Control Of Friction And Wear On The Nanometer Scale

E. Meyer, E. Gnecco, A. Socoliuc and O. Pfeiffer
Institute of Physics, Klingelbergstr. 82, CH-4056 Basel, Switzerland

The discussion about superlubricity or motion with ultralow friction has become a prominent issue during the last years. One of the scientifical and technological challenges is to enter this regime of ultralow friction. Several strategies may be applicable: (1) Incommensurate surfaces move across each other with small friction. Dienwiebel et al. [1] have observed that sheets of graphite can be oriented at different angles. In the incommensurate case a drastic reduction of friction is observed. (2) Sharp probing tips with small normal can be used to enter a regime of ultra-low friction by the control of the normal force. The work presented in this paper is focussed on friction force microscopy under ultrahigh vacuum (UHV) conditions, which is an ideal tool to investigate small contacts. The samples are prepared under UHV-conditions, where contaminants can be excluded. The normal force can be adjusted in the range from 0.1 to 100nN. Atomic-scale stick slip is observed on surfaces, such KBr(001) or NaCl(001). The velocity dependence of atomic-scale stick-slip shows a logarithmic increase [2,3]. This logarithmic increase can be interpreted in terms of the Tomlinson model, when thermal activitation is included. At lower speeds the number for thermal activation events is increased, which leads to a reduced average frictional force. Atomic-scale stick slip can also be observed on closed-packed surfaces, such as Cu(111). More open surfaces, such as Cu(100) are more difficult to be imaged, because wear is most often observed. The velocity dependent data can be used to determine microscopic parameters, such as the surface potential barrier height and the attempt frequency of this atomic sized contact. The dependence of friction as a function of normal force has been revisited recently [4]. For small applied normal forces, a transition from atomic-stick slip to smooth sliding with minimum dissipation is observed. The results are found to be in reasonable agreement with the Tomlinson model, which predicts that instabilities disappear below a certain threshold. It is observed that the lateral contact stiffness does depend only weakly on the normal force. The experimental results are compared with simulations, where different tip geometries are investigated. A further increase of the loading can lead to the observation of another transition into the wear regime. Nanometer-scale modifications are produced and monitored by force microscopy. Questions to be addressed are:

Is it possible to operate NEMS-devices with ultralow friction and negliglibe wear?

Can microscopic or macroscopic bodies be moved without friction and wear?

Another area of research to be discussed are the development of force sensors with sensitivities in the attonewton range. Applications are the magnetic resonance force microscope (MRFM) with its ability to detect small numbers of electron or nuclear spins. The vision of MRFM is to perform chemical analysis on the nanometer-scale. Competitive methods are combinations of time-of-flight mass spectroscopy and force microscopy, which require novel developments in microfabrication [6].

References

[1] M. Dienwiebel et al., *Phys. Rev. Lett.* 92, 126101 (2004).
[2] E. Gnecco et al., *Phys. Rev. Lett.* 88, 215501 (2002).
[3] E. Riedo et al., Phys. Rev. Lett. 91, 084502 (2003).
[4] A. Socoliuc et al., *Phys. Rev. Lett.* 92, 134301(2004).
[5] O. Pfeiffer et al., *Phys. Rev. B* 65, 161403R (2002).
[6] D.W.. Lee, A. Wetzel, R. Bennewitz, E. Meyer, M. Despont, P. Vettiger, C. Gerber ,*Appl. Phys. Lett.* 84, 1558 (2004).