CONDUCTIVE ATOMIC FORCE MICROSCOPY OF DELICATE NANOSTRUCTURES IN TORSIONAL RESONANCE MODE

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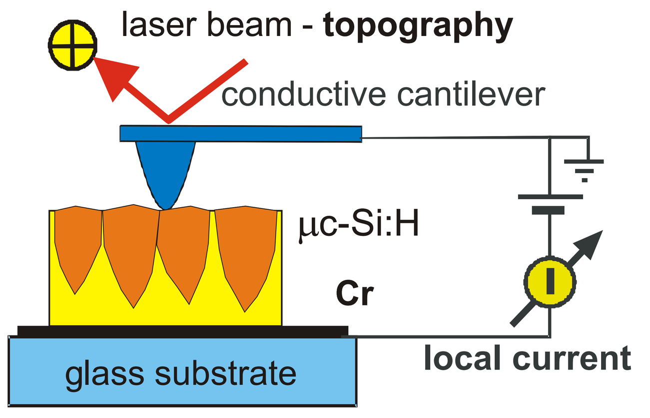
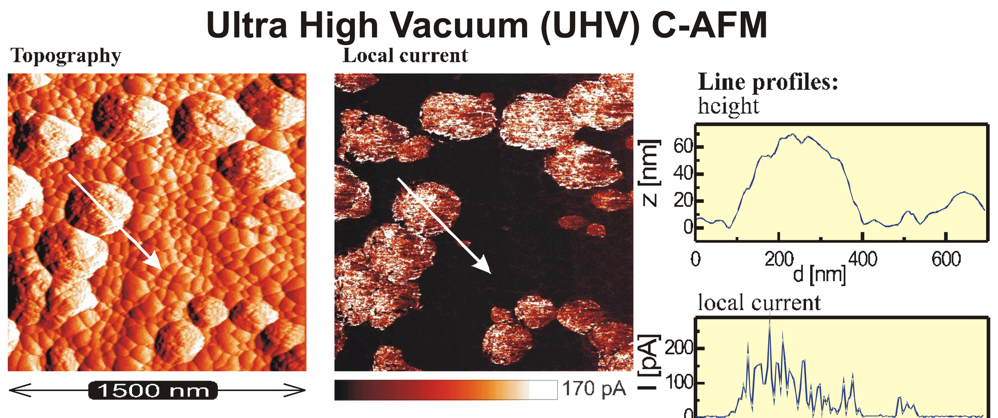
Conductive Atomic Force Microscopy (C-AFM)



C-AFM uses a nanoscopic electrically grounded probe (conductive cantilever), which scans the surface of an actively biased sample. While the tip scans the surface in contact mode (measuring of the topography), one can measure local current in each point of the scan at the same time, obtaining the map of local electric properties of the sample.

Ultra High Vacuum (UHV) C-AFM

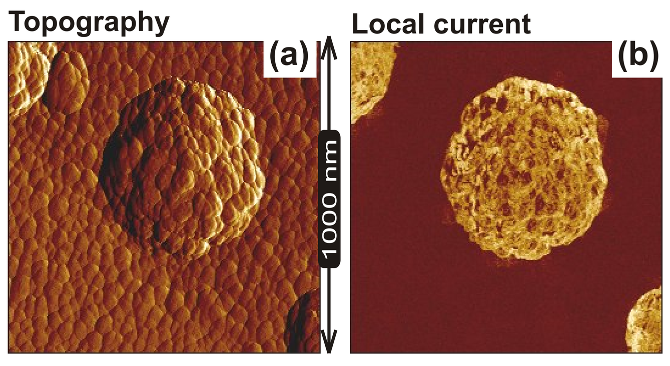


B. Rezek et al, ApplPhysLett 74 (1999) 1475

Advantages:
- clean surface
- high tunneling currents

Disadvantages:
- expensive maintenance
- time consuming

Ambient C-AFM

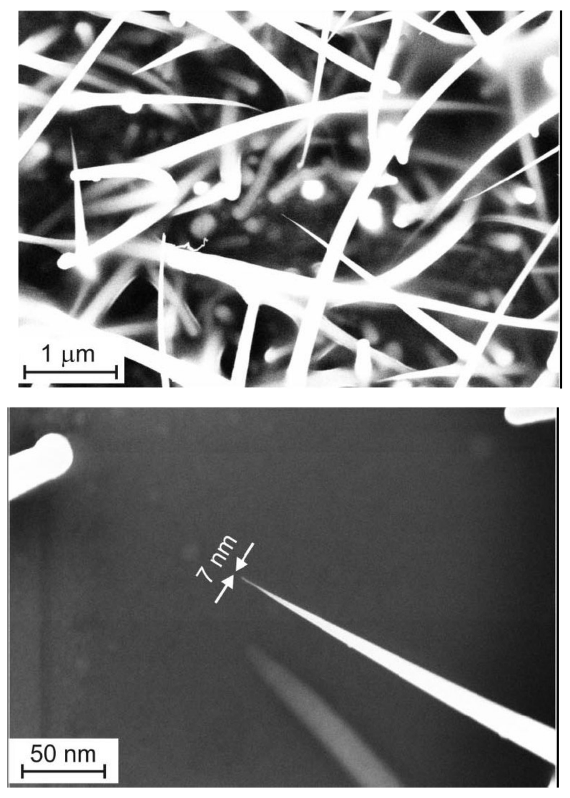


T. Mates et al., J. Non-Crystalline Solids, 352 (2006) 1011.

Advantages:
- fast technique
- easy

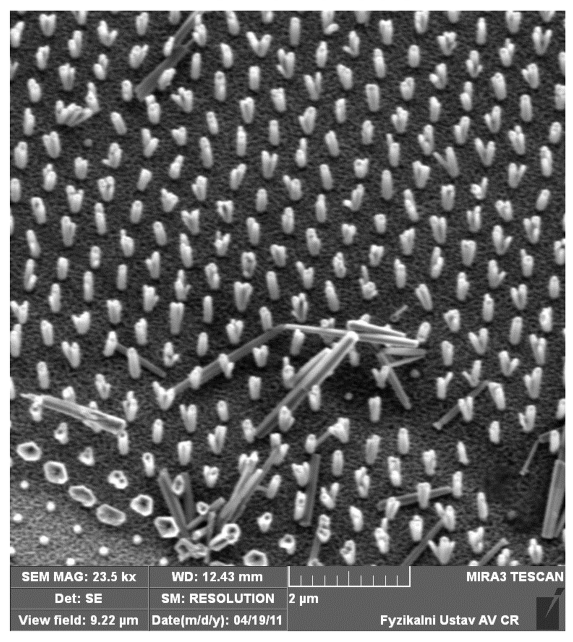
Disadvantages:
- native oxide layer
- condensed water layer

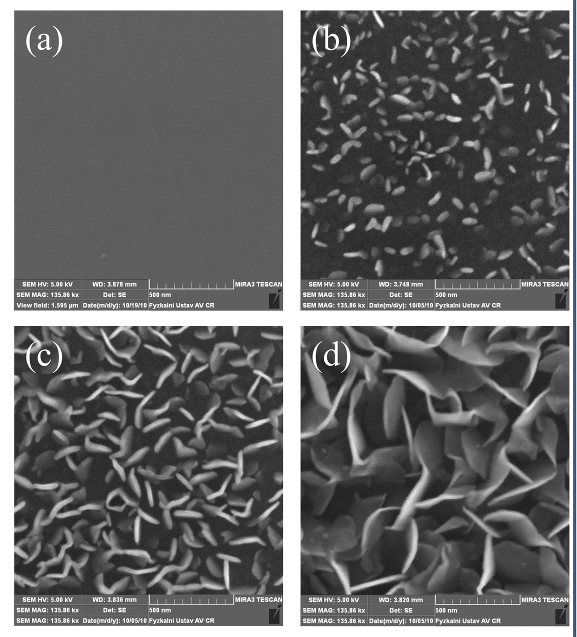
Semiconductor nanostructures



Silicon nanowires

ZnO nanorods



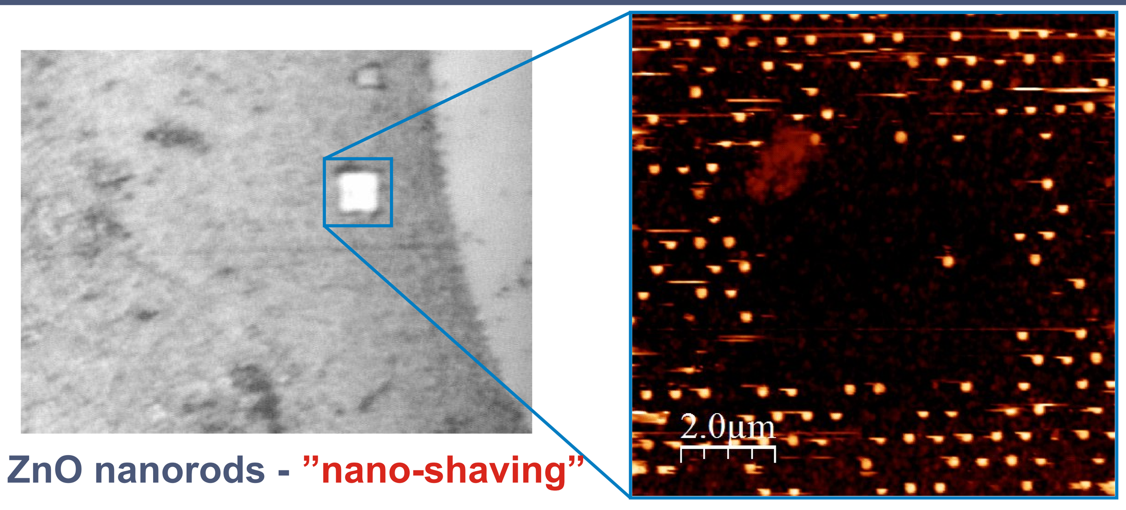


Carbon nanowalls

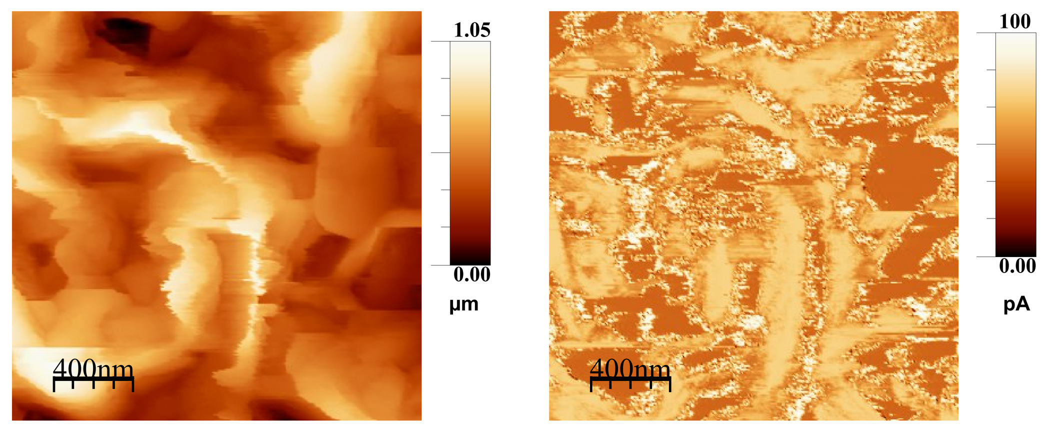
Restrictions of the contact mode

Common C-AFM technique requires scan of a sample in contact mode with applied normal force about 10-1000 nN, which may be too high for delicate samples, such as silicon nanowires, ZnO nanorods, carbon nanowalls etc.

Silicon nanowires - no image!

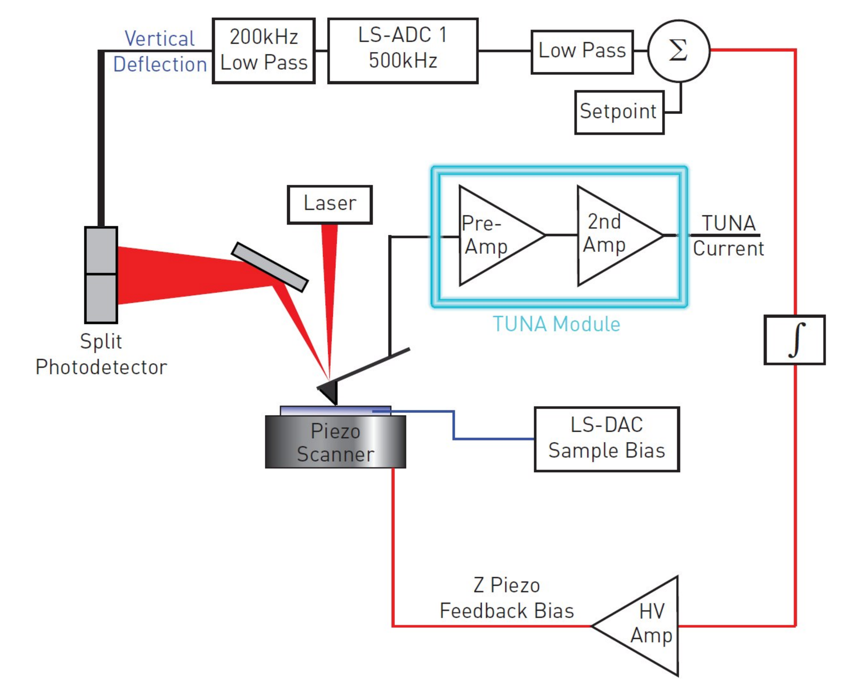


ZnO nanorods - "nano-shaving"



Height Carbon nanowalls Local current

Torsion Resonance Mode



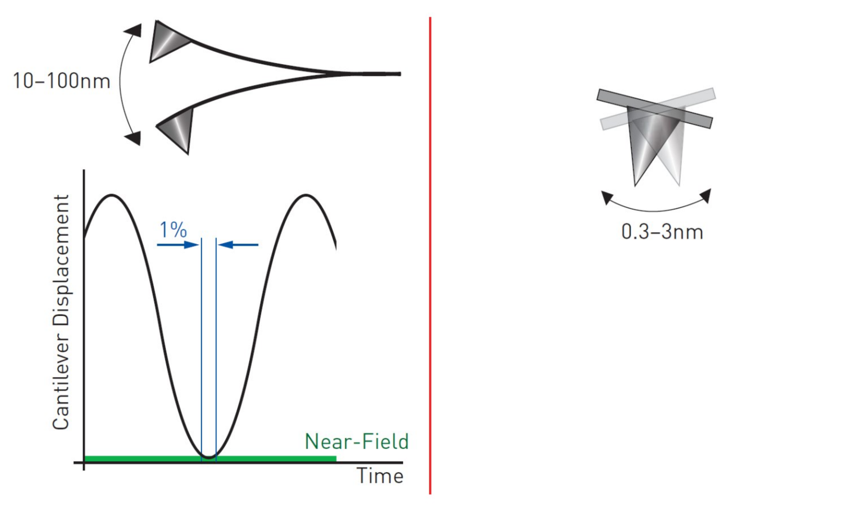


Figure 2. The tip is in close proximity to the sample for approximately 1% of the oscillation cycle when using standard Tapping Mode. In comparison the tip can be in close proximity to the surface all of the time when using Torsional Resonance Mode with small oscillation amplitudes

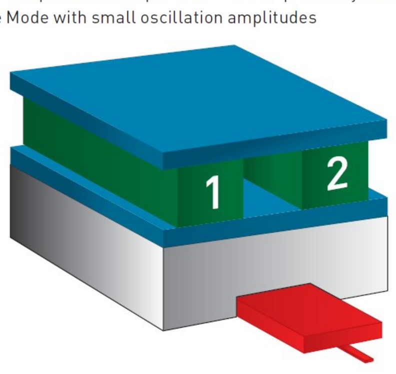


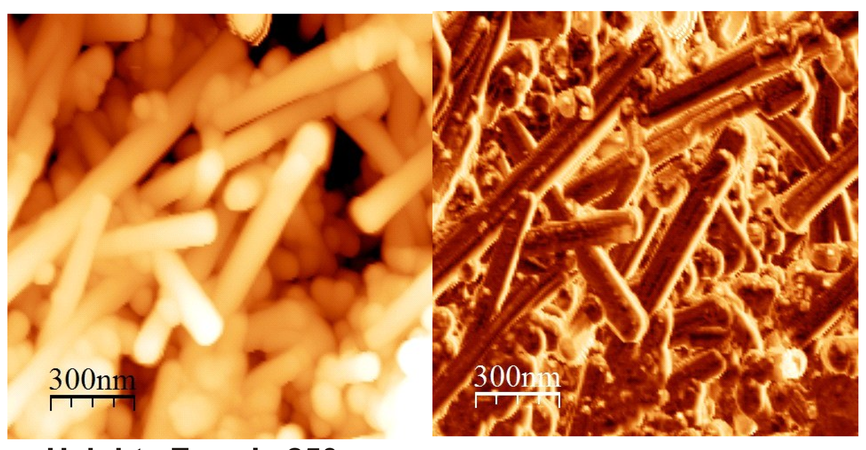
Figure 3. The TR probe holder employs two parallel actuators using drive signals of opposite phase.

Electrical testing of soft delicate samples using Torsional Resonance Mode and TUNA

by: Peter Harris, Lin Huang, Chanmin Su. Veeco Instruments

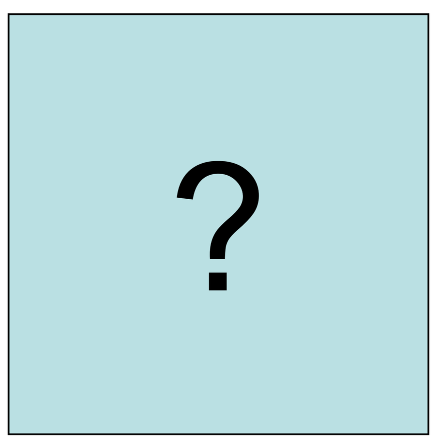
Si nanowires & ZnO nanorods

Silicon nanowires



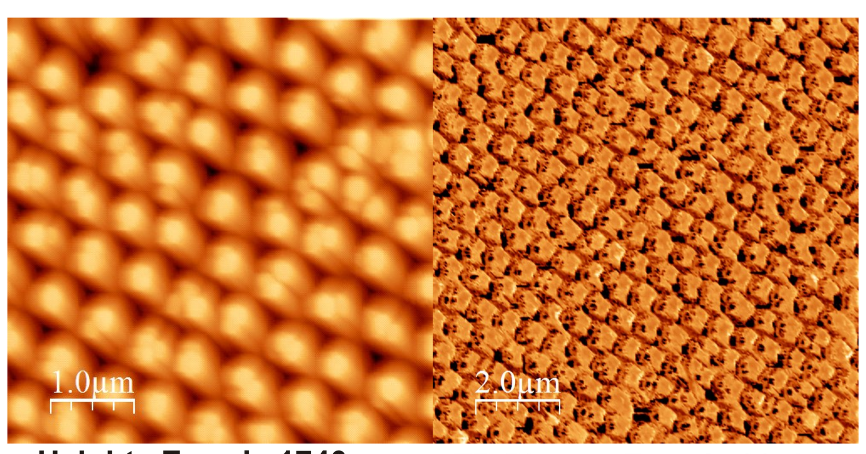
Height Z scale 250 nm | TR Phase Z scale 40 deg

Map of local currents



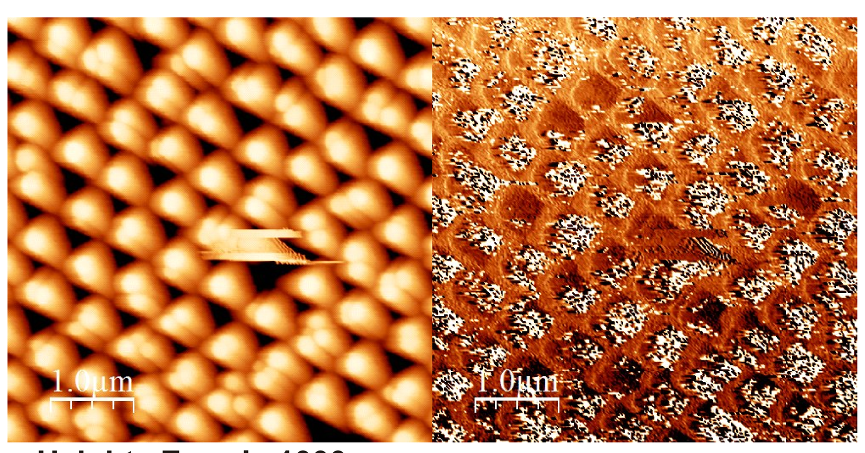
ZnO nanorods

Topography & TR phase



Height Z scale 1740 nm | TR Phase Z scale 30 deg

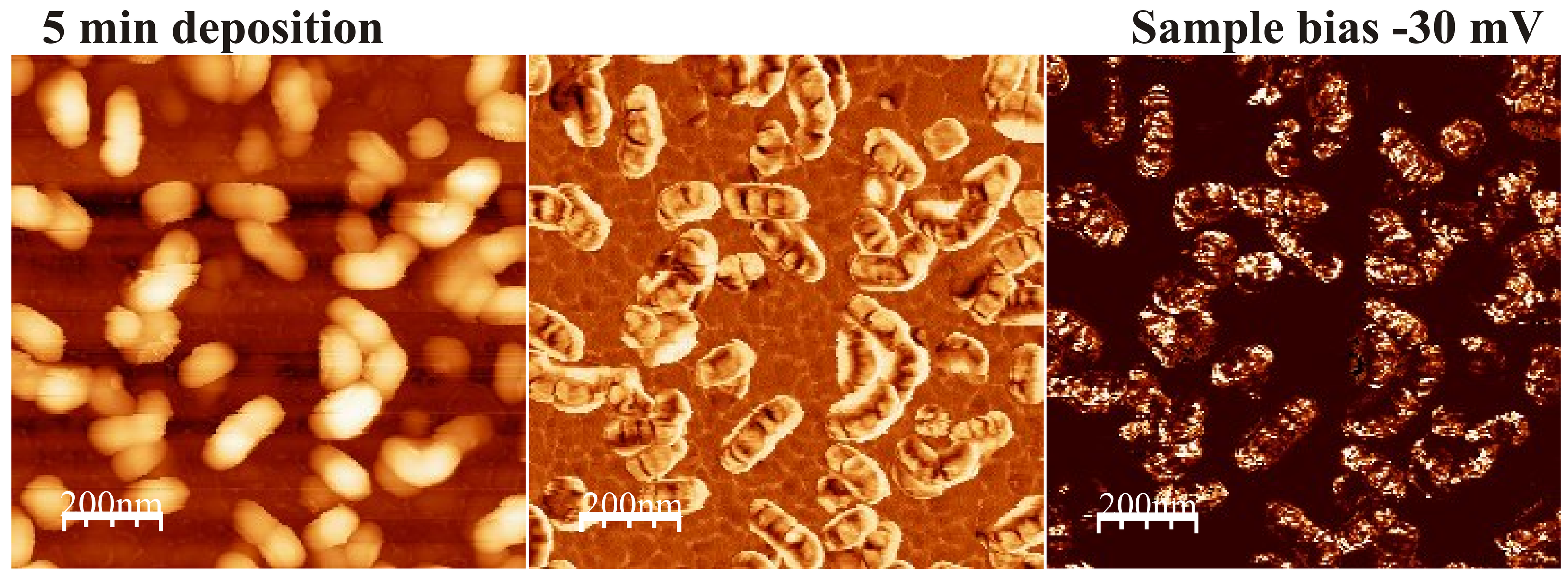
Topography & Local currents (sample bias -1 V)



Height Z scale 1000 nm | TR TUNA Z scale 10 pA

Carbon nanowalls

5 min deposition — **Sample bias -30 mV**

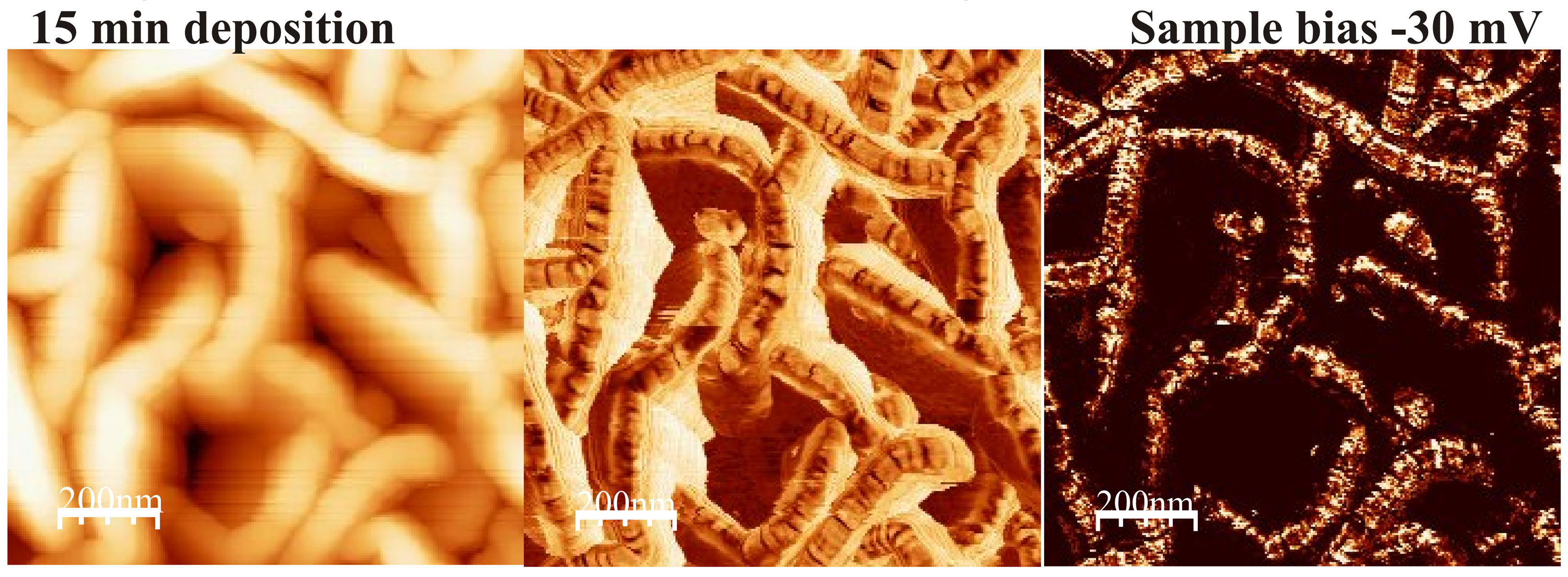


Height. Z scale 100 nm | TR-Phase. Z scale 37 deg | Local current. Z scale 6 pA

10 min deposition — **Sample bias -30 mV**

Height. Z scale 150 nm | TR-Phase. Z scale 45 deg | Local current. Z scale 10 pA

15 min deposition — **Sample bias -30 mV**



Height. Z scale 350 nm | TR-Phase. Z scale 53 deg | Local current. Z scale 10 pA

Acknowledgements

ZnO nanorods sample was provided by **Neda Neykova** (neykova@fzu.cz) and **Milan Vanecek**, Institute of Physics of Academy of Sciences CR, v.v.i. (http://www.fzu.cz/~vanecek/)

Carbon nanowalls samples were provided by **Takashi Itoh**, Department of Electrical and Electronic Engineering, Gifu University, 1-1 Yanagido, Gifu 501-1193, Japan, itoh@gifu-u.ac.jp

This research was supported by AV0Z 10100521 and FP7 240826, LC510, LC06040, KAN400100701 projects.

Advantages of Torsional Resonance C-AFM:

- it is non-contact mode (therefore there is no damage for a sample and for a AFM-tip as well)
- at the same time, the phase signal is stronger than the same one of tapping mode
- AFM-tip oscillates in the near field of a sample, so tunneling of electrons is possible