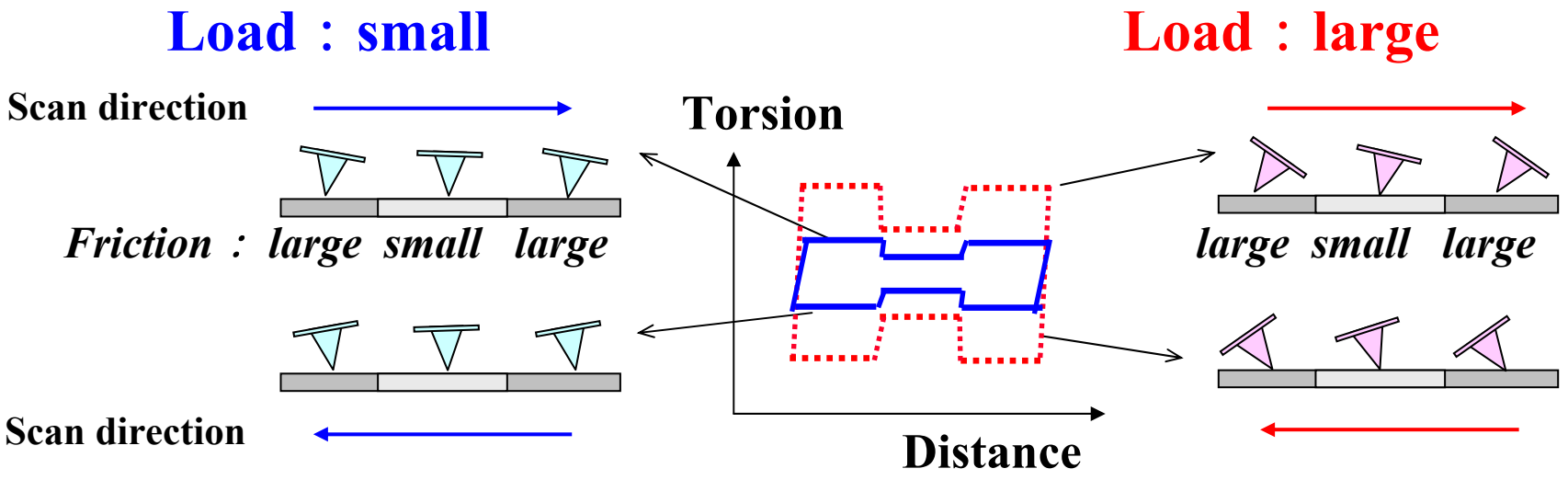


Fig.1　Schematic representation of frictional curve

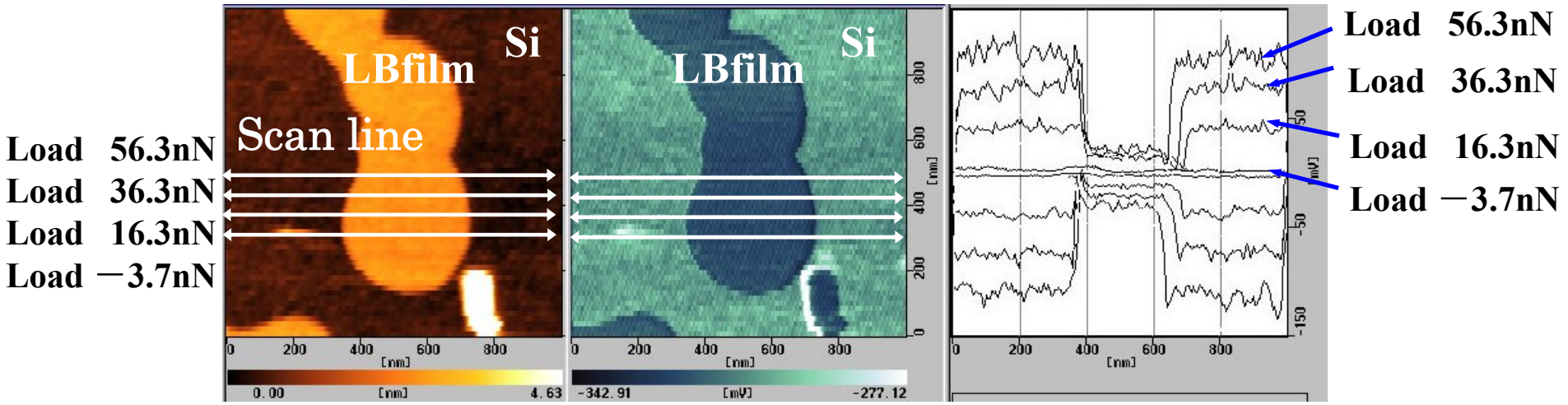
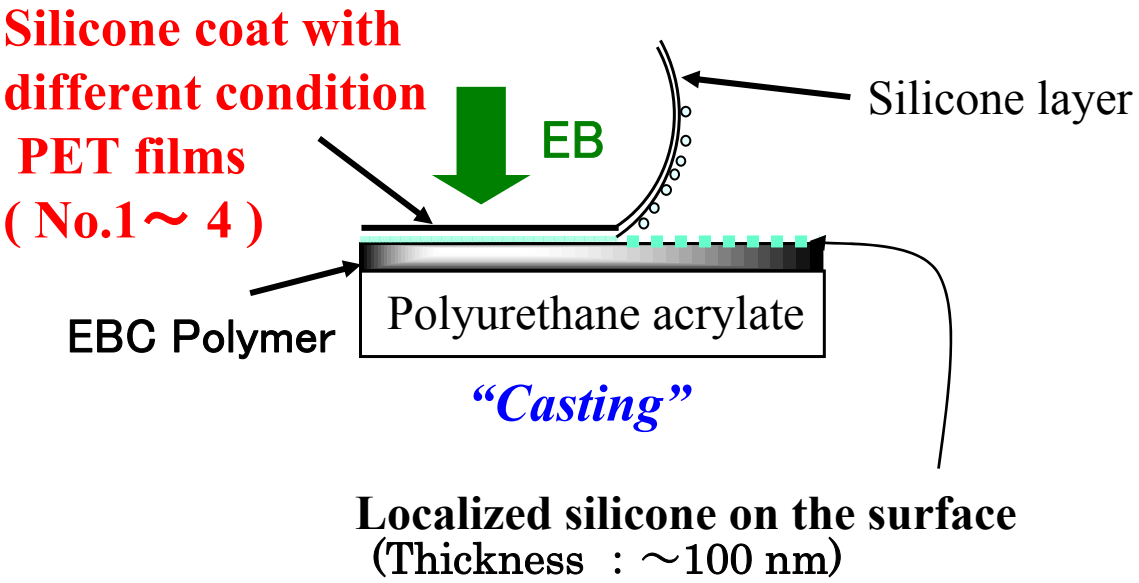


Fig.2　Examples of Frictional curve : The LB (Langmure Blodgett) film on Si wafer

(Left:Topography　Center:FFM image　Right: Frictional curve)

3. Experimental Details(1) Samples



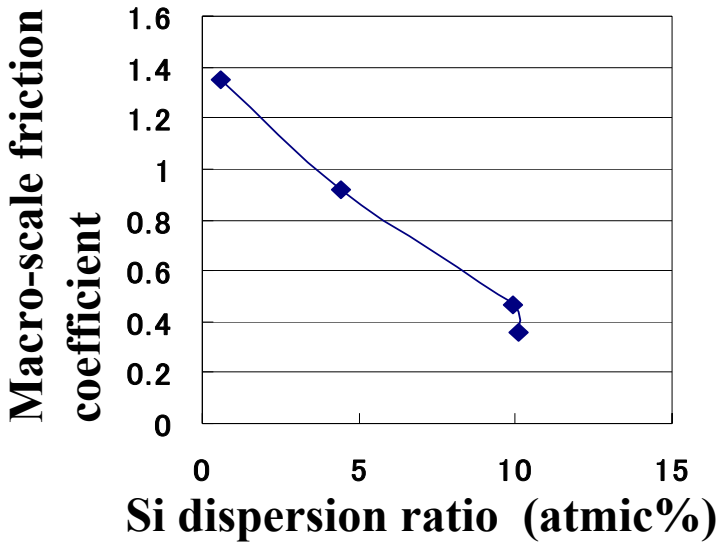


Fig.3 EB cured polymer films with the surface treated by silicone

Fig.4 Macro-scale friction coefficient

Tab.1 Different silicone treated EBC polymer samples

Sample	Si dispersion ratio (atmic%) by ESCA (LAB250 VG Scientific)	Macro-scale friction coefficient by ASTM D-1894(HEIDON Type-14DR)
No. 1	10.1	0.361
No. 2	9.9	0.468
No. 3	4.4	0.917
No. 4	0.6	1.347

The macro-scale friction coefficient measured by ASTM(American Standard for Testing Material) is inversely proportional to the ratio of Si.

3. Experimental Details(2)　Cantilever and Frictional curves

Cantilever : Spring constant : 0.37N/m(deflection)　315.4N/m(torsion)

Material : Si_3N_4　Lever length : 100 μ m　Tip length : 2.8 μ m
Lever width : 20 μ m　Lever thickness : 0.8 μ m

SPM : SPI3800N/SPA400 (SII)

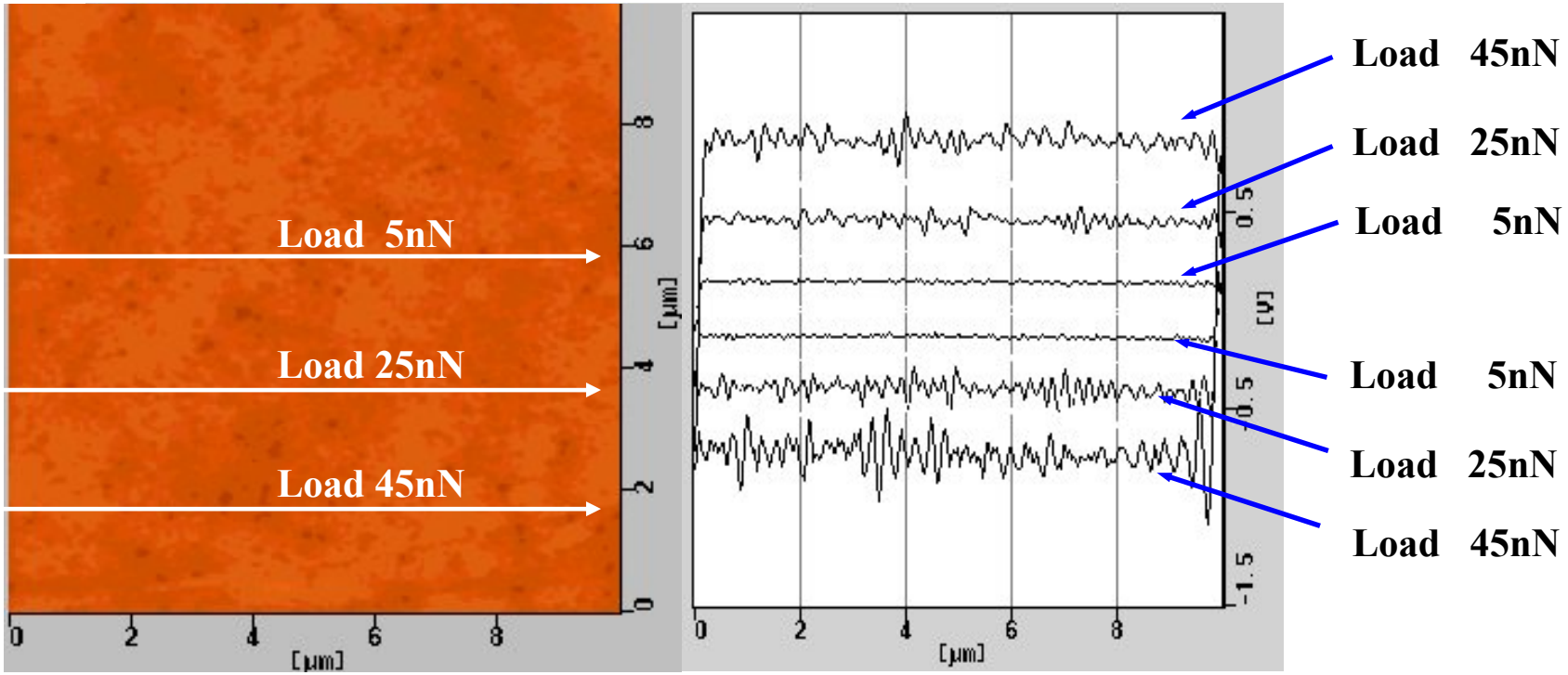


Fig.5 The AFM topographic image and frictional curves of EB cured polymer film with the surface treated by silicone

4. Results and Discussion(1)

Micro-scale friction coefficient in relative small load (0～50nN)

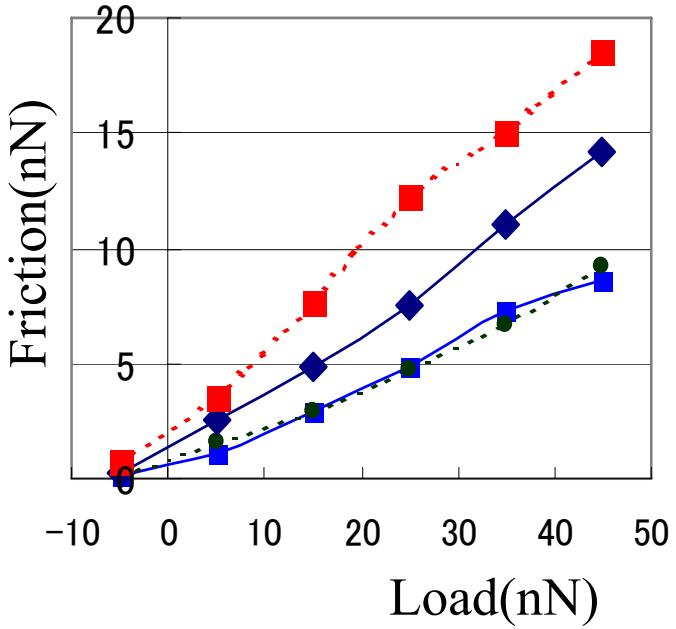


Fig.6 The correlation between load and friction

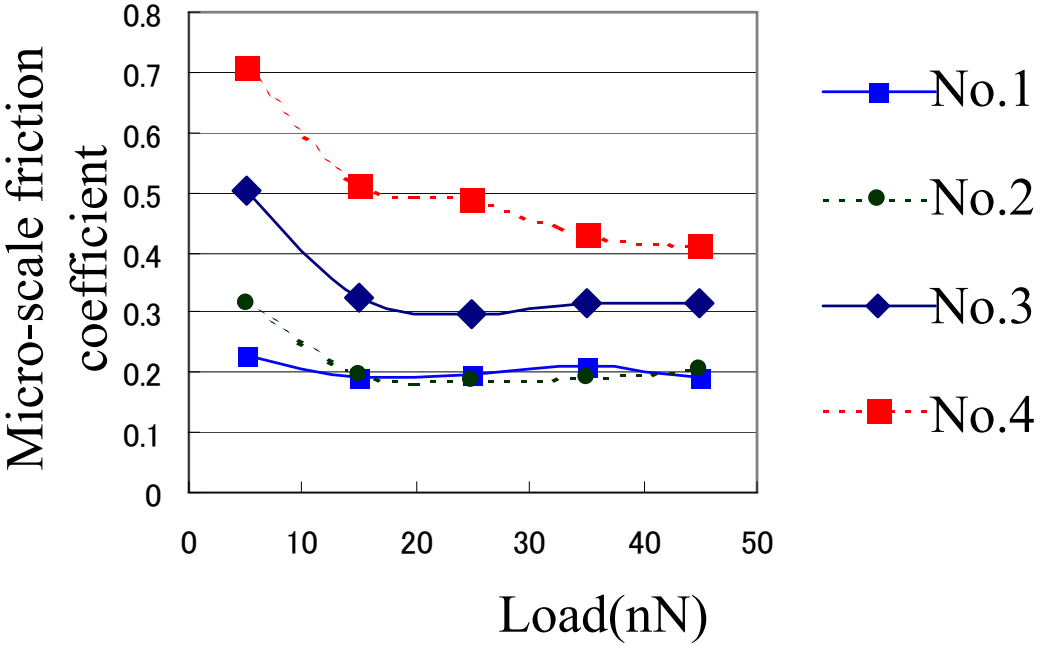


Fig.7 The correlation between load and micro-scale friction coefficient

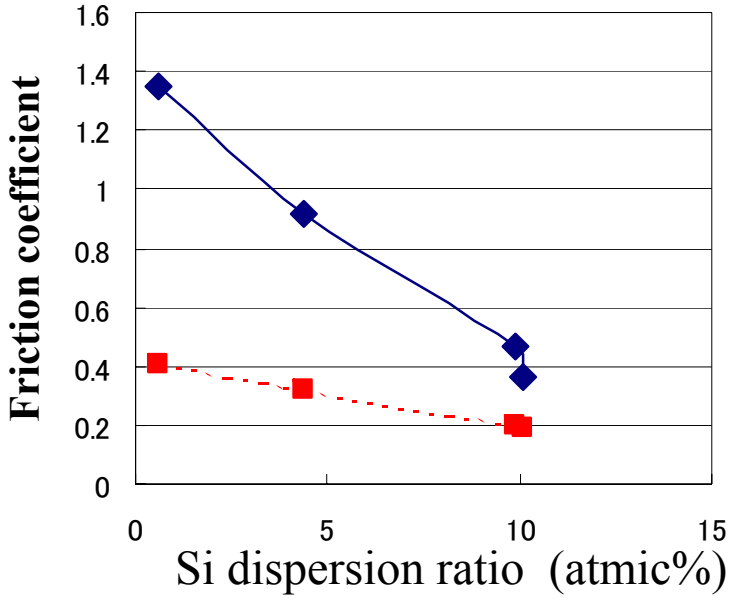
Friction is almost proportional to load in relative small region(～50nN).
At smaller load region(≦20nN), micro-scale friction coefficients are larger by influence of adsorption.

※ Micro-scale friction coefficient ≡ Friction / Load

⇒ The load does not include adhesive force. See appendixes.

4. Results and Discussion(2)

The correlation between micro- and macro-scale friction coefficient



macro-scale friction coefficient

micro-scale friction coefficient

(Average value between 30nN to 50nN in Fig.7)

Fig.8 Comparison of micro-scale and macro-scale friction coefficient

The inversely proportional relationship between micro-scale friction coefficient and Si dispersion ratio is the same as macro-scale friction coefficient.

Good liner relationship

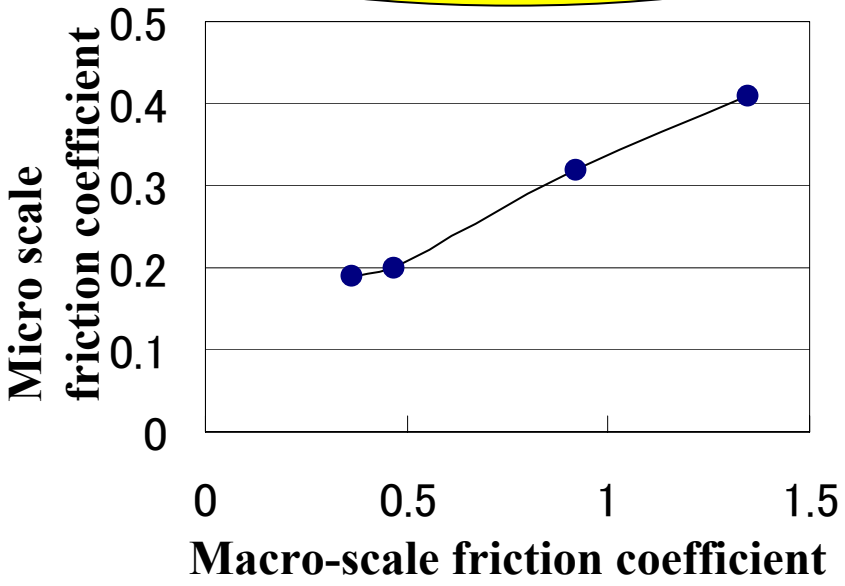
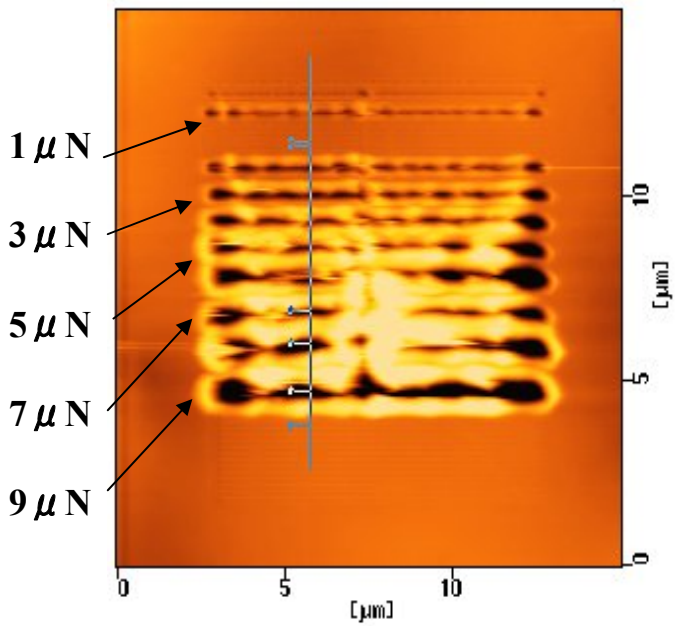
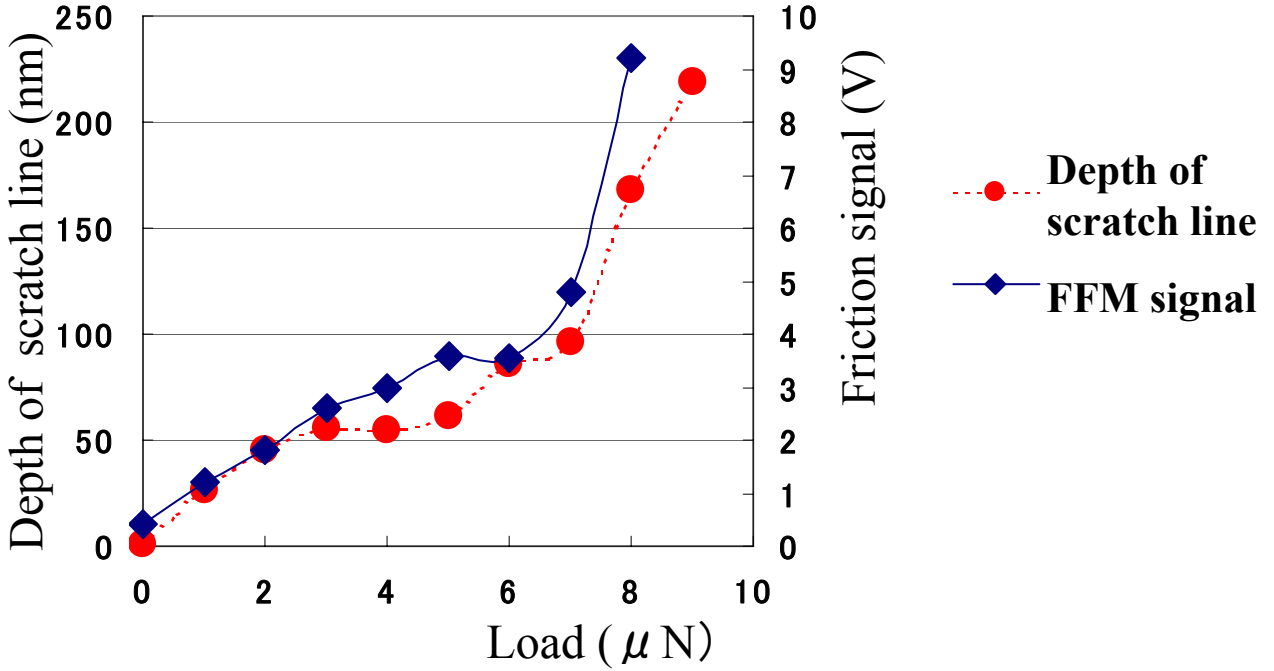


Fig.9 micro- and macro-scale friction coefficient

4. Results and Discussion(3)
Scratch depth and FFM signal in relative large load (～10 μN)





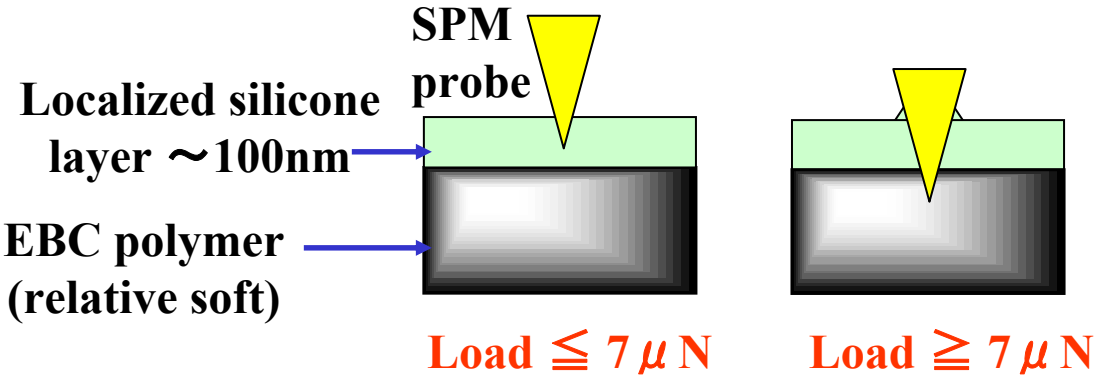


Fig.10 Scratch depth and FFM signal in relative large load (～10 μN)

At relative large load, frictional curve measurements produce scratch process.

FFM signal measurement : during scan

Scratch depth measurement : after scan

⇒ correspond to film structure

Summary

1 Micro-scale friction coefficients in relative small load (0～50nN) are quantitatively measured with frictional curve measurement.

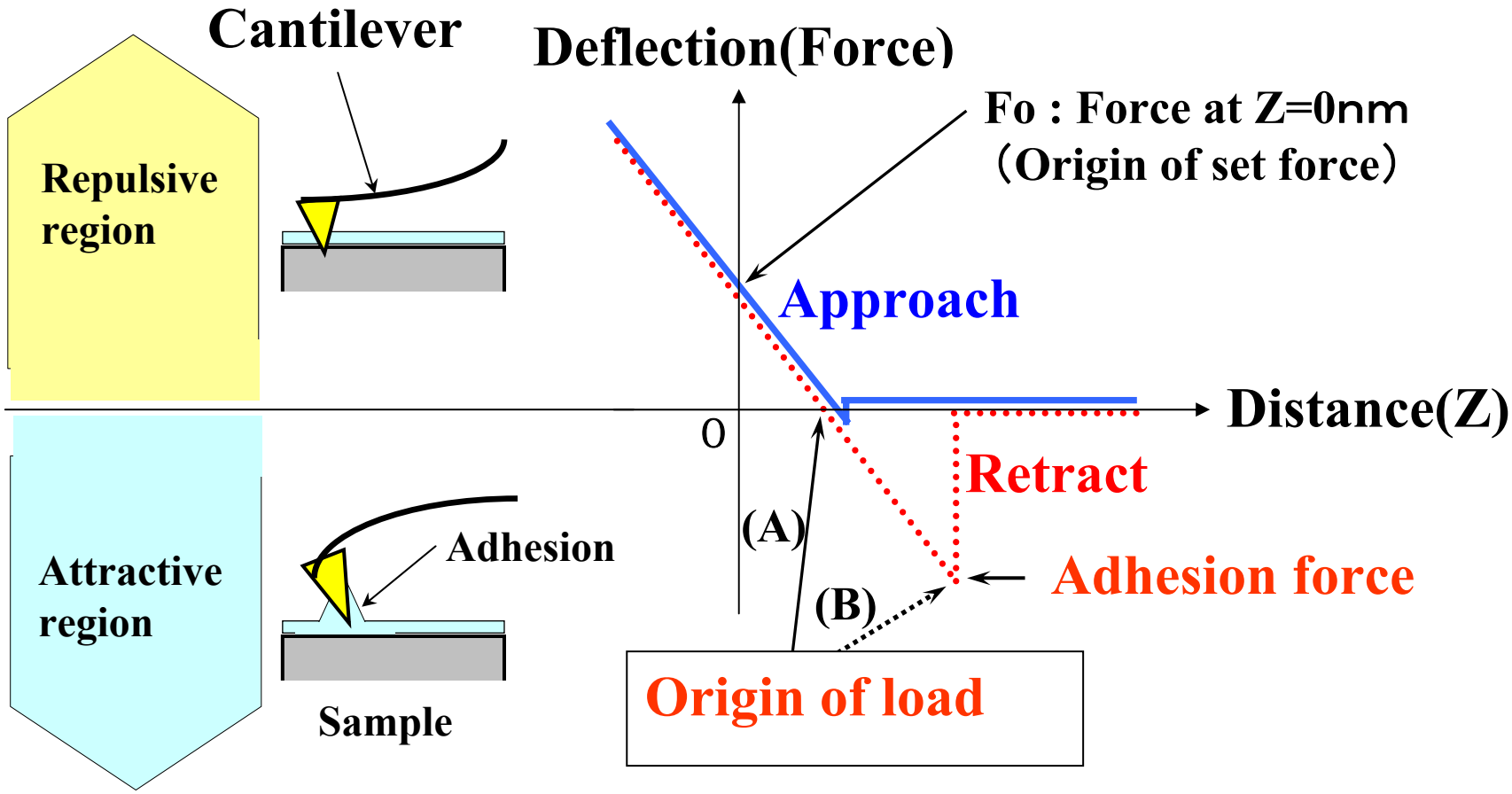
The inversely proportional relationship between micro-scale friction coefficient and Si dispersion ratio is successfully observed. This relationship is supported by macro-scale measurement.

2 The structural factor of thin film is successfully observed with FFM.

The relationship between scratch depth produced during FFM measurment and observed FFM signal in large load is demonstrated.

Frictional curve measurements in SPM is useful tool for quantitative analysis as micro-tribological tester.

Appendix 1 : Force curve and adhesion force



(A) Load = Set force + Fo
(B) Load = Set force + Fo +Adhesion force

Fig.11 Schematic representation of force curve

Appendix 2 : Transport FFM signal to friction force

Friction force Ft [N] and FFM signal FFM [V] are given by

$$Ft = Ct \times \Delta x, \quad FFM = S_{FFM} \times \Delta x$$

when Ct[N/m] : spring constant in torsion mode, S_{FFM}[V/m] : sensitivity in torsion mode, Δx : lateral displacement.

S_{FFM} is expressed below.

$$S_{FFM} = (G_{FFM} / G_{DIF}) \cdot (L/d) \cdot S_{DIF}$$

when S_{DIF} [V/m] : sensitivity in deflection mode (measurable), G_{FFM} / G_{DIF} : Gain of torsion / deflection mode decided by machine, L:lever length [m], d:tip length [m].

Friction force Ft is express to use S_{FFM},

$$Ft = Ct \times FFM / S_{FFM} .$$

To substitute $G_{DIF} = 2$, $G_{FFM} = 5$(known parameter for SPA400) for S_{FFM} and use practical unit,

$$Ft\ [nN] = 0.4 \times (d/L) \cdot Ct\ [N/m] \times FFM\ [mV] / S_{DIF}\ [mV/nm]$$

Appendix 3 : micro-scale friction coefficient in LB film/Si

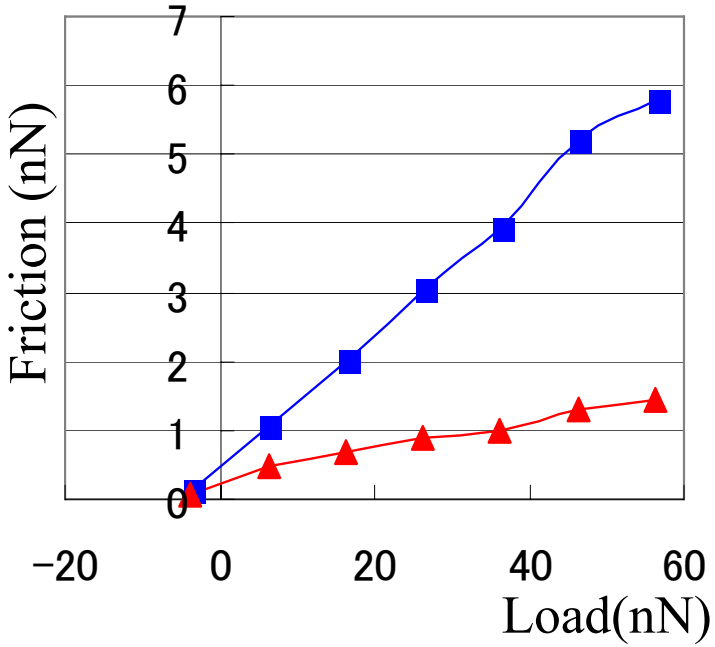


Fig.12 The correlation between load and friction

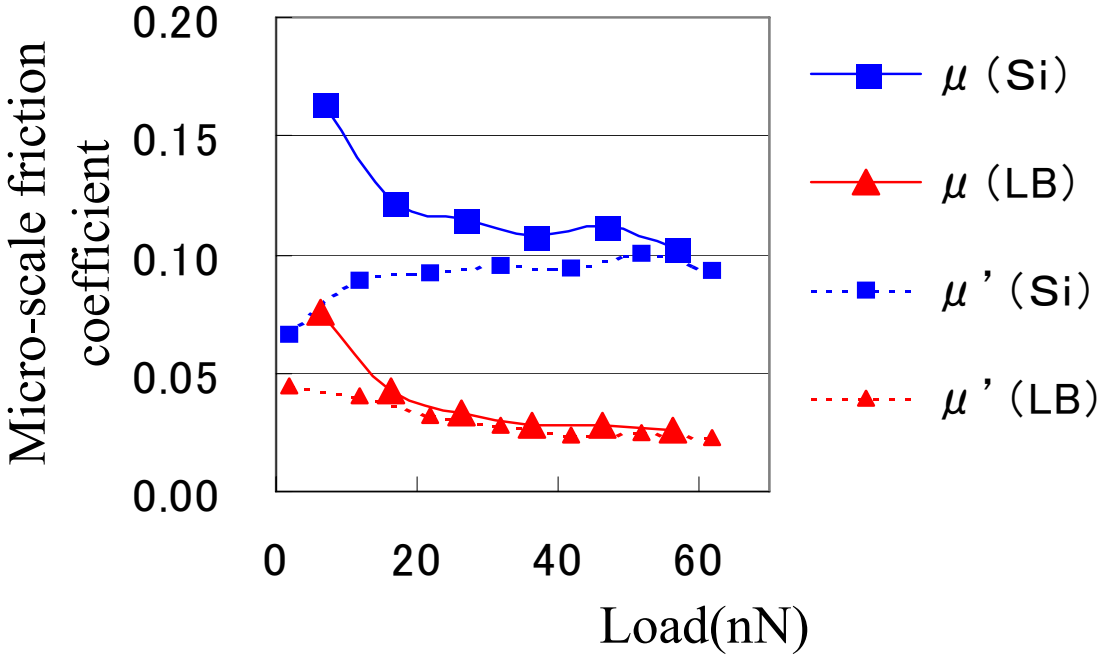


Fig.13 The correlation between load and micro-scale friction coefficient

micro-scale friction coefficient = friction / load

μ : (A) Load ≡ Set force + Fo

μ' : (B) Load ≡ Set force + Fo +Adhesion force

Both μ and μ' are very close at lager load escape from influence of adhesion.

LB film is more slippery than Si wafer.