

# Figure for the aim4np Report

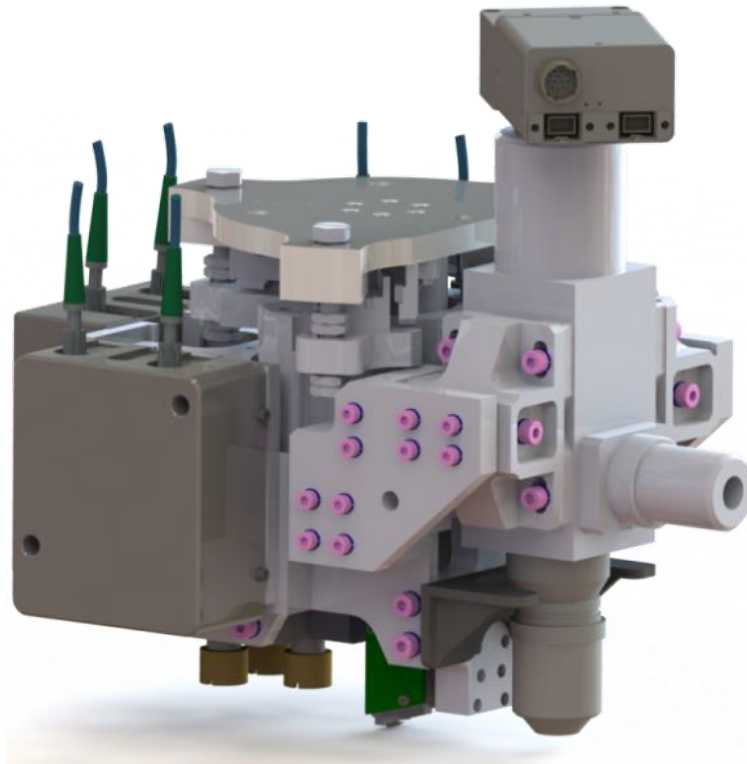
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This file contains the figures to which reference is made in the text submitted to SESAM. There is one page per figure. At the beginning of the document, there is the front-page with all the logos from each partner, followed by a list of all figures, the figure captions and the page where the figures can be found in this document. Then the figures follow in the same order as they have to be introduced into the main text, such that the cross-reference are correct. If there are several sub-figures (a,b,c,d...) these sub-figures could be spread over several pages. In that case, the page indicated in the table refers to the page where the caption is written.

Automated in-line Metrology for Nanoscale Production

# aim4np

*Final Report*



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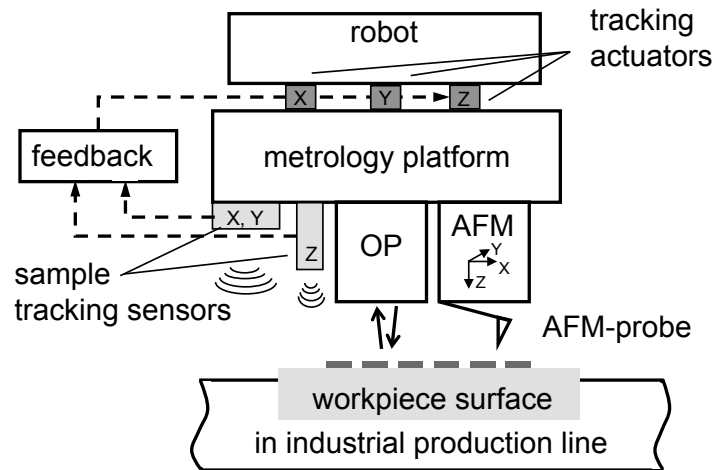


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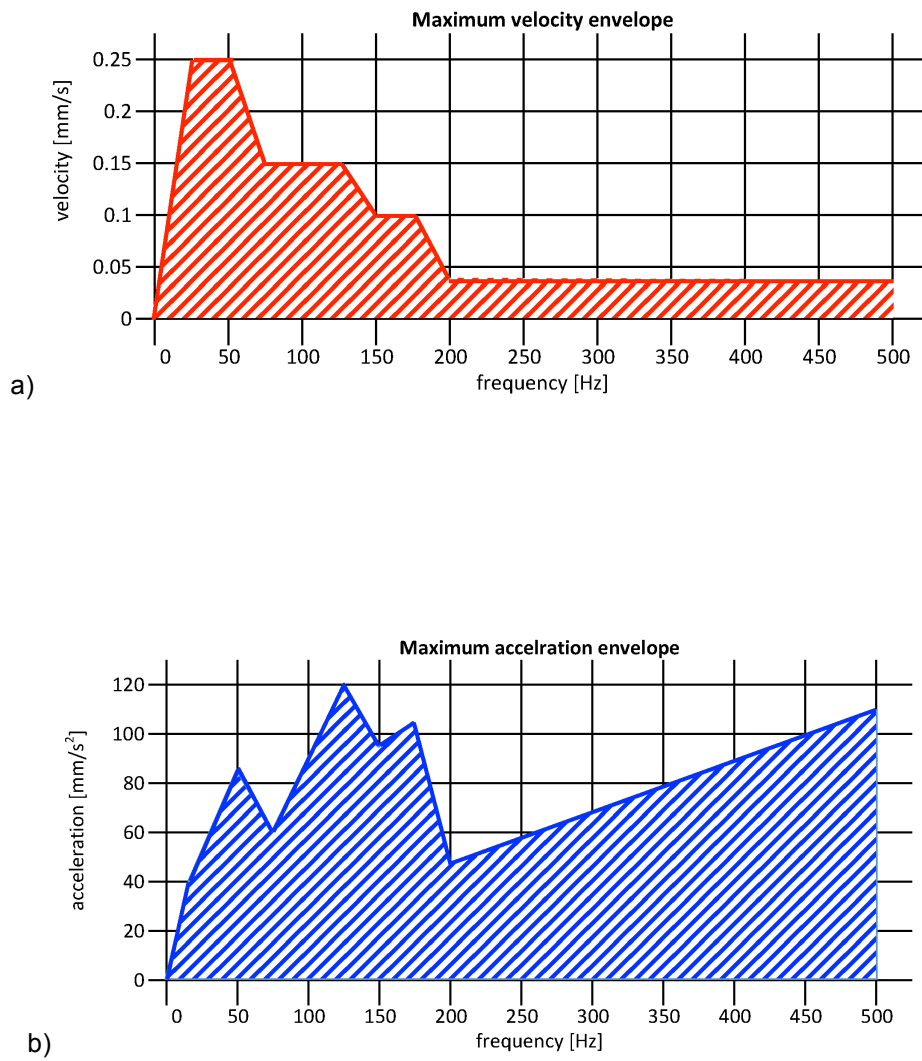


Figure 2 a) Maximum velocity envelope and  
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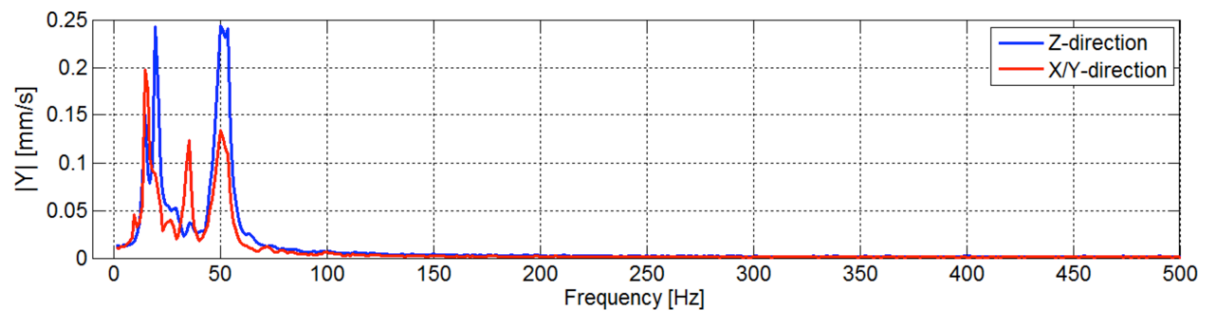


Figure 3 Measured and analysed worst-case velocity spectra of the robot with Waterfall-FFT timeslots of 0.8 seconds and a total measurement interval of 20 seconds.



Figure 4 Schematics of the control loop with plant inputs ( $F_1 \dots F_6$ ) and plant output ( $S_1 \dots S_6$ )

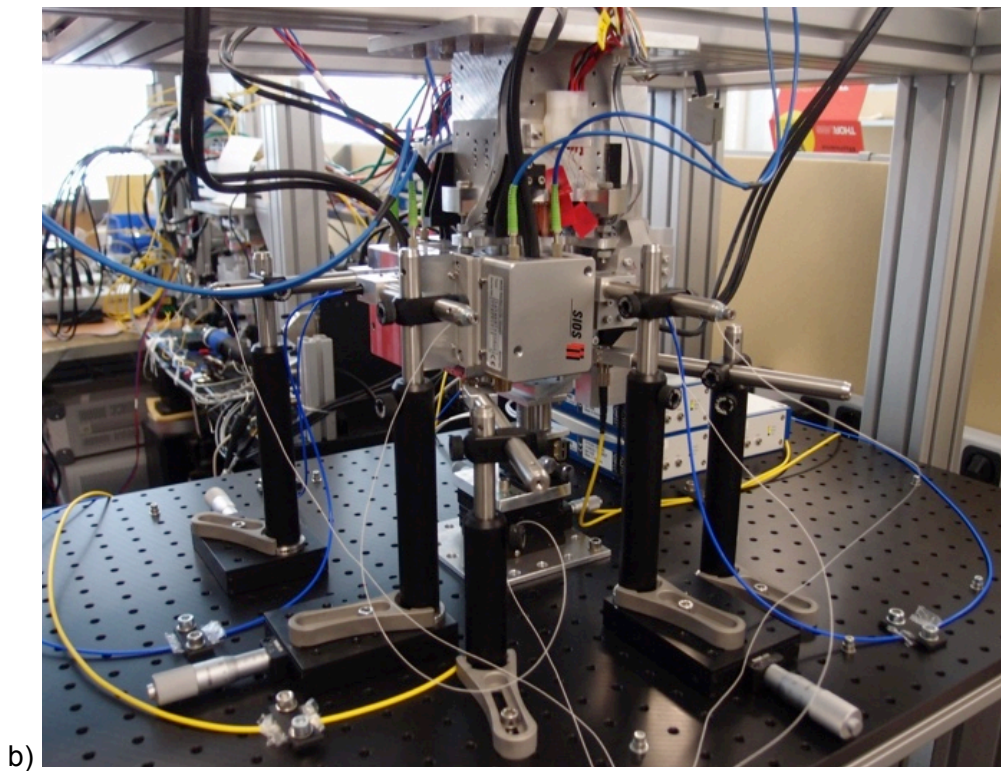
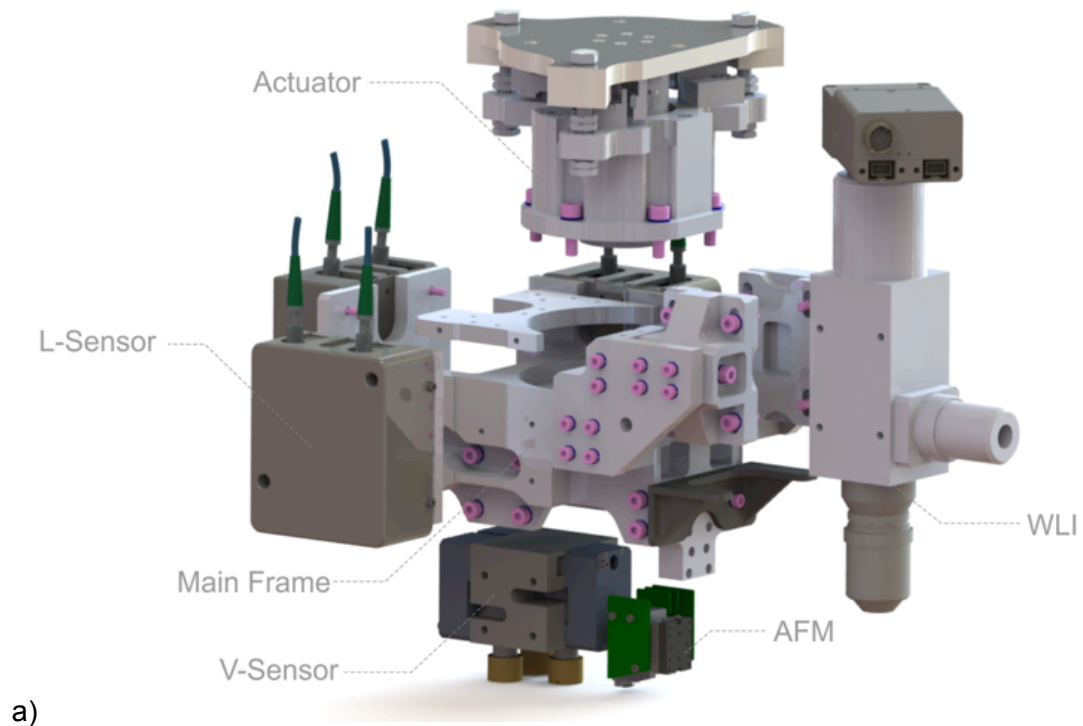
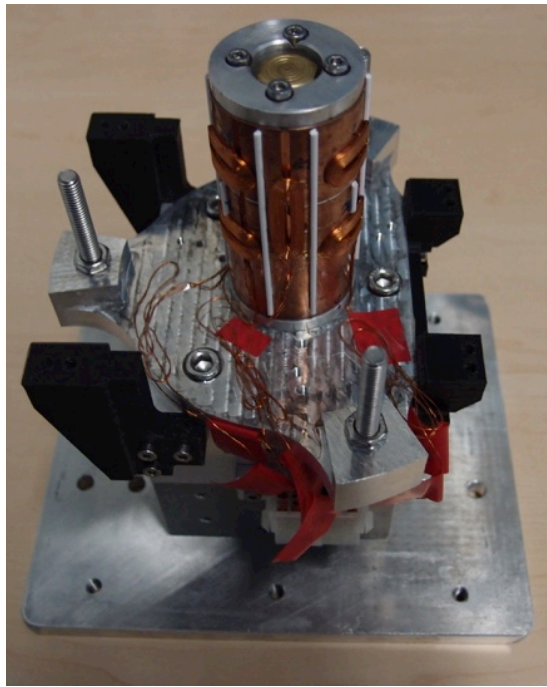
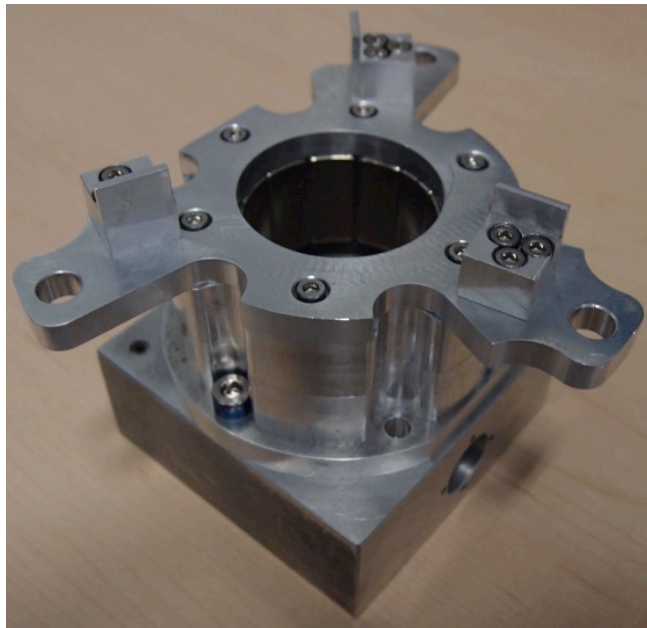


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b) The Metrology Platform in the test stage. The view is partially obstructed by cables and external tracking sensors that were added for test purposes.

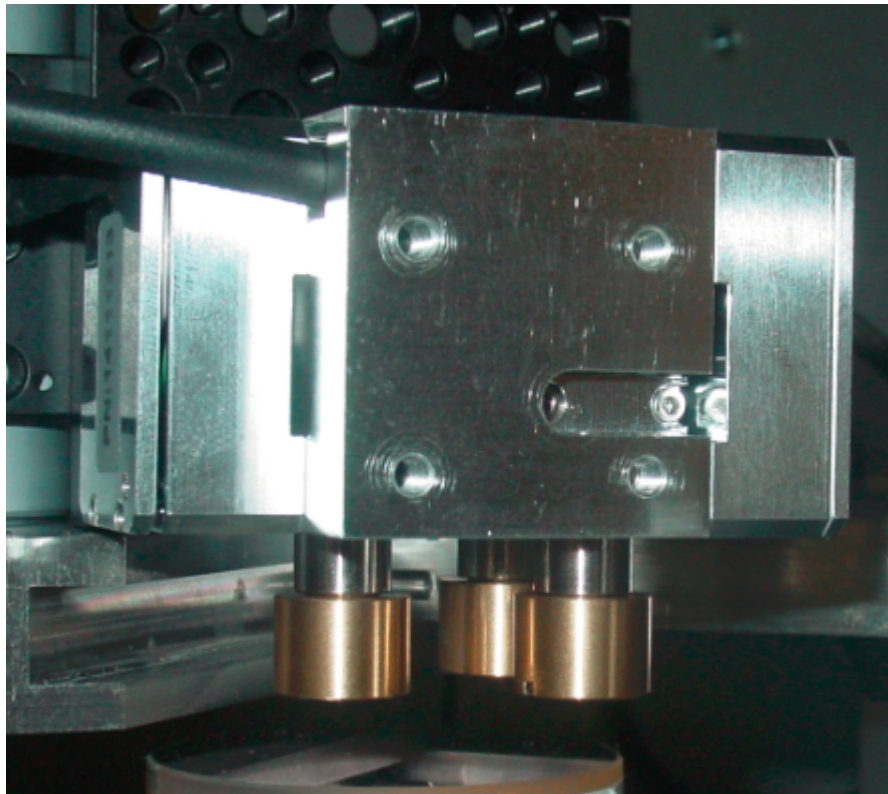


a)

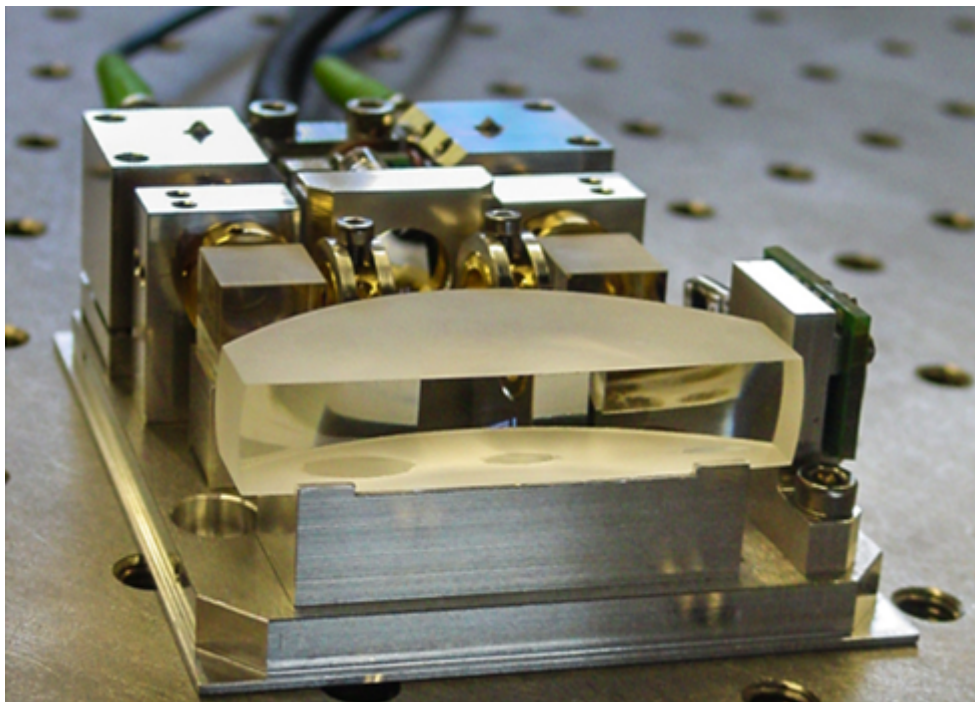


b)

Figure 6: Tracking actuator fabricated by TU Vienna. The design is based on 3D-CAD drawings, which were delivered by TU Delft.  
(a) Stator (up-side down) and  
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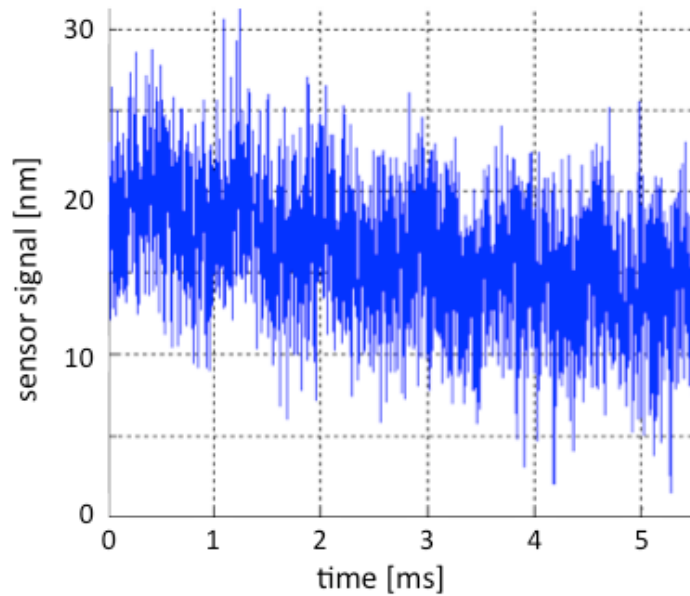
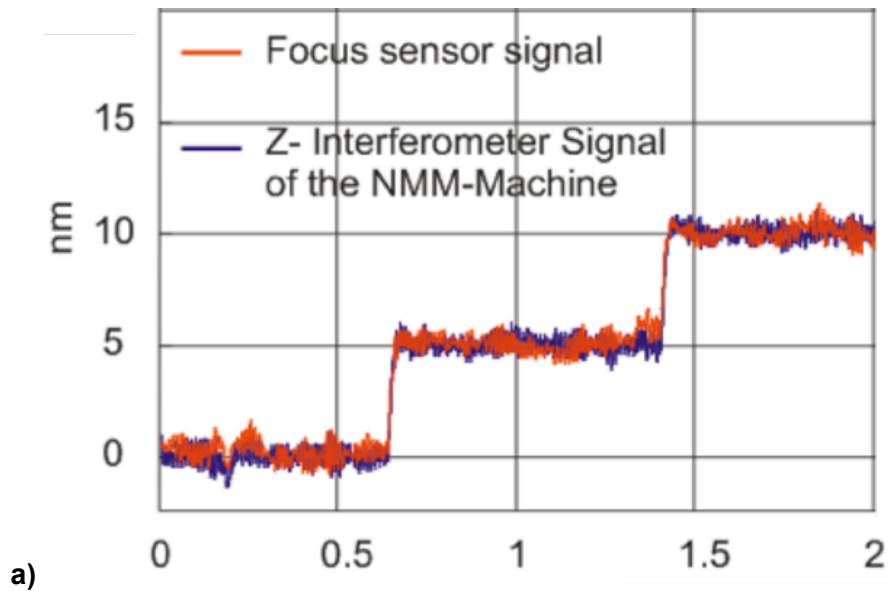


a)



b)

Figure 7 a) Photograph of the combination of three vertical tracking sensors.  
b) Photograph of lateral tracking sensor with its cover removed.



b)

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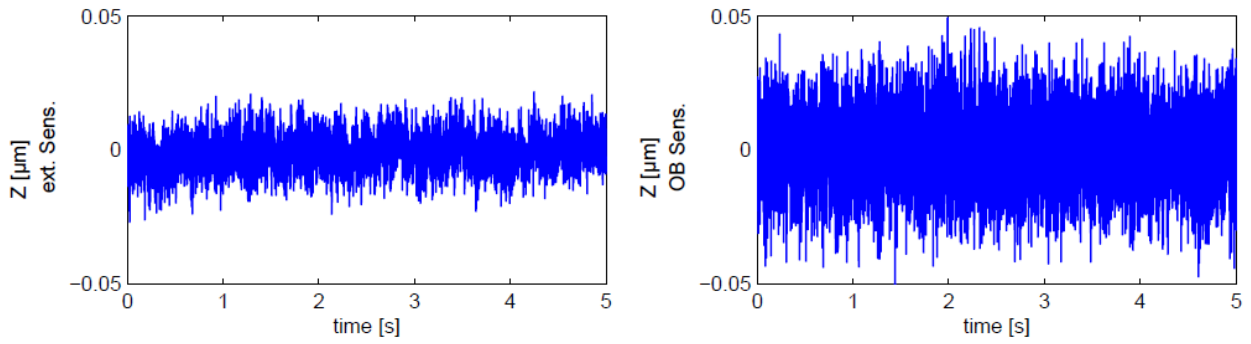


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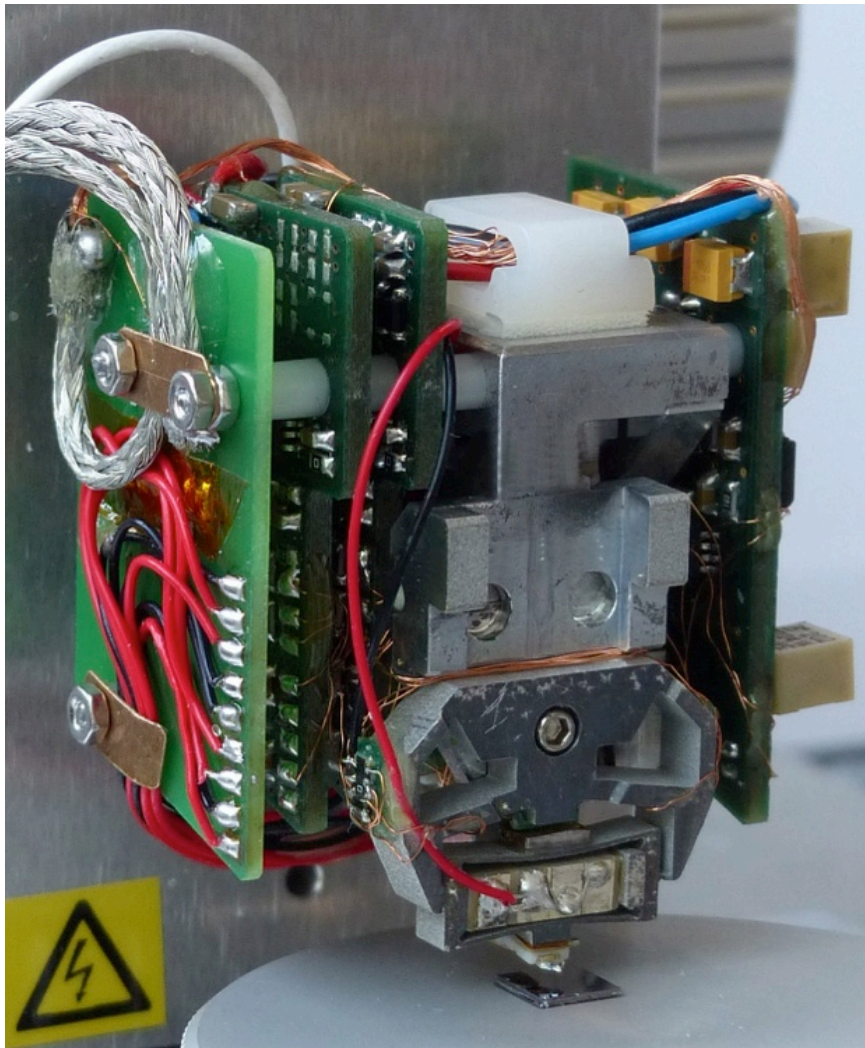


Figure 10: Assembled AFM measurement-head with preamplifiers for position sensors and cantilever deflection sensor (without housing).

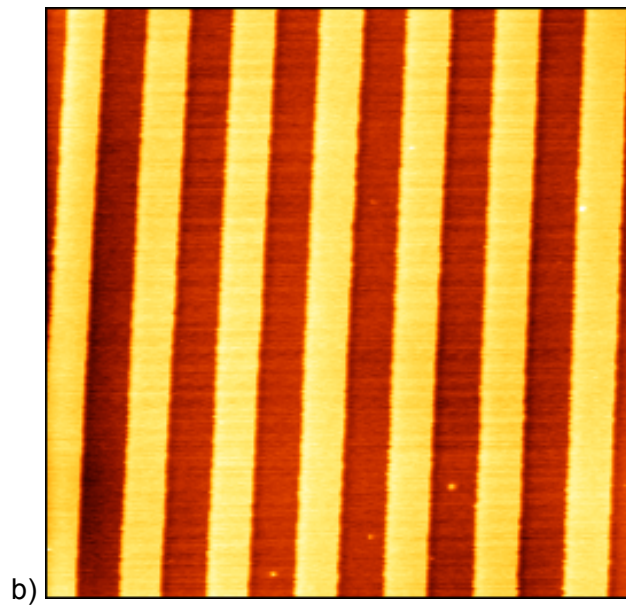
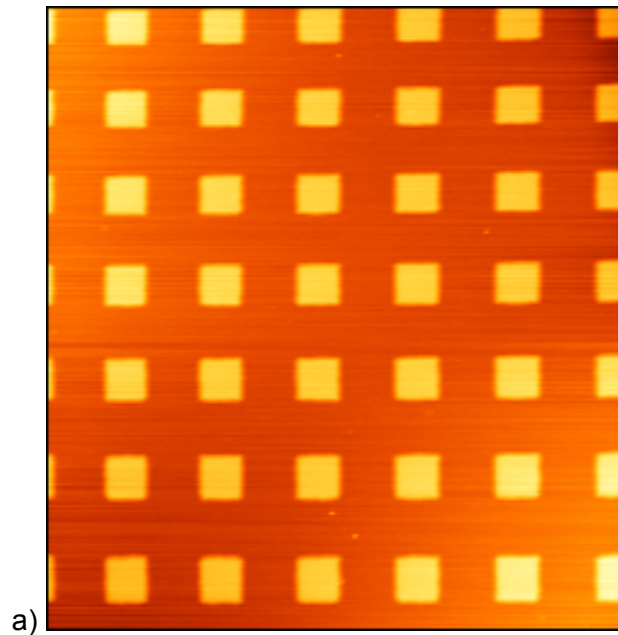


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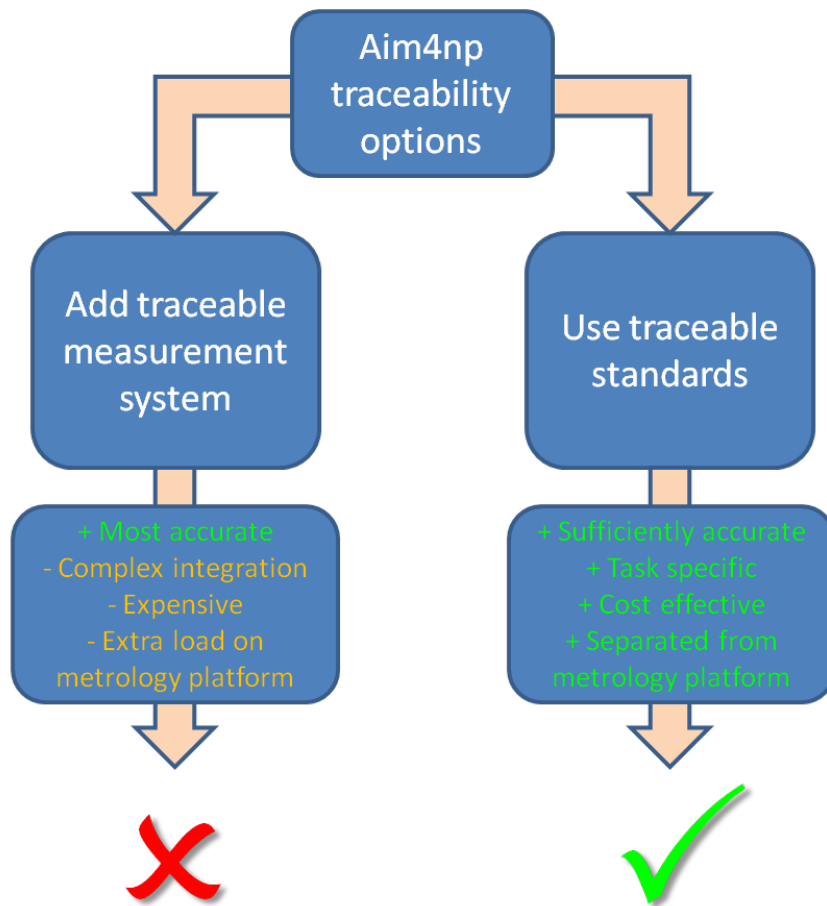


Figure 12 The overall traceability strategy based on traceable standards was considered as the best option for the aim4np project

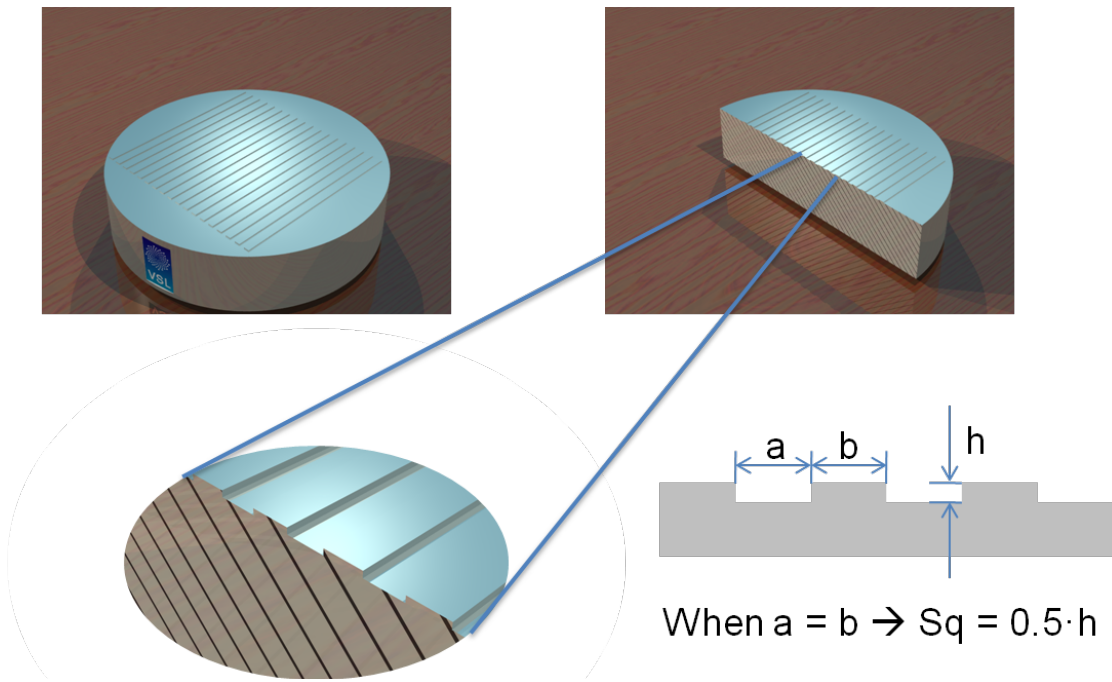


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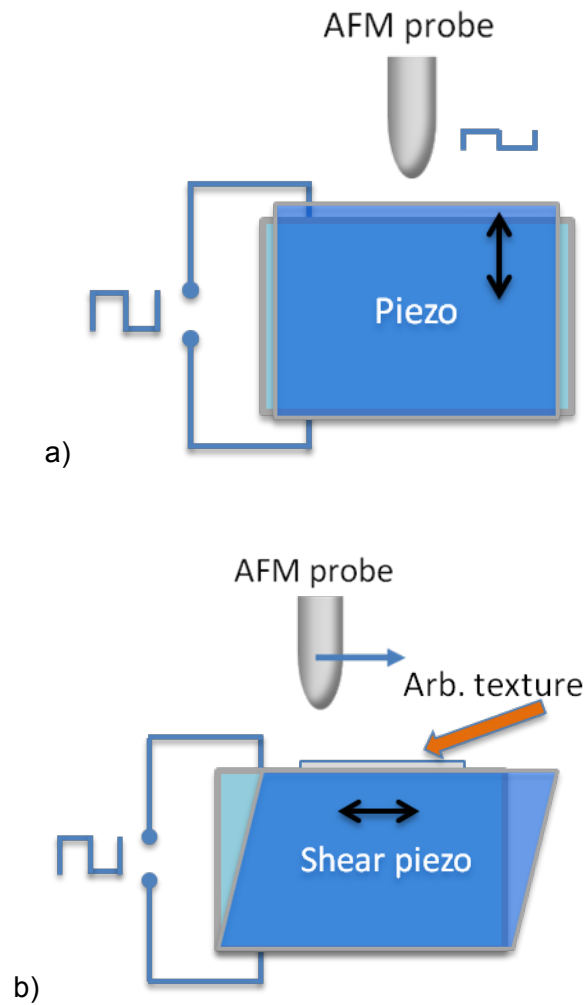


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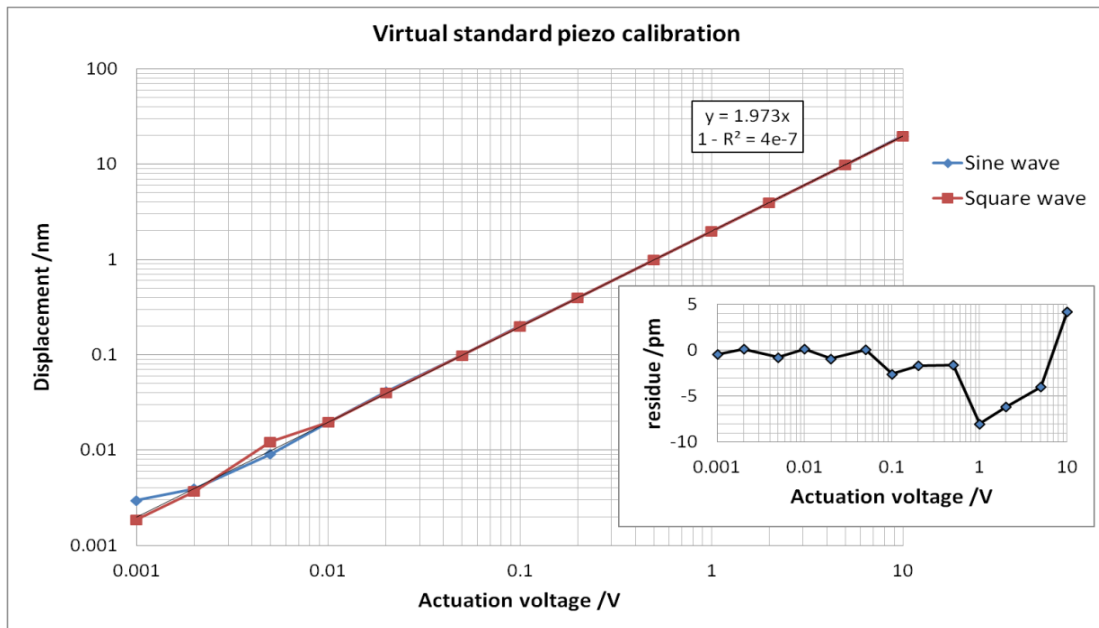


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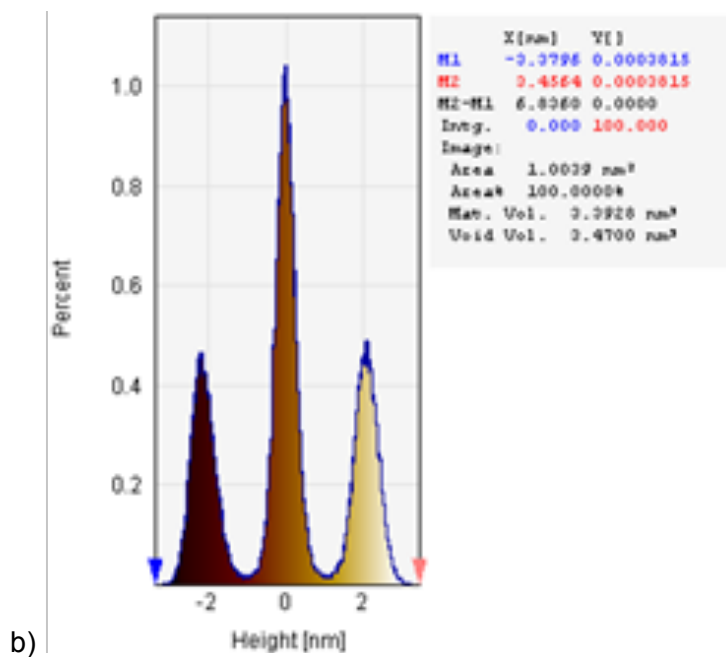
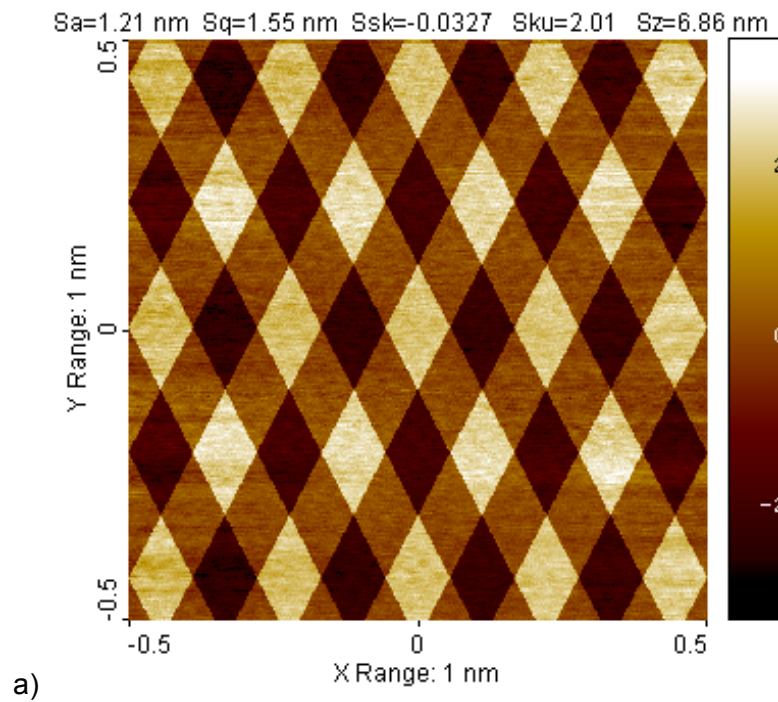
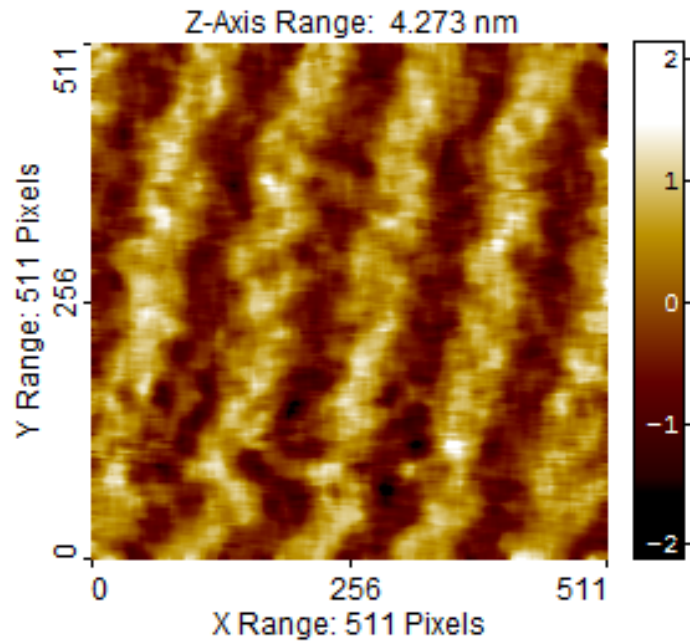
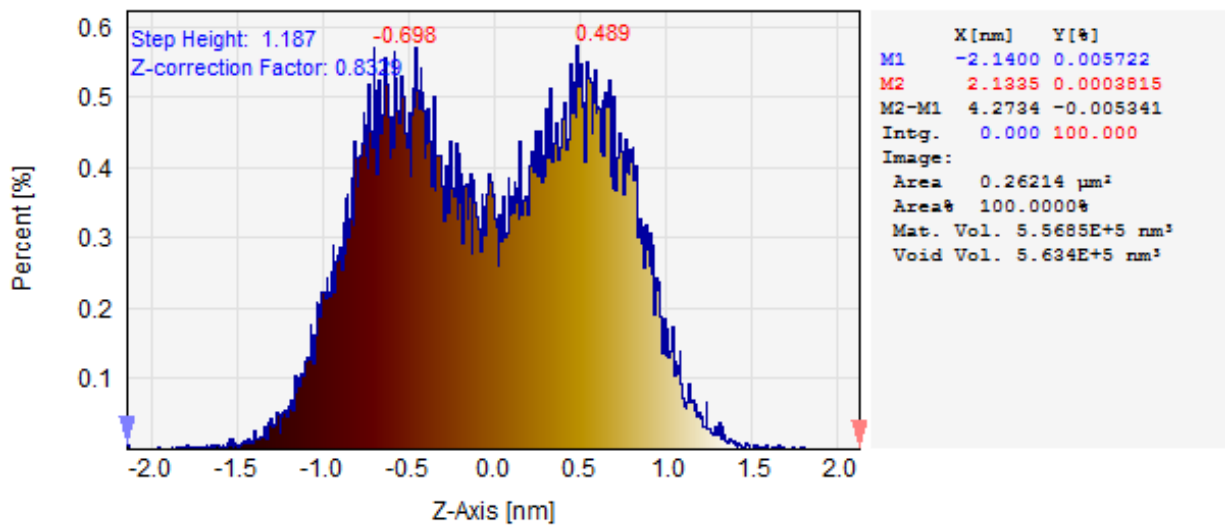


Figure 16 Measurement result on the virtual Sq standard as performed by VSL. The image in (a) shows the difference of the trace and retrace AFM image to eliminate most of the measurement noise. The histogram analysis (b) provides an Sq value of 1.1 nm.

Image00181.nid Filter Result.tz



a)



b)

Figure 17 Median filtered measurement for a 1 nm (nominal) step height as measured by the aim4np Nanosurf AFM (a) and histogram analysis (b). The average calibration coefficient calculated from this measurement is 0.83.

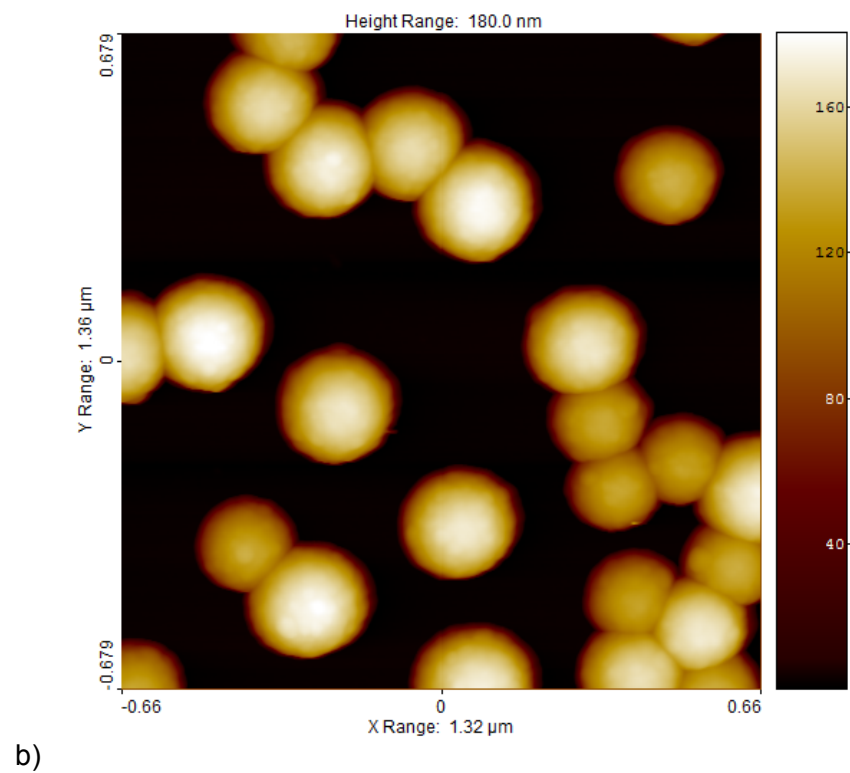
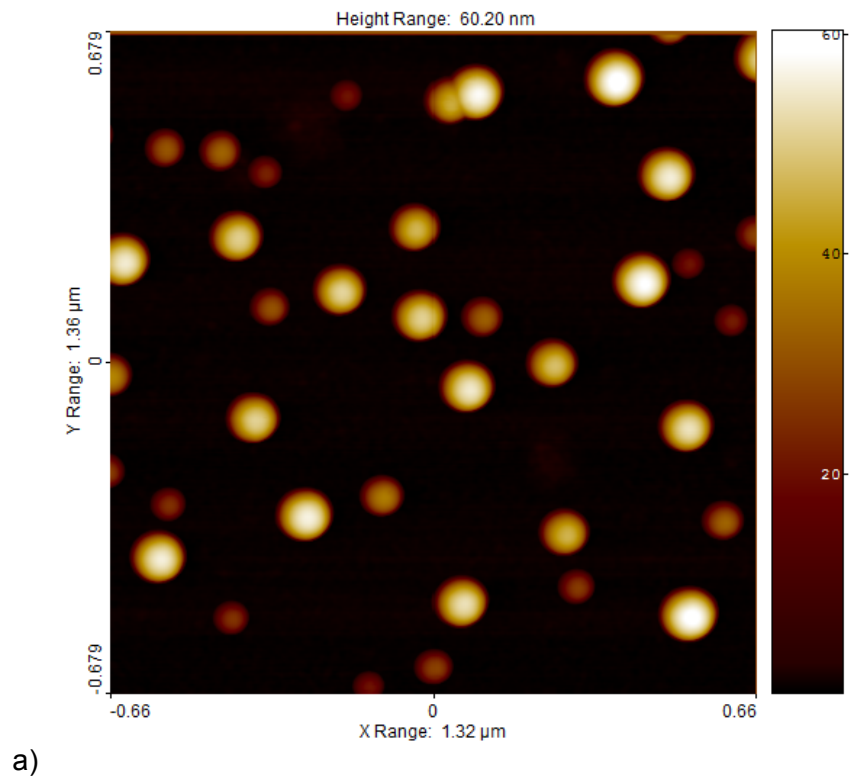


Figure 18 Examples of nanoparticle depositions for the calibration of the AFM probe shape. Polystyrene particles with a wide diameter distribution (a) and silica particles with a bimodal distribution (b) are used to calibrate different parts of the AFM probe. Both images show an area of  $1.32\mu\text{m} \times 1.36\mu\text{m}$  in x and y resp.

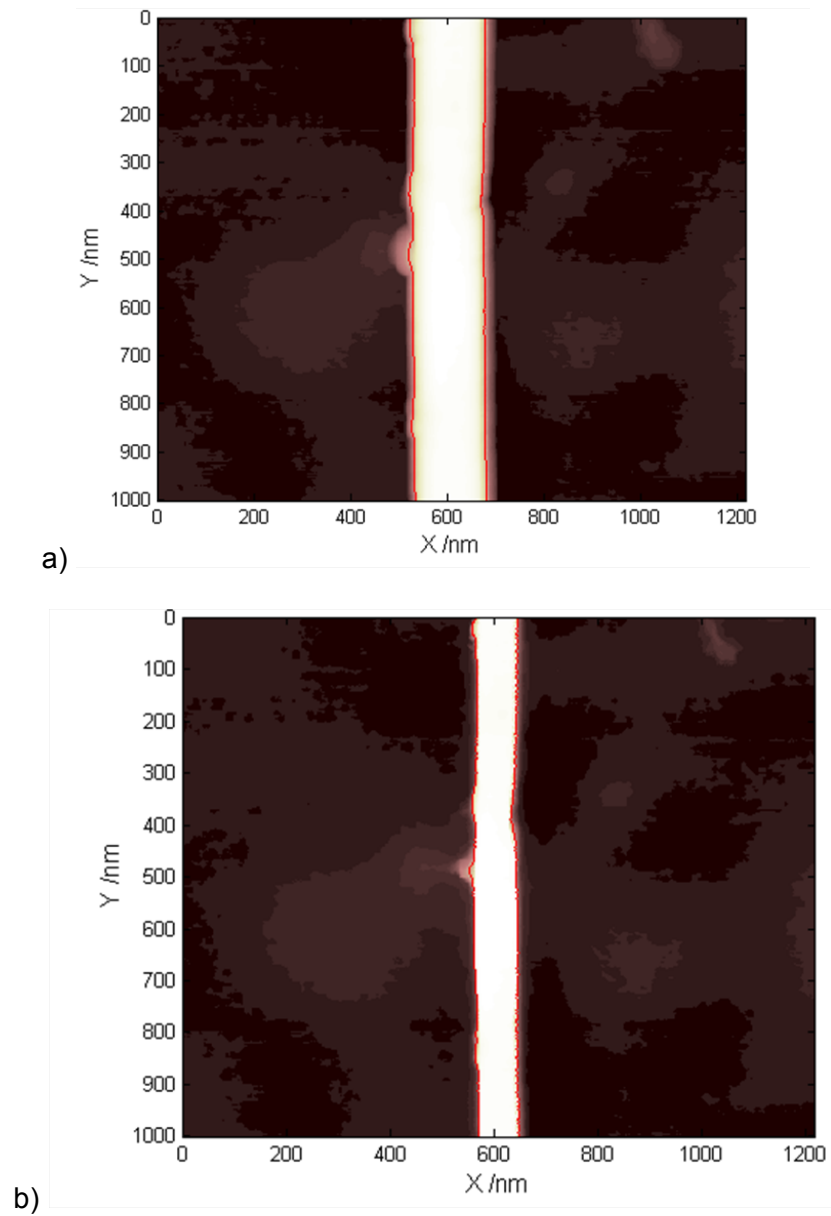


Figure 19 Example of the application of probe shape correction for a measurement of a line structure. The probe had a conical probe with a spherical apex. The line broadening due to the probe shape (left) is reduced to reveal the actual line width (right).

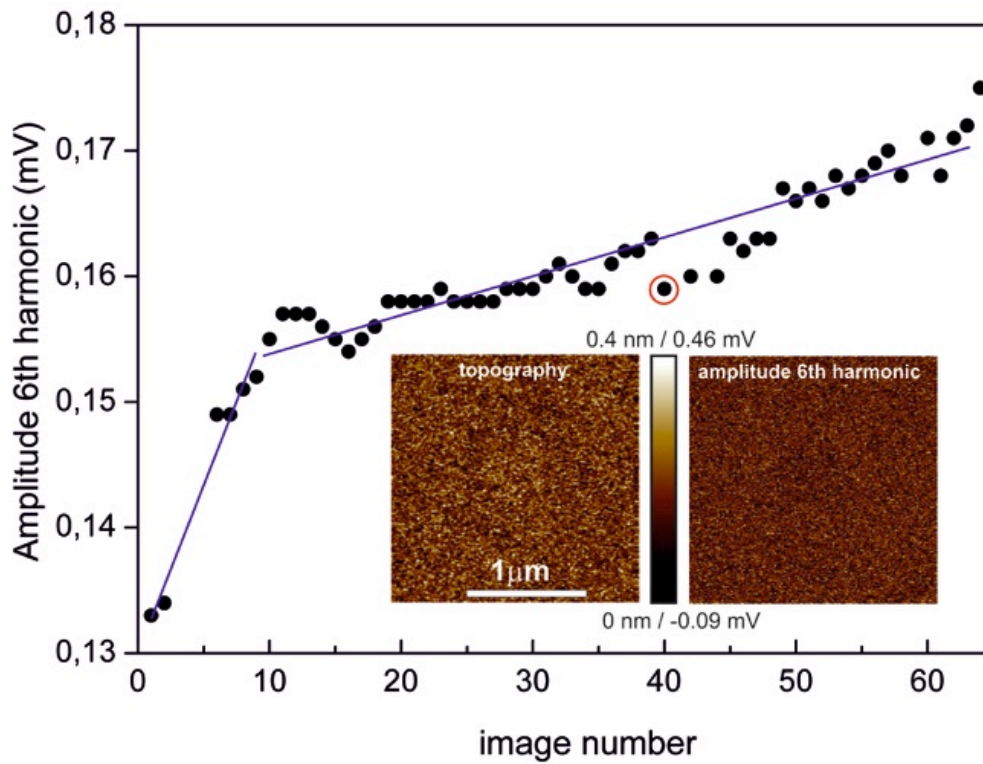


Figure 20: Evolution of the mean value of the amplitude of the 6<sup>th</sup> harmonic extracted from the amplitude image (right of the inset) simultaneously acquired with the topography (left of the inset) and phase images. Experiments have been performed with a nominally 44 Nm<sup>-1</sup> rectangular AFM cantilever with resonance frequency  $f_0 = 350$  kHz on silicon surfaces under ambient conditions. The time evolution is expressed in terms of sequentially acquired images. The free oscillation amplitude was set to 30 nm and set-point to 27 nm, respectively. The inset corresponds to the point marked with the red circle. The continuous blue lines are guides to the eye.

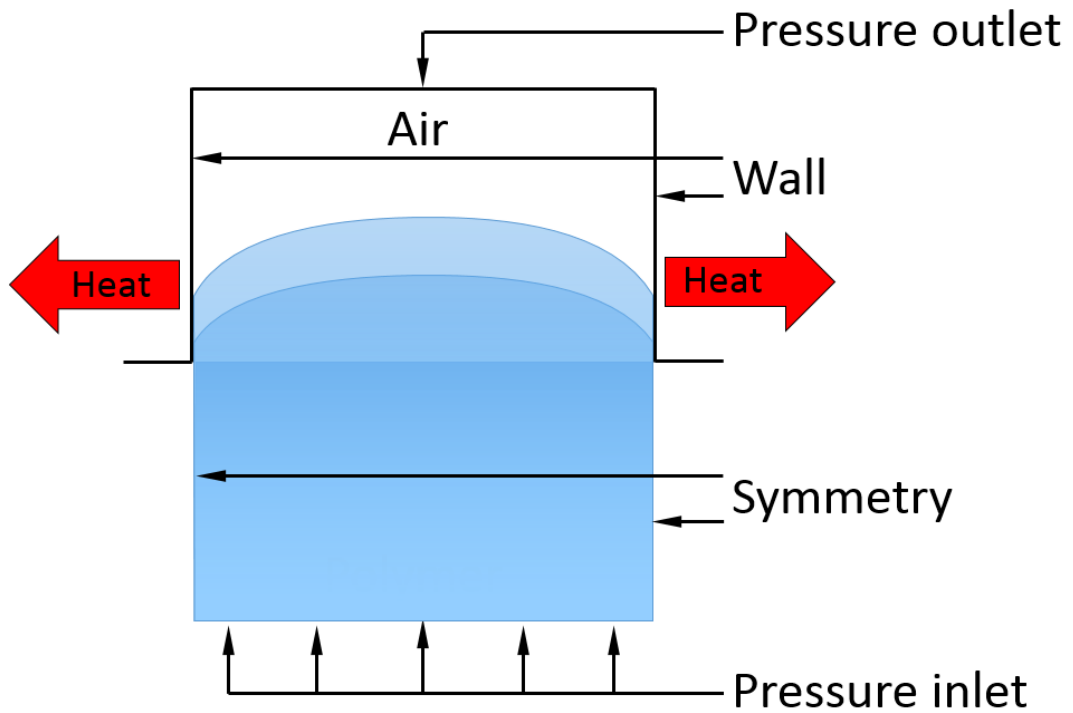
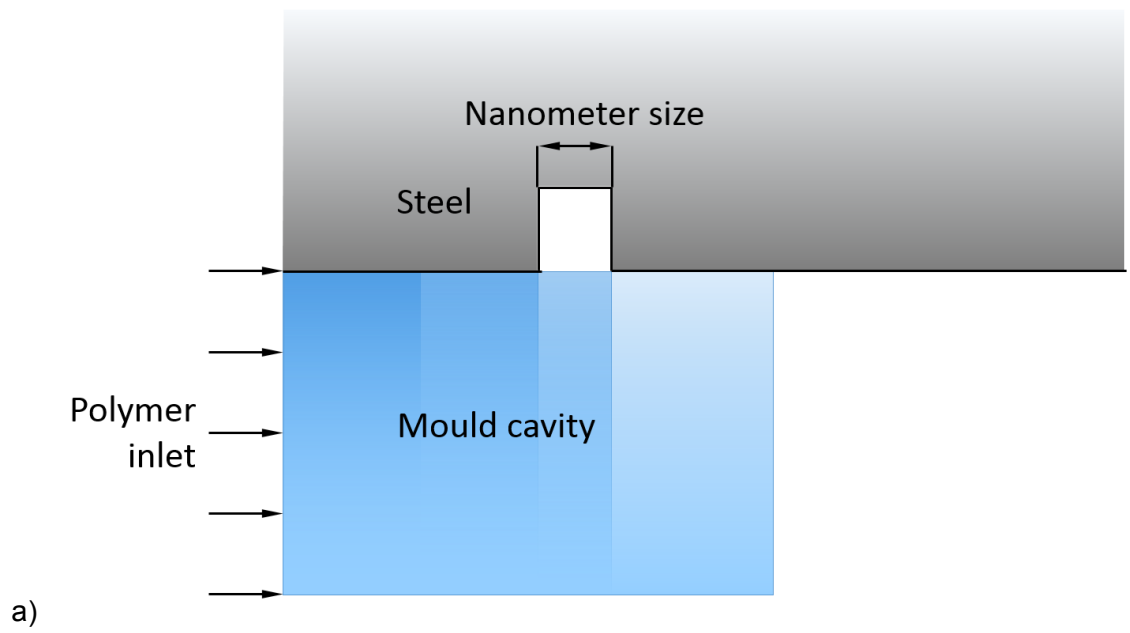


Figure 21: a) Submodelling simulation of the filling of a rectangular cavity with a constant velocity input.  
 b) Nano simulation of the filling of a 2D cavity. The gradated blue tones indicate the advance of the polymer melt.

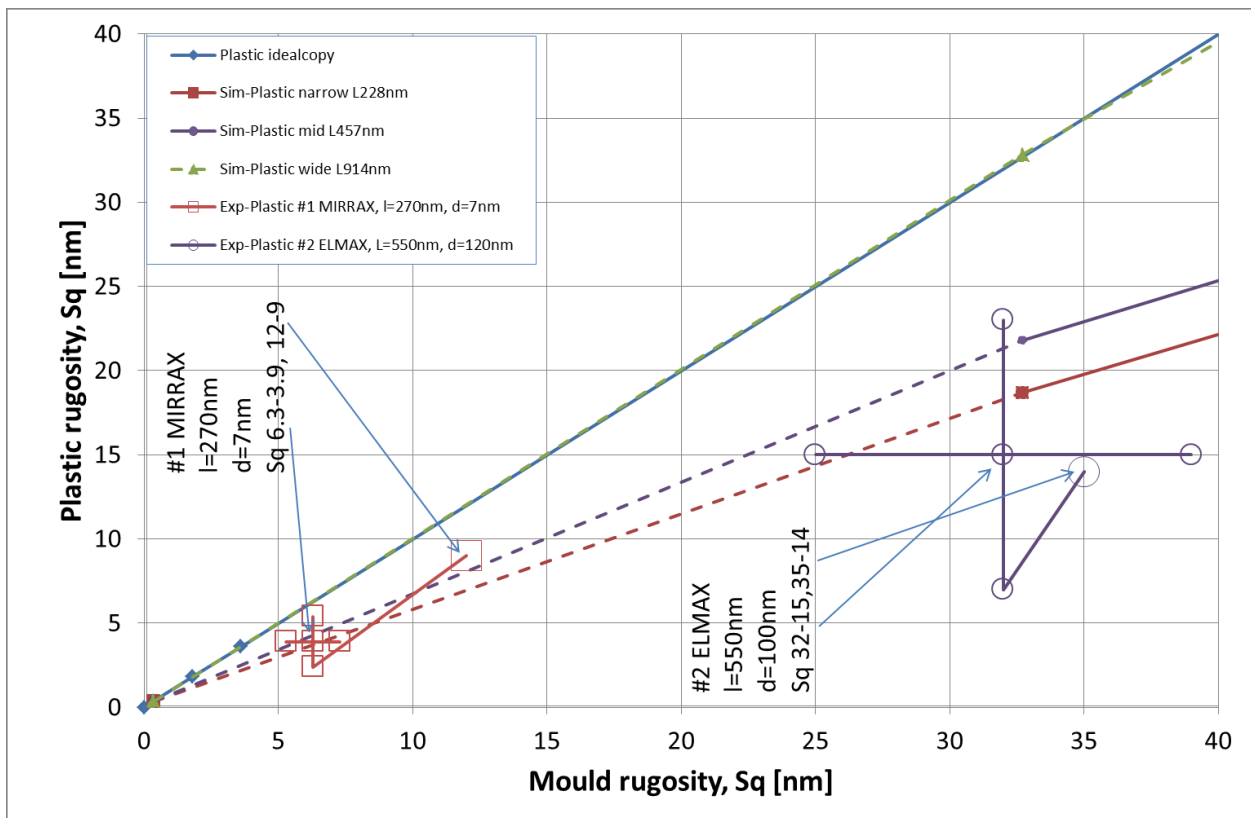
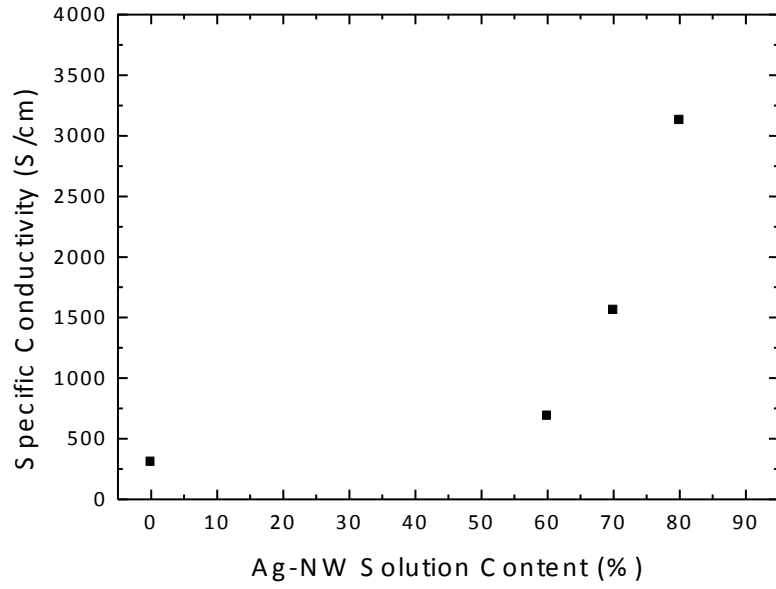
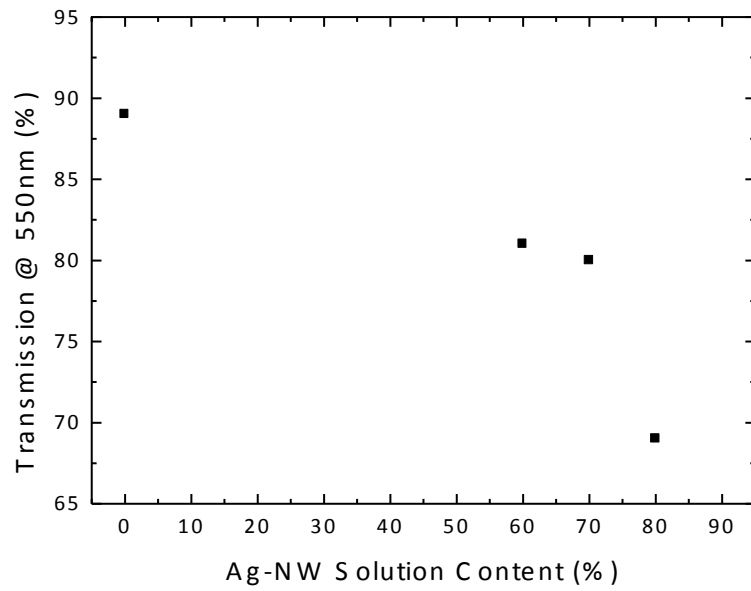


Figure 22: Comparison of surface roughness of the polycarbonate pieces vs. mould roughness. The predicted values (dashed lines) are compared to the experimental points (unfilled squares and circles).



a)



b)

Figure 23 Specific conductivity (a) and optical transmission (b) in dependence on the Ag-NW solution content.

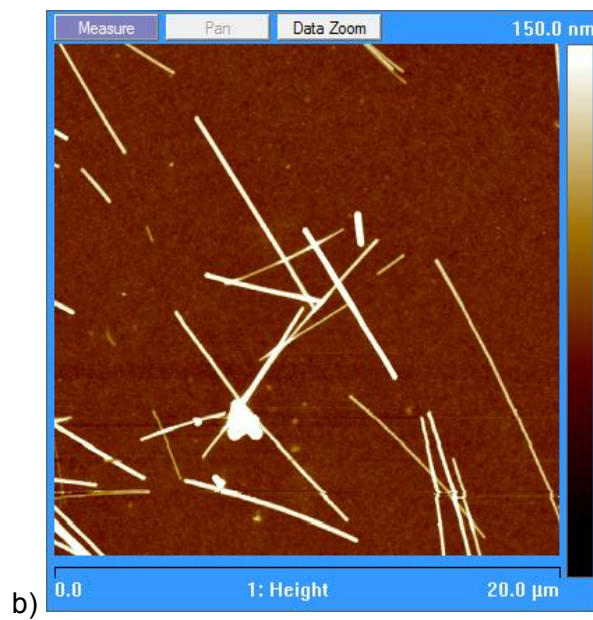
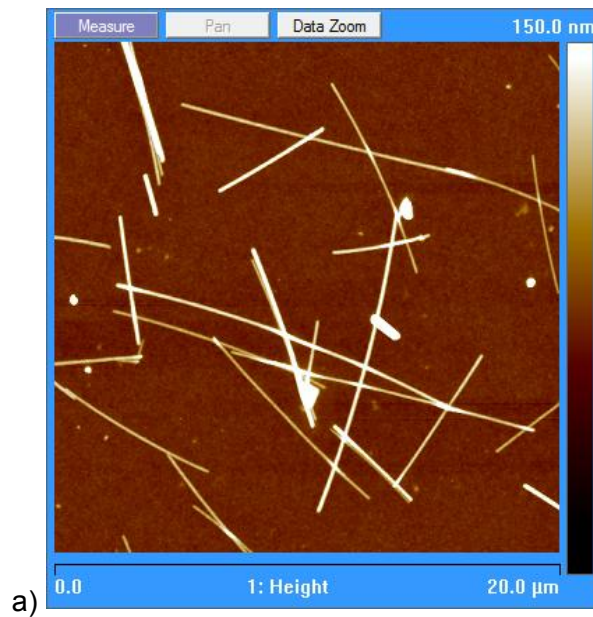


Figure 24 AFM height image of PEDOT:PSS/Ag-NW blend films; Left (a): 60% Ag-NW content, RMS-Roughness  $R_q=19,1\text{nm}$ ; Right (b): 70% Ag-NW content, RMS-Roughness  $R_q=23,2\text{nm}$ .

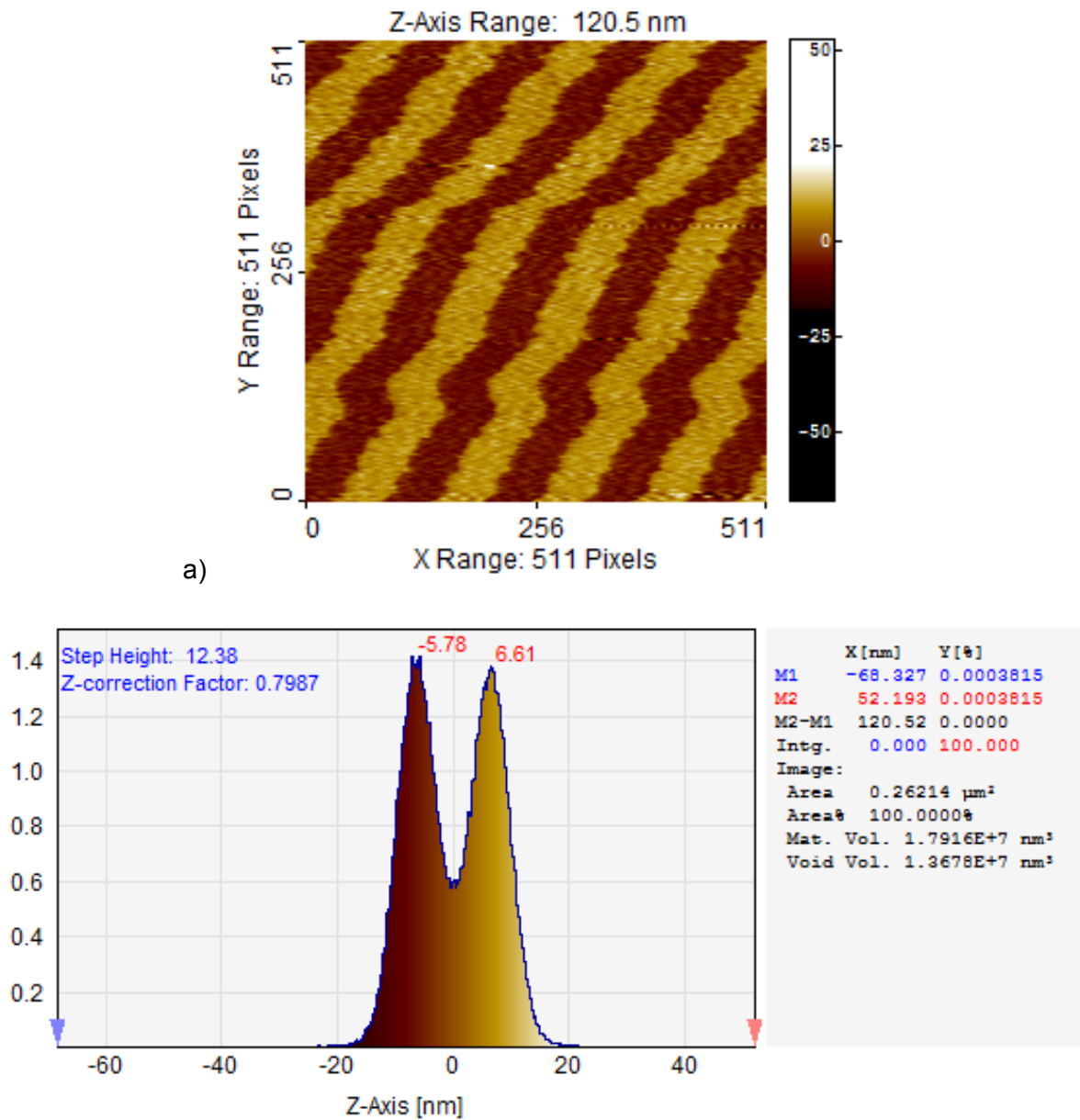


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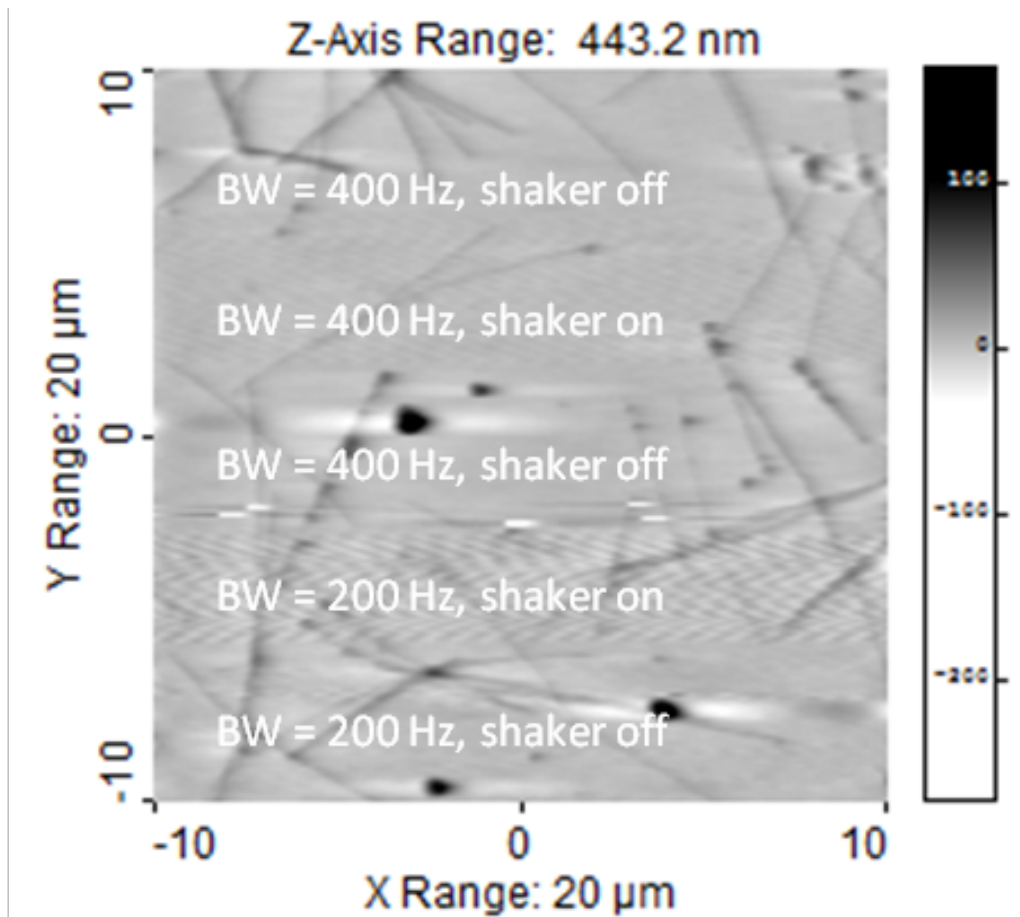


Figure 26 Exp. #10: 5 Vpp; 9.473 kHz;  
 Scanning frequency: 2 Hz;  
 Image bottom to top:  
 Sequence of the experiments:  
 (Control gain in z direction/Shaker):  
 [200 Hz / Off]; [200 Hz / On]; [200 Hz / Off];  
 [400 Hz / Off]; [400 Hz / On]; [400 Hz / Off]

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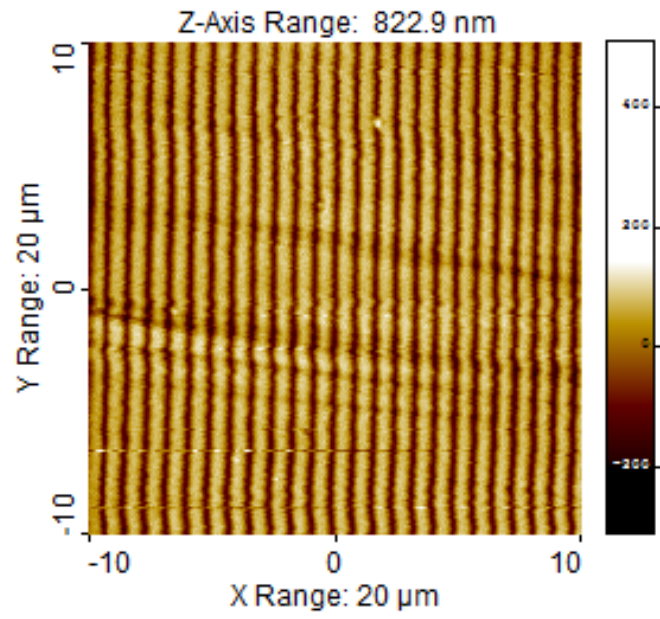
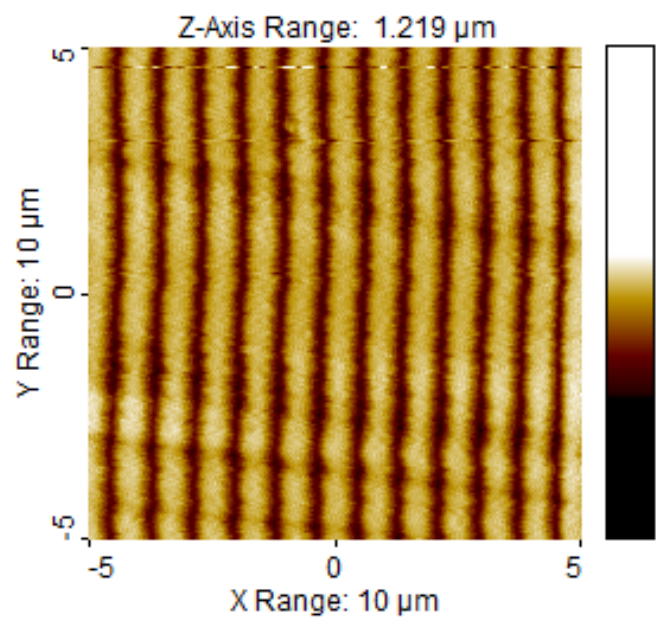


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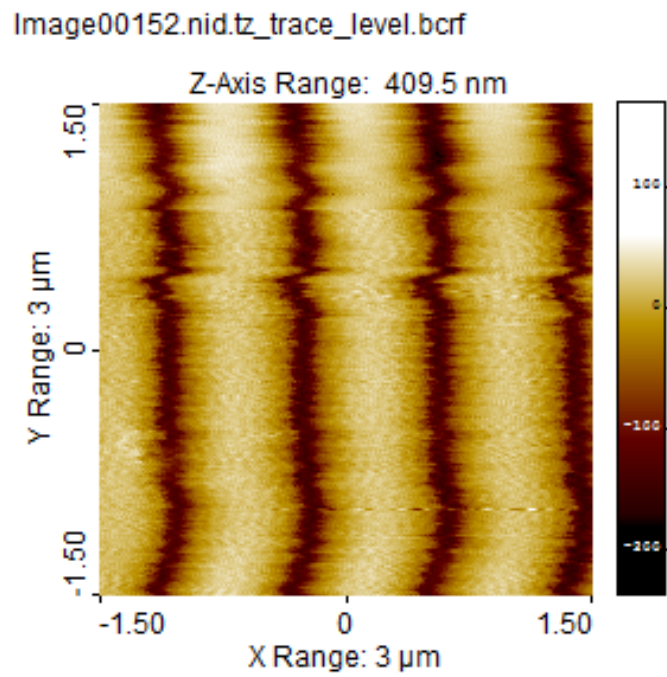
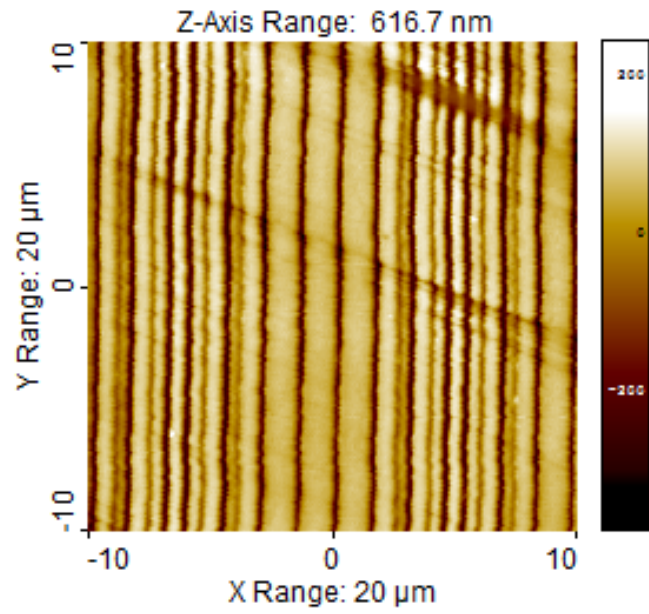


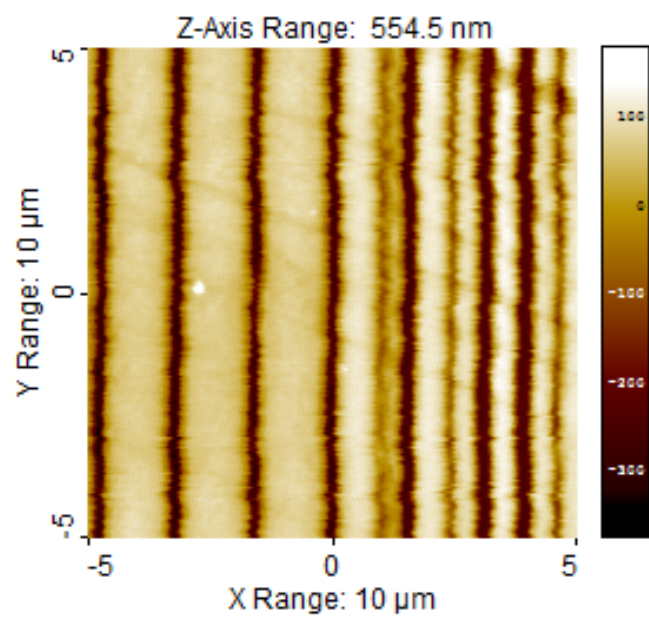
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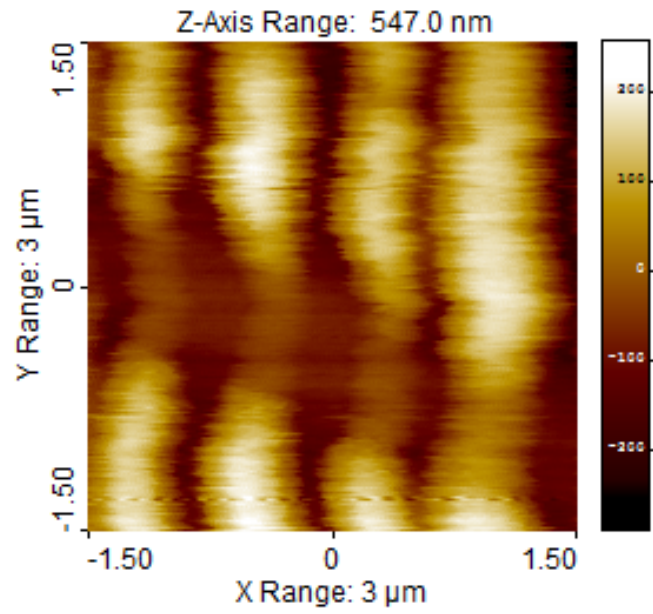
a)

Image00137.nid.tz\_trace\_level.bcrf



b)

Image00141.nid.tz



c)

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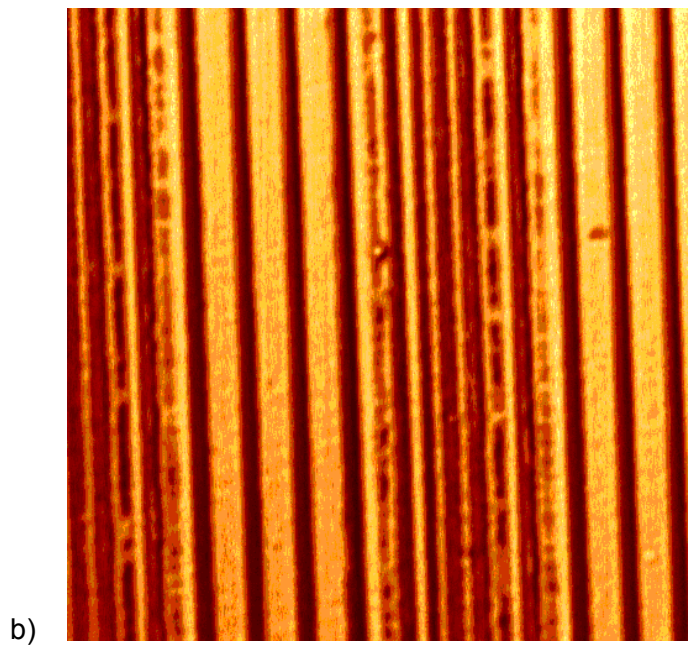
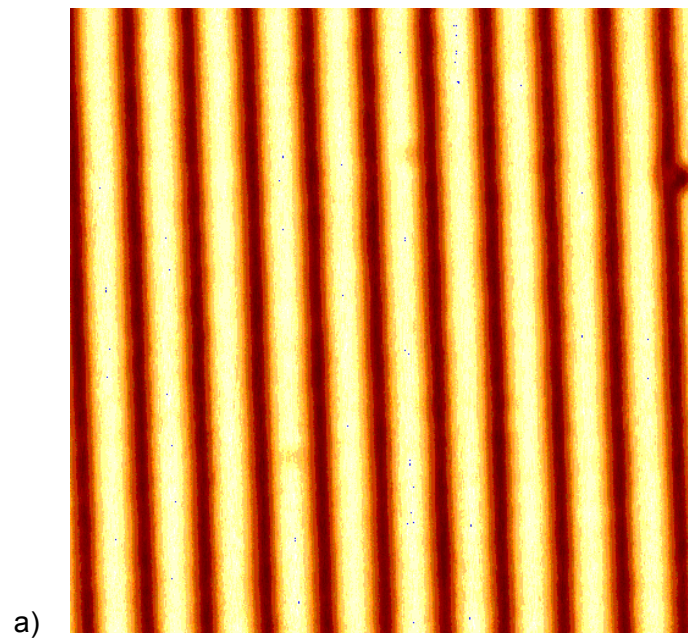


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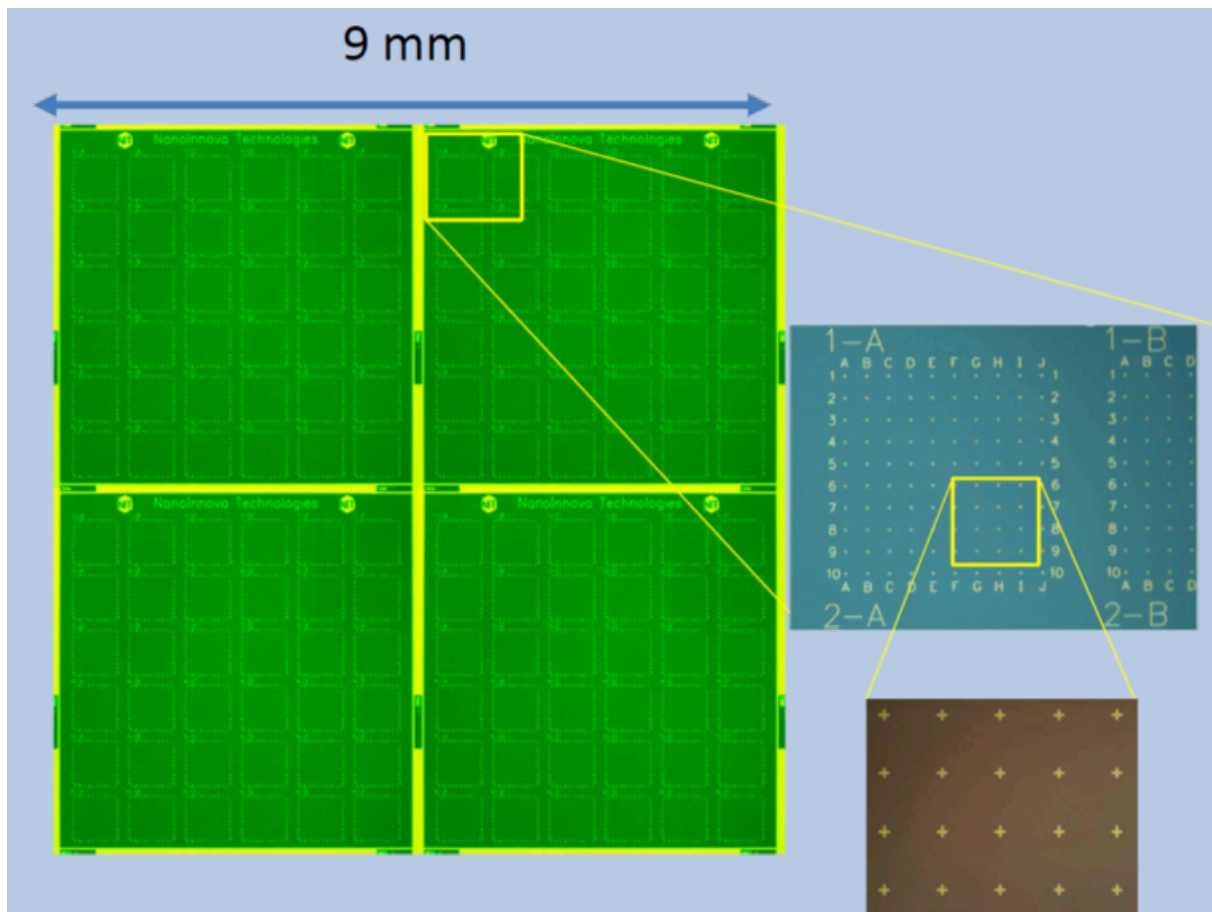


Figure 30 Overview and structure of the navigation sample. The images were recorded with an optical microscope.

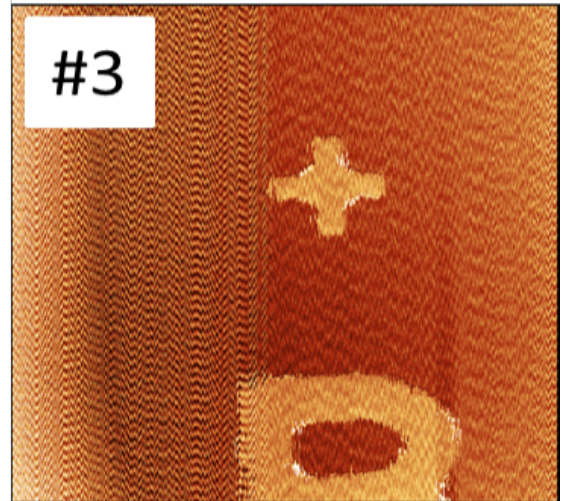
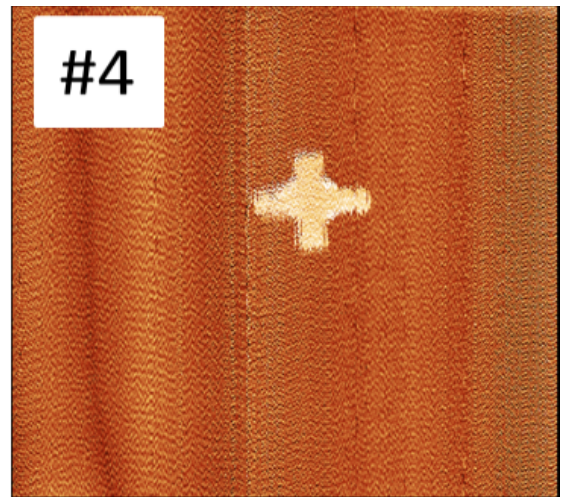
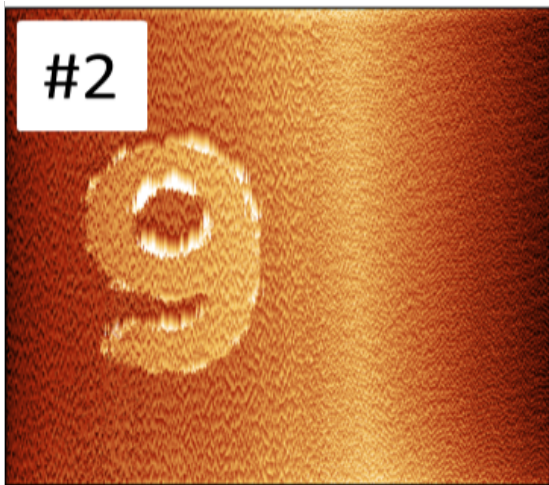


Figure 31 The two AFM images #1 and #2, resp. #3 and #4 were measured after the robot has moved the AFM laterally by  $50\mu\text{m}$ . Between #2 and #3, the tip was exchanged. The noise is due to the lateral jittering of the robot, caused by its controller. At least a 3DOF MP would be needed to fully eliminate them.

# aim4np

## AUTOMATED IN-LINE METROLOGY FOR NANOSCALE PRODUCTION



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### SUMMARY

The aim4np project combines the state of the art in science and technology from a range of R&D partners and innovative SME 's. It is coordinated by the Department of Precision and Microsystem Engineering of the Delft University of Technology in the Netherlands. This is an SME oriented project, funded under the NMP Theme of the FP7 Programme (NMP.2012.1.4-3 *Nanoscale mechanical metrology for industrial processes and products*) started on 1 March 2013 with a duration of 42 months.

#### Introduction

Knowing the mechanical properties of workpieces and machine-tools also at the nanometer scale is an absolute necessity for an efficient nanoscale production. Current technologies are lacking the flexibility and robustness needed for measuring such key parameters as topography, morphology, roughness, adhesion, or micro- and nano-hardness directly in a production environment. This hinders rapid development cycles and resource efficient process and quality control.

#### Goal and Deliverable

The project aim4np strives at solving this problem by combining measuring techniques developed in nanoscience with novel control techniques from mechatronics and procedures from traceable metrology. The main deliverable will be a fast robotic metrology platform and operational procedures for measuring with nanometer resolution and in a traceable way the nanomechanical properties of large samples in a production environment.

### NEWS & EVENTS

#### OUR APPRECIATED PARTNER PEPM HAS HAD TO LAY DOWN ITS ACTIVITIES

We regret to inform you that due to unforeseen health issues our...  
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#### AIM4NP PRESENTS RESULTS AT INDUSTRIAL TECHNOLOGY CONFERENCE IN ATHENS, APRIL 2014

aim4np will present first results of its research during the...  
[read more...](#)

#### FIRST PROJECT MEETING

The first project meeting after the kick off was held during 22 and 23...  
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#### KICK OFF MEETING OF AIM4NP

On 3 and 4 April 2013 the project was kicked off with a high level...  
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Figure 32 Screen-dump of the start-page of the website www.aim4np.eu