Design of Machines and Structures, Vol 4, No. 2 (2014) pp. 19–25.
https://doi.org/10.32972/dms.2014.014

DIFFERENT METHODS FOR 3D MEASUREMENT OF SURFACE ROUGHNESS ETALONS

VALERY LYSSENKO–SERGUEY KONONOGOV–SERGUEY ZOLOTAREVSKIY
Russian Research Institute for Metrological Service
115280, Avtozavodskayast. 16, Moscow, Russia
lysenko@vniims.ru

Abstract: Scanning probe microscopes (SPM) are a family of instruments used for studying surface topography. But it is difficult to select object for testing SPMs. So the investigation of metrological characteristics of the atomic-force microscope (AFM) "NanoScan" (Russia), AFM "Nanotop" (Belarus) SPM P4-SPM-MDT (Russia) devices Talystep and Nanostep, Interference-microscope was worked out.
Keywords: *scanning probe microscope, interference microscope, contact stylus profilometer, nanometrology*

1. Introduction

Under term – "nanotechnology" we understand creating and using of materials, devices and systems, structure which contain in nanometer range. Nanometrology is science and practice for metrological assurance quality of nanotechnology. For measuring objects of nanotechnology a lot of measuring equipment of geometrical values are applied. All of them are 2Dimensional and 3Dimensional coordinate – measuring devices of nanometer range. Among them accuracy of measurement geometrical values till present time not enough assured. For metrological assurance of nanotechnology are very important the next tasks:

To investigate the accuracy ability of the 2D and 3D measuring devices worked in nanometer range;

To define how to execute calibration and verification of coordinate measuring devices with nanometer range of working;

Scanning probe microscope (SPM) are a family of instruments used for studying surface topography and properties of materials at the atomic to micron level. Their metrological support is non-satisfactory, because it is difficult to select object for testing SPM and compare the results of measurements of this object by different methods.

As a rule for coordinate measuring machines it is necessary to execute calibration of working volume in the X0Y plane (for measuring in X0Y plane) and along Z axis (for measuring of height along Z axis). In plane X0Y this calibration usually executes with help diffraction grid.

In this work for calibration in X0Y plane we used two diffraction grid: the first – produced by "LOMO" company (Russia), – the second – produced by "Holograit" company, calibrated in BIPM (France).

As the standard of height it may be used separate block gauges or unite standard, consisted from three or more heights.

We used for calibration of measuring devices along Z axis the set of 3D nanostructures consisted from different configurations of height with nominal 7 nm, 70 nm, and 800 nm. This set of standards was complimentary given to us by our colleges from PTB (Germany).

We studied the metrological characteristics of the atomic-force microscope (AFM) planar technology with known geometrical sizes. These test-objects were obtained in our disposal from PTB, Braunshweig, Germany.

We compare our results with analogous measurements by other devices such as AFM "Nanotop" from Metal-Polymer Systems Institute of Byelorussian Academy of Science, Scanning Probe Microscope P4-SPM-MDT from Nanotechnology MDT Inc., Russia, devices Talystep and Nanostep, Interference-microscope and others.

We propose to discuss the problems of creation the standard metrological security of the devices for surface parameters measurements with nanometer scale resolution.

2. Method of scanning probe microscopy

In AFM [1] the tip with radius of curvature commensurable with the atomic size in located near to a surface in a scope of atomic forces. Thus the area of contact between tip and surface can be about the sizes of atom. Force between probe tip and a surface is used as probing interaction in AFM. Probe tip can positioning as in the range of repulsion forces and in the range of Van der Vaals attractive forces when AFM functioning, accordingly contact and noncontact mode. The probe on which tip is fixed reacts to value of these forces. On its reactions determine mechanical properties of a surface of researched object and its geometry. In the majority modern AFM a bend of a console beam with a tip fixed on its end supervises by optical methods. Microscopes in which cantilever with a tip is oscillating and tip to an investigation surface contact change of frequency or amplitude are known.

All SPM are devices of a scanning type. During scanning observation of a surface adequate a constant level force active between a probe and surface or tunnel current is carried out. Devices based on the above-stated principles allow to receive the images of surfaces with the horizontal and vertical resolution up to 0,1 nm that is their basic advantage before optical. On this parameter they do not concede scanning electronic microscopes (SEM). Besides these devices allow to measure height relief in a large range and with the height resolution, that is inaccessible SEM. The simplicity of use SPM, their universality and more simple interpretation received data gives them significant advantages before SEM not only in scientific researches but also in technological applications.

In submitted work the described above objects were investigated on AFM NanoScan, developed and production by HTE Co., Moscow, Russia. This device works in a so-called contact dynamic mode of scanning. The principles of this mode consists that tip contact with a surface is fixed on the end of the oscillation console. This mode of work is sensitive to the mechanical characteristics of a surface material that enables to receive relief both viscous surfaces and rigid being under a viscous layer. The last peculiarity is especially important for research of objects on air, when on surface is present absorption a viscous layer, which smooth down relief elements. Besides, the device allows mapping a surface mechanical properties (Young modulus) and to measure hardness by an indentation and sclerometry methods with submicroand nanometer scale. The results received at measurement on NanoScan topology of a test-objects surface were compared to data, received at research of the same objects on following AFM.

AFM NanoScan, developed and production by HTE Co., Moscow, Russia used the noncontact mode of scanning (bend cantilever under influence of attractive forces is supervised – Figure 1).



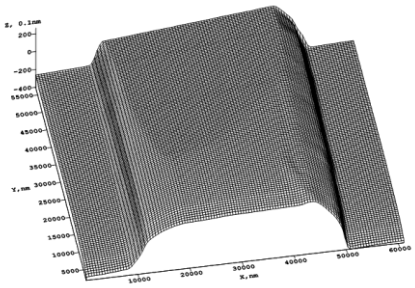
Figure 1. AFM NanoScan

P4-SPM-MDT from Nanotechnology MDT Inc., Moscow, Russia used the contact mode of scanning (bend cantilever under influence of repulsion forces is supervised – Figure 2).

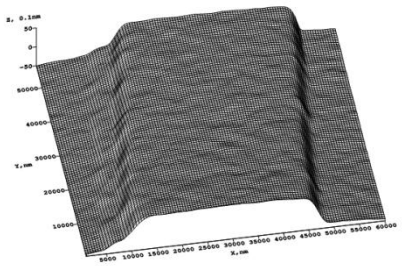


Figure 2. P4-SPM-MDT

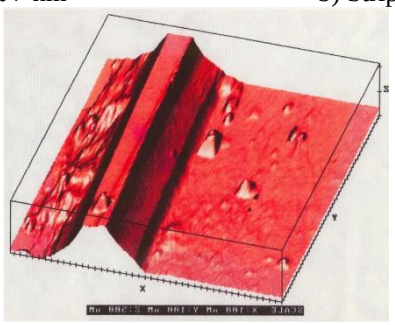
In particular, the comparison was carried out by results of received on the following samples, which represent structures from SiO2 on a silicon substrate (Figure 3): Strip of height 7 nm; Strip of height 70 nm; Square grid with a step 4 microns and depth about 0.5 microns.



a) Strip of height 7 nm



b) Strip of height 70 nm



c) Strip of height 800 nm

Figure 3. Gauges

Received results have allowed to make the following conclusions. The test object as a square grid can be used for determination of the scanning field sizes and coordinates system nonlinearity in a XY plane. As a whole, the spent researches have confirmed perspective of similar test-objects application for calibration of various SPM parameters.

Table 1

Results of measurements

Devices	Test-objects			
	Square grid		Strip 7 nm	Strip 70 nm
	step, μm	depth, μm	Measured height, nm	Measured height, nm
NanoScan	4±0.1	0.5±0.1	7±1	70±5
NanoTop	4±0.1	0.4±0.1	–	–
P4-SPM-MDT	4±0.5	0.5±0.2	8±1	70±10

Comparisons of measuring ability different scanning probe microscopes

3. Method of interference microscopy

The next device the new modification of interference microscope MII-4 was developed for the automatic identification of the achromatic land in white light interferometers and for the digital measurements of its centre position.

But new modification New View 6200 (Figure 5) is a powerful tool for characterizing and quantifying surface roughness step heights critical dimensions and other topographical features with excellent precision and accuracy.



Figure 4. Interference microscope MII-4

The new modification of interference microscope MII-4 (Figure 4) was developed for the automatic identification of the achromatic land in white light interferometers and for the digital measurements of its centre position. It can:

– to automatic the measuring process in white light;
– to control processing of data with a computer;
– to display (or print) graphics and digital information about object under investigation;
– to increase the accuracy and sensitivity of interferometric methods and widen in the range of measurement both of low and high film thickness.

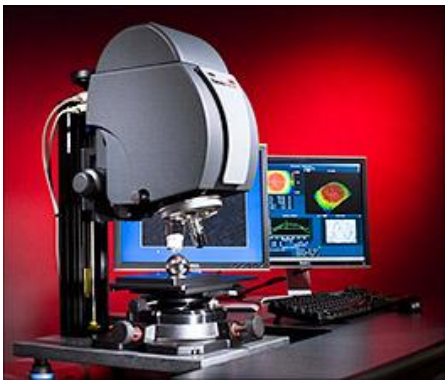


Figure 5. Zygo New View 6200

So, with these interferometers we can measure profiles of the surfaces with high accuracy.

In interference microscope MII-4 the wavelength is used as standard (it is the natural standard). Therefore this interferometer can be used as primary standard for traceability in nanometer range. The New View 6200 can be used as reference standard for traceability of

surface nanoroughness measurements. We executed measured nanostructures with nominal height 7, 70 and 800 nm on the interference microscope.

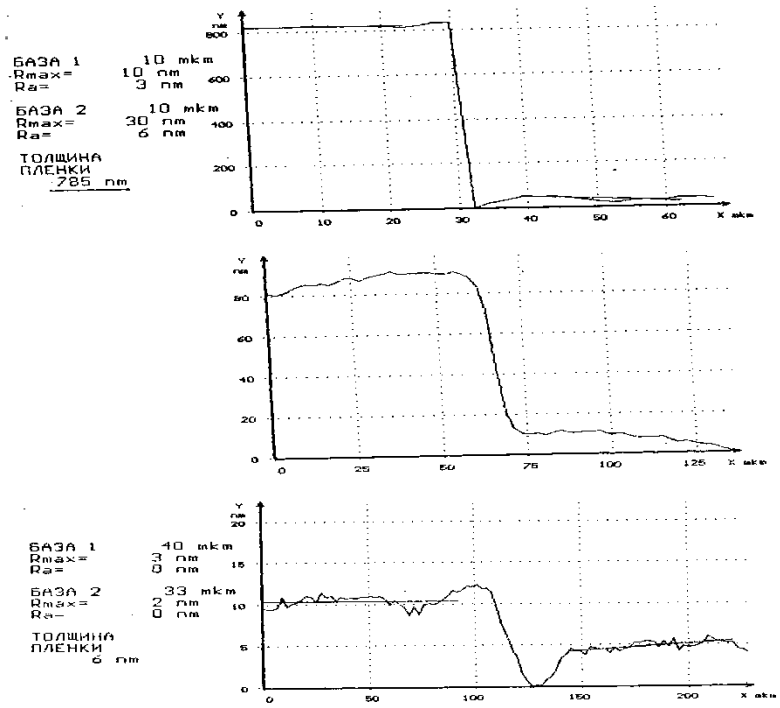


Figure 6. Results of measuring artefacts with height 7 nm, 70 nm and 800 nm

4. Method of contact stylus profilometry

Talystep is a stylus instrument designed topography at the atomic to micron level (Figure 7). Talystep has a vertical resolution better than 1.0 nanometer. It provides simple, direct measurement of nanotopography, and produces permanent graphical recordings of step height and surface texture, magnified up to 2 000 000 times.

We used this devices for investigation the samples of thickness with compound structure of steps with nominal height of 7, 70 and 800 nm. The results of investigations were compared with methods of SPM and interference microscopy.

On the base of investigating ability of measurements nanostructures on the interference microscope MII-4 and contact profilographTalystep were defined Results of key comparisons PTB (Germany) – VNIIMS (Russia). Results of comparisons showed a good reproducibility.

On the base of executing research of the accuracy ability of the 2D and 3D measuring devices in nanometrology was created calibrating hierarchy scheme, which allows to achieve traceability of length measurements in nanotechnology.



Figure 7. Talystep

5. Conclusion

1. The investigations of possibilities of precision measurement of 2D and 3D nanostructures by different measuring devices of nanometer range are executed. We determined that investigated measuring devices of nanometer range allow to measure geometrical size both in horizontal plane XY and along vertical axis Z.

2. Since the wavelength of light is used as a standard in interference microscope (it is the natural standard), this interferometer can be recommended as a primary standard for assurance traceability in nanometer range.

3. Investigated and calibrated 2D diffraction greed and multilayer step gauges can be used as a working standard for traceability in nanometer range.

4. Traceability of measurements in nanotechnology can be achieved by executing calibration of measuring devices nanometer range according calibrating hierarchy scheme.

6. References

[1]Kononogov, S.–Lyssenko, V.: High precision PC based measurement system for etalon roughness analysis. *International Journal Advanced Engineering*, No. 2 (2008).