Übungen zur Oberflächenphysik

Blatt 6 - 07.05.2013

Preparation: Please read chapters 2.5 – 3.2 of *Scanning tunneling microscopy in Surface Science* from Peter Sutter (part 15 of the book "Science of Microscopy", available from http://www.springerlink.com/content/978-0-387-25296-4#section=329973&page=1&locus=0 – only with a Unibas IP address, e. g. from VPN).

1) Bias-dependent STM imaging

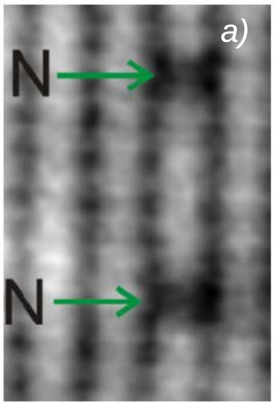
a) Explain the origin of the high-resolution image contrast on the Si(001) 2x1 surface for negative and positive sample bias (see link above).

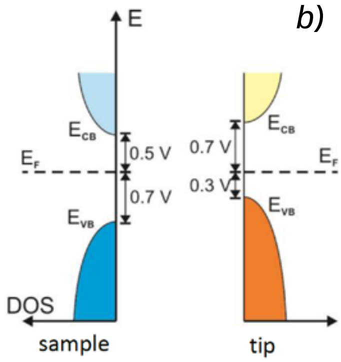
b) The image to the right shows a GaAs(110) surface with two single N atoms in the topmost layer, acquired at a sample bias of -4.9 V. Explain what can be seen as bright dots and why the N atoms appear as dark spots.

Note: please consider both electronic contrast – Ga is a group III atom, N and As are group V – and topographic contrast – an N atom with its bonds is much smaller than a Ga or As atom.

c) Imagine a semiconducting tip and a semiconducting sample with band gaps as sketched to the right. Which sample bias must be applied in order to image

i) empty states of the sample and
ii) filled states of the sample?





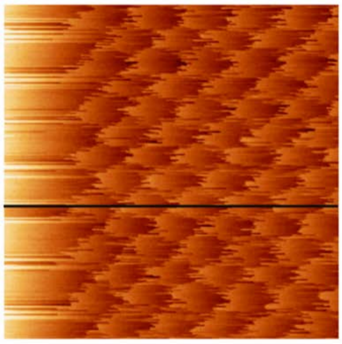
2) STM and AFM

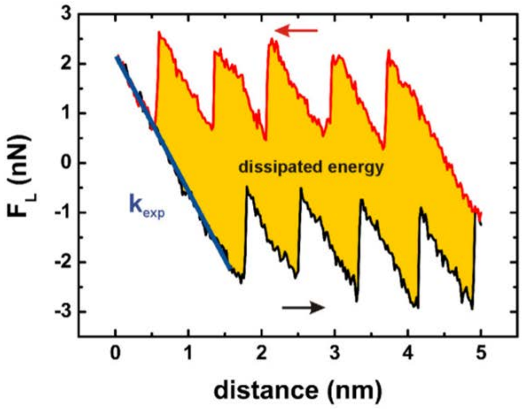
Explain the differences between scanning tunneling microscopy and atomic force microscopy. Please concentrate on the following questions:

- Which additional elements are required for an atomic force microscope?
- Why is atomic force microscopy so popular, although scanning tunneling microscopy reaches the better spatial resolution? The different modes for data acquisition should be explained focusing on the properties deduced.

3) Friction Force Microscopy

A sharp tip slides on a KBr surface (lattice constant a = 0.66 nm) driven by a flexible rectangular cantilever. The tip experiences a stick-slip motion as shown in the measurement below. The cantilever has a normal spring constant $k_N = 0.11$ N/m and a lateral spring constant $k_L = 31$ N/m.





a) Determine the experimental spring constant k_{exp} and the maximal lateral force F_L^{max}.

b) What is the peak-to-peak amplitude ("corrugation") of the tip-surface interaction potential?

c) Estimate the value of "friction parameter" η.

4) Dynamic force microscopy

We would like to use a tip with a normal spring constant of $k_N = 0.11$ N/m and a resonance frequency of $f_0 = 9.853$ kHz to acquire images in non contact mode.

a) Assuming that the oscillation amplitude is much smaller than the interaction length, which force gradient would correspond to a frequency shift $\Delta f = -1$ Hz?

b) A colleague suggests that we use a stiffer cantilever with k = 30 N/m and $f_0 = 123$ kHz. Which frequency shift would we measure at the same distance from the surface following her/his advice?

c) Estimate the masses of both cantilevers from their resonance frequencies.

5) Kelvin Probe Force Microscopy

a) Derive the formula for the force measured by Kelvin Probe Force Microscopy between the AFM tip and sample surface. The energy of the capacitor is $E = (1/2)CV^2$.

b) On a graphite surface we measure a CPD of -200mV (applied to the sample, cantilever grounded) with a PtIr coated cantilever (work function Φ = 4.3eV). Determine the work function of the sample and explain why it is important to know where the bias voltage is applied to (cantilever or sample).