AFM investigation of the silicon micro structure steep walls created by reactive ion milling.

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In current work we discuss problems connected with investigation of silicon micro structure steep walls using standard Scanning Probe Microscope. In our case the microstructure was represented by silicon grating, created by reactive ion milling. It is shown that investigation of steep walls can not be provided using standard methods of positioning the sample and approach to it. We have developed the methodic, which can provide investigation of such kind of samples.

The structure (silicon micro grating) was created by the reactive ion milling of silicon substrate.

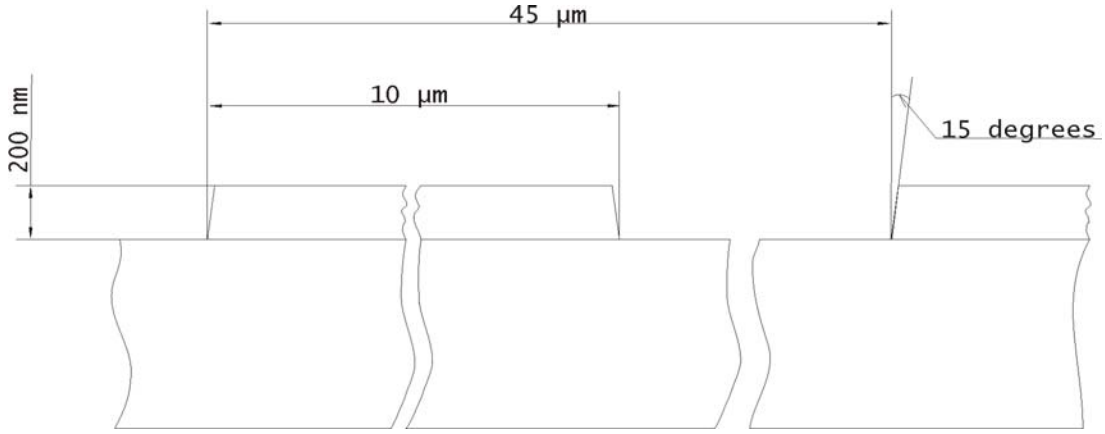

fig.1 Expected structure of the grating.

In our investigations we used the atomic-force scanning-by-tip microscope (AFM) Solver P-47H (NT-MDT, Russia) operated in resonance ("tapping") mode. The unit was completed with silicon cantilevers NSG10S (NT-MDT, frequency 255 kHz and a tip curvature radius 10 nm or less) and whisker-type cantilevers NSC05 (NT-MDT, frequency 255 kHz with carbin Focused Electron Beam (FEB) tips).

Investigation of the sample in its standard horizontal positioning using whisker-type cantilevers has shown the real structure of the grating's steep walls.

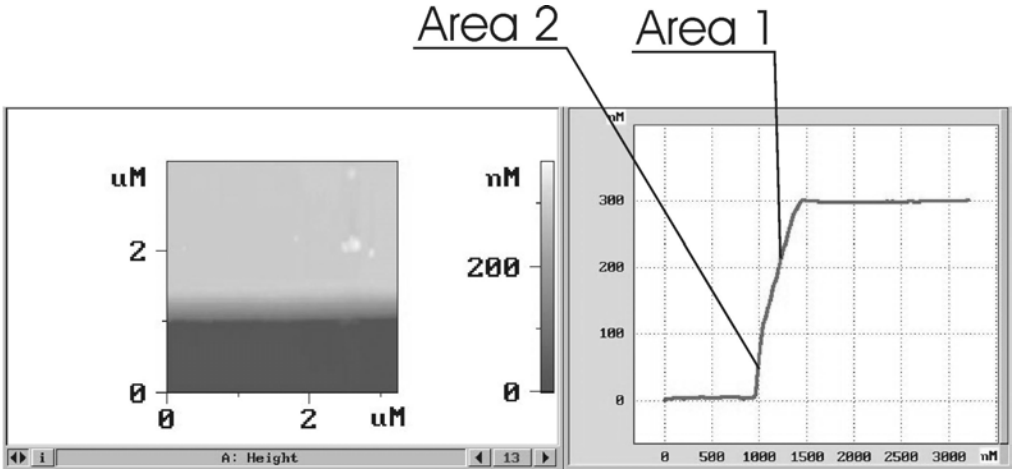

fig. 2 The real structure of the grating's steep walls.

As it is seen from fig.2, we can part the wall into two areas. Our main task was to investigate "Area 1".

The best resolution of AFM methods is obtained, when the SPM tip is normal to the examined surface [1,2]. From these considerations the better way to investigate steep walls of the grating would be its positioning at the "α" angle, which will provide the normal approach to the steep wall.

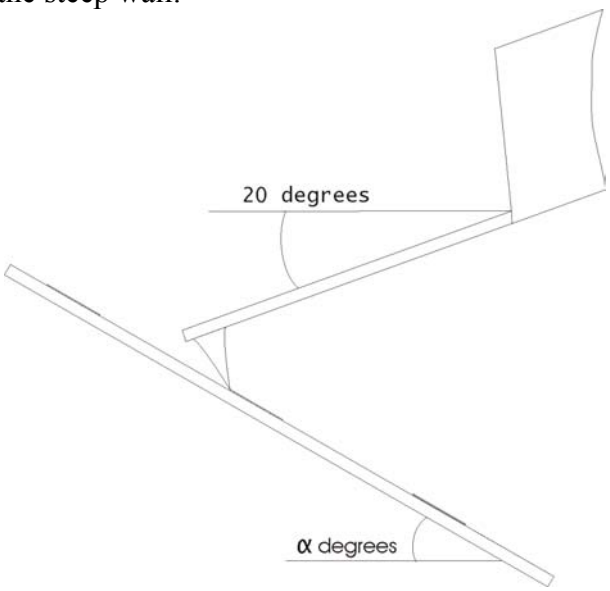

fig.3 Cantilever's approach to the sample

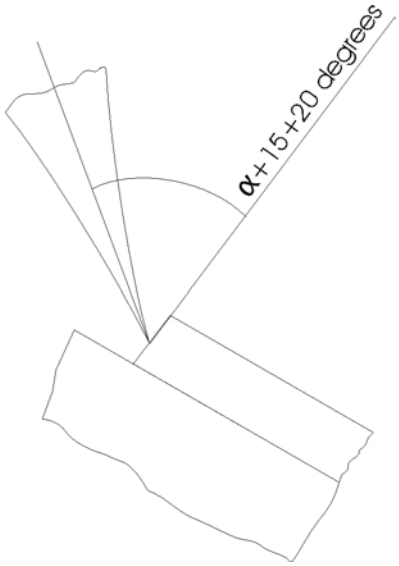

fig. 4 Relative angle between cantilever's tip and steep wall.

Analyzing figures 1, 3, 4 it's easy to come to a conclusion that α=55º will correspond for the necessary result. But in fact, we face with some problems, one of which is fundamental.

Typically scanner's Z-range varies from 2 to 5μm. If the sample is inclined, Z-range determines also the Y-range of the scanner.

$$Y\max' = Z\max \cdot ctg\alpha \qquad (1)$$

So if α=55º and Zmax=5μm in result instead of standard Ymax=50μm Ymax'=3.5μm.

and only 1.4μm in case of smaller scanner. All this causes problems with approaching to the wall and its further exploration.

Analyzing these two limitations we have determined optimal range of α angle value. It lies between 15º and 40º.

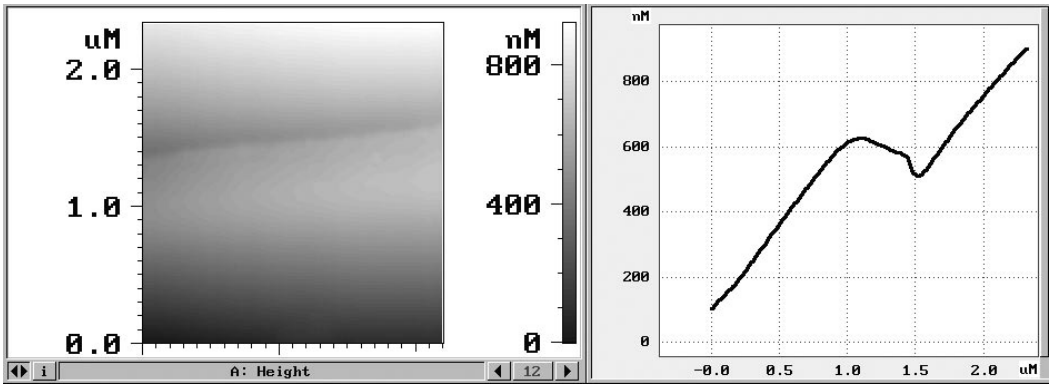

fig.5 Scan after approach to steep wall and its profile.

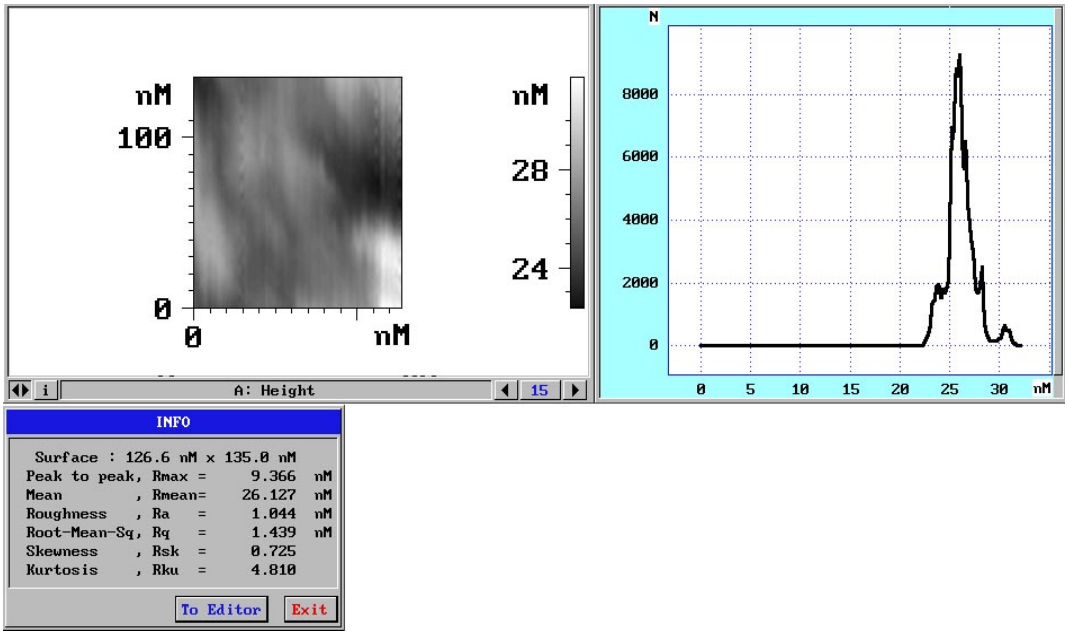

fig.6 Part of the wall's surface with results of its statistic analyses.

On the fig.5 is shown a part of a steep wall with adjacent areas. On the figure 6 a part of the wall with results of statistic analyses is present, for instance, such parameter of the surface like roughness is very important in technological process tuning and control.

The main problems of AFM investigation of the silicon micro structure steep walls were discussed and the constructive solution of its performance was found. The silicon micro structure (micro grating) steep walls were investigated and the statistical information about surface was obtained.

[1] G. Biening, C.F. Quate, C. Gerber, Phys. Rev. lett. 56 (1986) 930.
[2] F. Touhari, X. Bouju, Ch.Girard, M. Devel, G. Cohen-Solal, Appl. Science 125 (1998) 351-359