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Scanning strategies for long term and long distance AFM measurements

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Abstract

Long range AFM measurements are mainly affected by drift caused by relative long measurement times and by tip wear caused by large measurement distances. One way to avoid these effects is to reduce measurement times and scanning distances. Special intelligent scanning strategies were developed and investigated. These strategies are based on adaptive sampling and different trajectories. This paper gives an introduction into the implemented scanning strategies. This paper presents one example of the developed "adaptive sampling" strategy as well as first results of the circular scan.

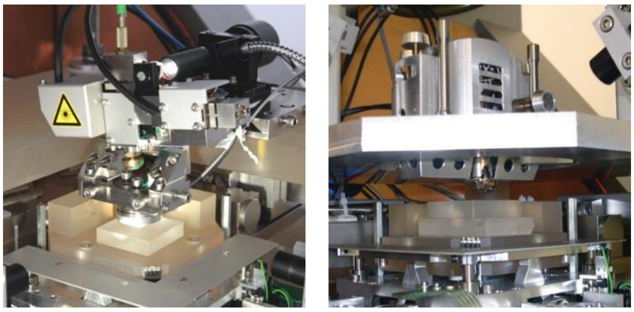
Keywords: nanopositioning and nanomeasuring machine, NPMM, SPM, AFM, long distance measurements, long term measurements, scanning strategies

1. Introduction

Atomic force microscope (AFM) is a highly resolution device for investigation, imaging and measurement primarily of surface topography.

The operating principle of the AFM is based on the detection of the prevailing forces acting over short distances between a sharp cantilever tip with a radius of a few nanometres and the sample surface during the scanning. These interactions led often to tip wear and therefore to a change in its radius [1]. The enlargement of the AFM tip results to a lower lateral resolution of the AFM measurements [2]. Therefore information about the shape of the tip and its wear behaviour (tip design, material combination), depending on the measured distance, the operation mode (CM, IM, NCM) as well as scanning and surface parameters (e.g. number of landings, scanning speed, probing force), is advantageous to plan, organise and realise the measurements. The wear of several different tips was investigated at the Technische Universität Ilmenau within the EMRP IND58 project [3].

Typically the measurement range of AFM amounts to a few hundred micrometres [4], the scanning motion is thereby provided by piezoelectric actuators. With the progression in precision engineering, micro- and nanotechnology as well as further key technologies, outstanding metrological properties and enhanced scanning ranges of the AFM are needed [5]. As example long range scans are advantageous for measurements of lateral standards or for complying with the standard determination of the nanoscale roughness [6]. The nanopositioning and nanomeasuring machine (NPMM) with its measuring range of 25 mm × 25 mm × 5 mm and subnanometre resolution in connection with the AFM-head with good metrological characteristics is particularly suitable for long distance measurements [7]. All investigations and measurements were performed by the interferometer-based AFM-head [8] as well the SMENA type scanning measurement head from NT-MDT Co. [9], both integrated into the NPMM (cf. fig. 1). The AFM-head and the NPMM were developed at the Technische Universität Ilmenau.



a) Interferometer-based head b) SMENA type head

Figure 1. AFM-head integrated into the NPMM.

Long distance and therefore long term AFM measurements are susceptible to environmental effects and often afflicted with the drift of the signals due to the long measurement time. Therefore the complete measurement setup (NPMM and AFM) is enclosed within an acoustically isolated chamber with a temperature stability of 10 mK [3]. The investigation of the long term stability was realized by continuous recording of the signals of the AFM-head (e.g. deflection and position of the cantilever). The waiting time after cantilever replacement and switch-on of the temperature control plus the long term stability of the AFM signals after the waiting (stabilization) time and at high environmental stability over several hours were determined during several measurements [3]. A good recommendation is the recording of the AFM signals and environmental data during the waiting time. With this information the start of the measurement can be decided.

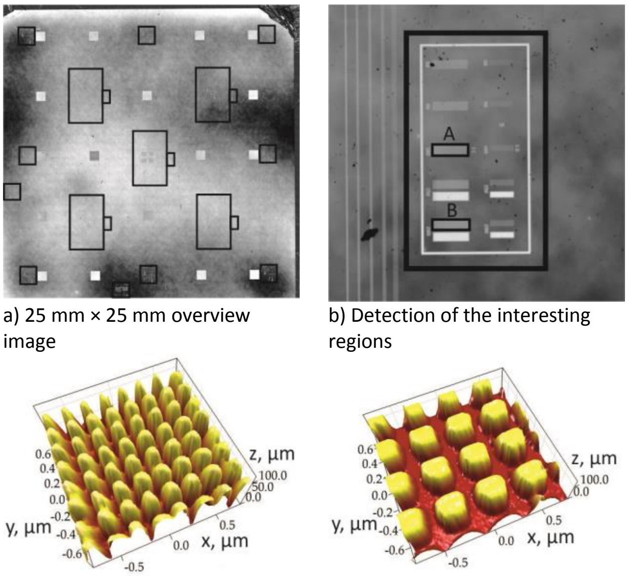
2. Scanning strategies

The goals of the developed scanning strategies are to reduce the scanning distances, time and overall size of sampled data as well as speedup of the measurements without loss of information about the measurement surface. Particular suitable scanning strategies are based on adaptive sampling and different trajectories.

2.1. Adaptive sampling

Often most of the sampled data during the measurement is thrown away afterwards and only small ratio is used for evaluation. The idea of adaptive sampling is based on the strategy to scan only areas with interesting structures.

The areas of interest can be automatically obtained using overview images taken by the AFM camera system and then created by stitching (cf. fig. 2 a)) [10]. Thereby the pixel indices of the overview image are calculated to the coordinates of the NPMM so the area of interest can be explicitly measured (cf. fig. 2 c) and d)). Although the necessary distance between the measuring points (raster), or rather the density of the measured data depends on the structure's geometry.



a) 25 mm × 25 mm overview image

b) Detection of the interesting regions

c) Fine scan A

d) Fine scan B

Figure 2. Performing measurements with the NPMM using "adaptive sampling".

2.2. Scan trajectories

Re the trajectories, the NPMM can make beside lines, rectangles (meander, forward-backward), also circular or helical and freeform scans with various sizes, rasters and speeds up to 1 mm/s [8]. The line and rectangle orientations are thereby arbitrary. The advantage of the circular or helical scan is continuous movement without hard turnarounds like by rectangular scans. Speciality of the implemented circular scan trajectories is the equal track speed in each circle during the meausurement and the same (arcs) distances between the measuring points independent from the circle radius. The received measurement data possesses beside irregular grid (raster) the consistent density.

As an example, figure 3 shows a circular scan performed with the NPMM and interferometer-based AFM-head. For this scan with the same dimension as a rectangular scan, the time saving is about 40%.

3. Measurement data processing

Non equidistant measurement data without a regular grid can be processed by the specially developed NPMM software, or by the open source software for AFM data analysis - Gwyddion. Each sampled measuring point is represented by three x, y and z coordinates and displayed by the software. Furthermore non equidistant data can be regularised by software for further evaluation and analysis.

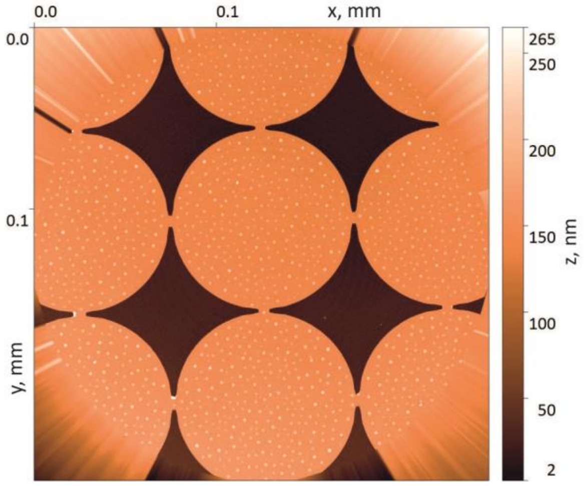


Figure 3. Performing measurements with the NPMM using "scan trajectories", circle with diameter of 0.25 mm.

4. Conclusions and outlook

This paper shows the approach for intelligent scanning strategies special developed for metrological AFM based on the NPMM. These strategies were implemented into the measurement routines (scripts) of the NPMM. Our next steps are to continue the tests of the routines on diverse structures and to compare the results after evaluation of the data sampled using different scan trajectories.

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