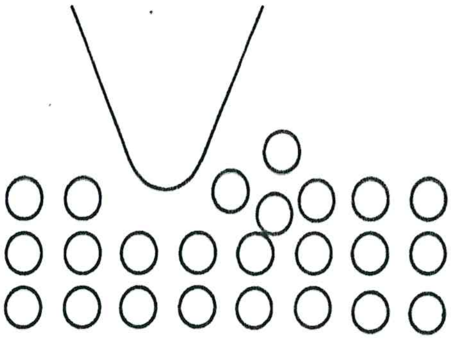

Abstracts

Fundamentals of Tribology and Bridging the Gap Between the Macro- and Micro/Nanoscales

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Influence of Applied Vibration on the Adhesion and Friction Between Nanometer Size Tip and the Surface

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We report evidence of possibility to control the adhesion of nanometer size solid bodies by applying the vibrations. The control of adhesion between the tip of atomic force microscope (AFM) and the surface was achieved by varying the amplitude and frequency of applied vibrations. Both AFM cantilever and/or surface vibrations enabled to reduce tip-surface adhesion to zero. This effect is of interest for application in micro- and nanomechanics.

Recent advance of microelectromechanical systems, micro and nanomechanics, and ongoing projects for molecular nanotechnology pose requirements for deeper understanding of such tribological processes as friction, adhesion, wear and lubrication, on the scale of nanometers and below. Much research work is being carried out in this direction recently. Besides other findings, the reduction of adhesion and friction force by ultrasonic sample surface vibrations were independently reported in the literature.

In this paper we report experimental evidence of possibility to control adhesion at nanometer contact area by applied vibrations of sample surface or cantilever. The theoretical model and simulation results are compared with experiment.

The experimental setup was based on the commercial AFM QScope-250 by Quesant Instr. Corp. The AFM was modified to enable the operation in dynamic mode, where the cantilever is vibrated by piezoceramic plate. V shaped silicon cantilever with spring constant of 0.24 N/m and fundamental resonant frequency 22.5 kHz was used. Cantilever had an integrated tip characterized by apex radius of 10 nm and length of 4 μm (as reported by manufacturers). Dynamic deflection of cantilever was monitored by AFM software and digital oscilloscope. Hot pressed alumina ceramics sample was used as a surface for investigation. Experiments were performed in ambient air, room conditions.

The control of adhesion was achieved by varying the frequency and amplitude of applied vibrations. The used frequency range was varied from 5 kHz up to 5 MHz and cantilever vibration amplitude from few nanometers up to hundreds of nanometers. Both surface and cantilever vibrations allowed to reduce tip-surface adhesion up to zero at selected frequencies.

The behavior of adhesion is strongly dependent on the frequency of applied vibrations. For the lower frequencies of vibrations, higher amplitudes are required to promote the reduction in adhesion. For example, vibrating the cantilever at 51 kHz, 7.5 nm amplitude was required to produce notable reduction in adhesion. Monitoring the ocilloscope traces of cantilever vibrations revealed that usually onset of chaotic cantilever vibrations due to nonlinear surface-tip interaction is observed at the point where adhesion vanishes. This suggests that the mechanism of adhesion reduction is the chaotization of cantilever motion and as a result an increase in average distance between cantilever tip and surface.

In conclusion, we demonstrated evidence of possibility to control the tribological behavior of solids on nanometer contact area by applied vibrations. By varying the frequency and amplitude of surface or cantilever vibrations, reduction of adhesion up to zero was achieved. The research results demonstrate the possibility to use high frequency vibrations to decrease the friction or avoid stick-slip between moving parts in micromachines.