MEASUREMENT OF SURFACE TOPOGRAPHY USING AN ATOMIC FORCE MICROSCOPE

Faculty of Mechanical Engineering and Naval Architecture
Ivana Lučića 1, 10000 Zagreb, CROATIA

ABSTRACT

In this paper the analysis of influence quantities to the measurement of surface topography using the atomic force microscope (AFM) was conducted. By measuring the surface of a sample with an atomic force microscope, the surface quality can be expressed quantitatively and qualitatively. Qualitative representation implies an image of the surface condition in 2D and 3D form, while surface roughness parameters quantitatively describe the surface of the sample. In this paper the influence of scan area, scan resolution, scan rate and the influence of the filtering of the primary surface on the results of roughness parameter measurements was performed on the selected samples.

KEYWORDS

atomic force microscope
filtering of the primary surface
surface topography
surface roughness

CONCLUSION

Measurement of the surface topography of the sample was performed via AFM. The analysis of input sizes on the surface topographical parameter was conducted on the same sample, changing the input size values. Different scan resolutions visually demonstrate different levels of image quality. A higher resolution value gives clearer results of the scanned area. The filtering of the primary surface is necessary in order to calculate the values of surface roughness parameters. The Gaussian filter with different selections of the cut-off value was used to accomplish this. The obtained results show the impact of different selections of the cut-off value. The influence of the selection is seen both on the images and on the roughness parameters. It is necessary to choose the cut-off value carefully in order to obtainthe roughness parameters that can be used.

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1 INTRODUCTION

The atomic force microscope belongs to the group of microscopes with probes and works on the principle of raster scanning the sample surface with a sharp-tipped probe [1]. The AFM has the ability to scan the sample surface by contact mode, tapping mode and non-contact mode [2]. In this paper the results of the sample surface scan are obtained using the tapping method. The paper further analyzes the influence parameters of scanning on surface topography. Surface topography includes three basic components: roughness - short spatial wavelength component, waviness and form - longer spatial wavelength components [3]. The topography of the sample surface on the obtained images was analyzed and processed by a trial version of the image processing program – Mountains SPIP. The influence of scan input values on the surface parameters of the topography of measurement results as prescribed by the ISO 25178-2 : 2012 standard [4] was analyzed. The effect of filtering primary surfaces on measurement results of surface roughness parameters was also analyzed.

2 MEASUREMENT OF SURFACE TOPOGRAPHY

In this paper the influence of three input parameters on measurement results were investigated. All measurements were performed on the the same sample, a stainless steel plate. The experimental part of the researche was conducted at the Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb. The measurements were performed using the Oxford Ayslum Research, MPF-3D Origin scanner. The Scanning was conducted in the AFM tapping mode.

The input parameters that were changed during measurements are:

- scan size (20 × 20 ; 50 × 50 ; 100 × 100) μm
- scan resolution (128, 256, 512)
- scan rate.

The parameters from each of these three groups were combined to examine and compare their impact on the topography parameters of the sample. Measurements were performed at six different scan rates, three levels of resolution and three different scan size areas. Figure 1 shows the qualitative representation of surface conditions measured on the 100 μm × 100 μm scan area, with a scan rate of 0,5 Hz and a resolution of 512.

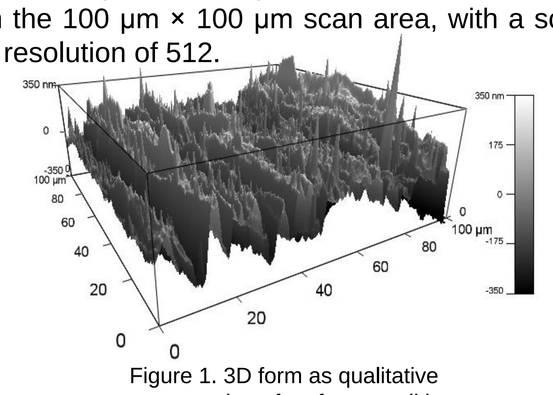

Figure 1. 3D form as qualitative representation of surface condition

Results obtained for different scan sizes, scan rates and scanning resolution are given in the following tables (Table 1 – Table 4).

Table 1. Topographical parameters for scanning rate 0,25 Hz and scanning size 100 μm × 100 μm

Topographical parameter		*Sq*	*Ssk*	*Sku*	*Sp*	*Sv*	*Sz*	*Sa*
Unit		nm	-	-	nm	nm	nm	nm
Scanning resolution	128	167.81	-0.890	4.772	611.60	668.60	1280.19	125.92
	256	172.05	-0.858	4.661	684.65	685.56	1370.21	129.64
	512	173.90	-0.765	4.461	774.52	701.68	1476.20	131.79

Table 2. Topographical parameters for scanning rate 0,5 Hz and scanning size 50 μm × 50 μm

Topographical parameter		*Sq*	*Ssk*	*Sku*	*Sp*	*Sv*	*Sz*	*Sa*
Unit		nm	-	-	nm	nm	nm	nm
Scanning resolution	128	198.72	0.199	-0.739	547.33	762.38	1309.70	149.38
	256	199.64	-0.684	3.990	576.07	761.54	1337.61	150.39
	512	197.84	-0.628	3.876	592.73	759.05	1351.78	149.43

Table 3. Topographical parameters for scanning rate 1 Hz and scanning size 20 μm × 20 μm

Topographical parameter		*Sq*	*Ssk*	*Sku*	*Sp*	*Sv*	*Sz*	*Sa*
Unit		nm	-	-	nm	nm	nm	nm
Scanning resolution	128	116.18	0.060	2.185	278.45	421.68	700.13	98.05
	256	116.34	0.072	2.167	290.08	419.33	709.41	98.24
	512	118.53	0.025	2.244	293.86	446.45	740.31	99.94

Table 4. Comparison of topographical parameters for different scan rates

Scan rate	Topographical parameter	*Sq*	*Ssk*	*Sku*	*Sp*	*Sv*	*Sz*	*Sa*
Hz	Unit	nm	-	-	nm	nm	nm	nm
0.50	Mean $\bar{x}$	77.381	-0.843	4.812	250.441	305.569	556.010	57.931
	St. deviation s	0.373	0.008	0.023	2.681	0.175	2.775	0.256
0.80	Mean $\bar{x}$	77.899	-0.831	4.796	252.675	309.055	561.730	58.266
	St. deviation s	0.950	0.018	0.043	2.496	1.961	4.438	0.590
1.20	Mean $\bar{x}$	77.569	-0.804	4.742	255.812	305.029	560.841	58.142
	St. deviation s	1.135	0.016	0.081	3.787	3.022	6.447	0.709
1.40	Mean $\bar{x}$	77.277	-0.798	4.800	250.463	306.319	556.782	57.502
	St. deviation s	0.546	0.003	0.053	3.673	1.058	4.728	0.583
1.60	Mean $\bar{x}$	74.555	-0.786	4.864	238.830	300.129	538.959	55.257
	St. deviation s	0.841	0.007	0.018	3.853	2.872	6.725	0.672
1.80	Mean $\bar{x}$	72.669	-0.742	4.777	233.751	293.900	527.651	53.994
	St. deviation s	0.148	0.006	0.011	0.258	1.004	0.839	0.116

3 INFLUENCE OF FILTERING OF THE PRIMARY SURFACE

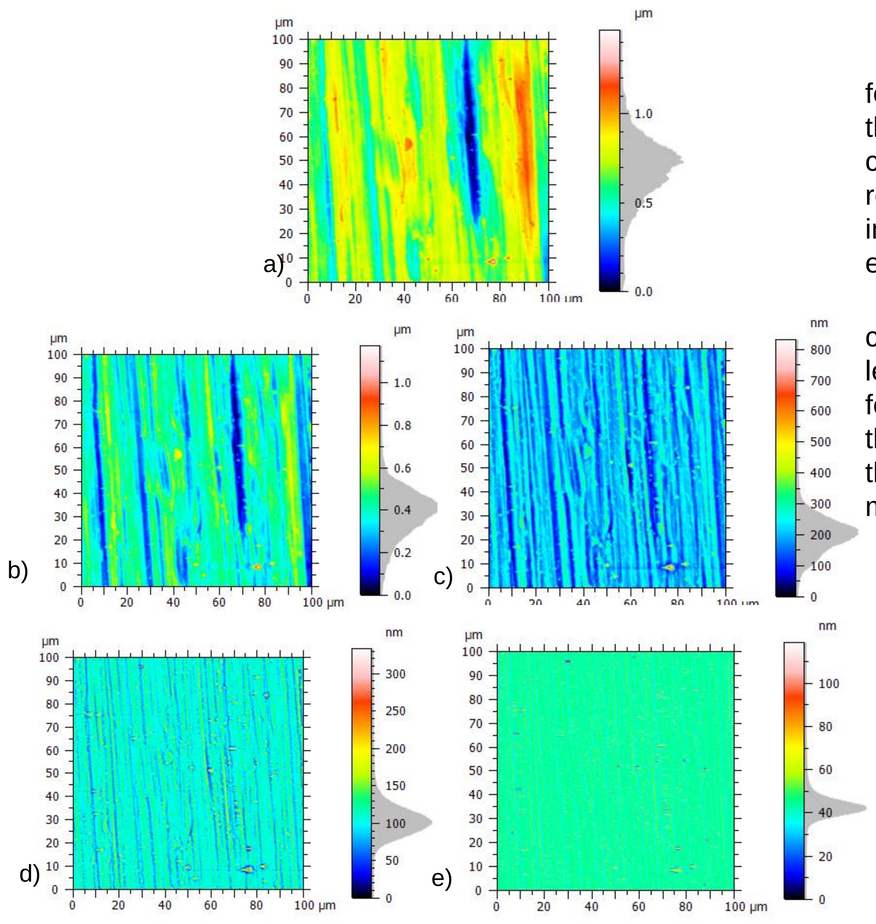

Figure 2. Comparison of the same area nonfiltered (a) and filtered by a Gaussian filter with cut-off value:
b) 25 μm c) 8 μm d) 2.5 μm e) 0.8 μm

Filtering is applied for the purpose of removing certain features of the primary surface. In other words, filtering can extract the roughness component from the shape deviation and corrugation components for the purpose of analyzing the roughness parameters [5]. A common occurrence in scanned area images is unwanted high- or low-frequency noise that can be easily eliminated by applying filters.

Figure 2 shows how different selections of the cut-off value changes the image display. The lower the filter limit, the higher the level of detail in the image and the more pronounced the individual features. With the application of the filter, the edges are clearer on these features, which improves their characterization. By applying this filter, low-frequency differences in height are reduced, which makes these mentioned features more clearly visible.

Table 5. Comparison of roughness parameters of unfiltered and filtered images

Topographical parameter		*Sq*	*Ssk*	*Sku*	*Sp*	*Sv*	*Sz*	*Sa*
Unit		nm	-	-	nm	nm	nm	nm
Cut-off / μm	-	173.90	-0.765	4.461	774.52	701.68	1476.20	131.79
	25	104.45	-0.398	3.601	784.73	389.59	1174.31	81.61
	8	54.69	0.166	4.883	628.89	202.62	831.51	42.50
	2.5	19.98	1.055	7.594	228.45	105.11	333.55	15.01
	0.8	5.08	1.905	16.101	75.43	43.52	118.94	3.45

Table 2. shows a comparison of the surface topographical parameters and the surface roughness parameters for the images filtered by this previously mentioned filter. So it is a scan size of 100 μm × 100 μm, scan resolution 512, scan speed 0.25 Hz and a Gaussian filter of different cut-off values was applied.

KORMAT 2020
Zagreb, CROATIA

Andrej RAZUMIĆ, Amalija HORVATIĆ NOVAK, Biserka RUNJE, Mateo CAREVIĆ