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The analyses of a new three body friction model with multi-scale and adhesive effects in the micro-contact situation

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ABSTRACT

Adhesion and friction become more important than inertial force, when the volume of a micro-device is decreased. Particles, which come from wear or dust of environment, usnally exists at the contact surface within the MEMS, and these particles can make adhesion, friction and wear to occur at the contact region. In 2004 year, Bhushan et al.[1] builded a analysis model, which consider these effects, including plow, adhesion and deformation of peak of micro roughness. They indicated that the friction was consisted from adhesion, deformation of micro roughness peak at the situation of two body contact, and deformation produced from plow at three body wear condition. In 2005 year, the scale effect was added into their model [2] in the analyses of the contact deformation of two and three body frictions. However, the friction produced from the elastic-plastic deformation of roughness peak was not considered in their study, and the elastic-plastic deformation friction dominates most micro-contact behavior at a three body contact system. In our study, the friction analysis model was base on the analyses of Bhushan et al.[1-2] and the the other researchs [3-5]. In our study, a new analysis model of three body friction was builded by calculate the elastic, elastic-plastic and plastic micro-contact deformation areas based contact mechanics, and also consider the adhesive friction, roughness peak deformation friction, deformation friction of particles and ratchet friction including the scale effect at the contact region. The model was used to analyze the characteristic variation of surface friction, and can provide for the reference in the MEMS fabrication.

From our study, the particle sizes dominate the distribution of the friction coefficients, as shown in Fig. 1. In the front part of curves of the friction coefficients rapidly decreased and then gently varied with the dimensionless mean sepration(d/σ), and a translative point A existed at there. The position of A, the friction coefficient and friction (F_{total}) were decreased with the increasing particle size. In the large value of d/σ, forces and friction coefficient were not varied with the various particle sizes. The adhesion (F_s) was almost equal to the contact force ($F_{contact}$) after the position of the pull-off point B. Therefore, the particle size dominates the contact behavior at the front region, and the adhesion increases its influence at the region between A and B, and then the adhesion rule the contact function after the position of pull-off point B. The friction coefficient with various particle sizes were decreased with various diamensionless scale factors (L/L_{lwl}), as shown in Fig.2. The particle size affect the distribution of friction coefficient curves before the translation point B, and the various diamensionless scale factors (L/L_{lwl}) dominate the value of the friction coefficients.

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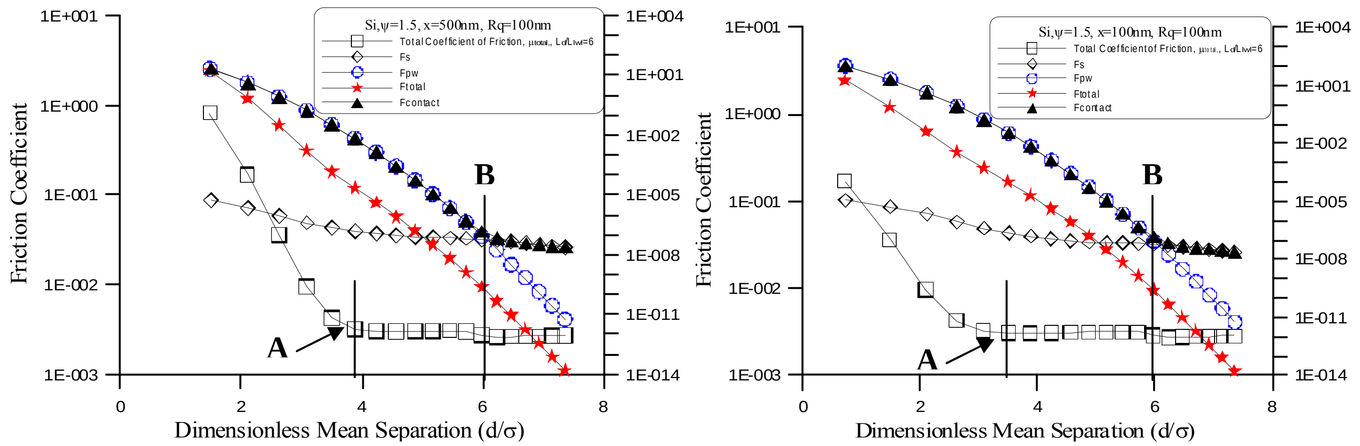
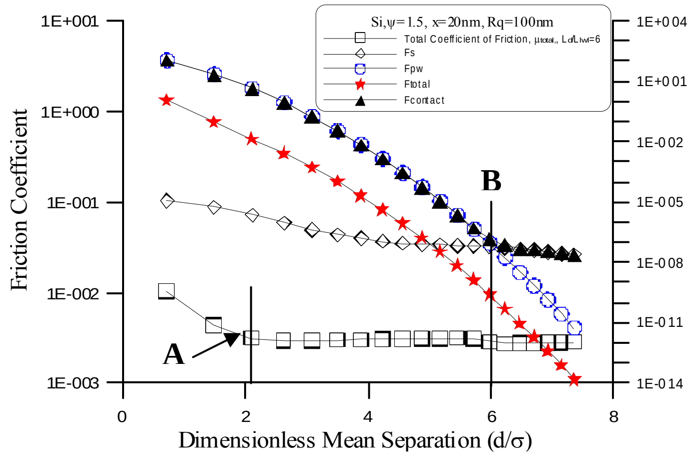


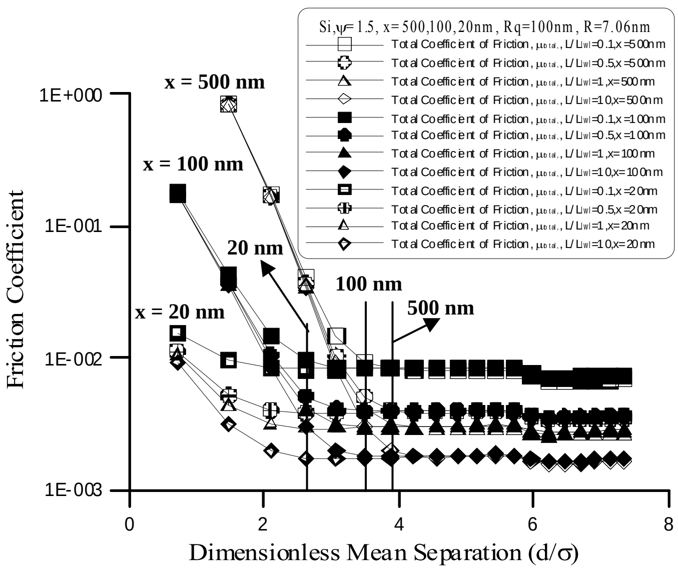
(a) (b)



(c)

F_s is the adhesion;
F_{pw} is the external force;
F_{total} is the total friction;
$F_{contact}$ is the contact force;
F_{pw} = Fcontact - Fs;
Friction coefficient = F_{total}/F_{pw}

Figure 1 Friction coefficient and forces relate to the dimensionless mean separation (d/σ) by various particle sizes (x); (a) x = 500 nm, (b) x = 100 nm, and (c) x = 20 nm.



L is the measure length;
Ψ is the plastic factor;
d is the Mean distance between two contact surfaces;
σ is the mean RMS roughness of the contact surface;
R is the peak radius;

Figure 2 Friction coefficients relate to the dimensionless mean separation (d/σ) by various long wavelength limit for roughness parameters (L_{lwl}) and particle sizes (x).