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Akiyama-Probe (A-Probe) guide

This guide presents: what is Akiyama-Probe, how it works, and its performance.

Akiyama-Probe is a patented technology.

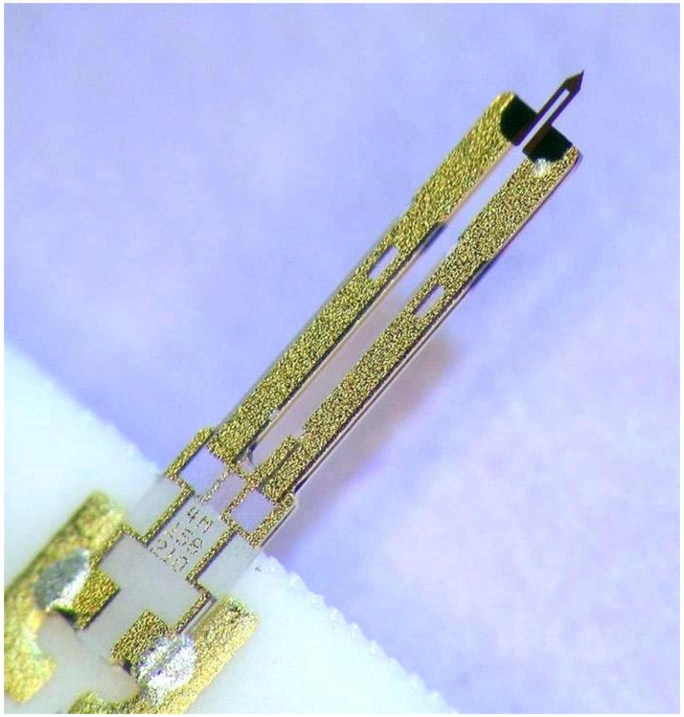
Version: 2009-03-23

Introduction

NANOSENSORS™ Akiyama-Probe (A-Probe) is a novel self-sensing and self-actuating (-exciting) probe based on a quartz tuning fork combined with a micromachined cantilever for dynamic mode AFM.

The great advantage of this novel probe is that one can benefit from both the tuning fork's extremely stable oscillation and the silicon cantilever's reasonable spring constant with one probe. Akiyama-Probe is equipped with a high-end sharp silicon tip and has an excellent imaging capability on various samples with different properties, which is as high as a conventional optical lever system.

Akiyama-Probe requires neither optical detection, nor external shaker. Akiyama-Probe occupies only a small space above the sample. These features make it very attractive for creating new generation SPM instruments.



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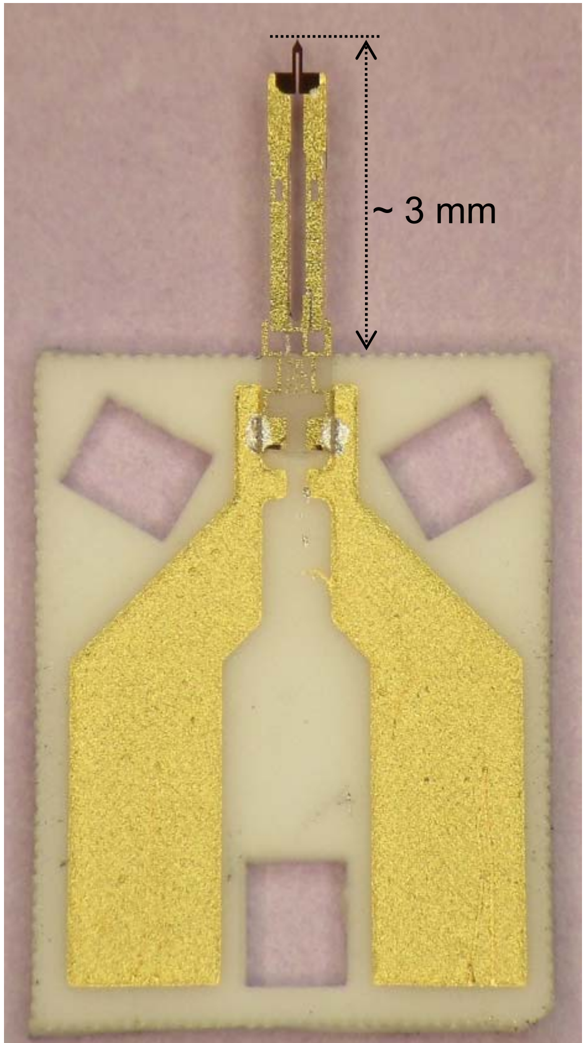
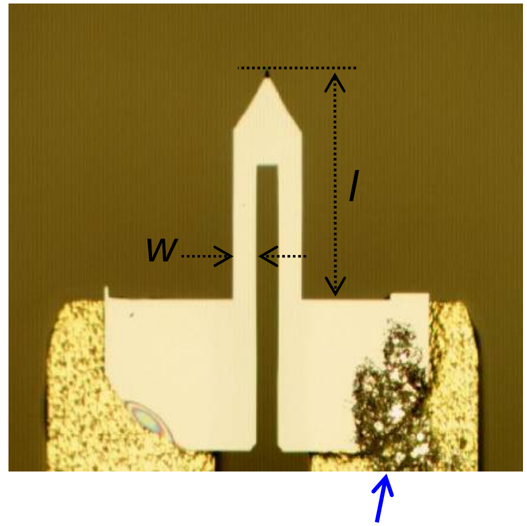
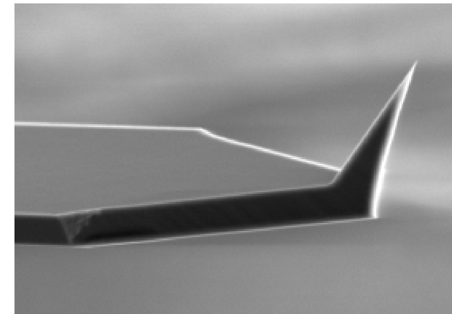
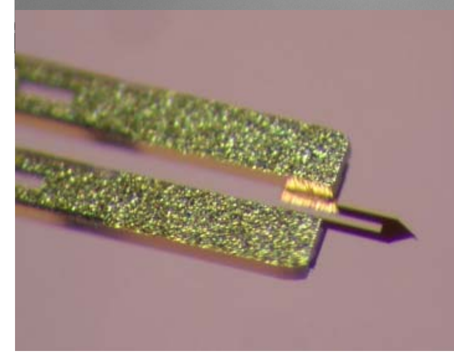
Akiyama-Probe specifications





The cantilever is electrically connected to one of the electrodes of the TF.





Specifications (typical values)

Cantilever	length: 310 µm, thickness: 3.7 µm, width: 30 µm each material: n^+ silicon (0.01 - 0.025 Ohm•cm)
Tip	AdvancedTEC™-like tip radius <15 nm, tip height 28 µm
Force constant	5 N/m (Si cantilever)
Resonance frequency	~ 50 kHz
Ceramic plate	approximately 6.5 mm x 5.1 mm x 0.4 mm

All values are subject to change without notice.

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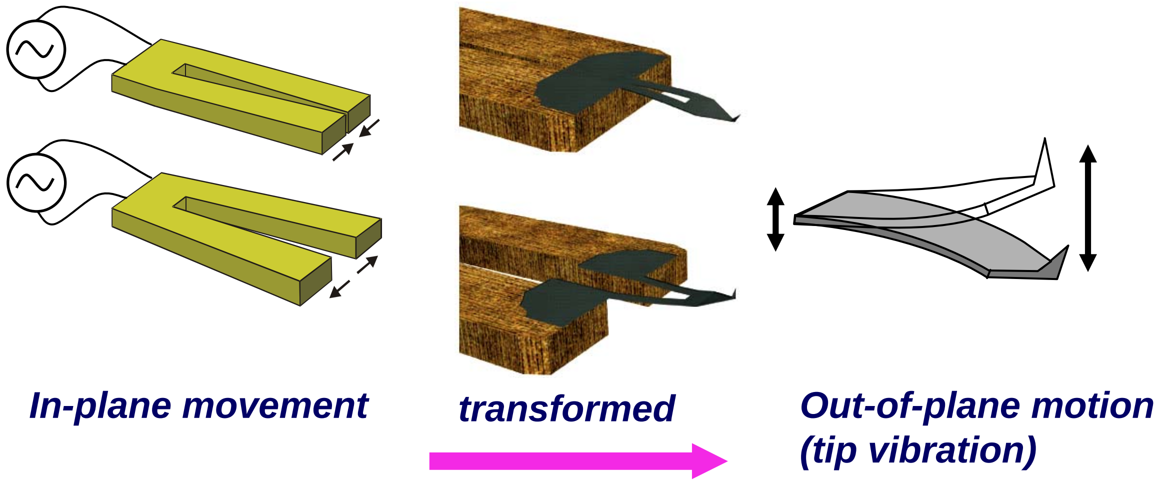
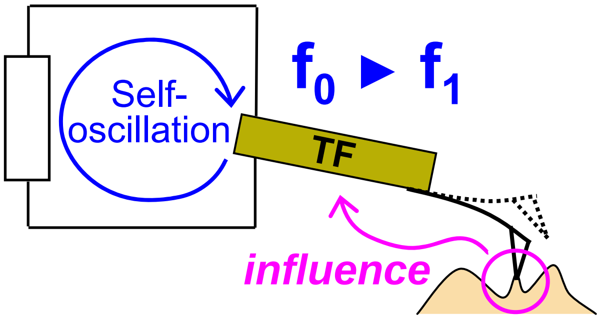
Working principle (1)



In operation, the electrical driving signal is directly applied to the electrodes of the tuning fork (TF) to excite it at its lowest resonance. In this mode, the ends of the two prongs are moving in-plane and have opposite phases, meaning that they approach and withdraw from each other. The vibration amplitude is typically in the order of tens of nm. This motion applies a small vibration at the glued ends of the cantilever, which always contains a component in z-direction (i.e., the axis of the tip) due to the twisting motion of the prongs (i.e., the cantilever disturbs a symmetry of the TF). The cantilever amplifies the vibration according to its mechanical property and a large out-of-plane motion of the tip is obtained.

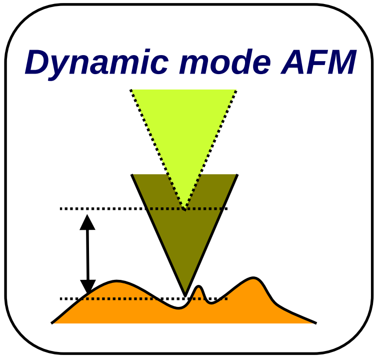
Working principle (2)

The TF is used as an oscillatory force sensor similarly to a quartz microbalance. Its frequency and amplitude are influenced by those of the tip motion. Consequently, the tip-sample interaction can be electrically detected with the TF.



The recommended operation mode for Akiyama-Probe is dynamic mode with the frequency modulation (FM) detection, where the TF is self-excited (oscillating) at its first resonance frequency.

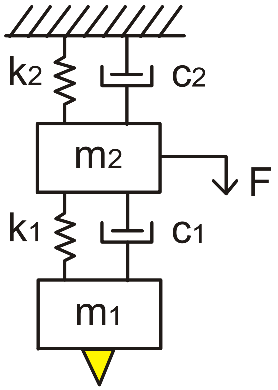
During sample imaging, the resonance frequency is tracked by a phase locked loop (PLL) and kept at a set value by adjusting the tip-sample distance with a feedback loop.

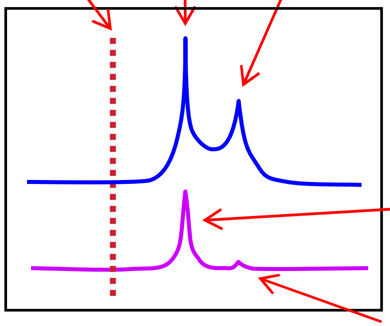


The amplitude modulation (AM) detection (fixed driving frequency) is also feasible, if one would accept a slower scan speed and compromise on spatial resolution.

Akiyama-Probe is designed for operation in ambient conditions. It may work in other conditions, like vacuum, UHV, or low temperatures, etc.

Working principle (3)

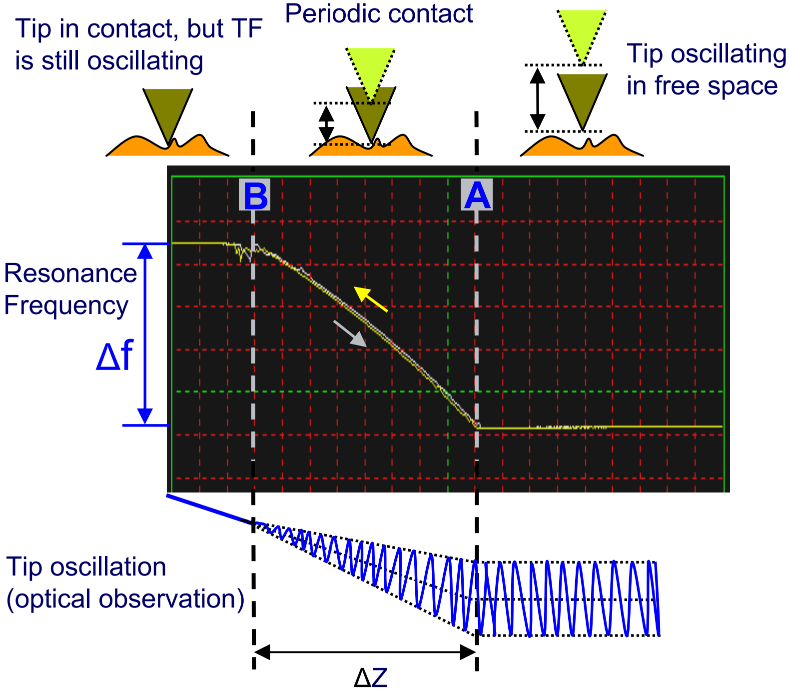




Akiyama-Probe is a system with two coupled resonators that are moderately matched in terms of resonance frequency. The left figure illustrates a simplified model of Akiyama-Probe, where the cantilever corresponds to Resonator 1 (m1, k1 , c1) and the TF to Resonator 2 (m2, k2 , c2). F is the driving force created by the piezoelectric effect of the TF.

Like with other similar systems, one obtains two typical resonances: in-phase (1st) and anti-phase (2nd) peaks. By sweeping the driving frequency, the two large vibration peaks can be observed at the tip by optical means. In the electrical signal from the TF, one observes a large peak at the 1st resonance and a small, or almost none, peak at the 2nd resonance. The large peak at the 1st resonance is the operation frequency of Akiyama-Probe.

Approach curve



The figure shows a typical approach curve of Akiyama-Probe. The dashed line "A" indicates the critical point where the tip starts periodic contact on the sample surface. Beyond this point, the resonance frequency increases almost linearly as the tip is moved closer to the sample surface in the periodic contact region. Oscillation amplitude of the tip decreases linearly and the center of the vibration is shifted in this region (i.e., illustration at the bottom of the figure).

The end of the periodic contact region is indicated by the dashed line "B". Beyond this point, the probe works in a "quasi" contact mode, i.e., the tip remains in contact with the surface during the full oscillation cycle, whereas the cantilever is still vibrated by the TF.

The maximum frequency shift obtained in the periodic contact region (denoted as Δf) is a specific and constant value for each probe. The distance ΔZ is about a half of the peak-to-peak amplitude of the tip oscillation in free space.

Approach curves

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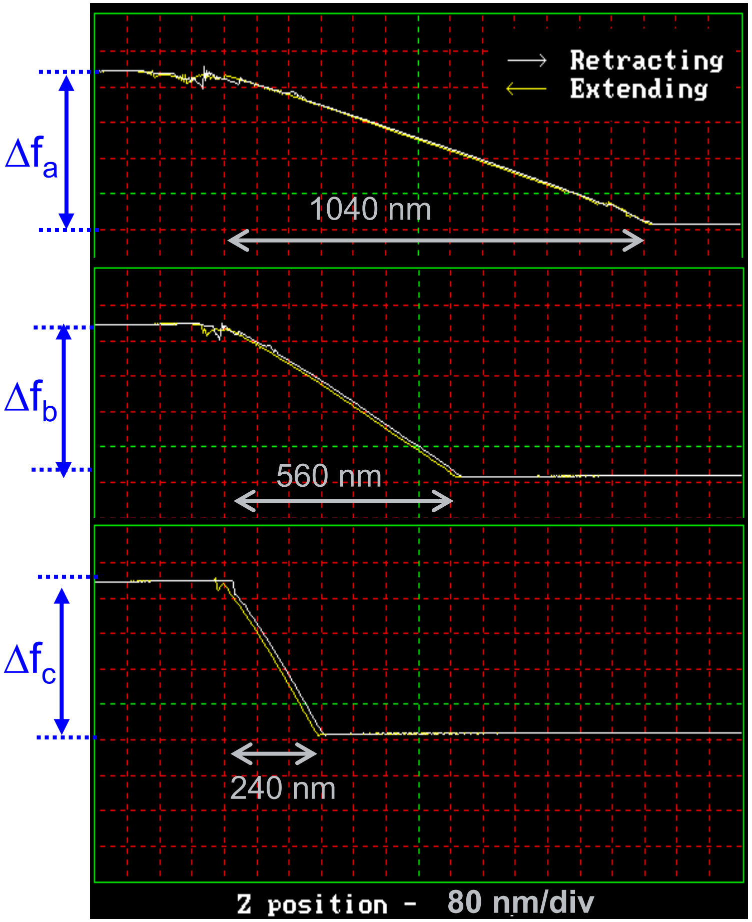
One of the important features of Akiyama-Probe is that the maximum frequency shift Δf does not depend on the tip vibration amplitude. The figure shows three approach curves with different amplitude settings. It demonstrates $\Delta f_a = \Delta f_b = \Delta f_c$.

The sensitivity defined as the maximum frequency shift divided by the amount of tip displacement in the periodic contact region differs for each setting of the tip vibration amplitude. The sensitivity is increased as the tip vibration amplitude is decreased.

The range of Δf is approximately 30 Hz ~ 400 Hz. This is not guaranteed and subject to change without notice. Δf varies depending on temperature and humidity.



Long range approach curve

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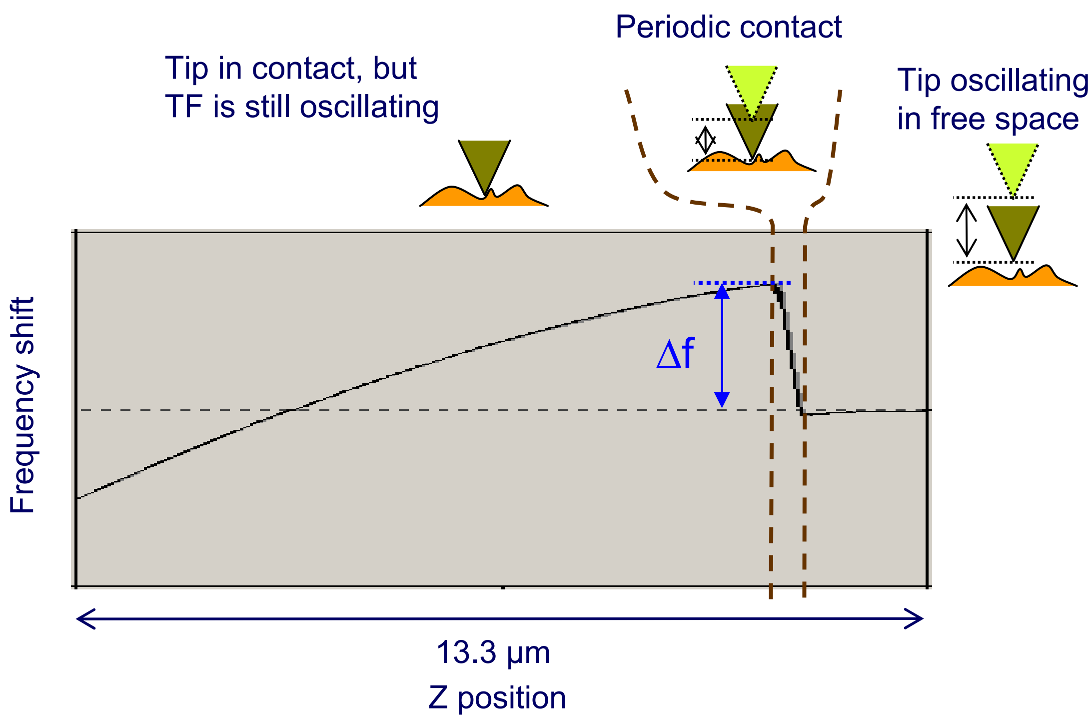

The figure shows a long range approach curve. The resonance frequency of the TF decreases gradually in the region of the “quasi” static mode. This region lies over a couple of tens µm in z-direction. Although Akiyama-Probe operated in this mode could be used for e.g. measuring displacement, the tip is strongly pushed onto the sample surface and, hence, operation in this mode is not recommended for AFM imaging.

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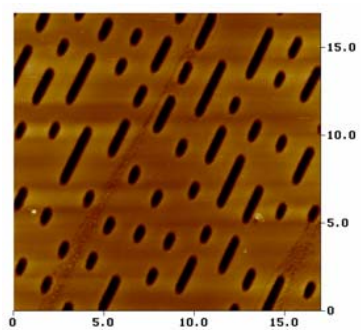
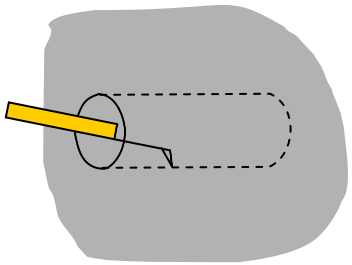
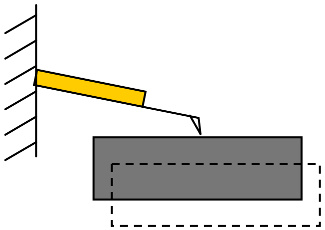
Applications



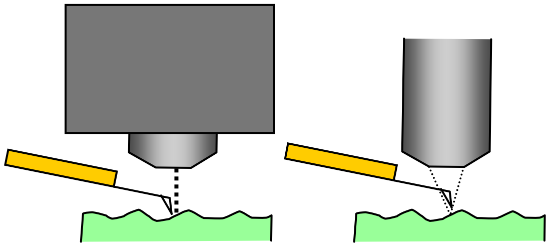
AFM imaging
(topography, roughness)



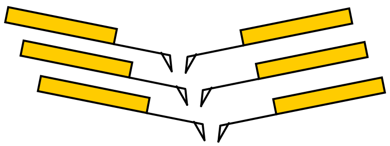
Measurement inside
of channel



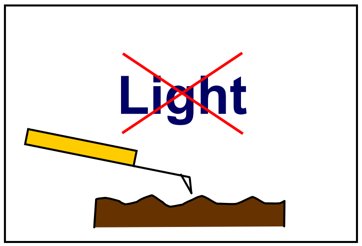
Displacement
measurement



Combination with SEM/
optical microscope



Multi-probe



AFM imaging of light
sensitive samples

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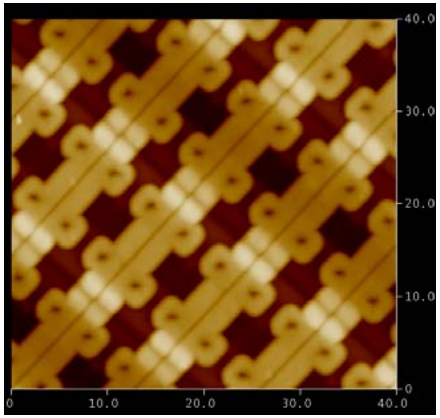
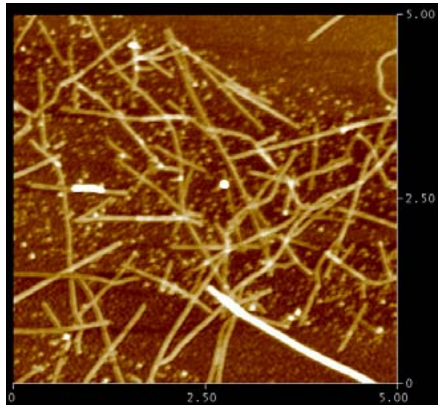
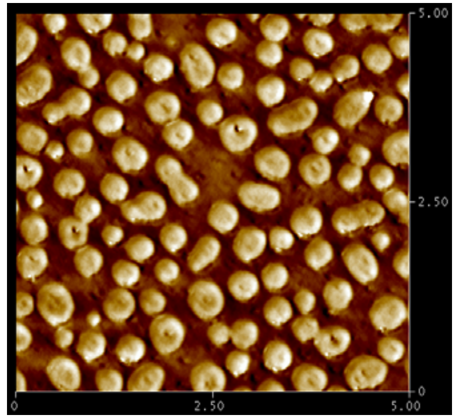
AFM images with Akiyama-Probe



IC chip (40 μm x 40 μm)



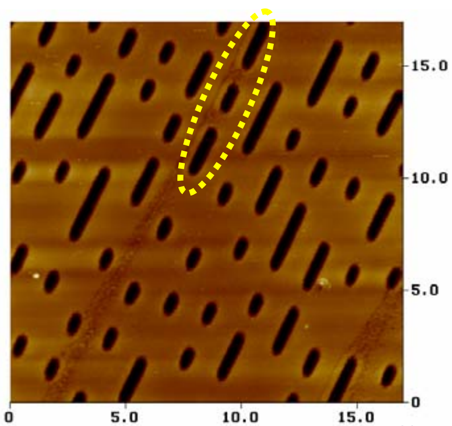
Carbon nanotube (5 μm x 5 μm)



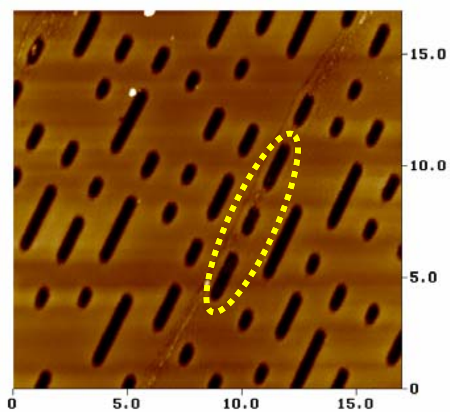
PS/PMMA film (5 μm x 5 μm)

Samples from Nanosurf AG.

Akiyama-Probe vs. Optical lever



Akiyama-Probe



Std. 40 N/m Si lever
Tapping mode

on Veeco Nanoscope III, with Nanosurf easyPLL, by IMT Univ. of Neuchâtel Switzerland

Akiyama-Probe in SEM

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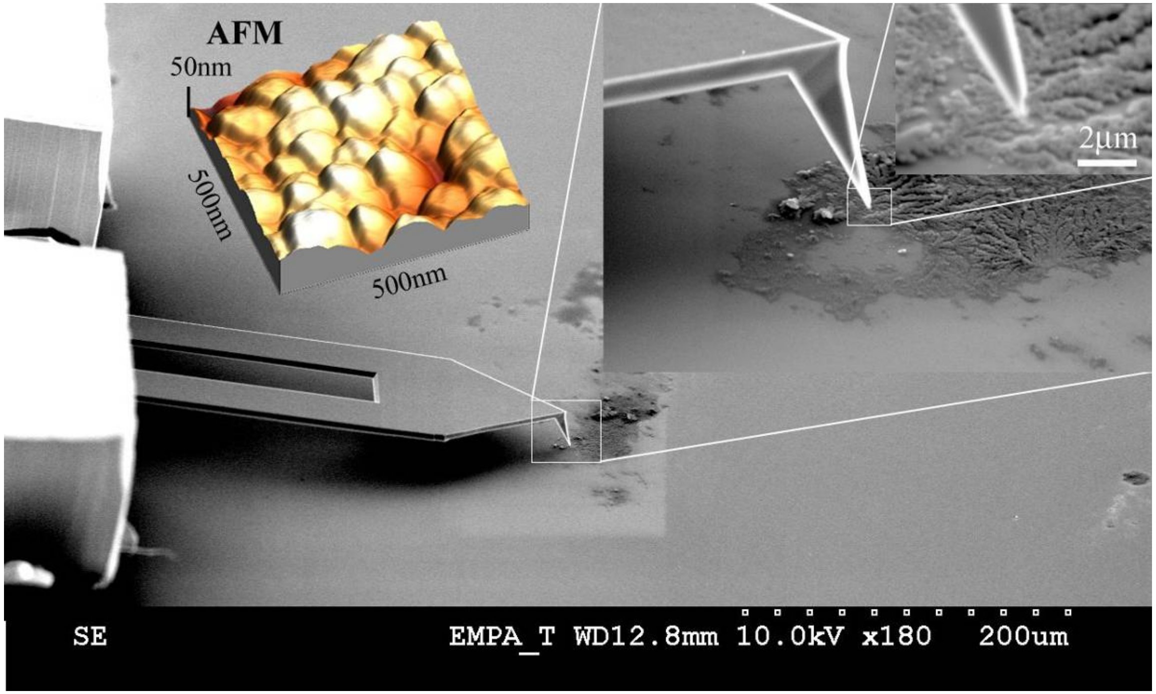

EMPA Switzerland

Dr. Vinzenz Friedli, “Focused electron- and ion-beam induced processes : in situ monitoring, analysis and modeling,” disseration EPFL, no 4036 (2008).

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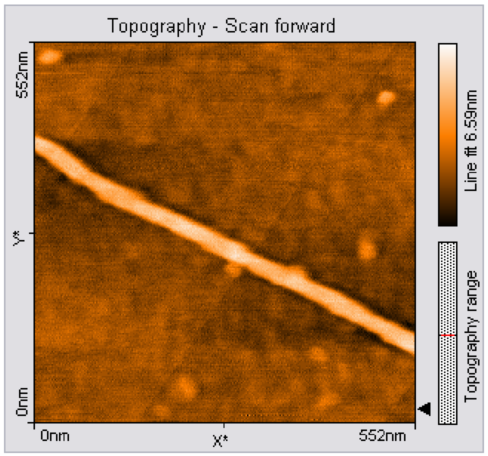
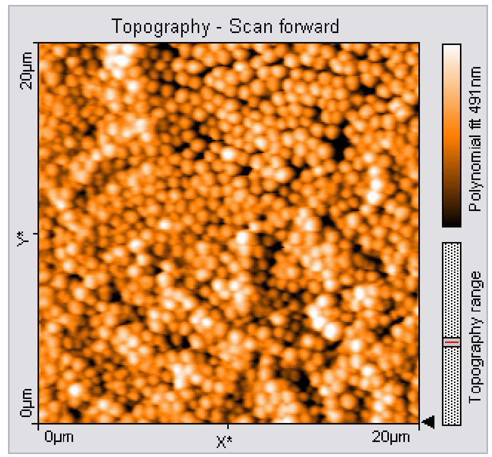
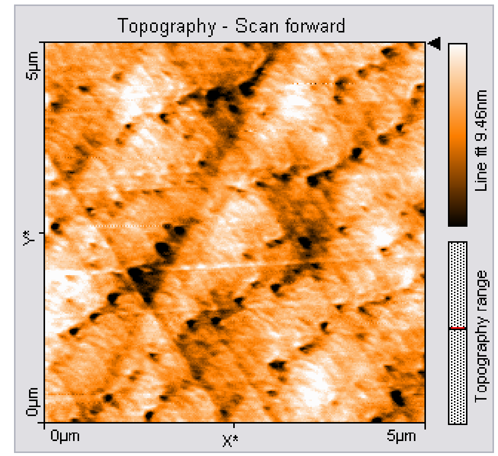
AFM images



Carbon nanotube



Staphylococcus aureus bacteria



Atomic steps on PbSnSe etch pits

Topographic images taken under ambient conditions in intermittent contact mode using Akiyama-Probe with *Nanosurf Nanite A100 A-Probe AFM*

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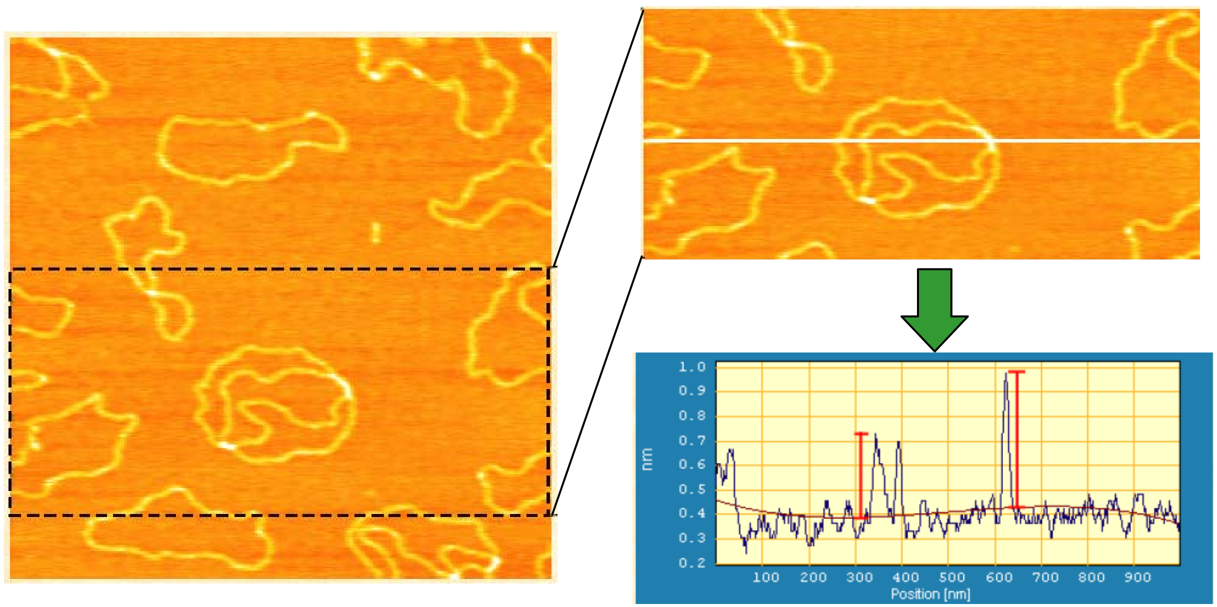
AFM image

Plasmid-DNA (2,686 bp)



Scan Size : 1x1 µm

Topographic images taken under ambient conditions in intermittent contact mode using Akiyama-Probe with *: SXM Standard (Research Institute of Biomolecule Metrology Co., Ltd., Japan)*

THANK YOU FOR YOUR INTEREST

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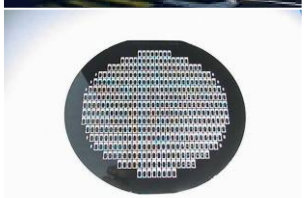


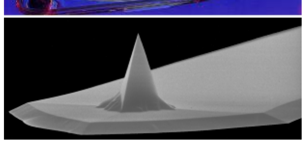

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