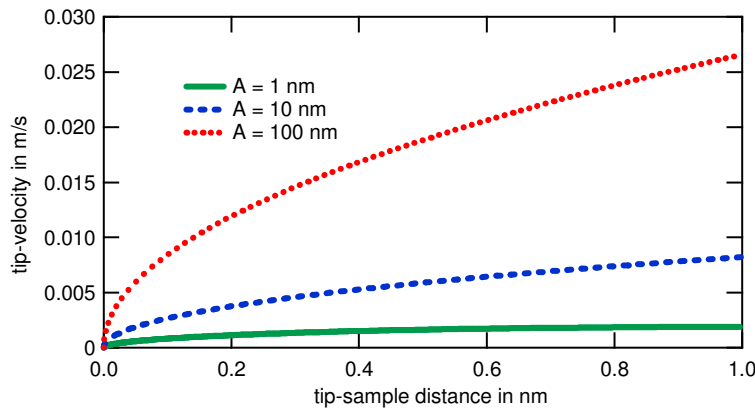


Velocity Dependence of the Energy Dissipation in Dynamic Force Microscopy

A. Schirmeisen, D. Weiner, H. Hölscher, H. Fuchs
CeNTech (Center for Nanotechnology), University of Münster
Münster, Germany

Dynamic force microscopy (DFM) in ultrahigh vacuum (UHV) is a powerful tool to measure conservative as well as dissipative tip-sample interactions with atomic resolution. During the last years a considerable dispute has arisen, as to what the underlying physical mechanisms are for the observed energy dissipation. Atomic instabilities, electric damping mechanisms and feedback artifacts have been argued to govern the dissipation. Motivated by macroscopic viscous damping models most authors introduce a velocity dependent friction model.

$$F_{diss}(z, \dot{z}) = \gamma(z) \cdot \dot{z}$$



This assumption, however, results into amplitude dependent energy dissipation. As shown in the left graph the velocity of the tip varies significantly with the oscillation amplitude. Consequently, the variation of this parameter can be used to study the validity of a velocity dependent friction model.

In order to investigate this widely used prediction we performed spectroscopy experiments with a variable temperature AFM in UHV. Two different cases are investigated: First, a silicon tip is approached towards a clean graphite (HOPG) surface, where short-range forces dominate the tip-sample interaction. Secondly, we investigate the energy dissipation of a voltage biased metallic tip on a clean gold surface, where long-range electrostatic forces are important. In both cases, a series of spectroscopy experiments acquired with different oscillation amplitudes allows us extract the velocity dependence of the dynamic friction coefficient. In the short-range case, the velocity dependence is negligible and the viscous damping model is not valid. Therefore, we will argue that hysteretic mechanisms based on atomic instabilities govern the short-range energy dissipation on HOPG. On the other hand, in the regime of long-range electrostatic interactions on metallic surfaces, the velocity dependence of the friction coefficient can be clearly observed. A model based on fluctuating electromagnetic fields is believed to govern this case of non-contact energy dissipation.