Final report of the research visit to Prof. Ernst Meyer's Group,
Basel University, Switzerland
within the ESF activity entitled "Nanotribology"

Title of proposed research:

Measurement of lateral forces in dynamic mode

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Duration of visit: From August 22nd, 2005 to October 30th, 2005 (10 weeks)

Lateral forces play an important role in friction studies as well as molecular and atomic manipulation. Non contact atomic force microscope is a fascination scanning probe technique that provides excellent tools for exploring these interesting effects.
Dynamic mode nc-AFM with small oscillation amplitude reveals itself to be a very promising, since the intrinsic sensibility to the short – range forces is increased, and combination of scanning tunneling microscopy and nc-AFM could be a unique tool.

During my visit to Prof. Ernst Meyer’s Group in Basel university, I have used a home-built combined tunneling and force microscope operating at room temperature in ultra high vacuum UHV (Fig. 1 and 2).

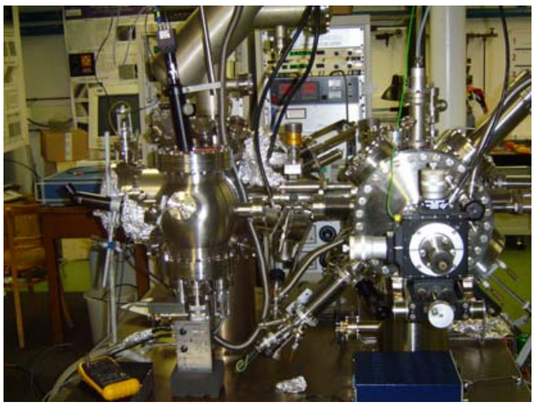


Fig. 1) Picture of the room temperature UHV system

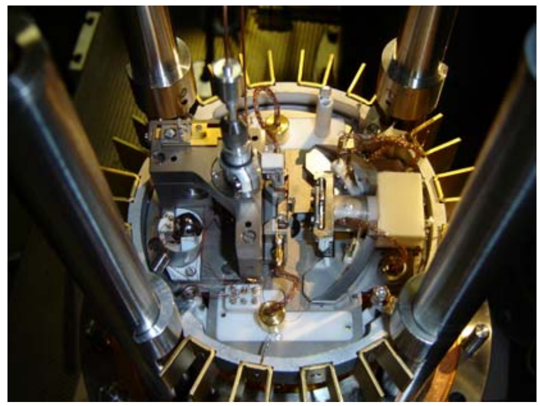
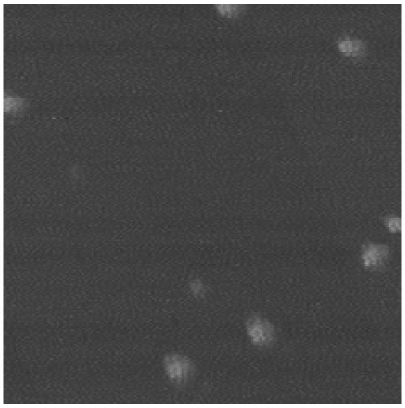


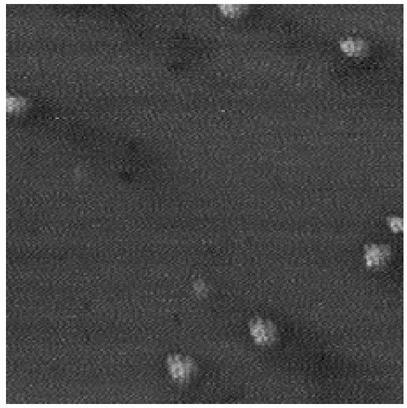
Fig. 2) Picture of the microscope

Commercially available rectangular conductive silicon cantilevers with an integrated tip. The deformation of the cantilever is detected via the deflection of a light beam reflected from the rear side of the cantilever. a four quadrant photodiode is employed to detect both bending and torsional deflections. In order to prevent the tip from jumping into contact with the surface due to the strong force gradients likely to develop at tunneling distances, relatively stiff cantilevers with a bending force constant k_n=43 N/m are used.
The eigenfrequency f_0 of the fundamental normal and torsional resonance frequency of the cantilevers are typically around 135 kHz and between 1 MHz and 3 MHz respectively, and the torsional force constant being about $k_t \approx 53000$ N/m.
the position of the reflected light beam is sensed by a negatively biased low-capacitance photodiode. The currents from the four quadrants are converted to voltages by fast operation amplifiers which are positioned a few millimeters from the photodiode. To circumvent heating problems in vacuum, the amplifiers are operated at low voltage. The photodiode and the current-to-voltage converter are mounted on a UHV compatible sapphire circuit board. Directly outside the vacuum chamber the voltage signal is again amplified to compensate the capacitive load of the output cable. Actual eigenfrequencies of the cantilever oscillation up to 3 MHz are detected by a digital phase-locked loop with a resolution of 10 mHz. A sinusoidal signal with the same frequency is used to excite the torsional oscillation by means of a piezoactuator. The actuator mainly shakes the cantilever holder in the normal direction, however the high quality factor and the tuning to the actual eigenfrequency the torsional oscillation can also be excited effectively .

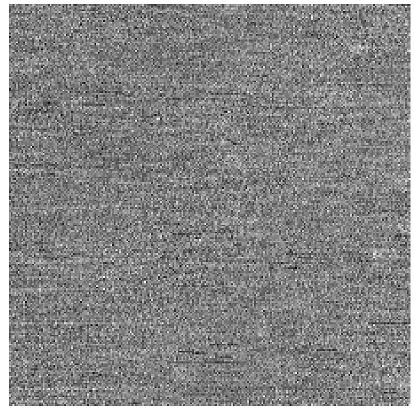
The amplitude of excitation is controlled so as to always maintain a constant amplitude of the tip oscillation.
During my visit, I mainly contributed to the imaging of Cu-tetra-3,5 di-tertiarybutyl-phenyl porphyrin (Cu-TBPP) molecules on Cu (100) in normal and torsional modes, which are required attempts toward measuring lateral forces in manipulation of Cu-TBPP on Cu (100). The results are as follows:



Topography



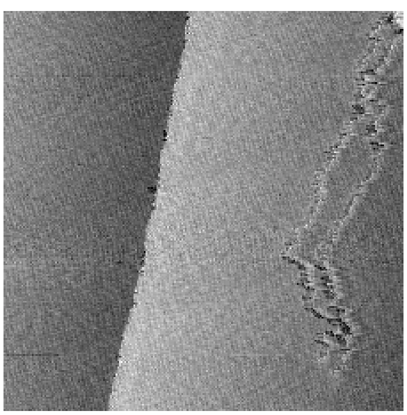
df signal



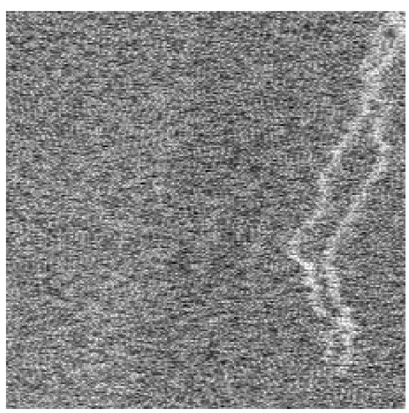
damping

Cu-TBPP on Cu(100): feedback on Tunnel current (normal oscillation mode)

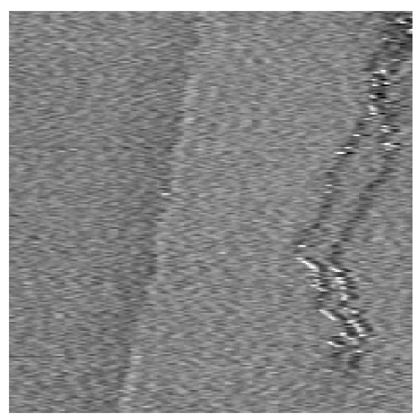
Image size=50 nm^2 Amplitude=0.120 (value between 0 to 1) V_{bias}=1V



Topography



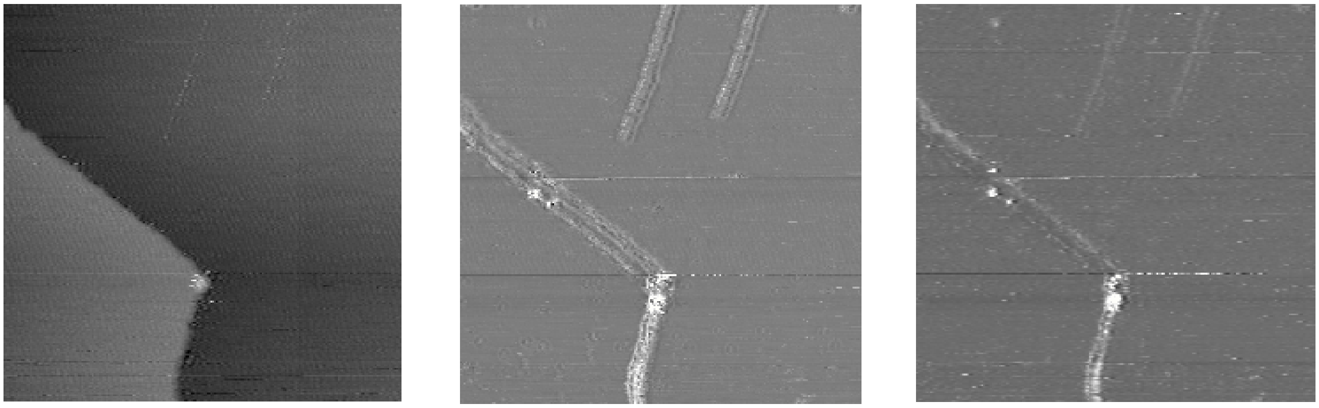
df signal



damping

Cu-TBPP on Cu(100): feedback on Tunnel current (normal oscillation mode)

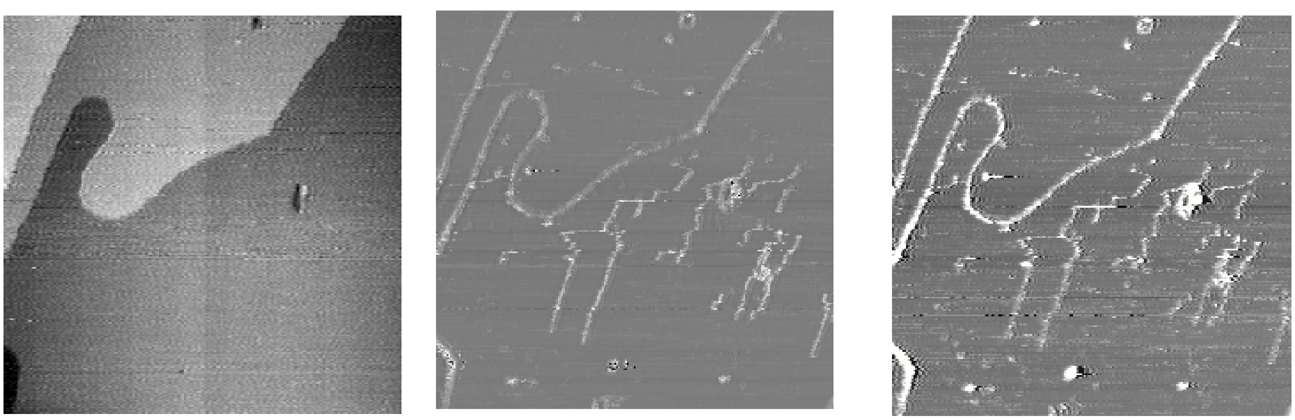
Image size=90 nm^2 Amplitude=0.060 (value between 0 to 1) V_{bias}=1.06V



Topography df signal damping

Cu-TBPP on Cu(100): feedback on Tunnel current (Torsional oscillation mode)

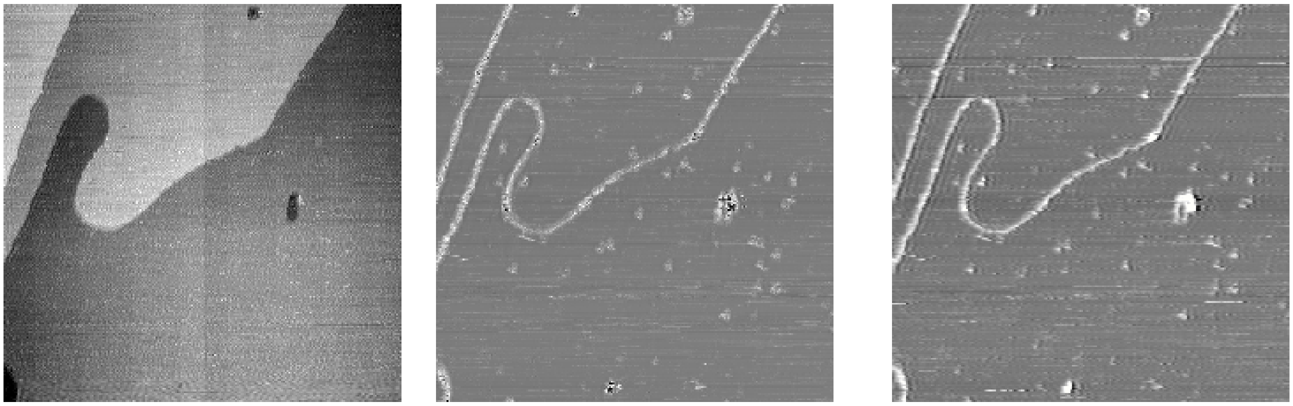
Image size=100 nm^2 Amplitude=0.02 (value between 0 to 1) V_{bias}= 0.6V



Topography df signal damping

Cu-TBPP on Cu(100): feedback on Tunnel current (Torsional oscillation mode)

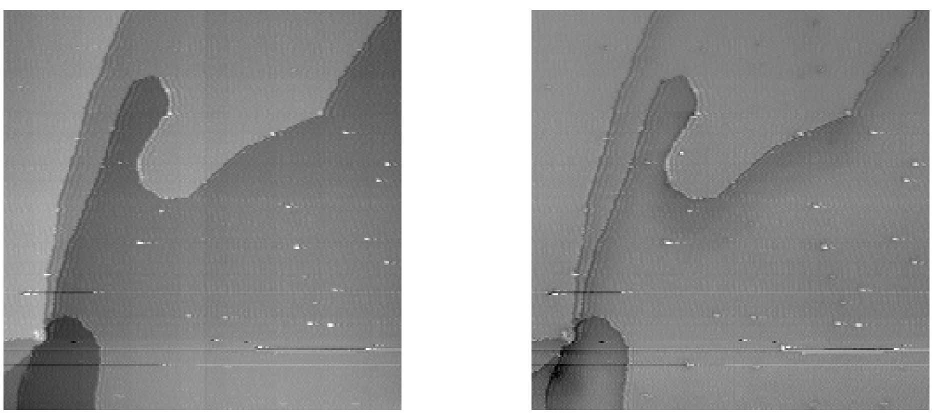
Image size=250 nm^2 Amplitude=0.01 (value between 0 to 1) V_{bias}= -1V



Topography df signal damping

Cu-TBPP on Cu(100): feedback on Tunnel current (Torsional oscillation mode)

Image size=250 nm^2 Amplitude=0.003 (value between 0 to 1) V_{bias}= 0.6V



Topography df signal

Cu-TBPP on Cu(100): feedback on Tunnel current (Normal oscillation mode)

Image size=250 nm^2 Amplitude=0.11 (value between 0 to 1) V_{bias}= 1V