Design of Machines and Structures, Vol 4, No. 2 (2014) pp. 27–34.
https://doi.org/10.32972/dms.2014.015

HIGH PRECISION AUTOMATED MEASUREMENT SYSTEM FOR 3D ANALYSIS OF SURFACE TEXTURE AT THE NANOSCALE

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Abstract: The automated PC based measurement system for high precision 3D analysis of surface texture at the nanoscale is described. Measurement system is based on the atomic-force metrological microscope with modified specimen table having extended horizontal range. System implies the 3D surface texture analysis according to recent standard ISO 25178-2:2012.
Keywords: *surface topography, nanoscale, measurement system, automation*

1. Introduction

Precision measurements of surface texture at the nanoscale are extremely required in many branches of modern precision engineering such as production of laser gyroscopes, laser mirrors, night vision devices, microchips etc. The atomic force microscopy is commonly used for the analysis of nanostructures on the surface [1].

Most of existing microscopes involves mainly qualitative assessment with little quantitative facilities. At the same time, the detailed parametrical quantitative technique of the surface texture analysis is well known and widely used at the microscale. The same analysis technique can be carried at the nanoscale as well.

Existing surface texture analysis standards includes traditional 2D surface profile analysis by ISO 4287-98 [2] and recently involved 3D topography analysis by ISO 25178-2:2012 [3]. Precision surface texture measurements at the nanoscale are naturally intended to be analyzed by more accurate and informative 3D technique.

Present article describes the development of high precision PC based measurement systems based on metrological atomic force microscope NanoScan 3Di. System implies the 3D surface texture analysis according to recent standard ISO 25178-2:2012.

2. Measurement system structure

Main technical properties of the proposed measurement system are presented in Table 1. Photo of the measurement system is presented in Figure 1.

Measuring system has a module architecture that is shown in Figure 2. It consists of the atomic-force microscope, the high range coordinate table and a personal computer with controlling software and analytical software.

The central element of this system is the atomic force microscope NanoScan 3Di having piezo-resonance probe with stiff console and solid mechanical indenters made of artificial diamonds.

Scanning of the surface texture implies horizontal movement of the specimen by means of three-coordinate table. Parametrical analysis of nanostructure texture imposes extended requirement to the horizontal range of the table. That is why system includes specially

constructed high range and high precision three-coordinate piezo-table equipped with heterodyne laser interferometer having digital phase detector (Figure 3).

Table 1

Main properties of the measurement systems

Property	**Description**
Measurement principle	Atomic force microscopy
Probe type	Diamond indentor
Horizontal range (um)	500
Vertical range (um)	50
Horizontal resolution (nm)	< 0,1
Vertical resolution (nm)	< 0,1
Time resolution of measurements (ms)	1
Max. measurement speed (um/s)	30
Axis orthogonality error (rad)	0,01
Digital filtering	3D Gaussian
Measured parameters	Sa, Sq, Sp, Sv, Sz, Ssk, Sku, Sdq, Sdr, Sal, Str, Std, Smr, Sdc, Sxp, Vmp, Vmc, Vvv, Vvc, Spd, Spc, S5p, S5v, S10z, Sda, Sha, Sdv, Shv

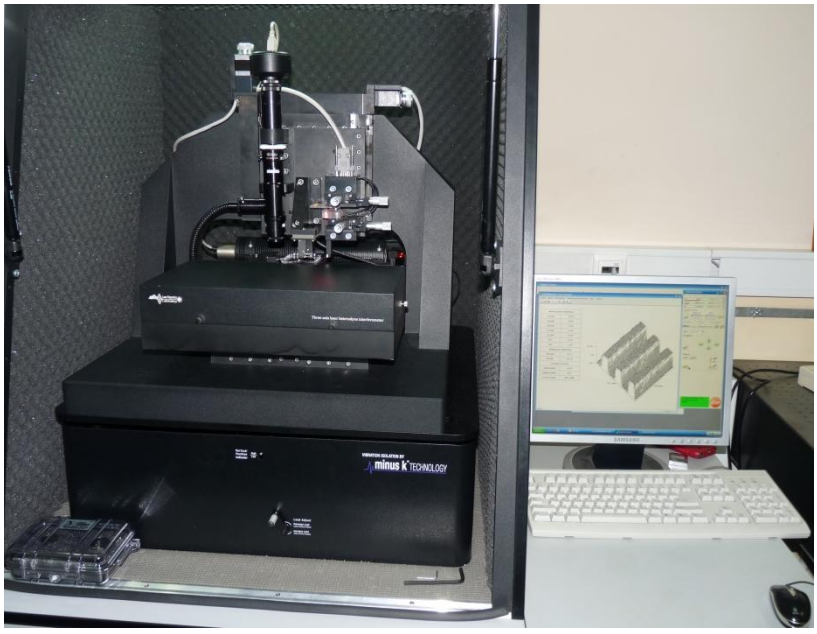


Figure 1. High precision PC based measurement system for a 3D surface texture analysis at the nanoscale

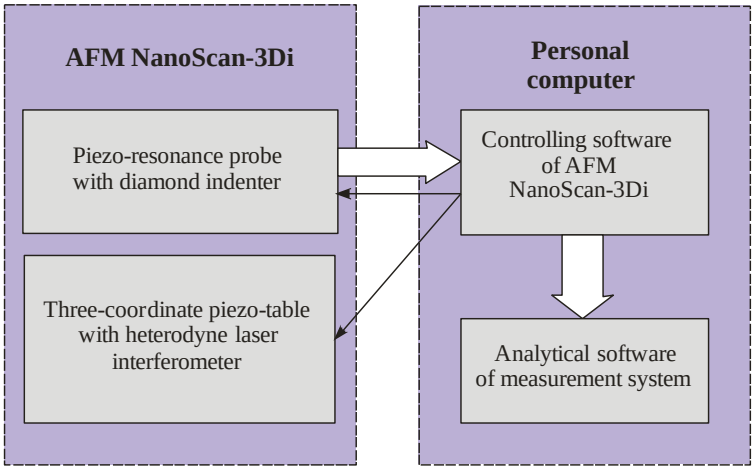


Figure 2. Architecture of the PC based measurement system

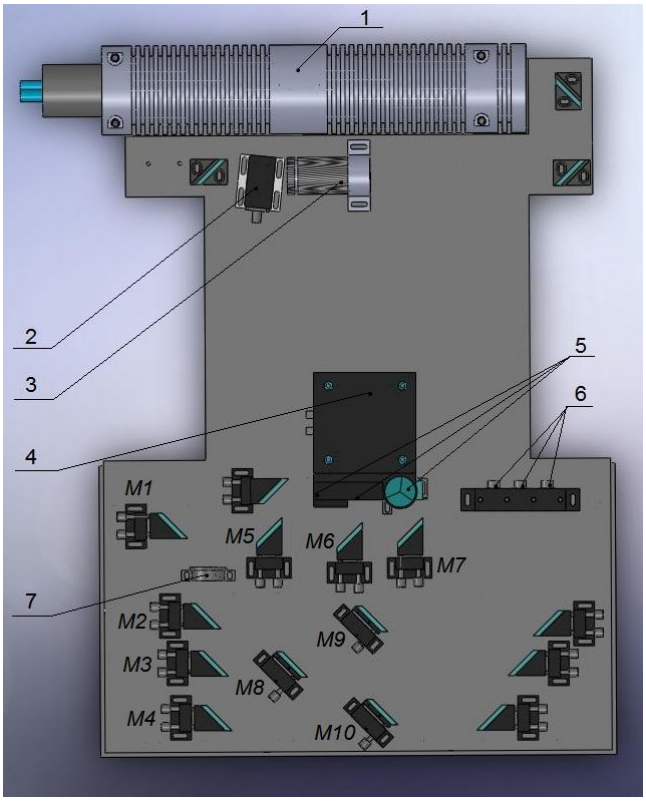


Figure 3. Optical scheme of heterodyne laser interferometer
1 – He-Ne-laser, 2 – acustooptic modulator, 3 – beam diffusor, 4 – translate piezo-table, 5 – trippel prisms, 6 – opticwire collimators, M1–M10 – justified optical elements

Electronic module of the three-coordinate table has time resolution of 1 ms that allows to perform surface scanning at up to 30 um/s speed. Measured data are transferred to the PC by means of USB interface.

Controlling software provides preliminary probe placement, motion control of table and probe, performing of single point measurement and incorporation of measured data into unified digital field.

After the measurement process is finished measured data are transferred to the analytical software. Analytical software implements surface visualization, form filtering (including specimen slope levelling), frequency filtering by means of digital phase-corrected Gaussian filter, parametrical assessment, correlation analysis and surface curve analysis. Parametrical analysis includes 28 parameters that are divided into groups of amplitude and hybrid parameters, spatial parameters, functional parameters, and segmentation parameters.

A number of preliminary measurements of the 3D surface texture were carried out to test the measurement system applicability. The preliminary measurements include calibrating lattice measures TGT and TGZ, diamond surface, grained surface and plasma processed surface. Example of the 3D analysis of the amplitude surface texture parameters of the grained surface and diamond surface in analytical software are presented in Figure 4–10.

The Sz (maximal surface texture height) values obtained during the analysis are equal to the nominal lattice values of TGZ and TGT. Combination of Sp (highest surface peak) and Sv (deepest surface valley) parameters is always equal to Sz.

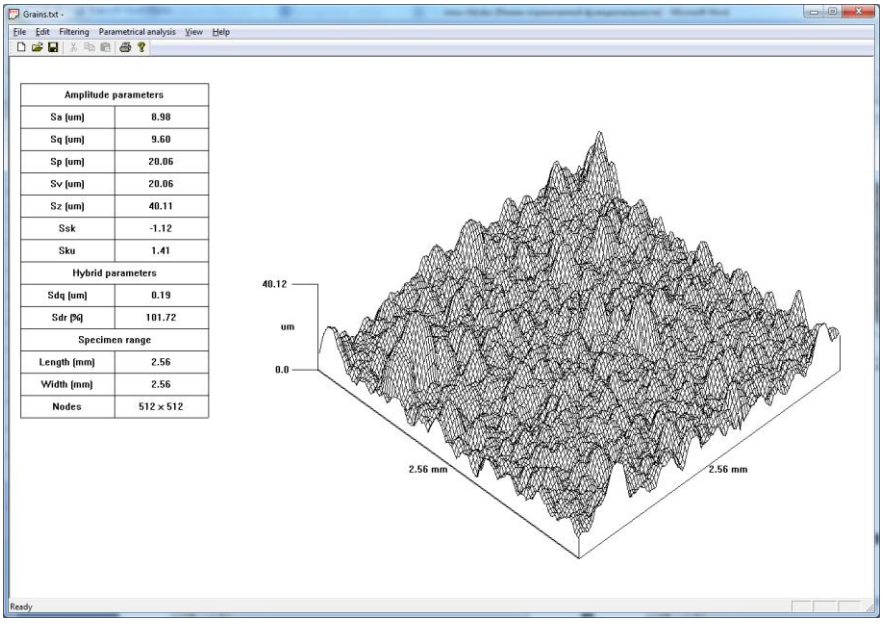


Figure 4. Sample of 3D surface topography of the grained surface

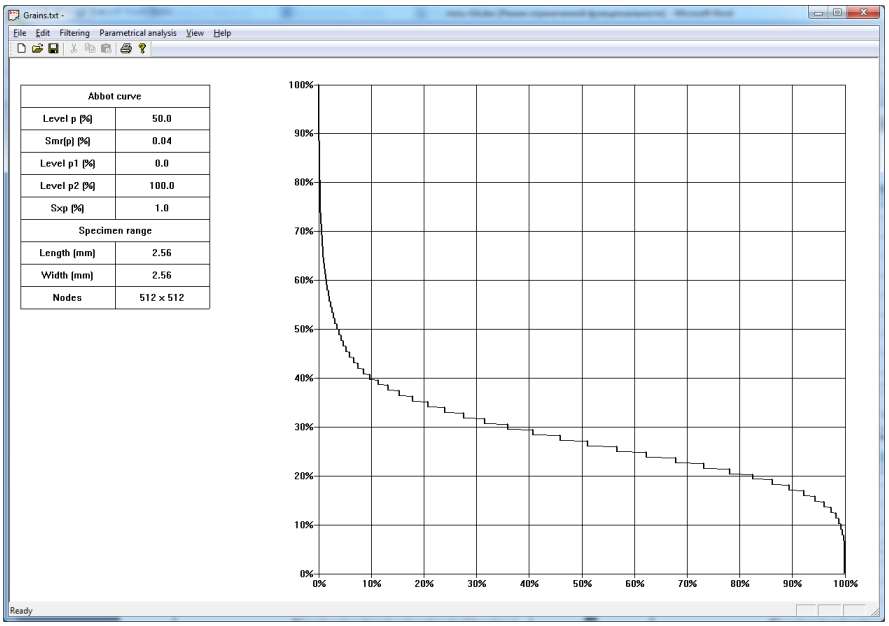


Figure 5. Sample of 3D surface topography of the grained surface

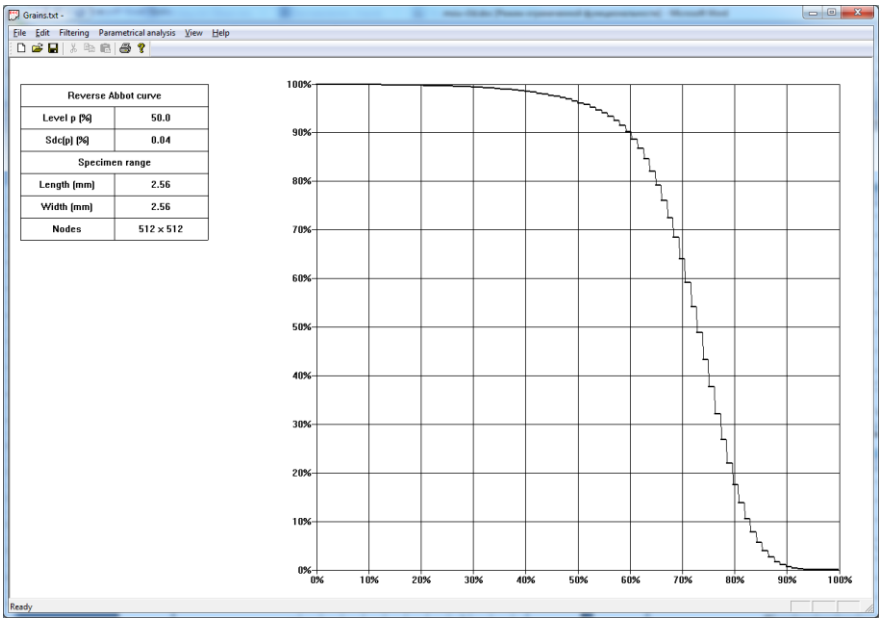


Figure 6. Sample of 3D surface topography of the grained surface

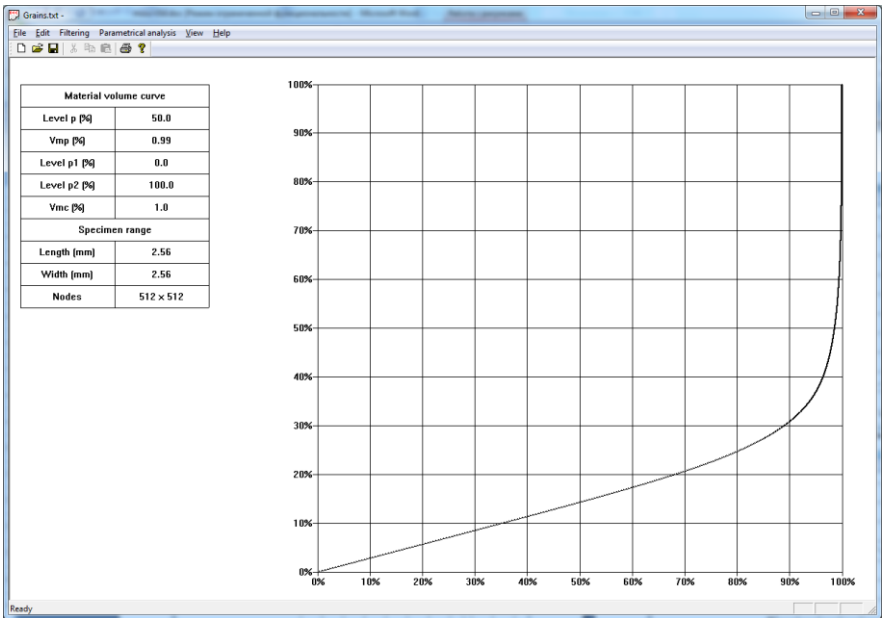


Figure 7. Sample of 3D surface topography of the grained surface

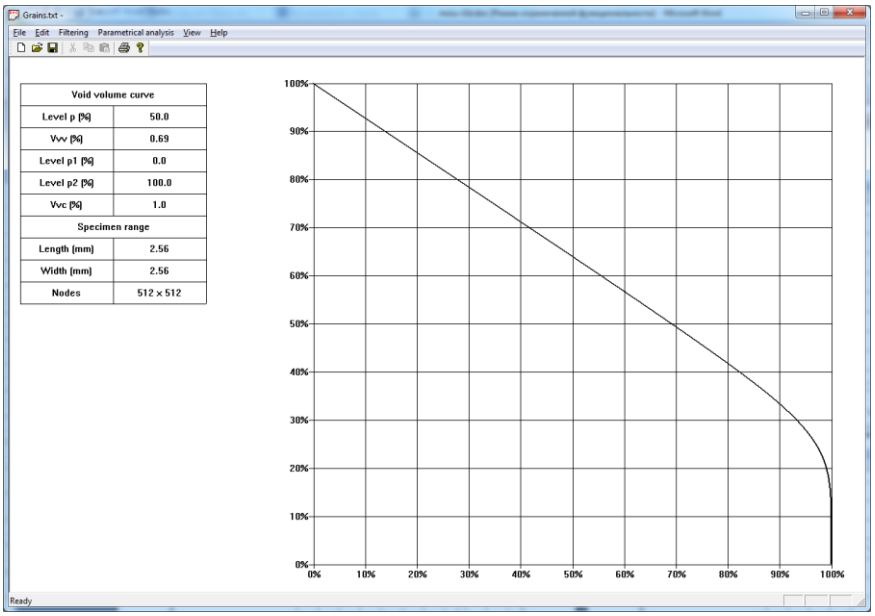


Figure 8. Sample of 3D surface topography of the grained surface

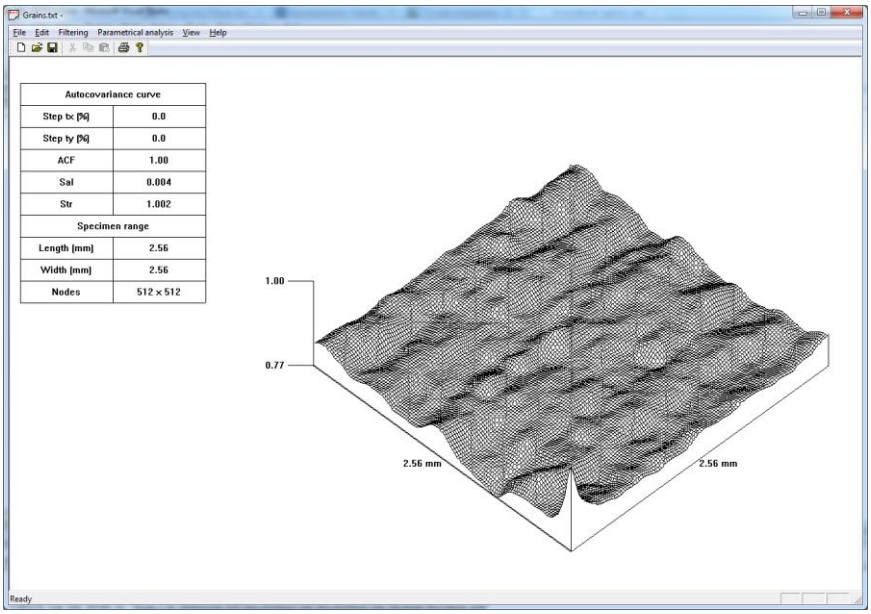


Figure 9. Sample of 3D surface topography of the grained surface

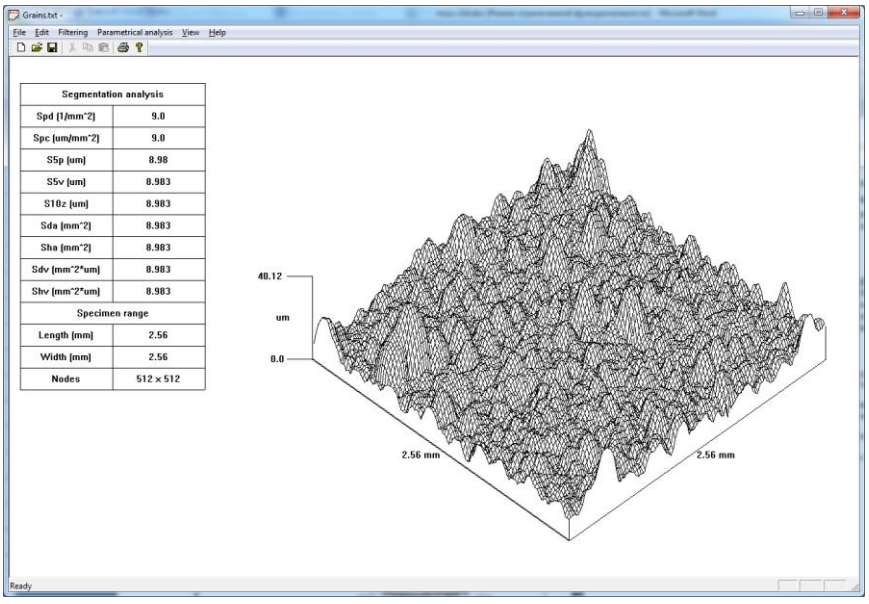


Figure 10. Sample of 3D surface topography of the grained surface

The Sa (arithmetic mean texture height) and Sq (root-mean-square texture height) are approximately similar and equal to 30–50% of Sz. The Sdr (developed interfacial area ratio of the scale-limited surface) is always exceeding 100%. It is minimal for the least height surface (calibrating lattice measure TGZ01).

So, preliminary results of the surface texture analysis of calibrating measures and real nano-surfaces allows to suggest that the described measurement system is suitable for providing the surface texture assessment at the nanoscale.

3. Conclusion

Proposed measurement system provides automated high precision measurements and complex PC based parametrical 3D analysis of surface texture at nanoscale. It can be recommended to use in modern nanotechnology and precision engineering laboratories.

The research was performed with the financial support of the Ministry of Education and Science of the Russian Federation for higher education institutions within the state job service.

4. References

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