

План вебинара

1. Вступление. Общие принципы

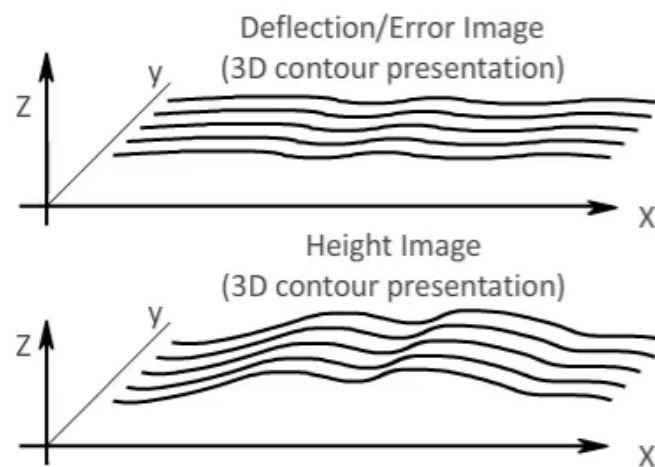
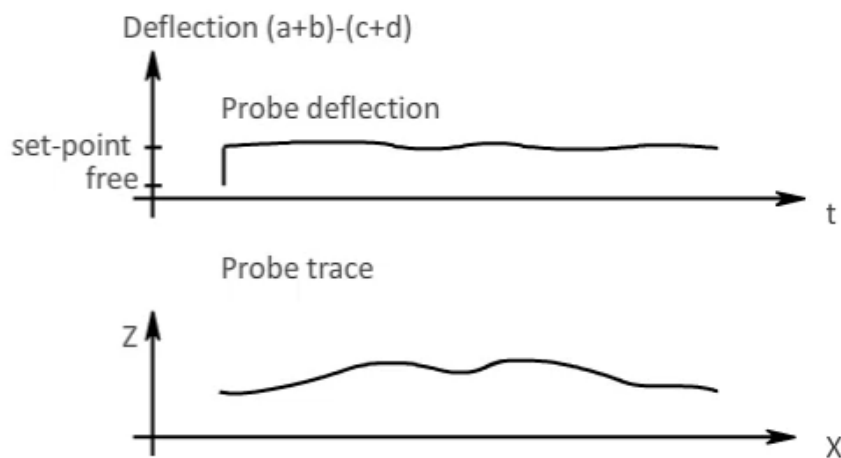
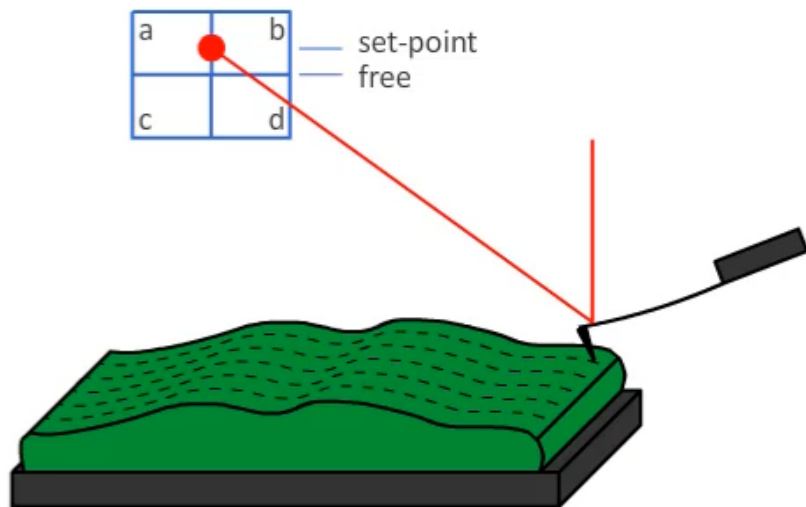
2. «Уплотнение»

3. Реконструкция

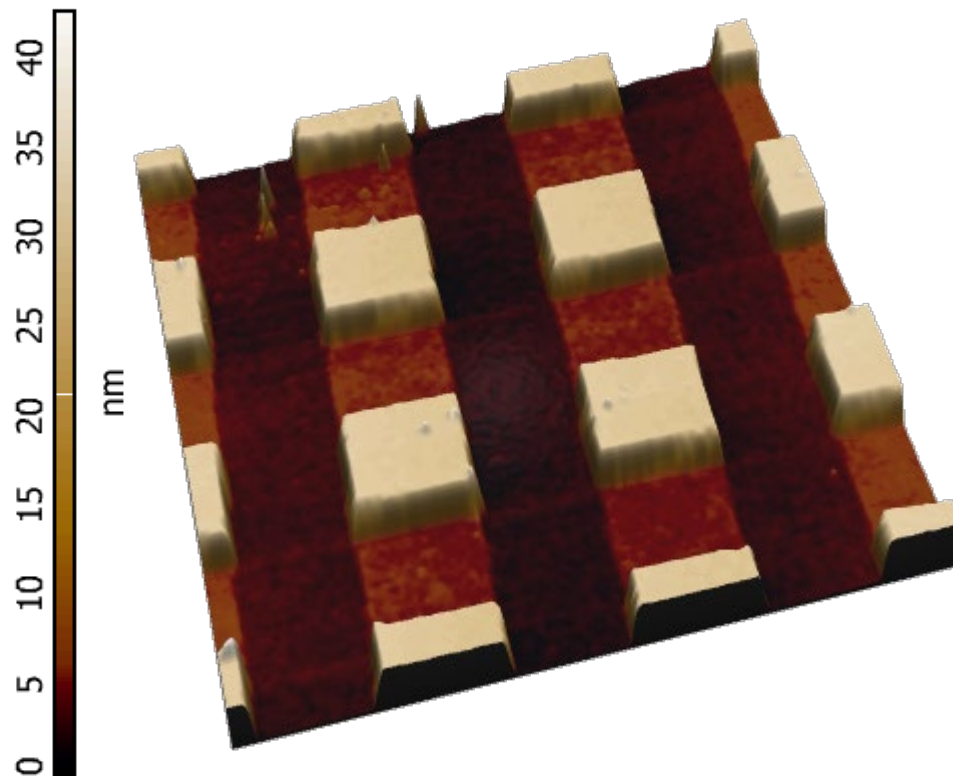
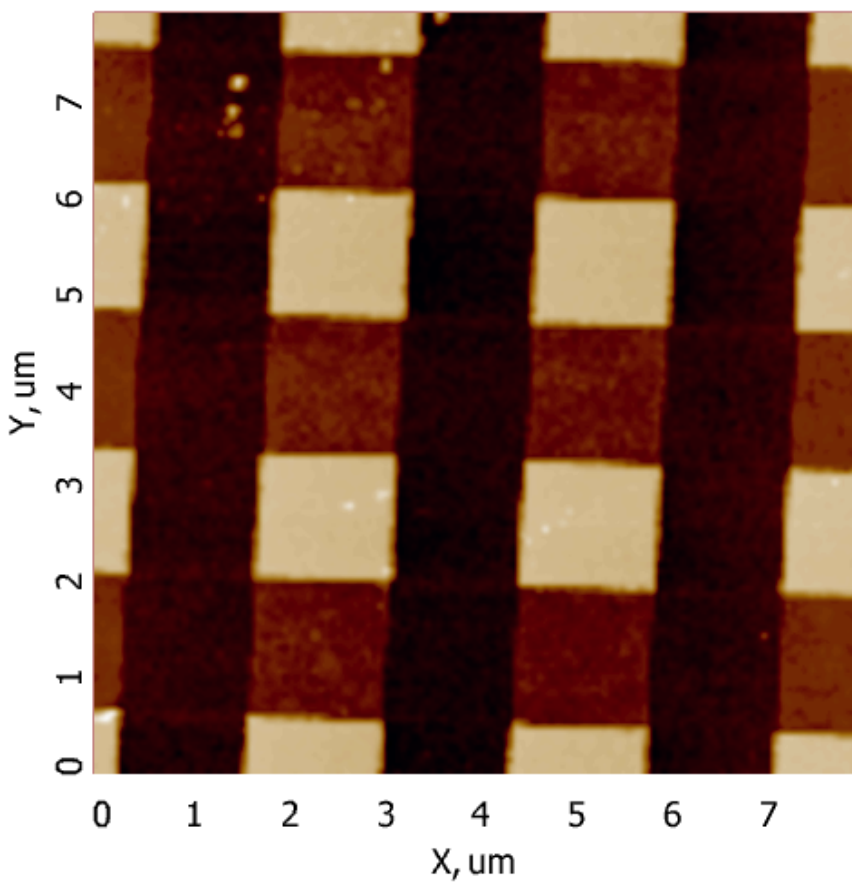
4. Представление

5. Анализ

Формирование изображения в

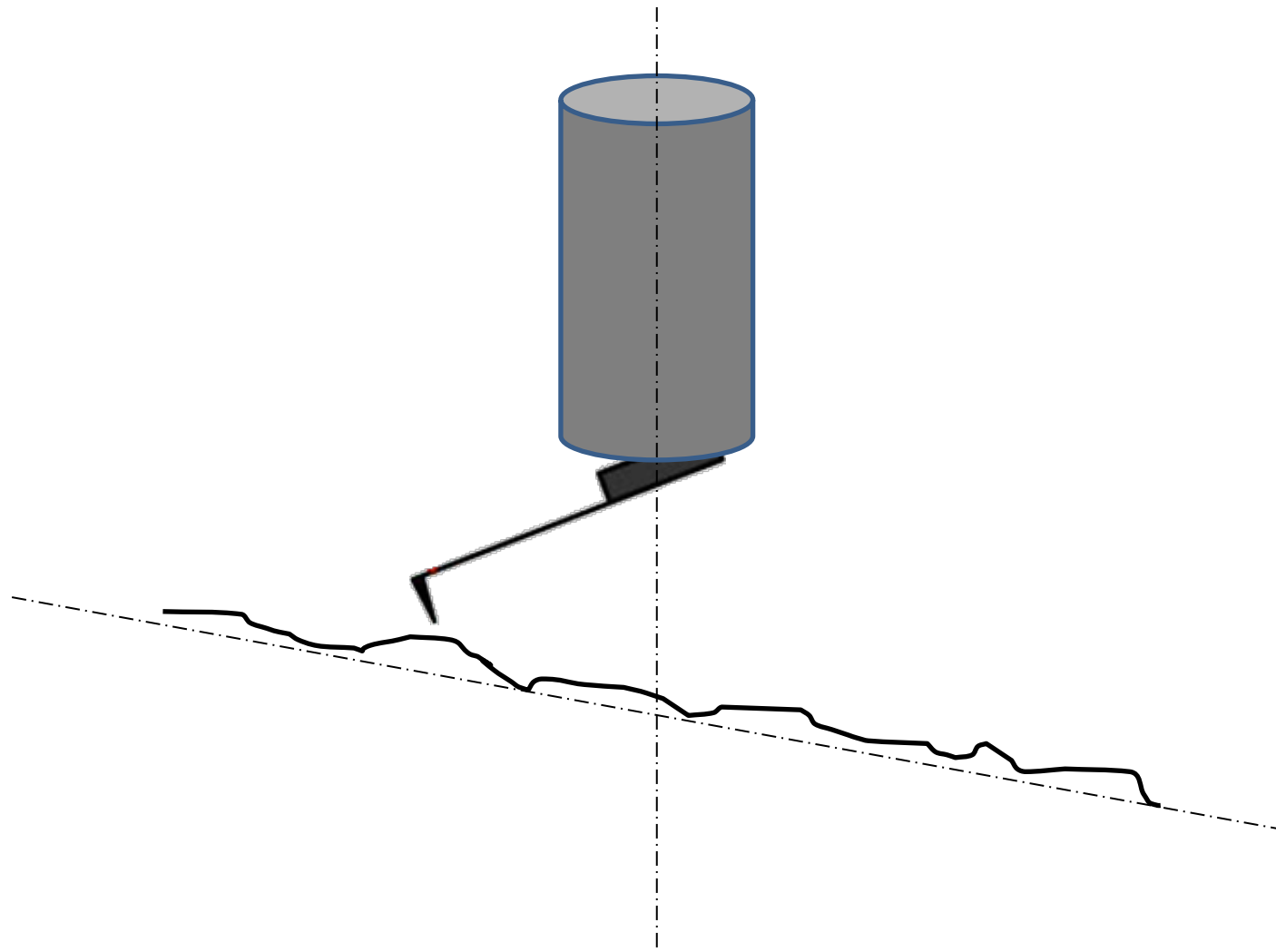


Изображения в АСМ

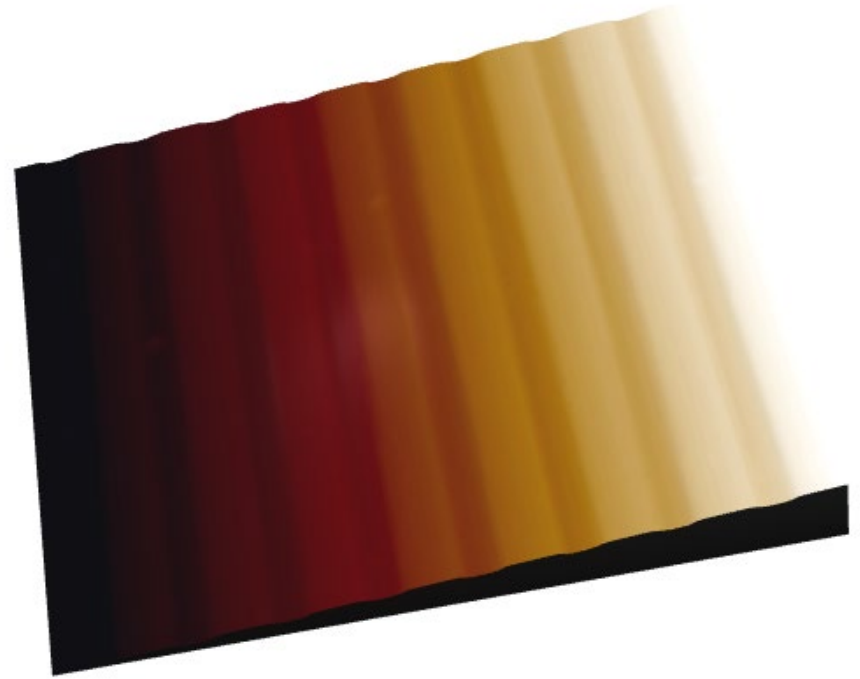
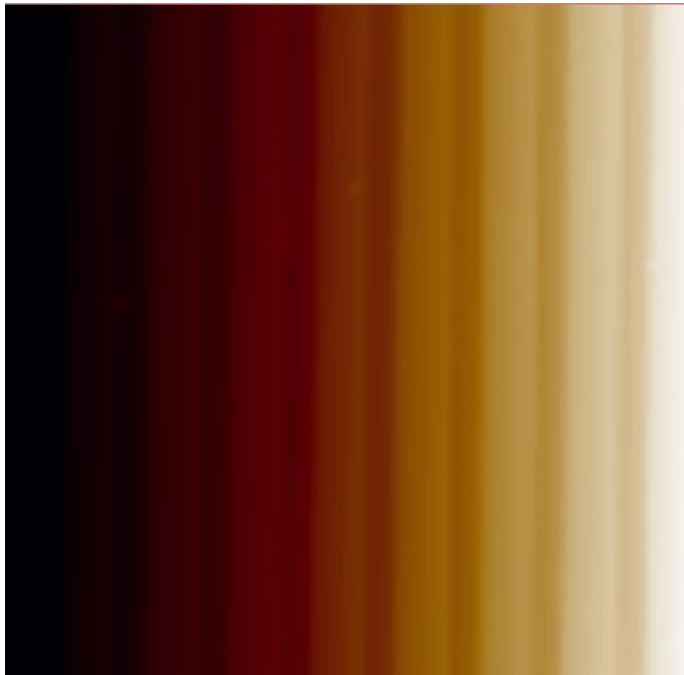


Уплотнение

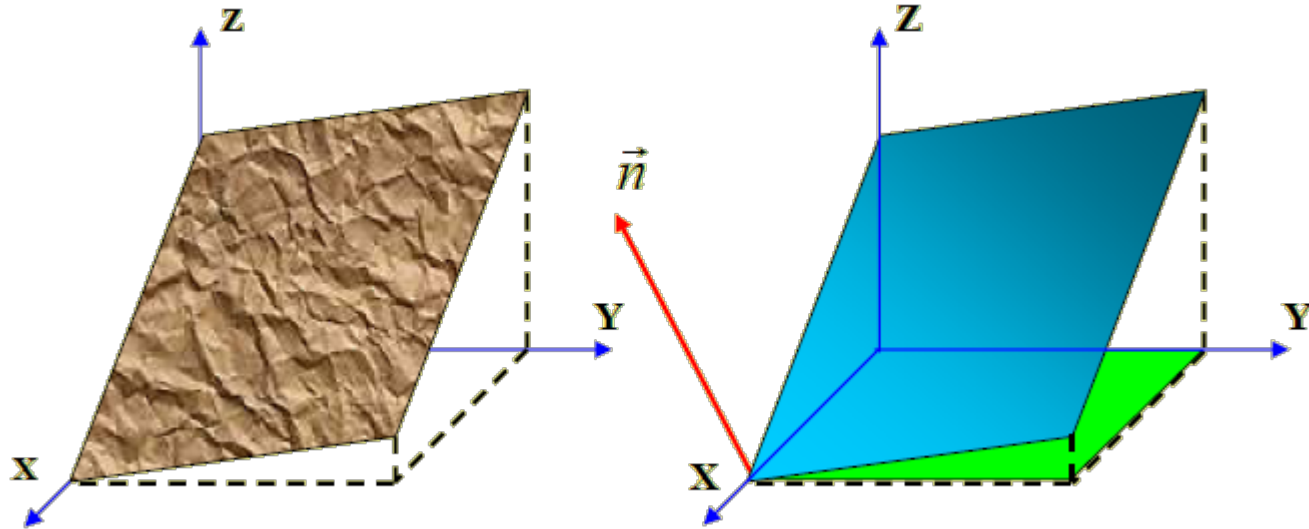
Наклон поверхности



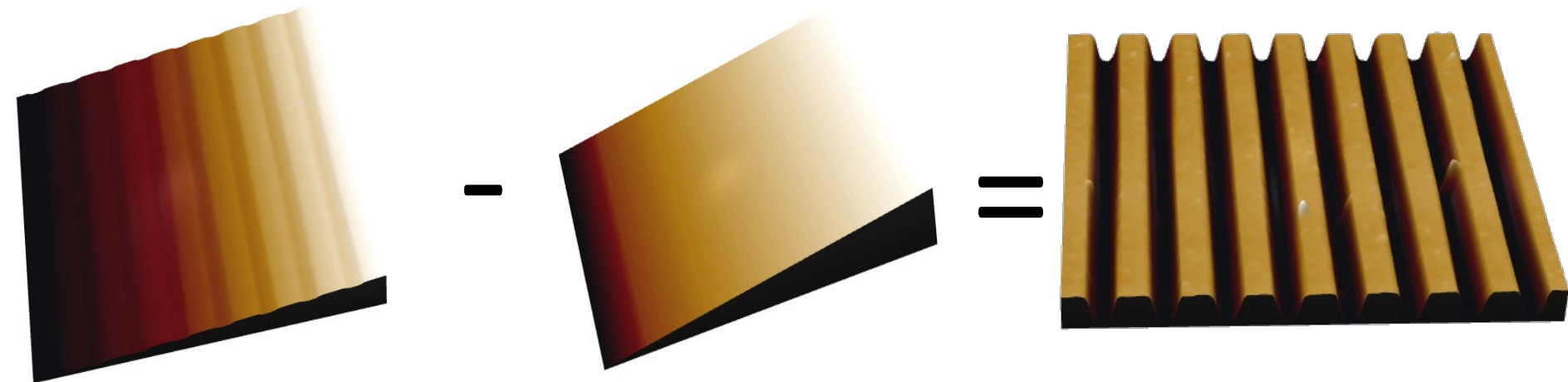
Наклон поверхности



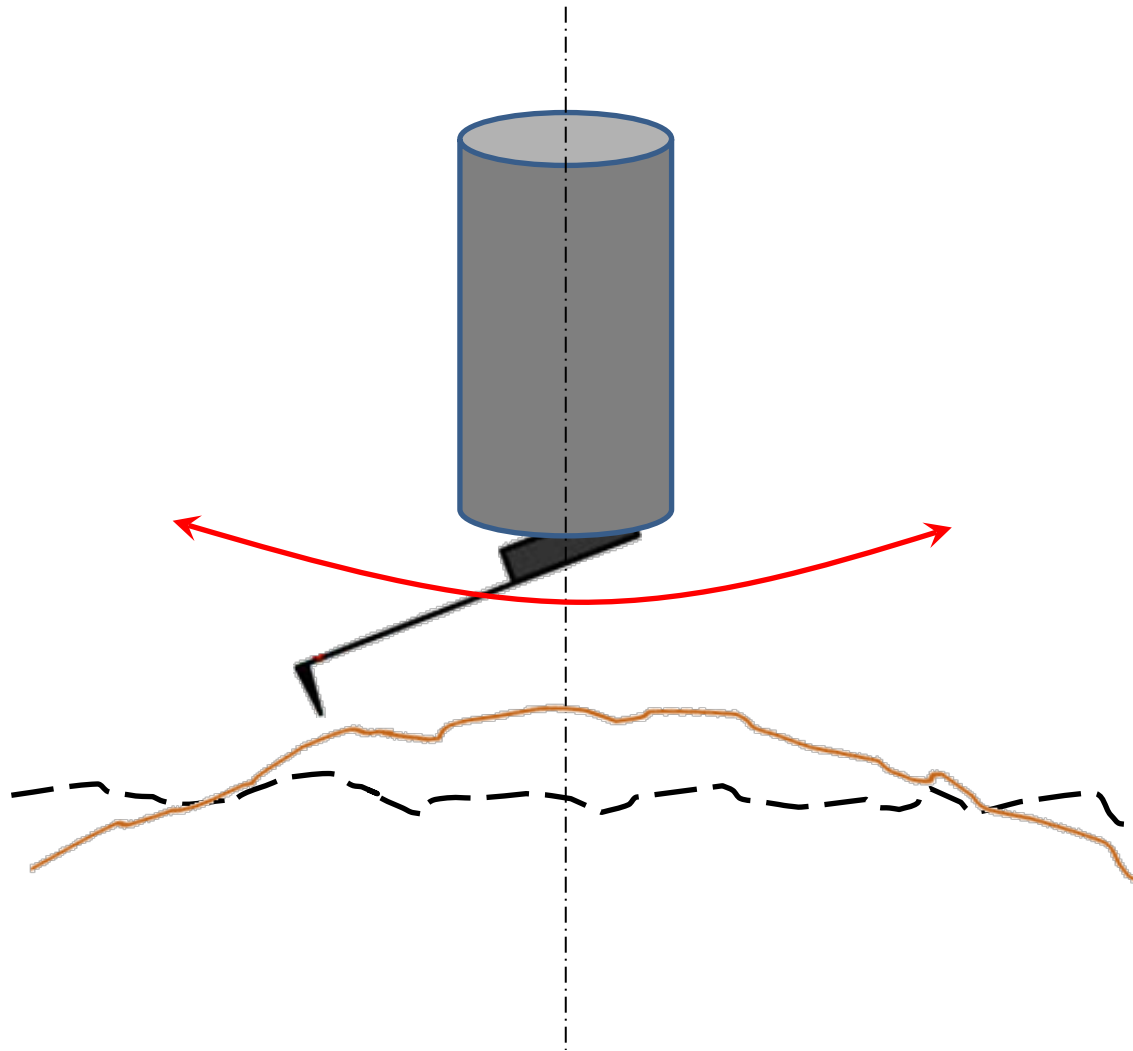
Вычитание наклона



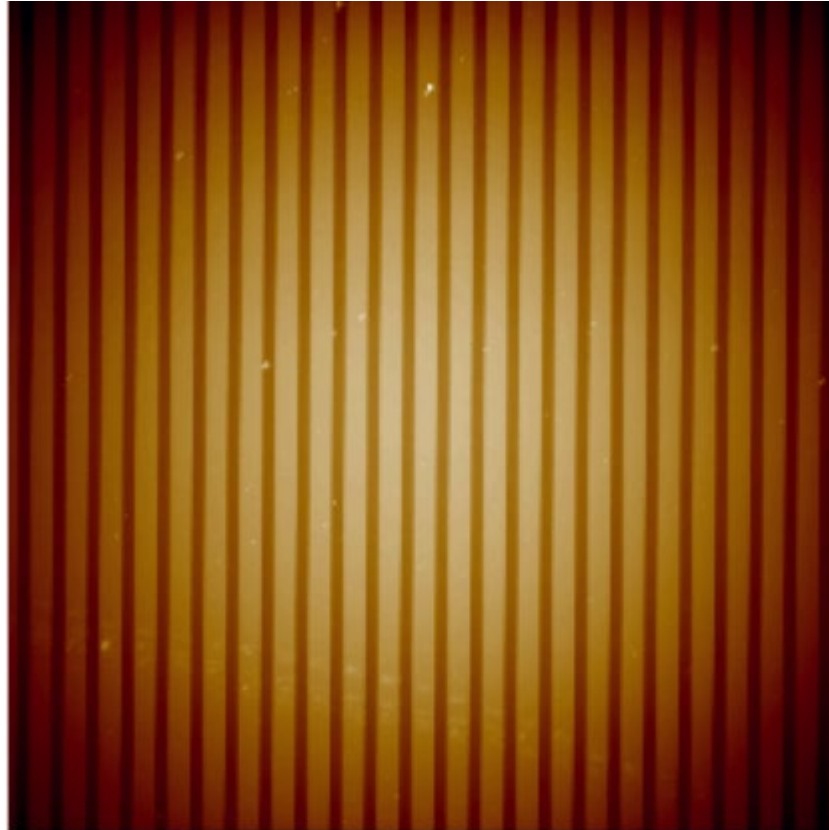
$$Ax + By + Cz + D = 0$$



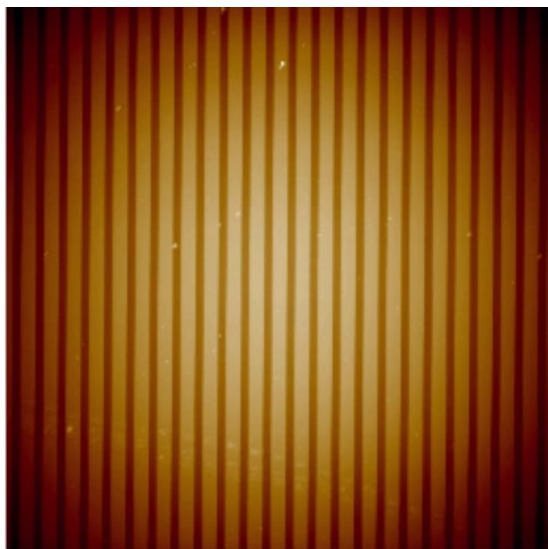
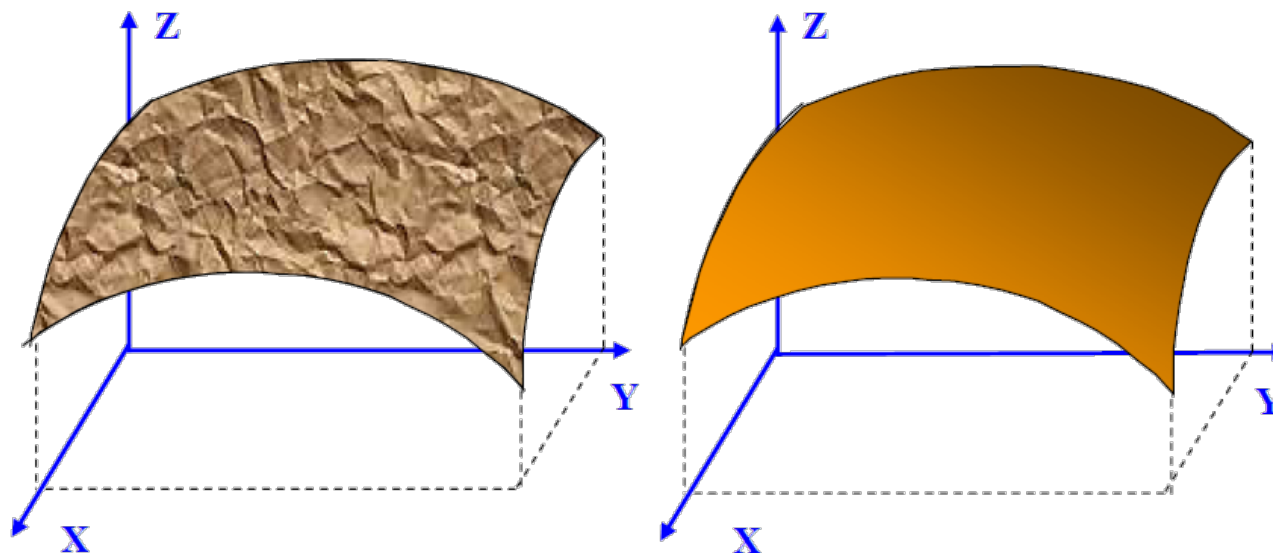
Изгиб



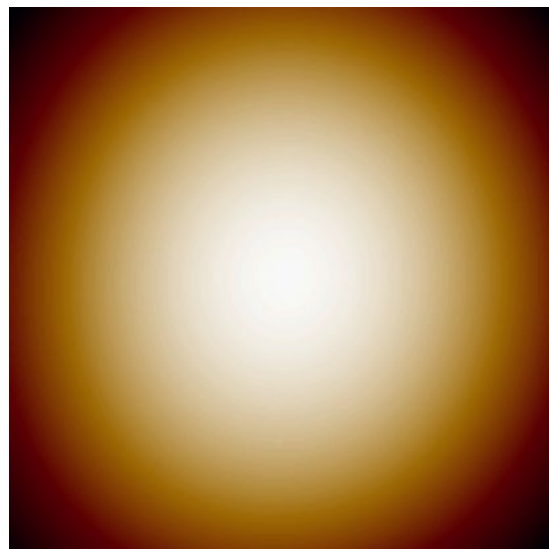
Изгиб



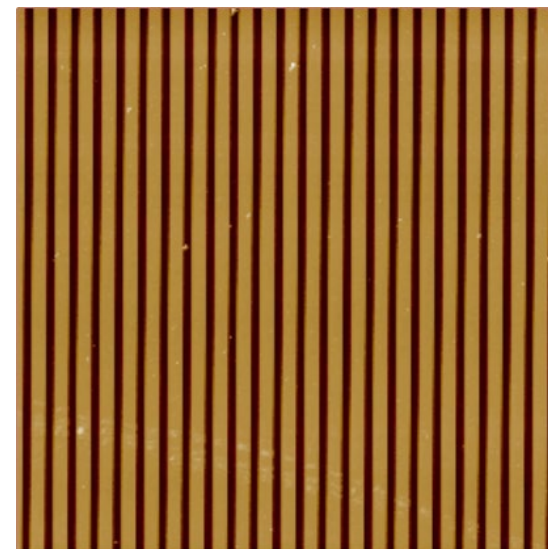
Вычитание 2-го порядка



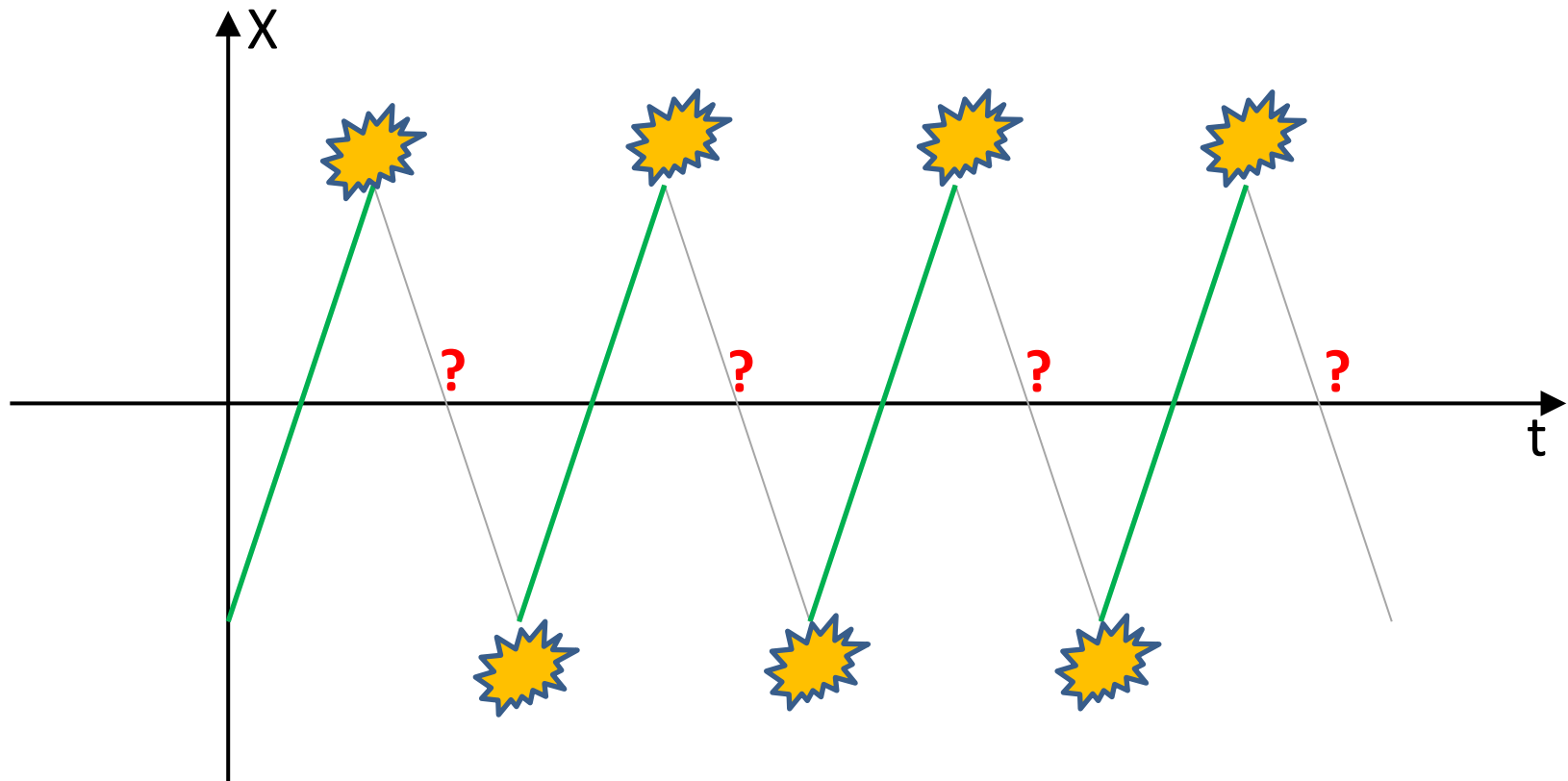
-



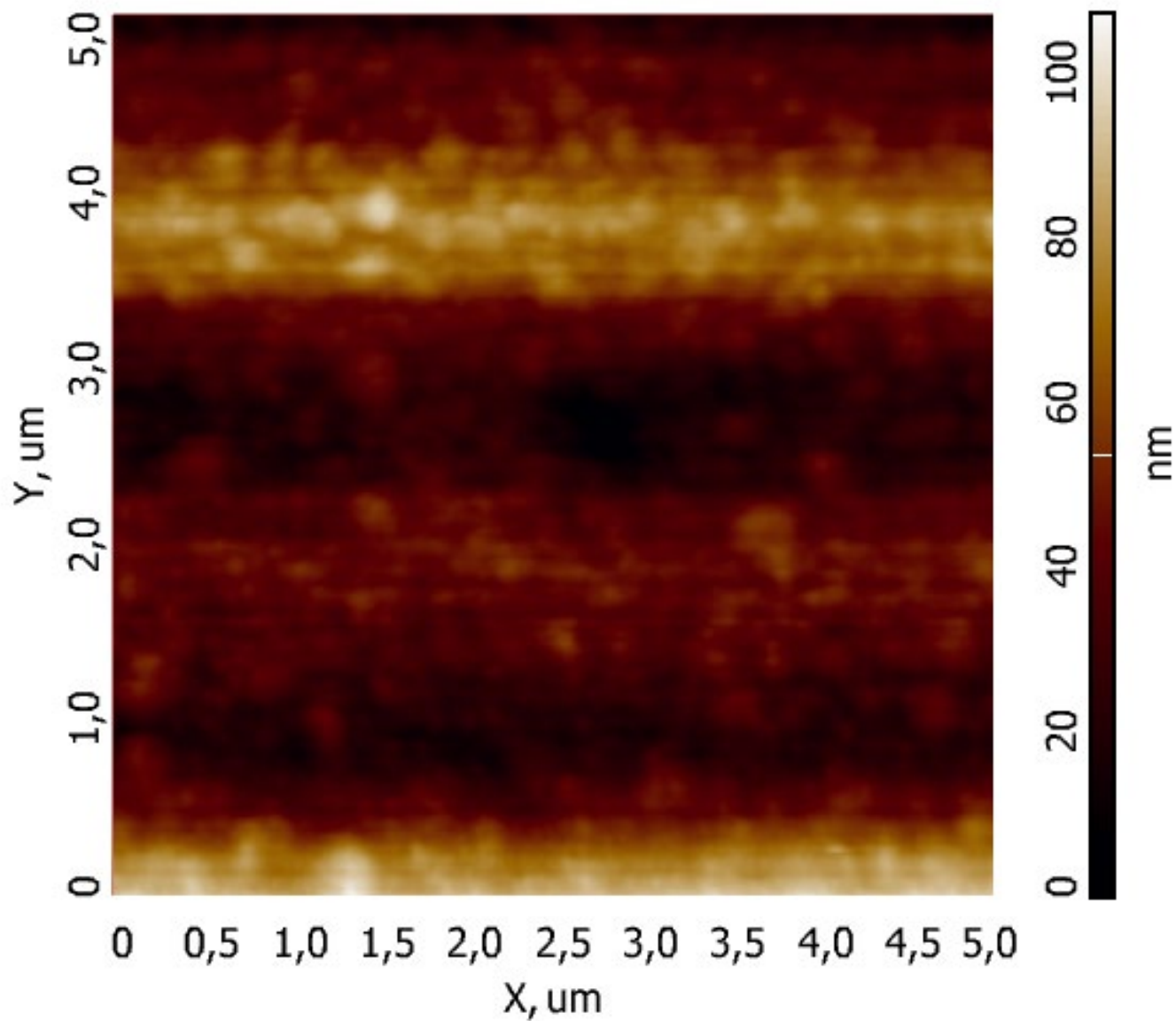
=



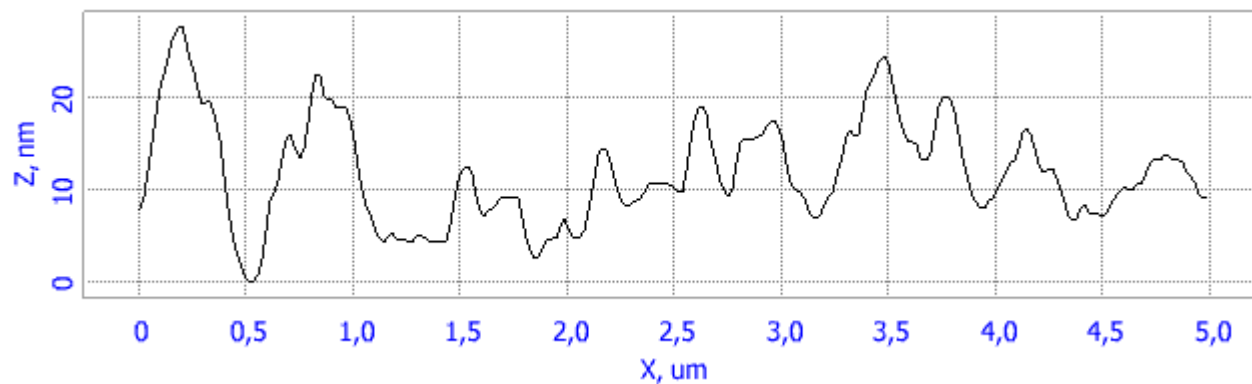
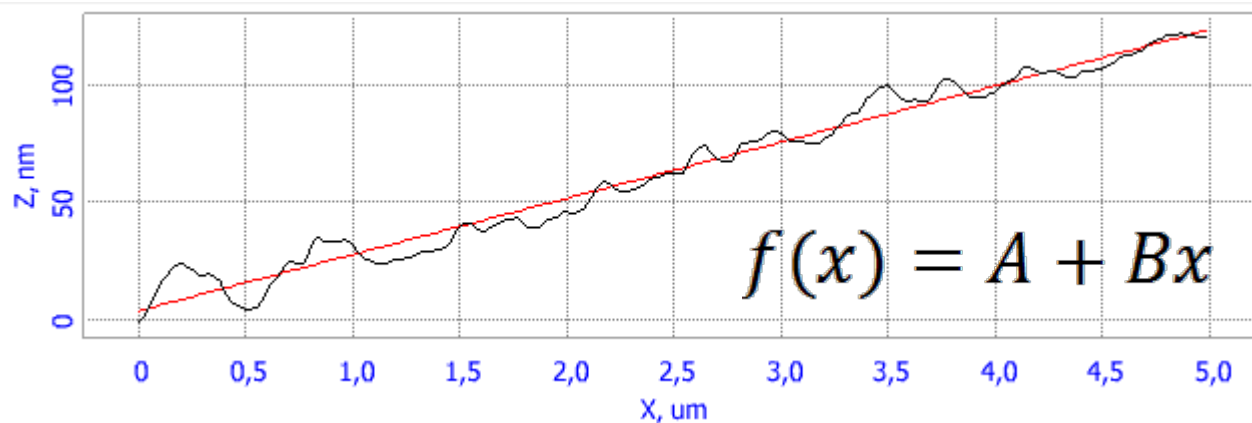
Межстрочные скачки



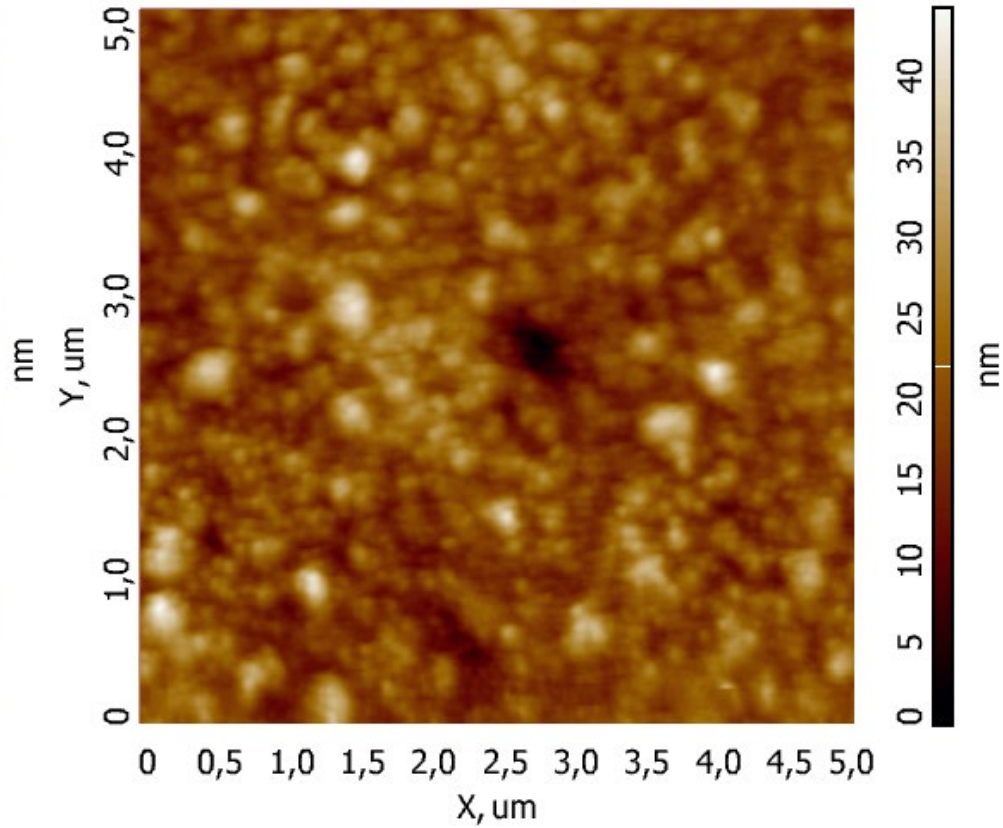
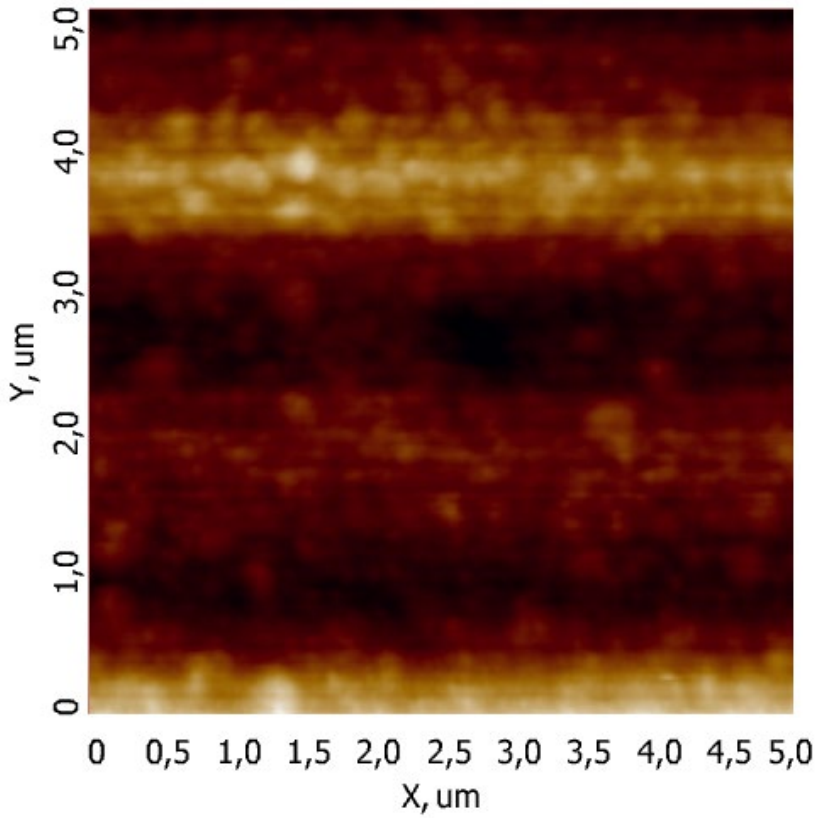
Межстрочные скачки



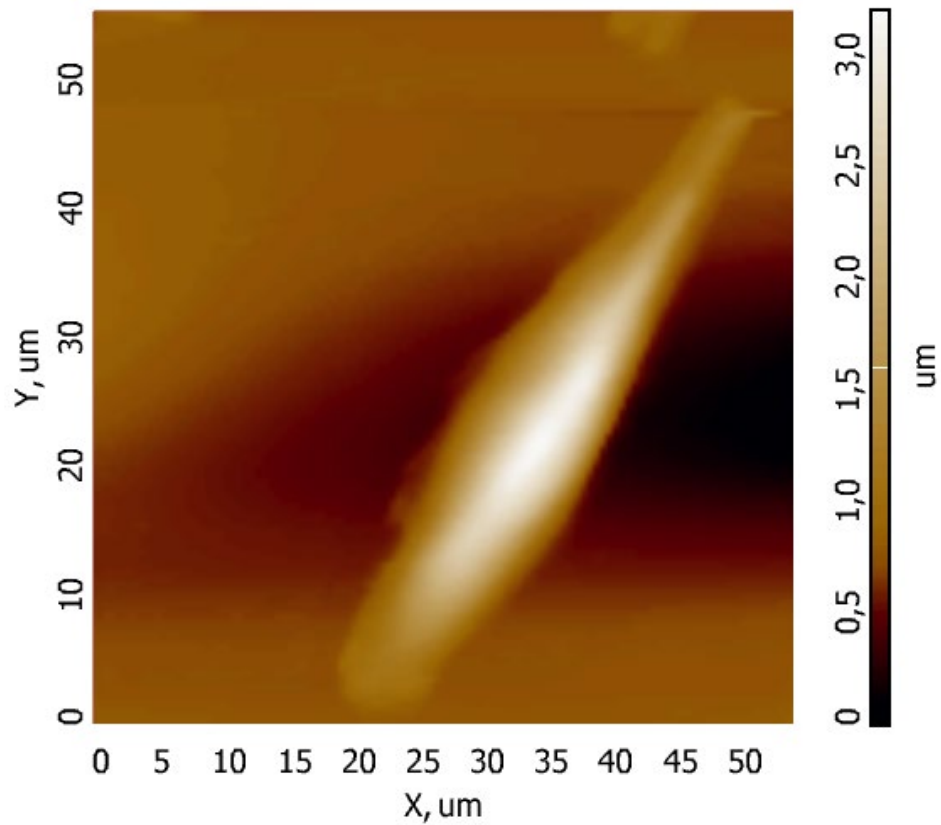
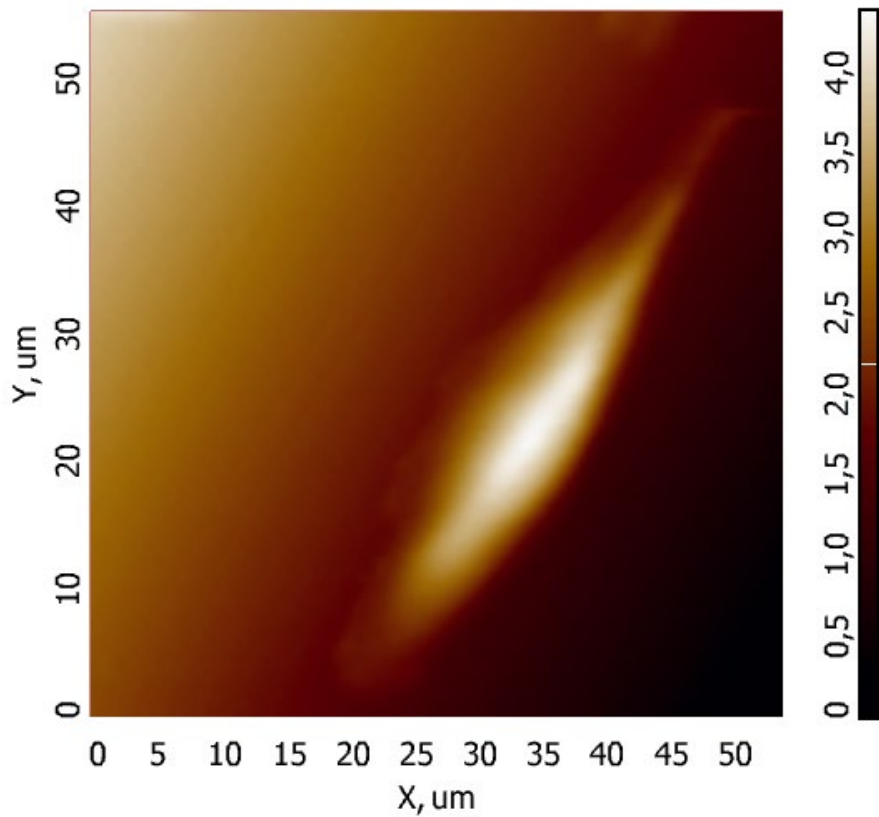
Линейная аппроксимация



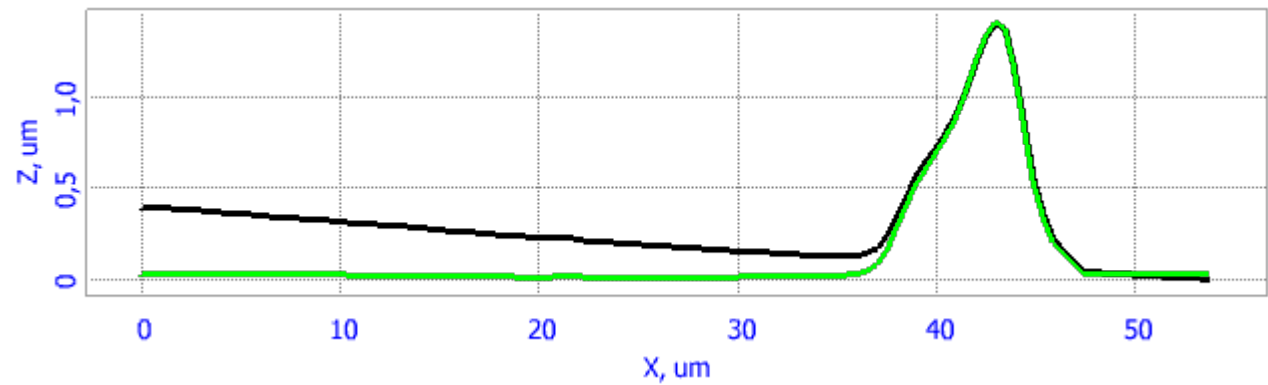
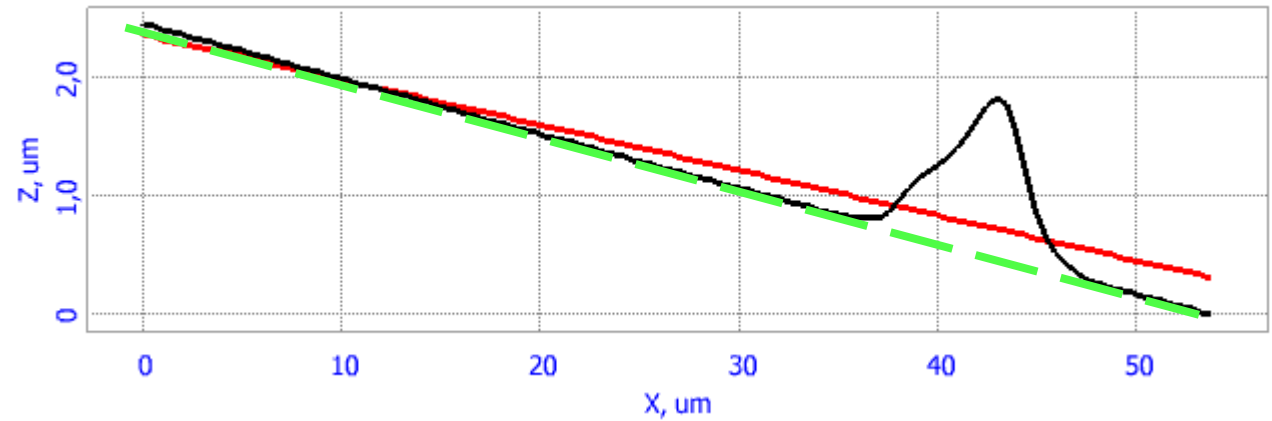
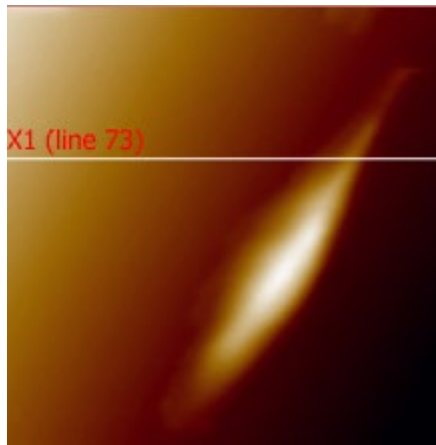
Линейная аппроксимация



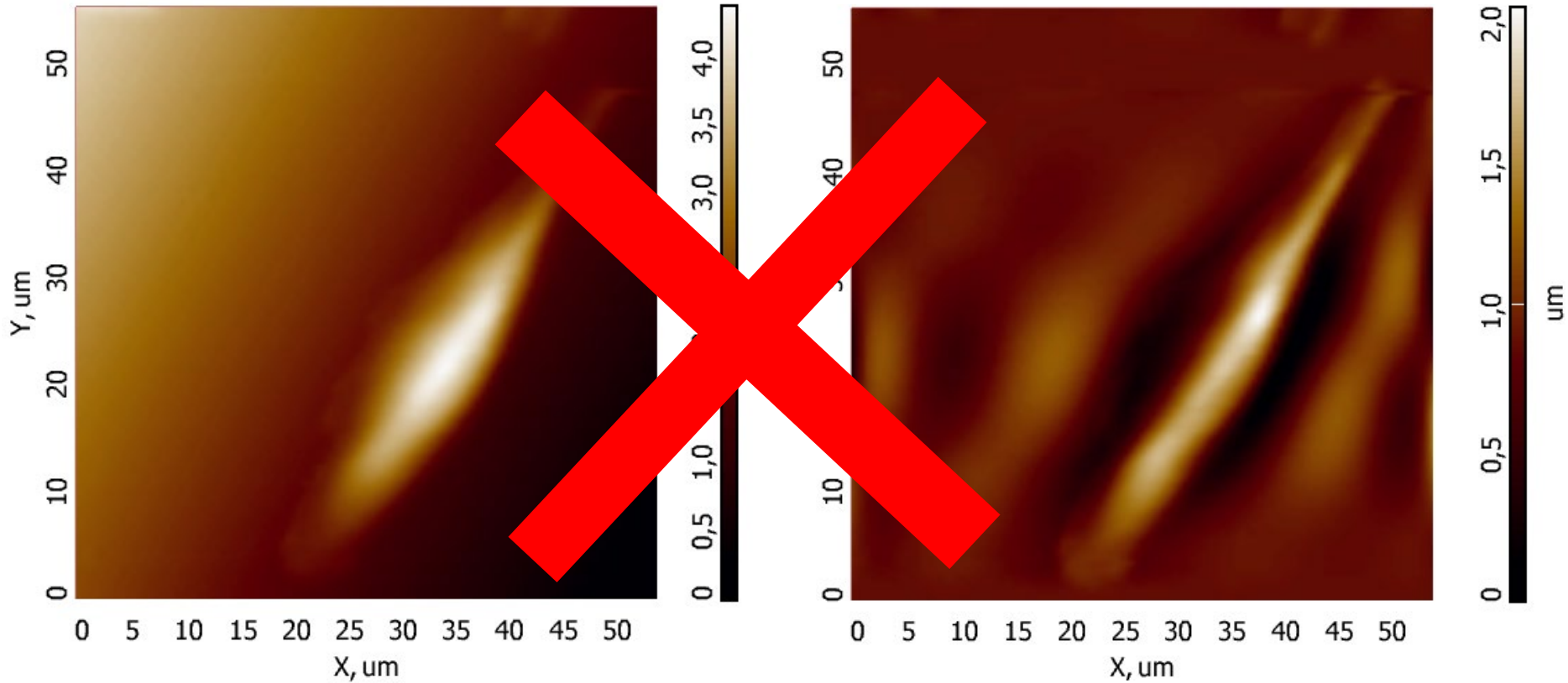
Высокие объекты на плоской подложке



Высокие объекты на плоской подложке



Слишком высокий порядок вычитания



$$f(x) = A + Bx + Cx^2 + Dx^3 + Ex^4 + Fx^5 + Gx^6 + Hx^7$$



НЕЛЬЗЯ ПРОСТО ВЗЯТЬ

И ОПУБЛИКОВАТЬ СКАН С ВЫЧИТАНИЕМ 7 ПОРЯДКА

Маска по области

Input Image Difference

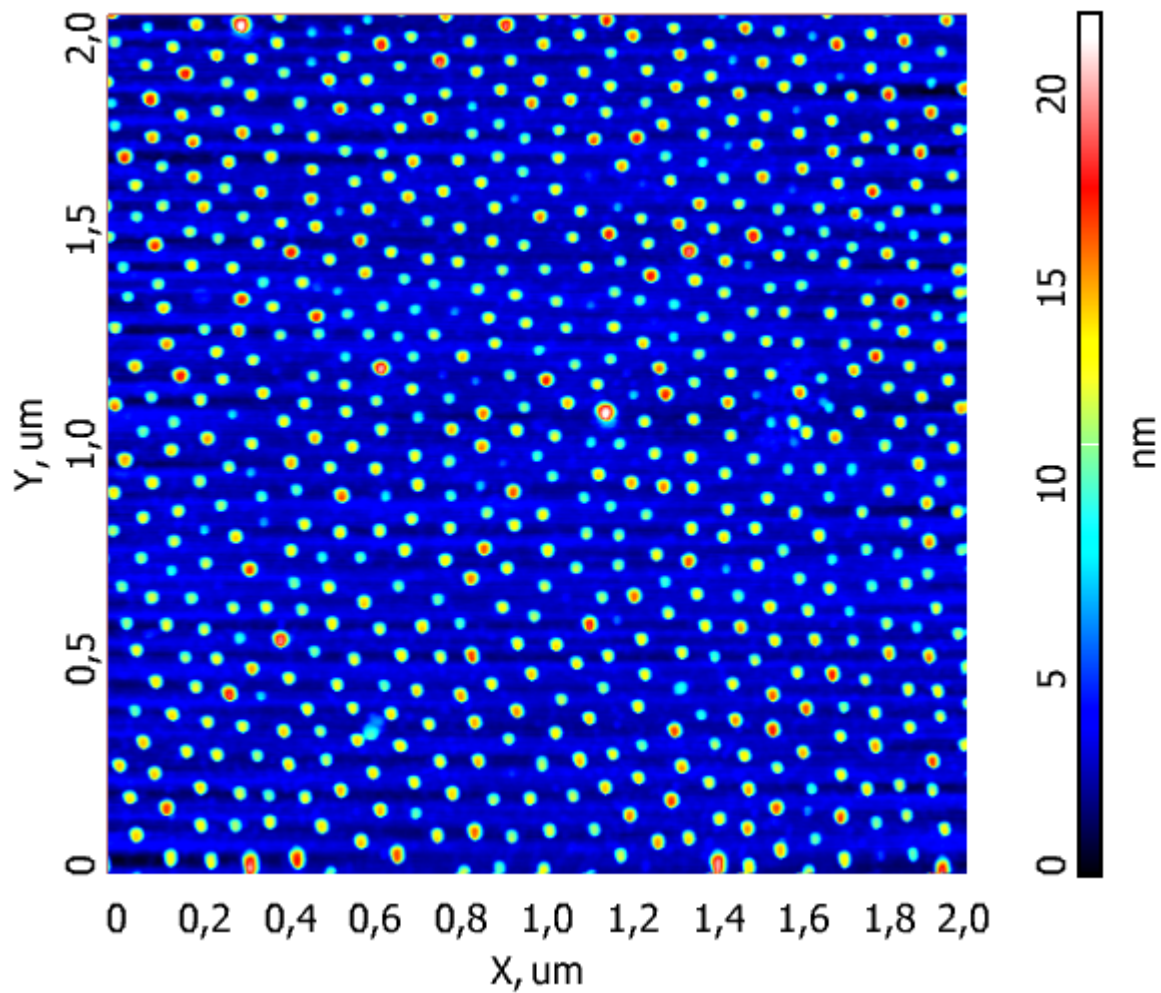
Output Image Difference

Order: 1 Selected Areas: Exclude Apply

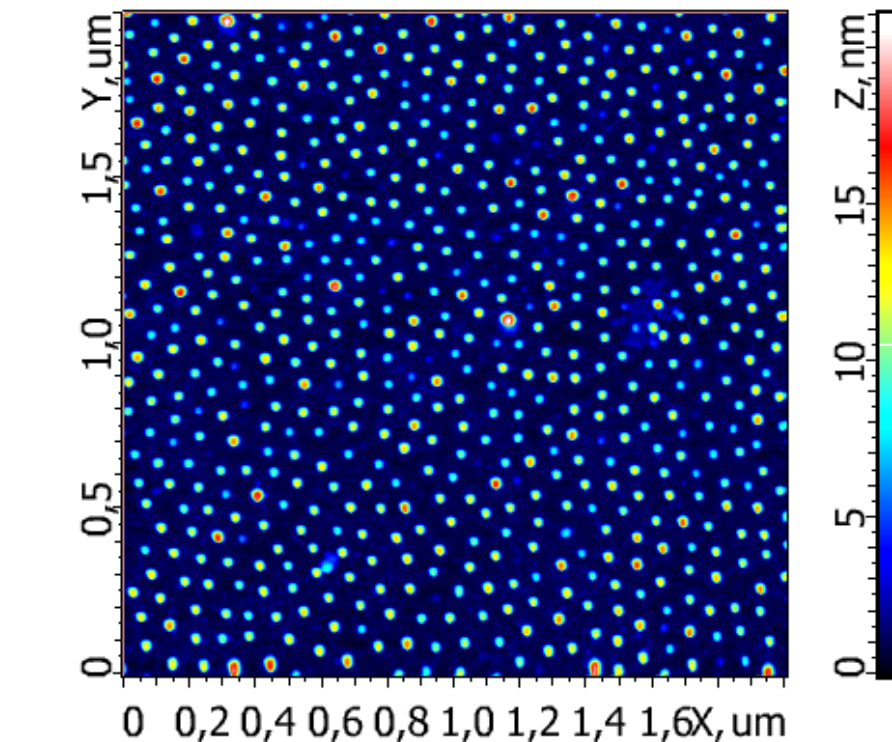
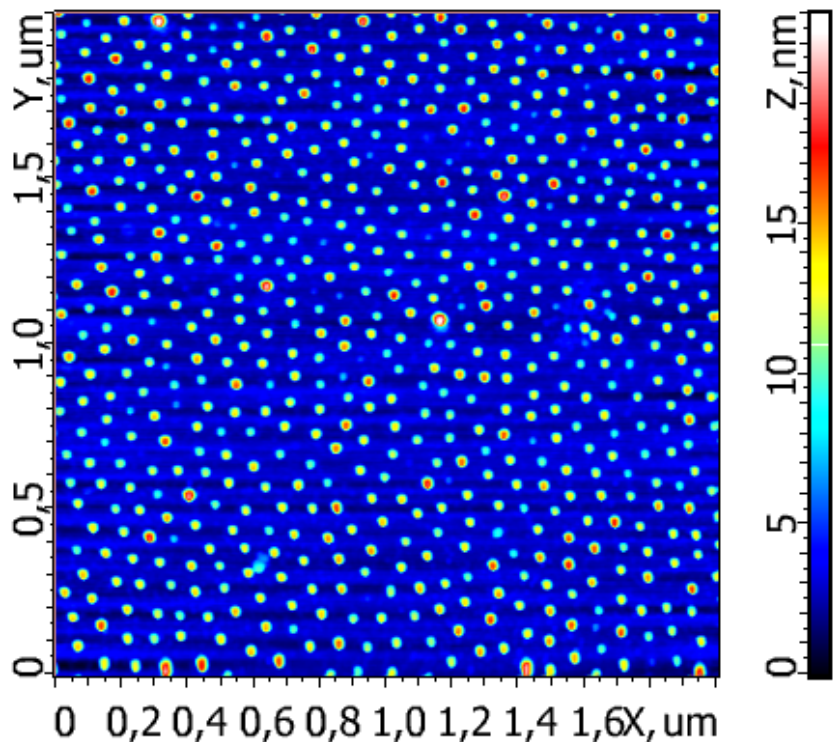
Fit Line: X Offset: Include Reset

Auto Calculate

Что делать, когда областей слишком много?



Маска по гистограмме



2D/3D Interline Surface 3 Points Histogram Paths Sphere

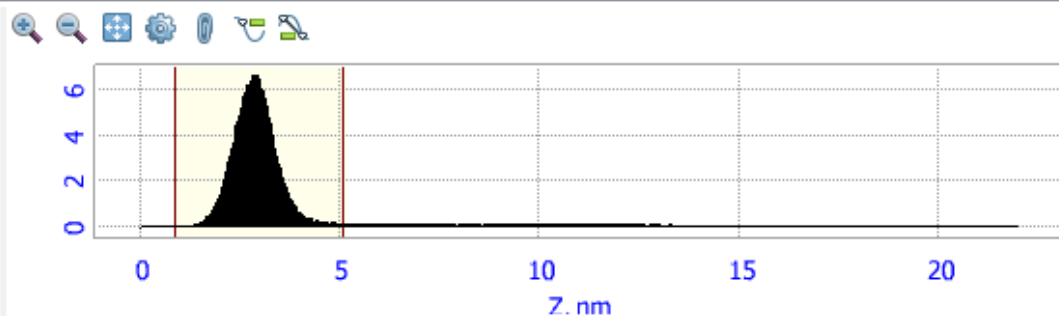
Z Min Polynomial order Auto

Z Max Direction X Y

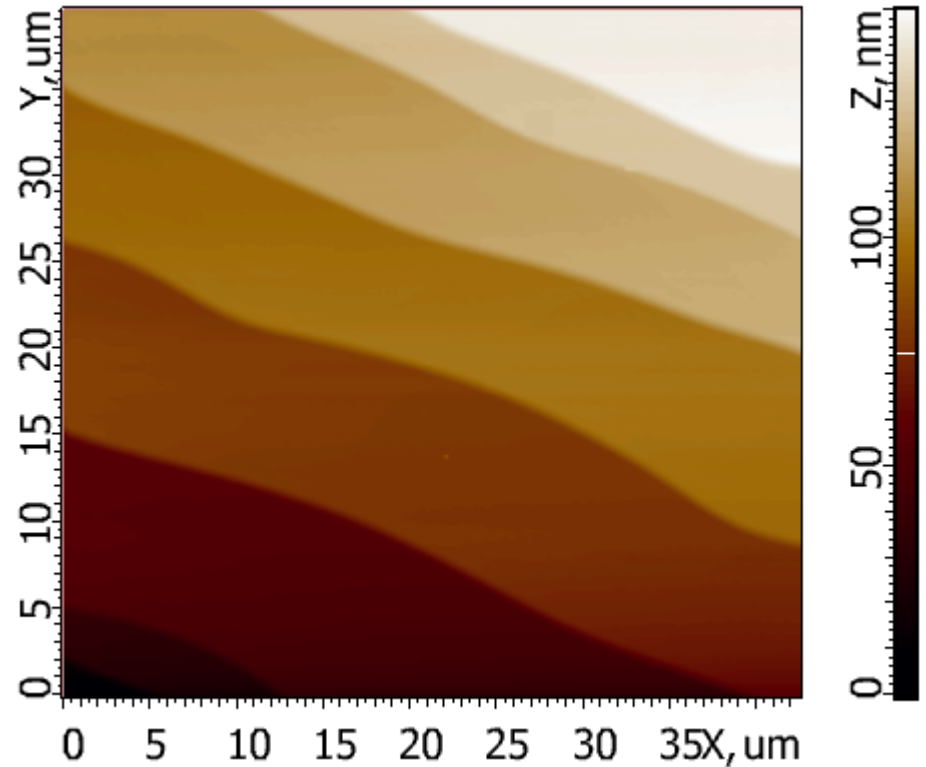
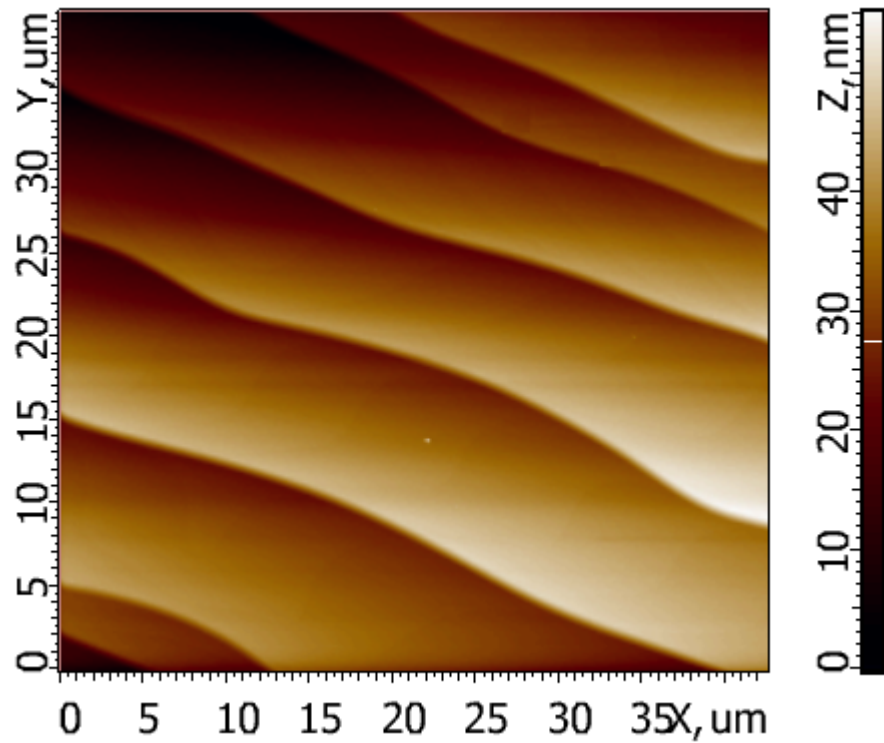
Interline Surface

ROI

Order

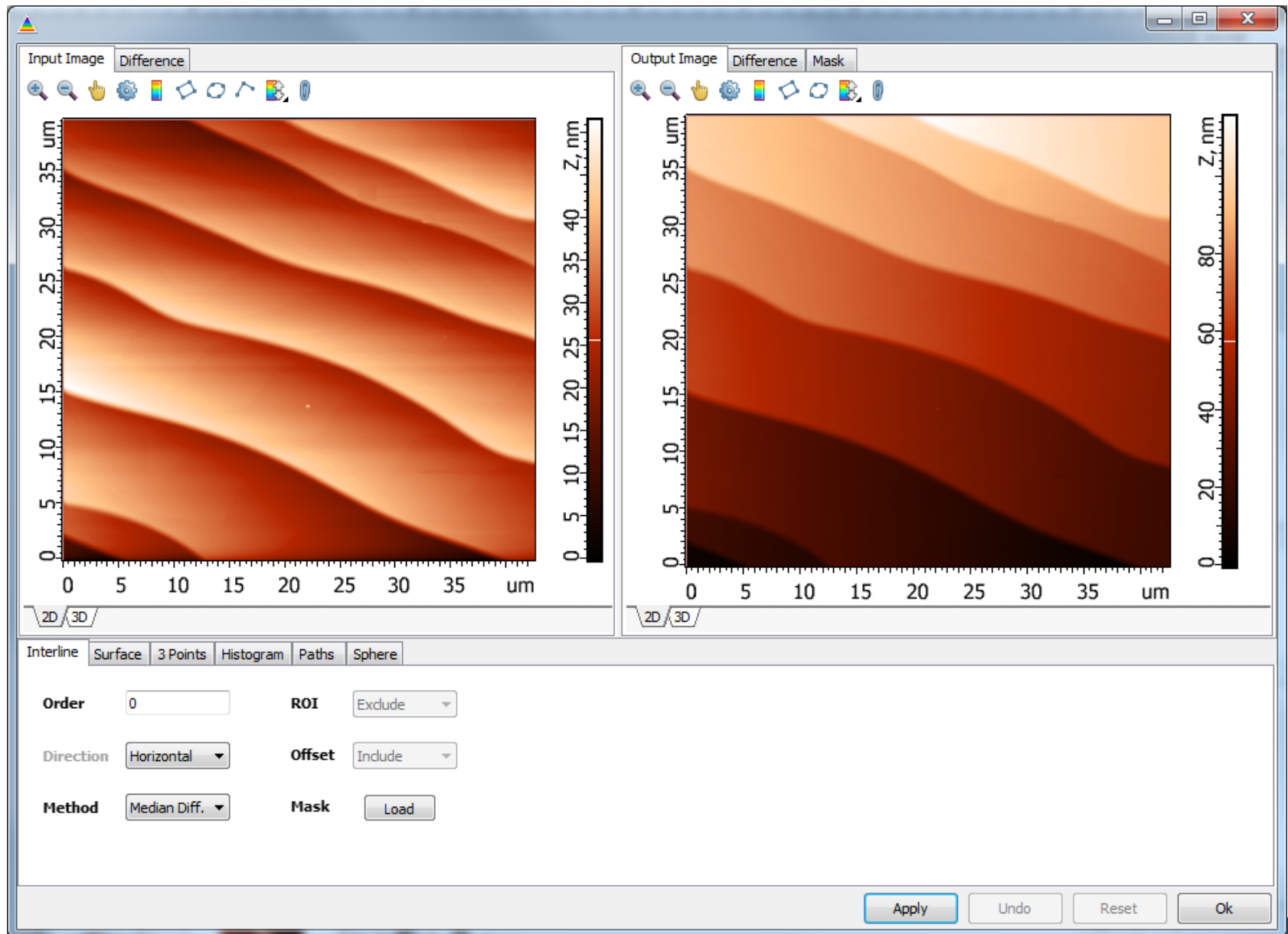


Фасеточное выравнивание ступенек



$$\nabla f(x) \rightarrow \min$$

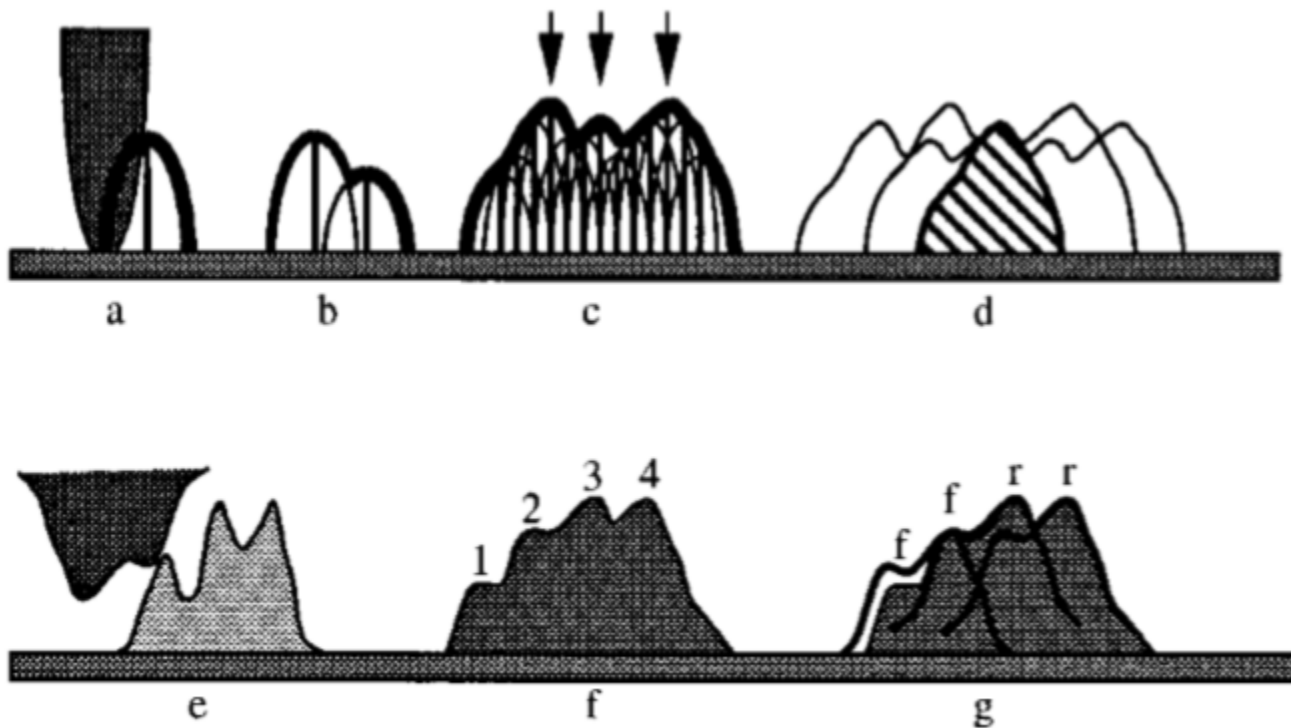
Интерфейс модуля Leveling (Leveling->Leveling)



Реконструкция изображений

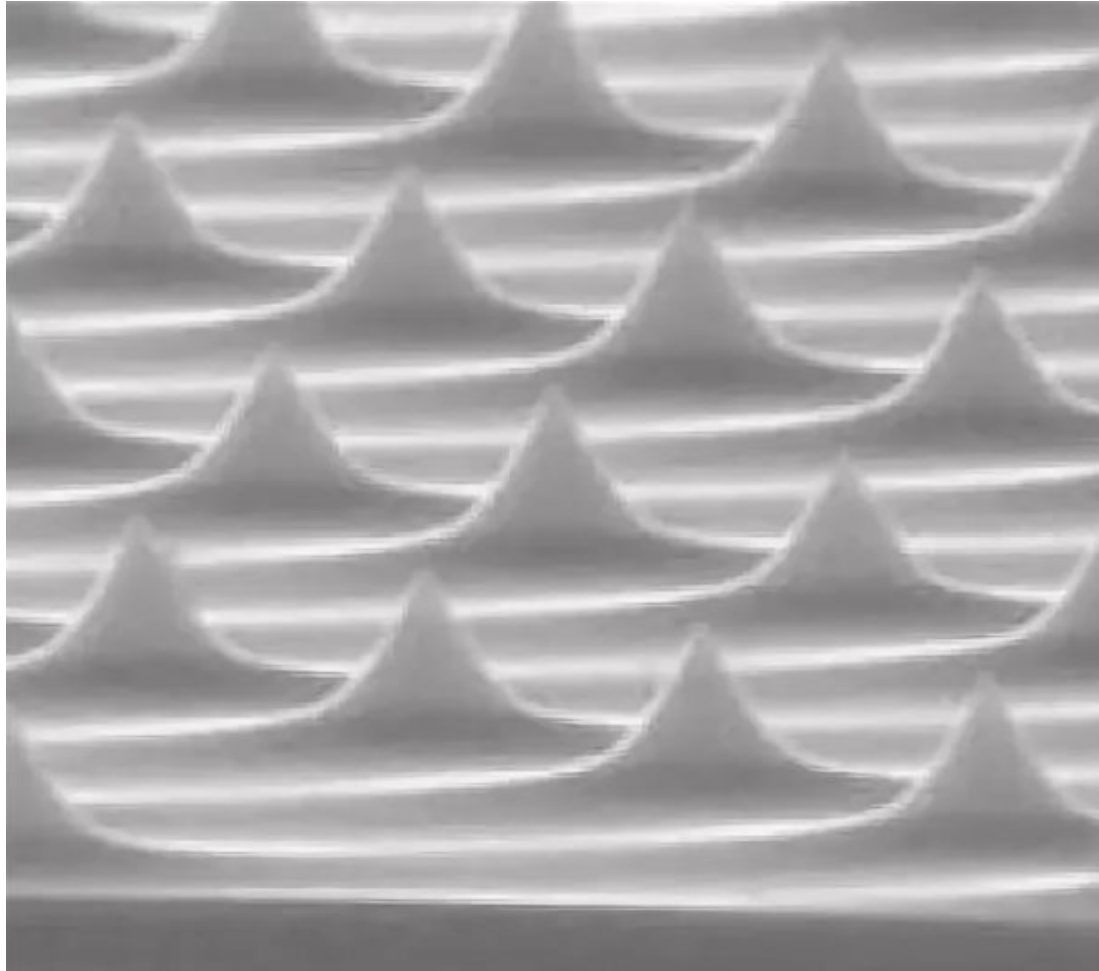
Деконволюция

Деконволюция



P.M.Williams, K.M.Shakesheff et al. - "Blind reconstruction of scanning probe image data". // J. Vac. Sci. Technol. B 14 (2) p. 1557-1562 (1996).

Восстановление формы зонда по специальным структурам



Деконволюция

Deconvolution

This module deconvolving with tip profile

Height

Calibration Image

Tip 2D

Target Image

Height

Tip Profile

Tip

Window X, px 21 Rx = 14,4 nm

Window Y, px 21 Ry = 11,1 nm

Blind tip estimation

Certainty Map

X Size, px 21

Y Size, px 21

Threshold 0,000

StartTipEst

TIP ESTIMATION

3 iters

EROSION DILATION Correlation = 9.859E-01

EROSION DILATION

Scan probe Ok Cancel Help

The screenshot displays the Deconvolution software interface. It features four main image panels: 'Calibration Image' (top-left), 'Tip 2D' (top-middle), 'Target Image' (top-right), and a deconvolved image (bottom-right). A 'Tip Profile' graph is located in the center, showing a cross-section of the tip. Below the graph are 'Tip' parameters: Window X (21 px, Rx = 14.4 nm) and Window Y (21 px, Ry = 11.1 nm). The 'Blind tip estimation' section includes a 'Certainty Map' checkbox, 'X Size' (21 px), 'Y Size' (21 px), and 'Threshold' (0.000). A 'StartTipEst' button and a progress bar for 'TIP ESTIMATION' (3 iterations) are also present. At the bottom, there are 'EROSION' and 'DILATION' buttons, a 'Correlation = 9.859E-01' value, and 'Scan probe', 'Ok', 'Cancel', and 'Help' buttons.

GTransform™

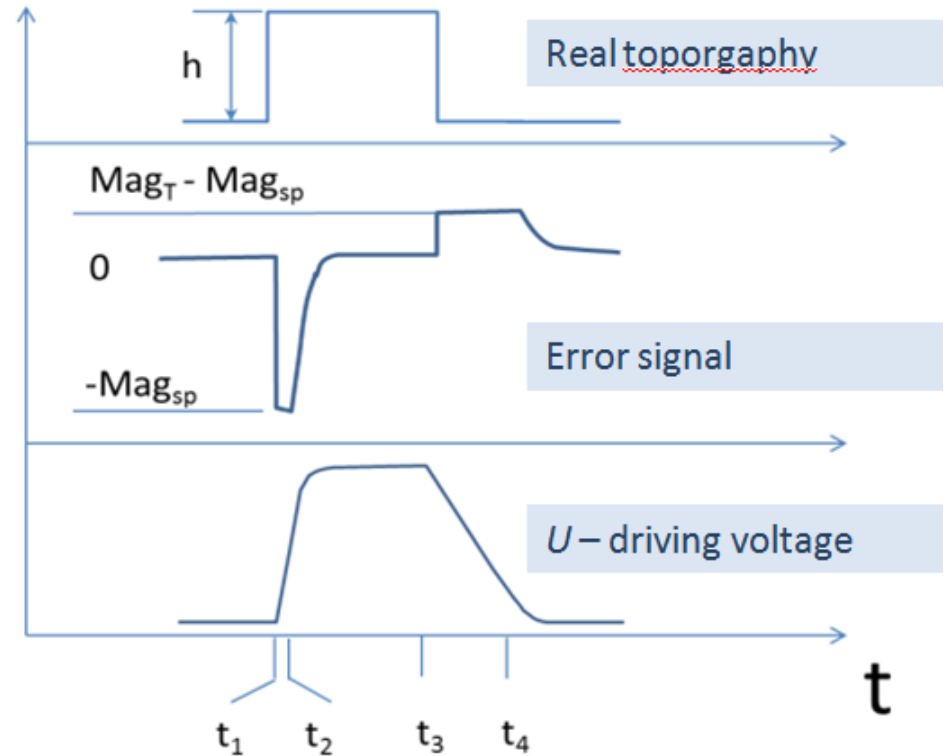
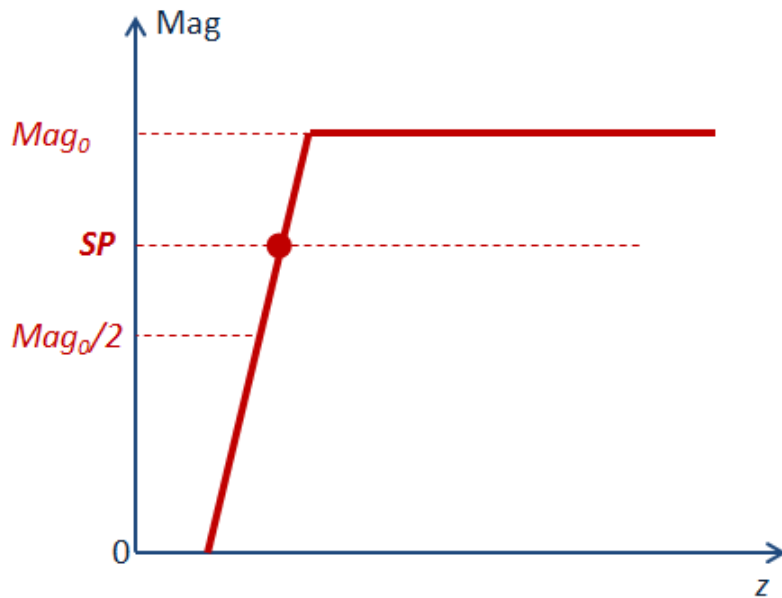
(Genuine Transformation)

Эффект парашютирования в АСМ

$$-SP \leq \varepsilon \leq Mag_0 - SP$$

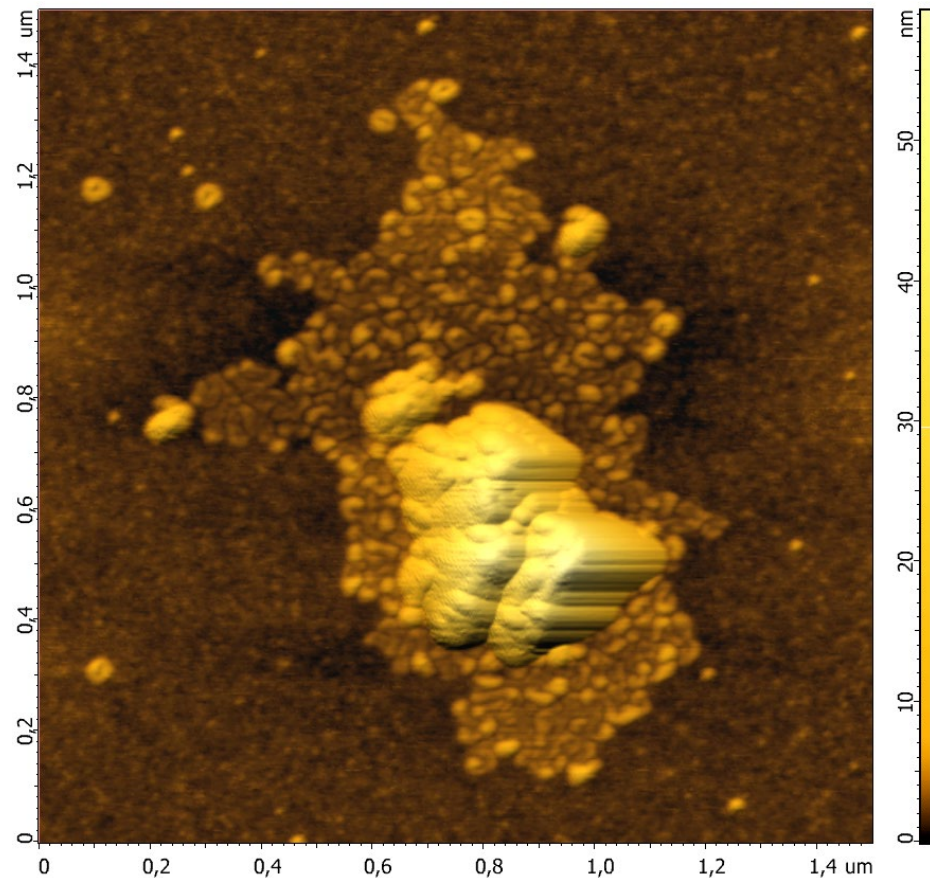
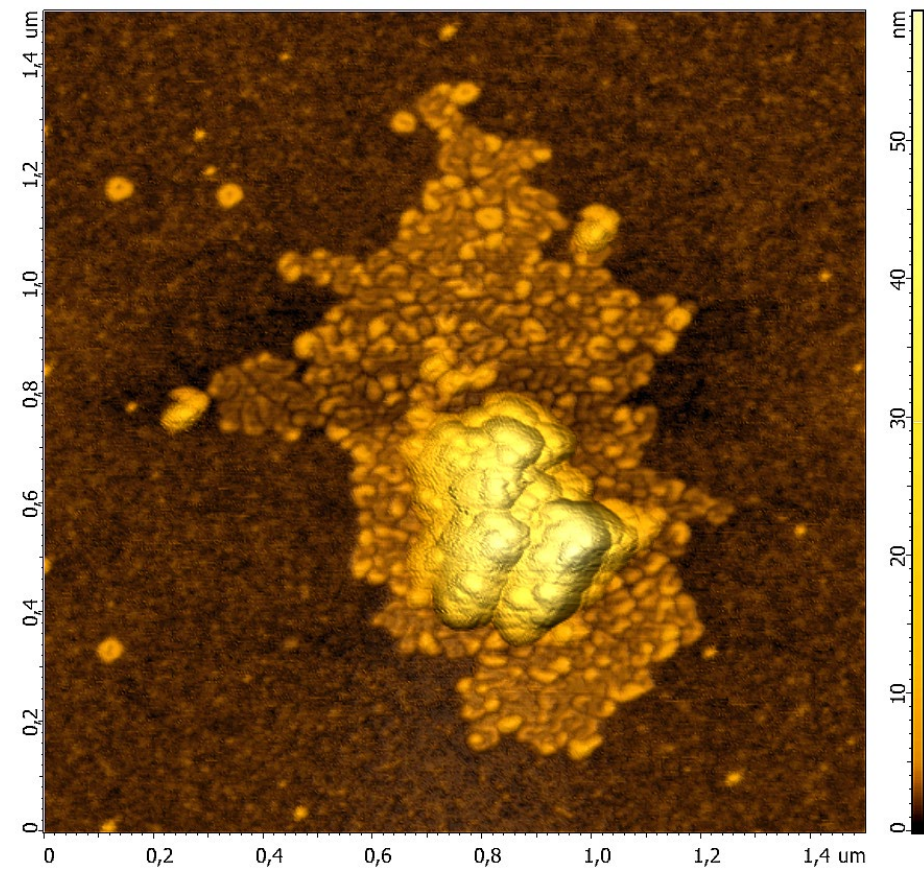
$$\frac{dU}{dt} = k_i \cdot \varepsilon = k_i(Mag_0 - SP)$$

$$U = k_i(Mag_0 - SP) \cdot t + U_0 \quad t_3 < t < t_4$$

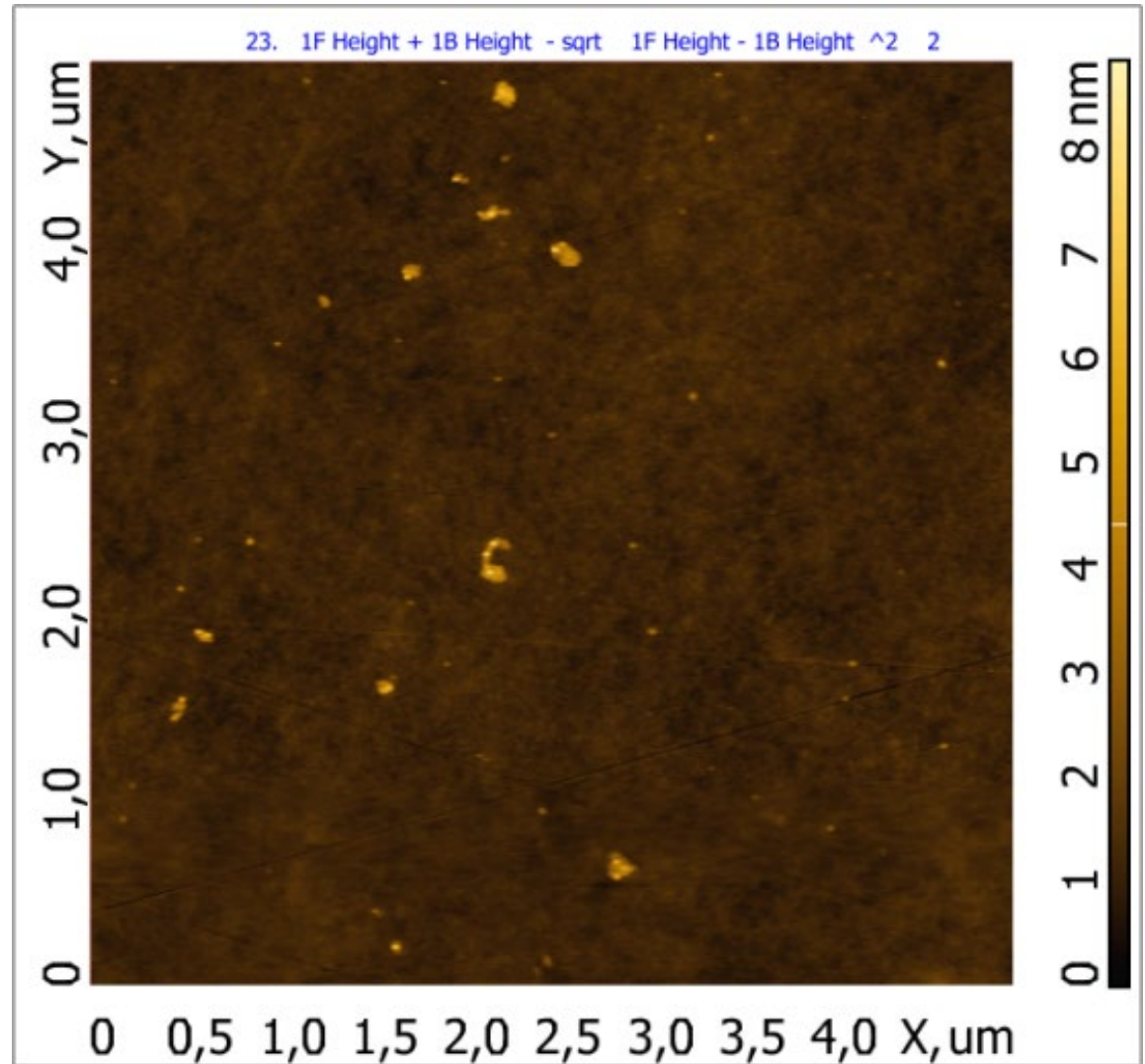
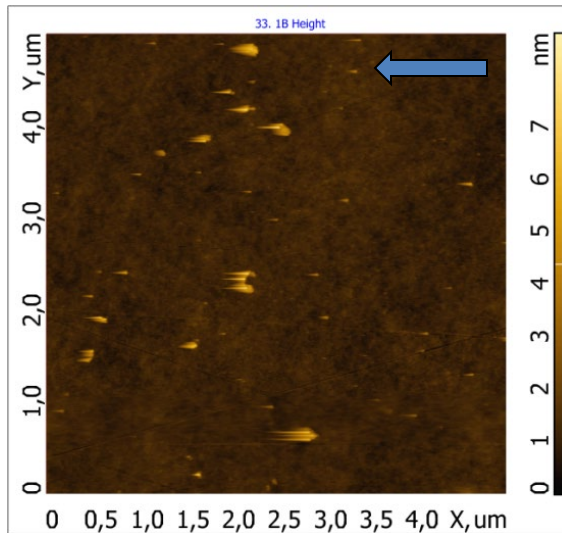
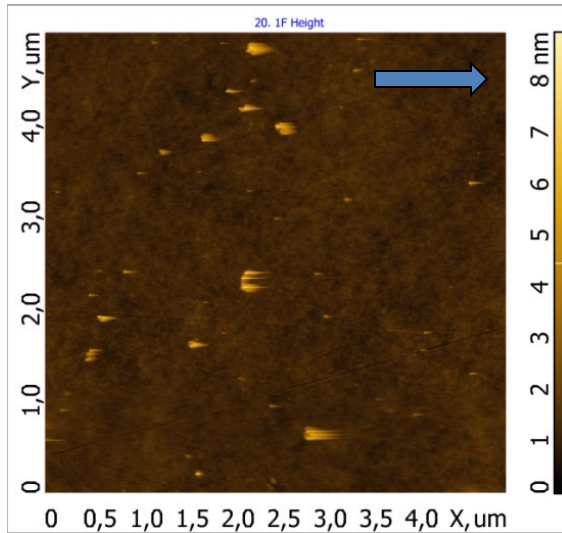


Ref.: T. Ando, "Control Techniques in High-Speed Atomic Force Microscopy," ACC: 3194-3200, 2008

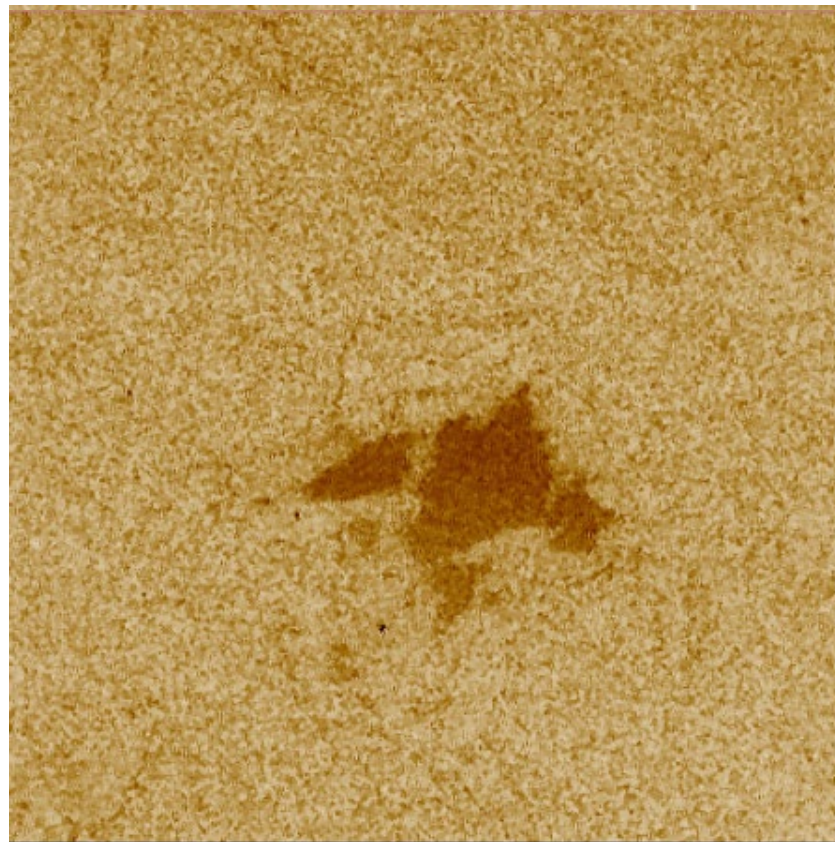
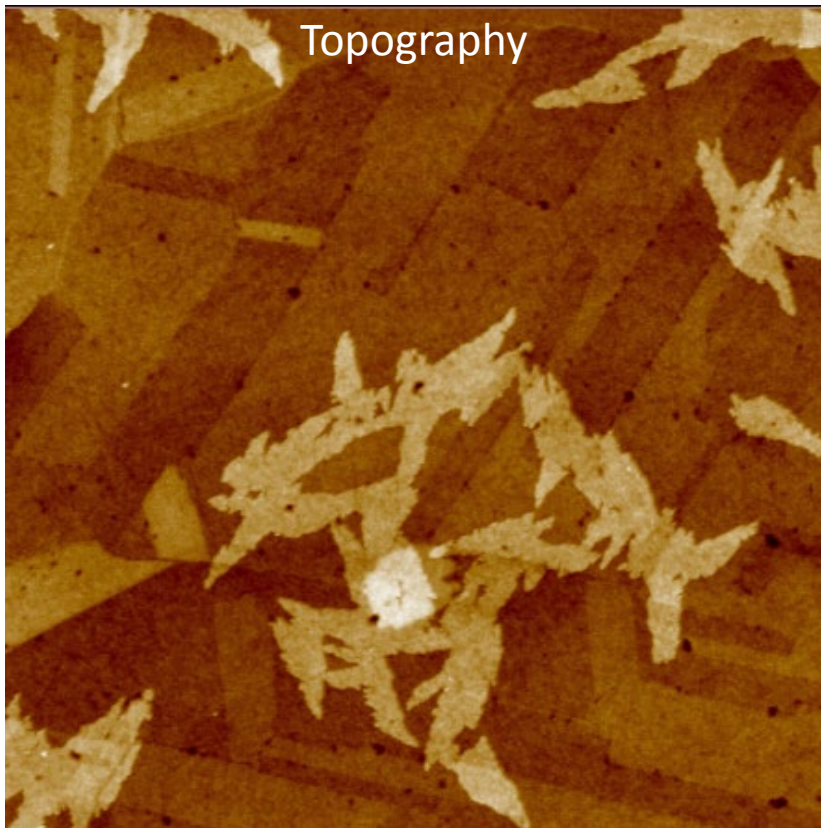
Эффект парашютирования



GTransform™ for Topography



GTransform™ для фазы и др. сигналов

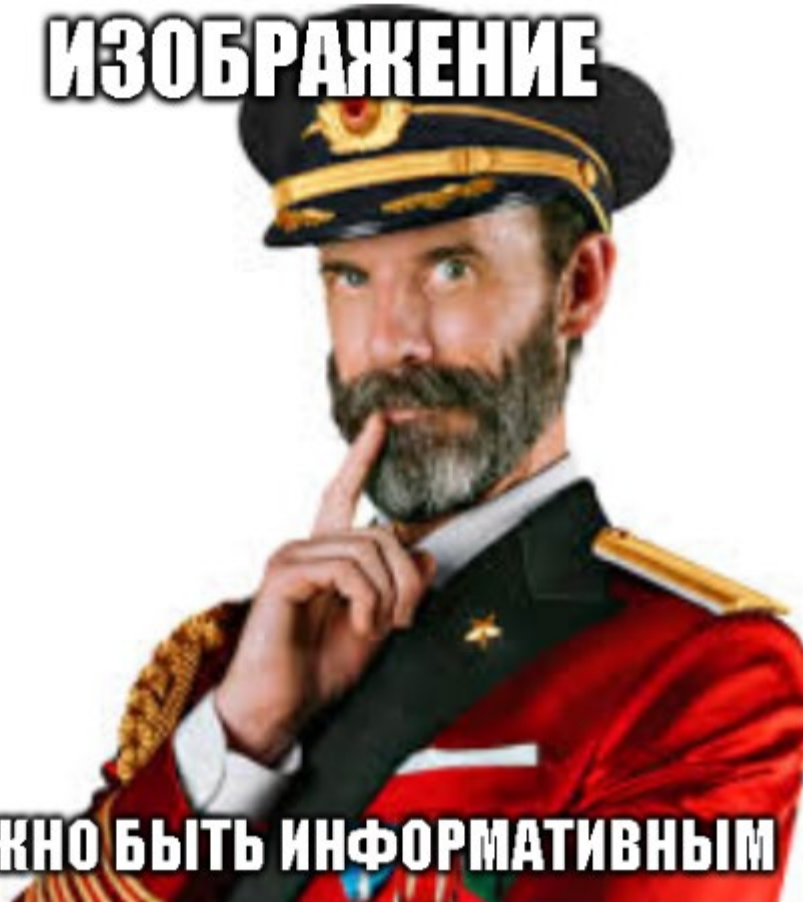


- Probe current
- Lateral force
- Mechanical properties
- etc...

Представление СЗМ изображений

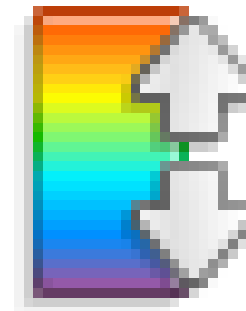
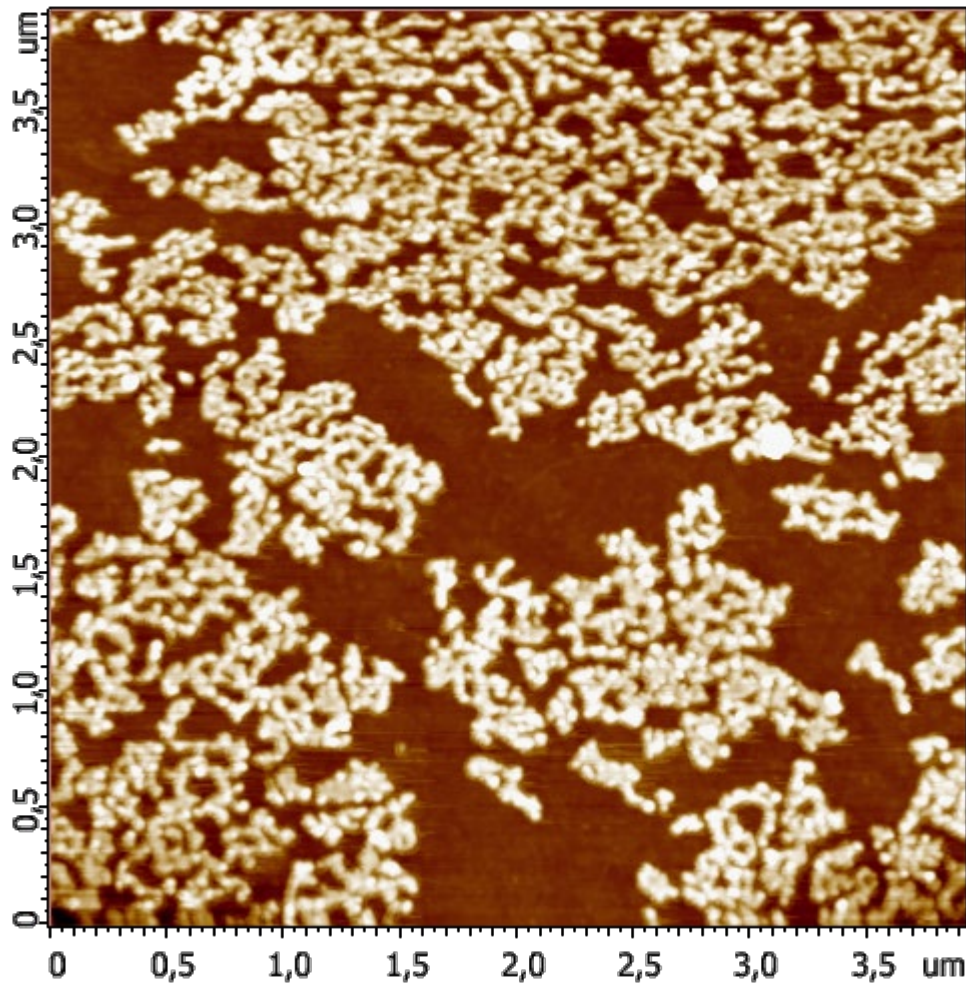
Главный принцип:

ИЗОБРАЖЕНИЕ

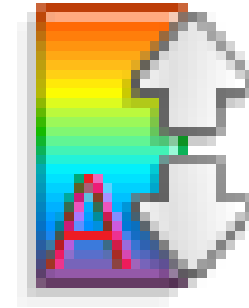
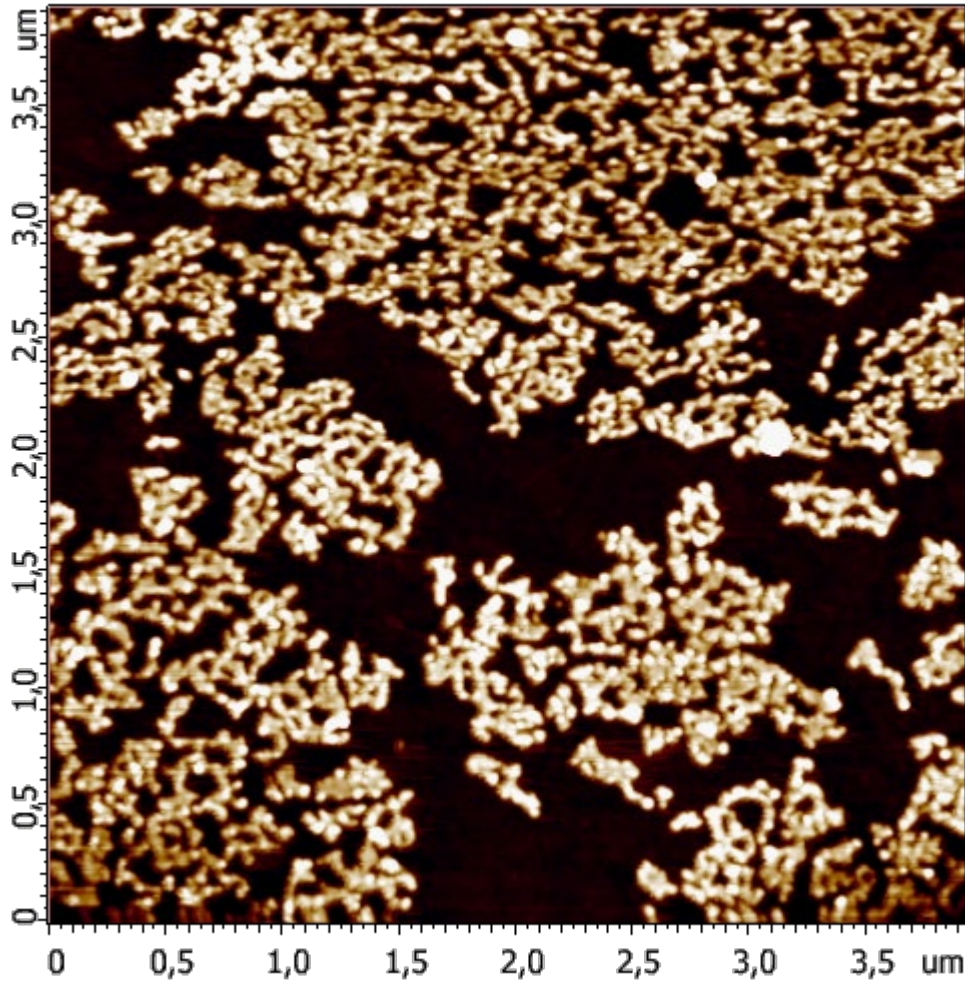


ДОЛЖНО БЫТЬ ИНФОРМАТИВНЫМ

Методы настройки палитры: Min-Max

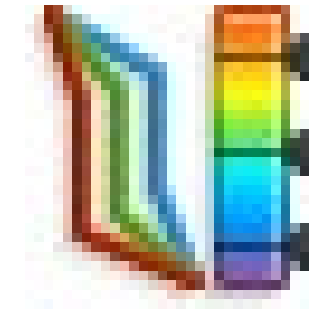
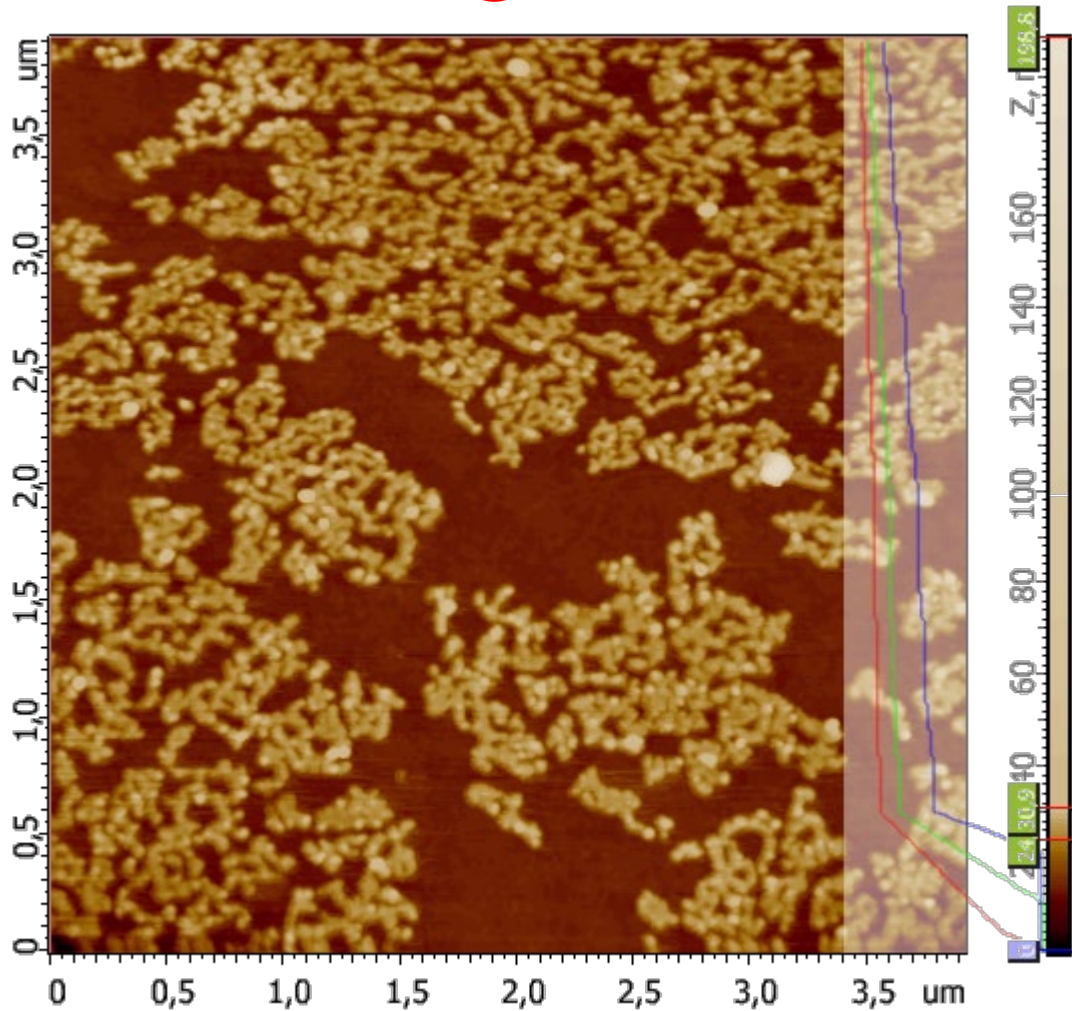


Методы настройки палитры: Auto



Settings-> 2D Settings -> Axes -> Histogram -> Auto Coloration Percent

Методы настройки палитры: Nonlinear



Редактор палитр

Palette Edit v.1.4.1

File Edit

Palette Name

Tools -> Palette Editor

2D 3D

Interpolation
Linear

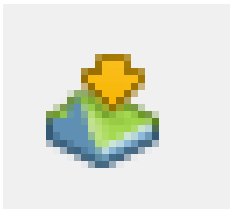
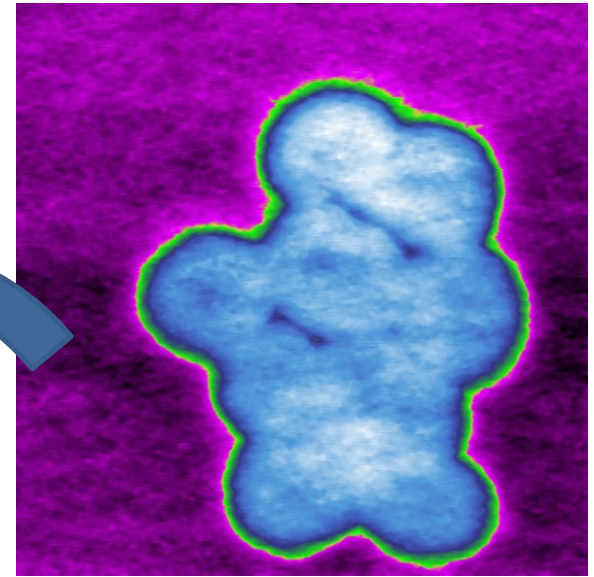
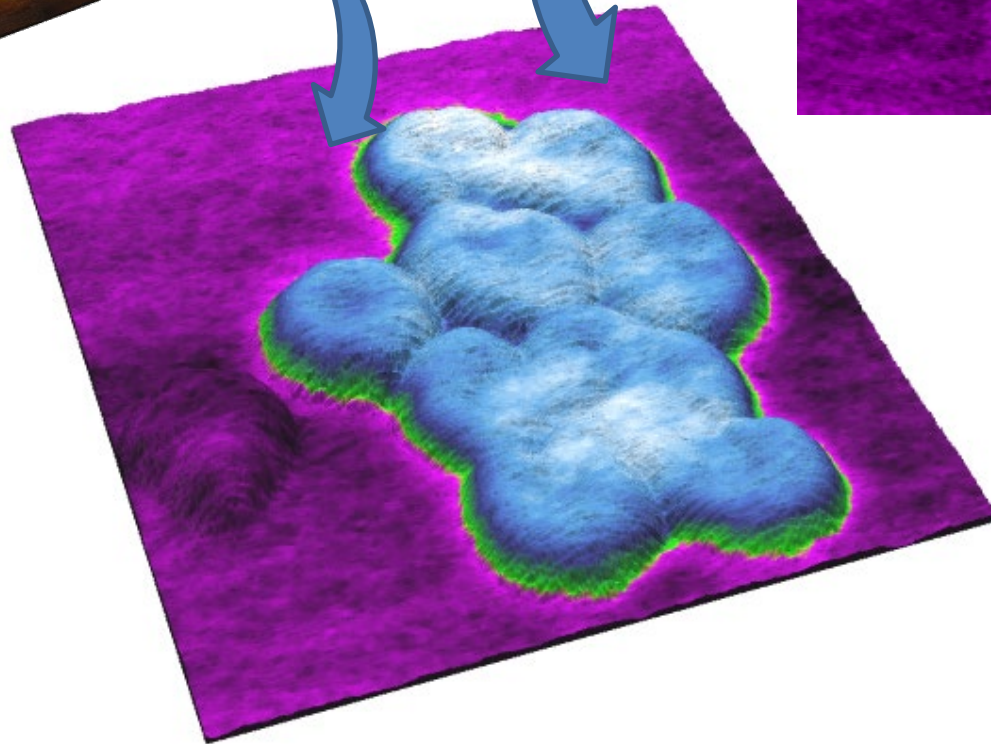
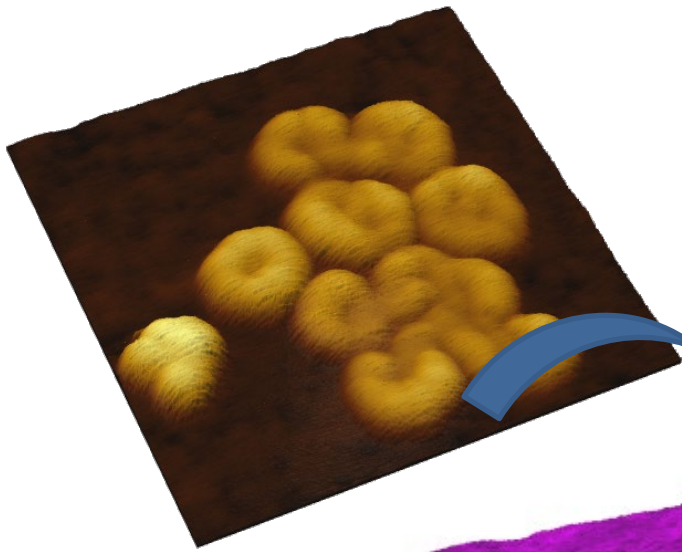
Hue/Saturation
Hue
Saturation
Brightness
Contrast

Apply Cancel

Color

X Value
Y Value

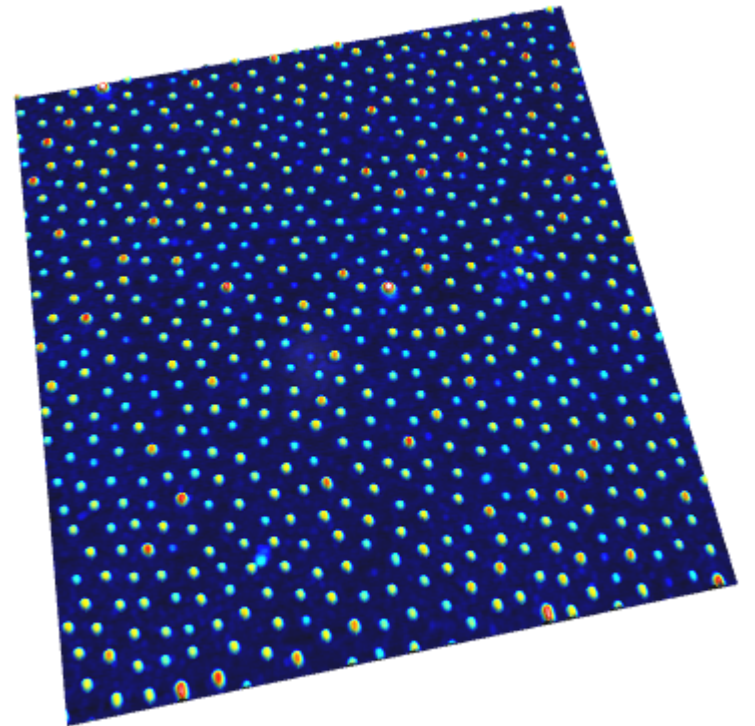
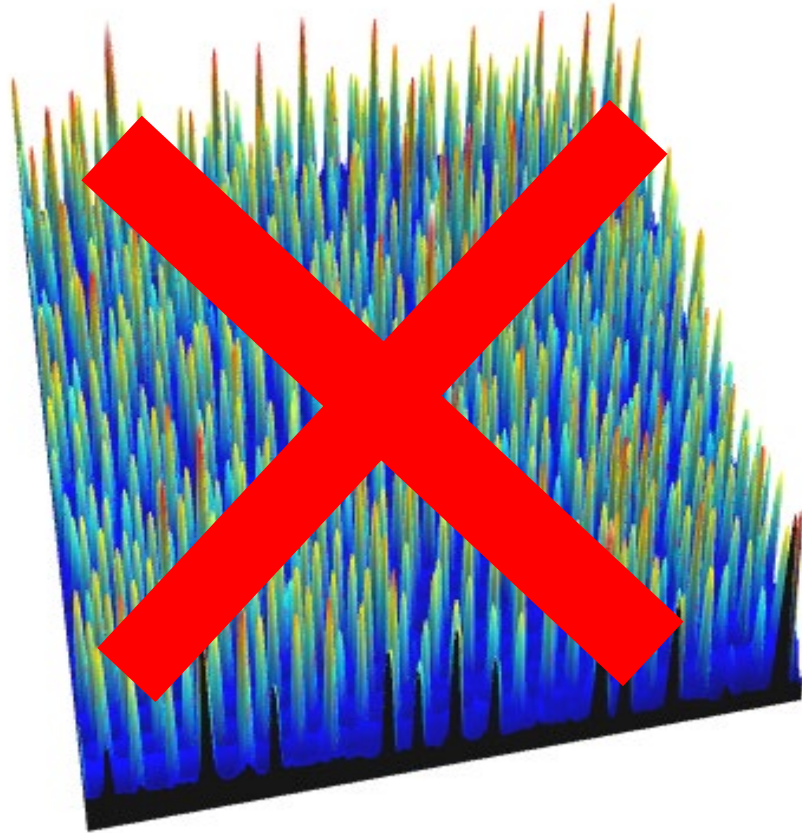
Наложение текстуры в 3D



2D

3D

3D

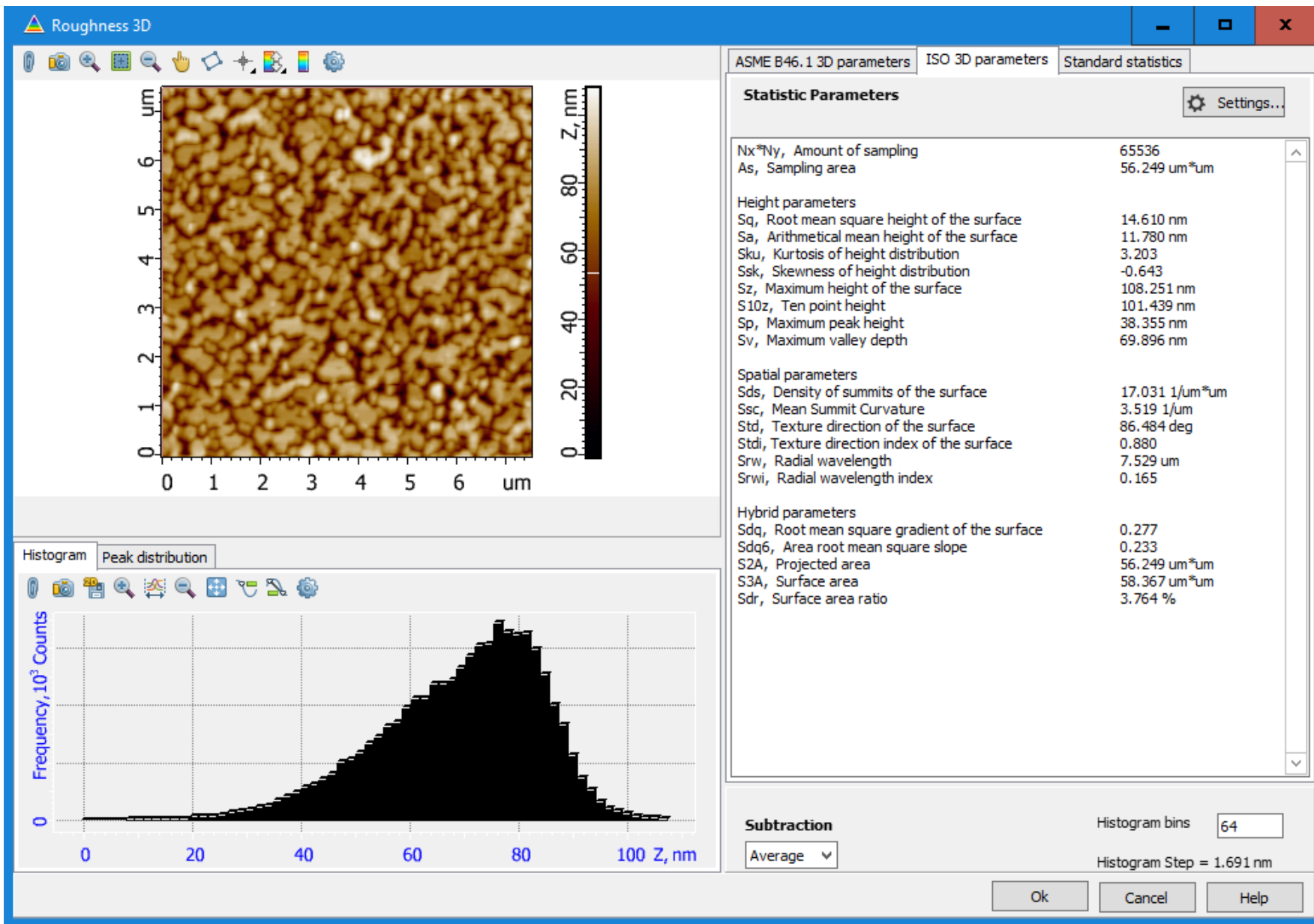




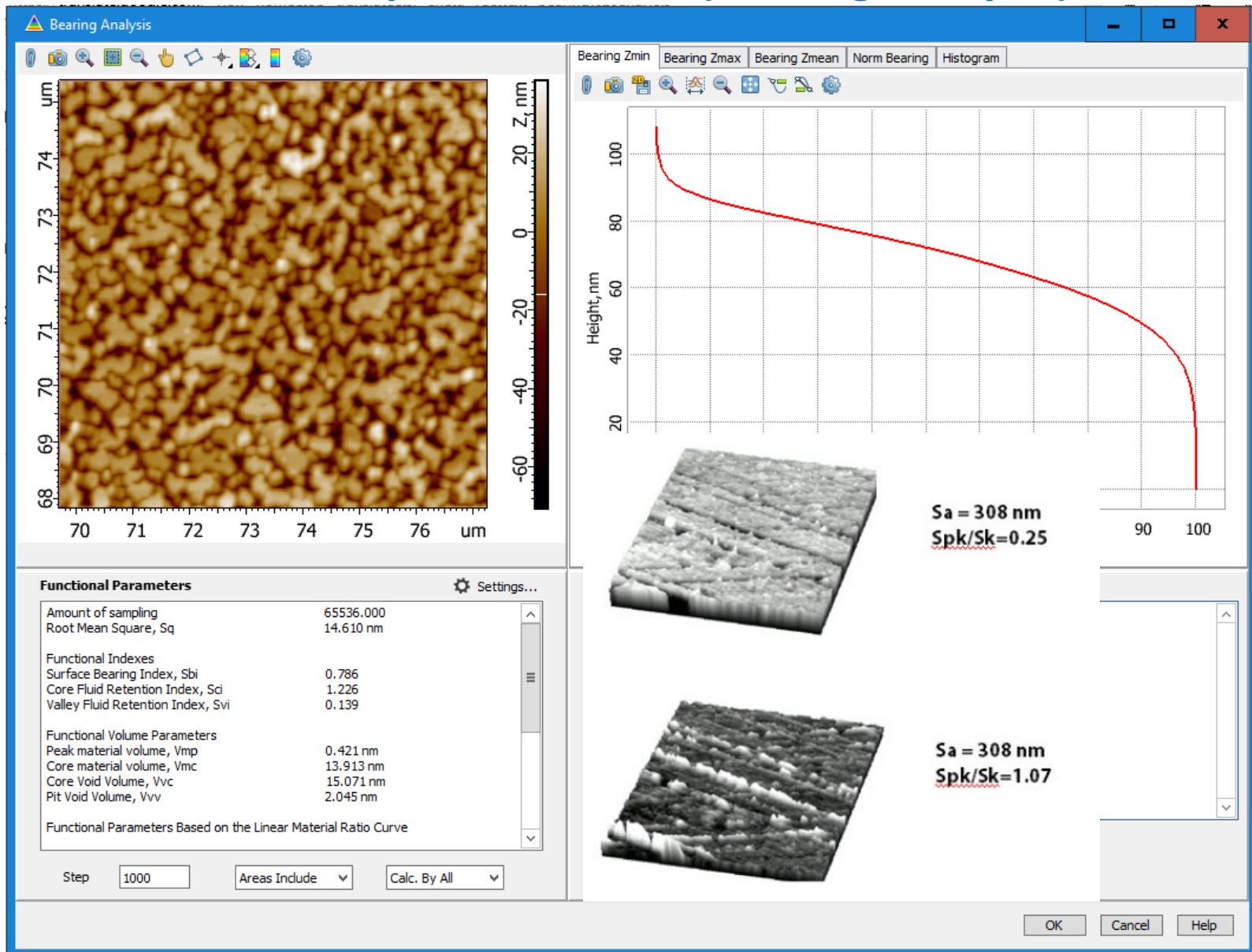
Анализ данных

Статистический анализ

Модуль Roughness 3D
















Анализ кривой Аббота (Bearing Analysis)



https://www.michmet.com/3d_s_functional_parameters.htm

Параметры шероховатости

Profile Material Measures of ISO 25178-70

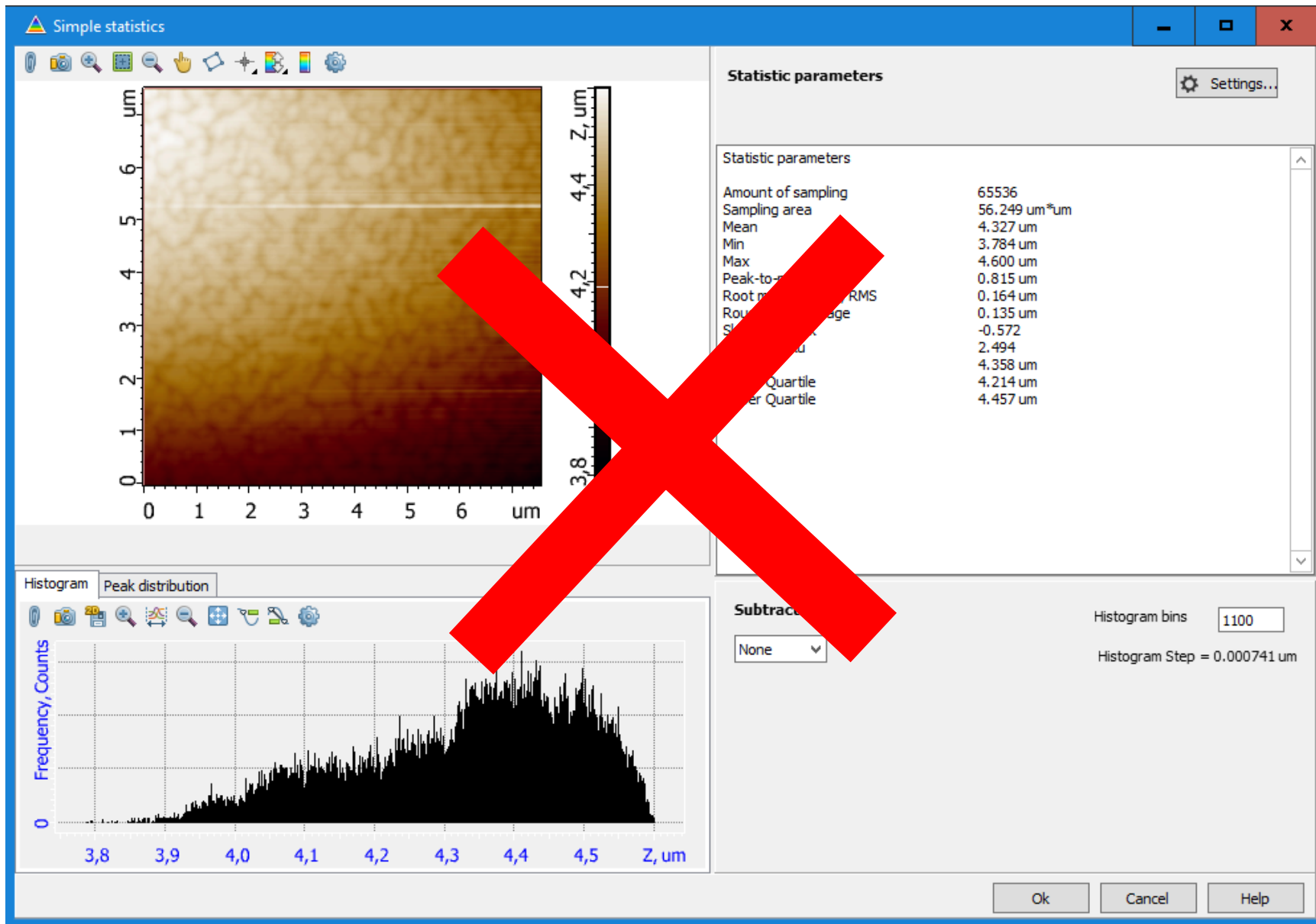
<p>Type PPS: Periodic Sinus Structure</p> 	<p>Type PPT: Periodic Triangular Structure</p> 
<p>Type PPR: Periodic Rectangular Structure</p> 	<p>Type PPI: Periodic Arcuate Structure</p> 
<p>Type PGR: Rectangular Groove</p> 	<p>Type PGC: Circular Groove</p> 
<p>Type PRO: Irregular Profile</p> 	<p>Type PCR: Irregular Circular Profile</p> 
<p>Type PRI: Prism</p> 	<p>Type PRB: Razor Blade</p> 
<p>Type PAS: Approximated Sinusoidal Structure</p> 	
<p>Type PCS: Contour Standard</p> 	<p>Type PDG: Double Groove</p> 

3D:
ASME B46.1
ISO 25178

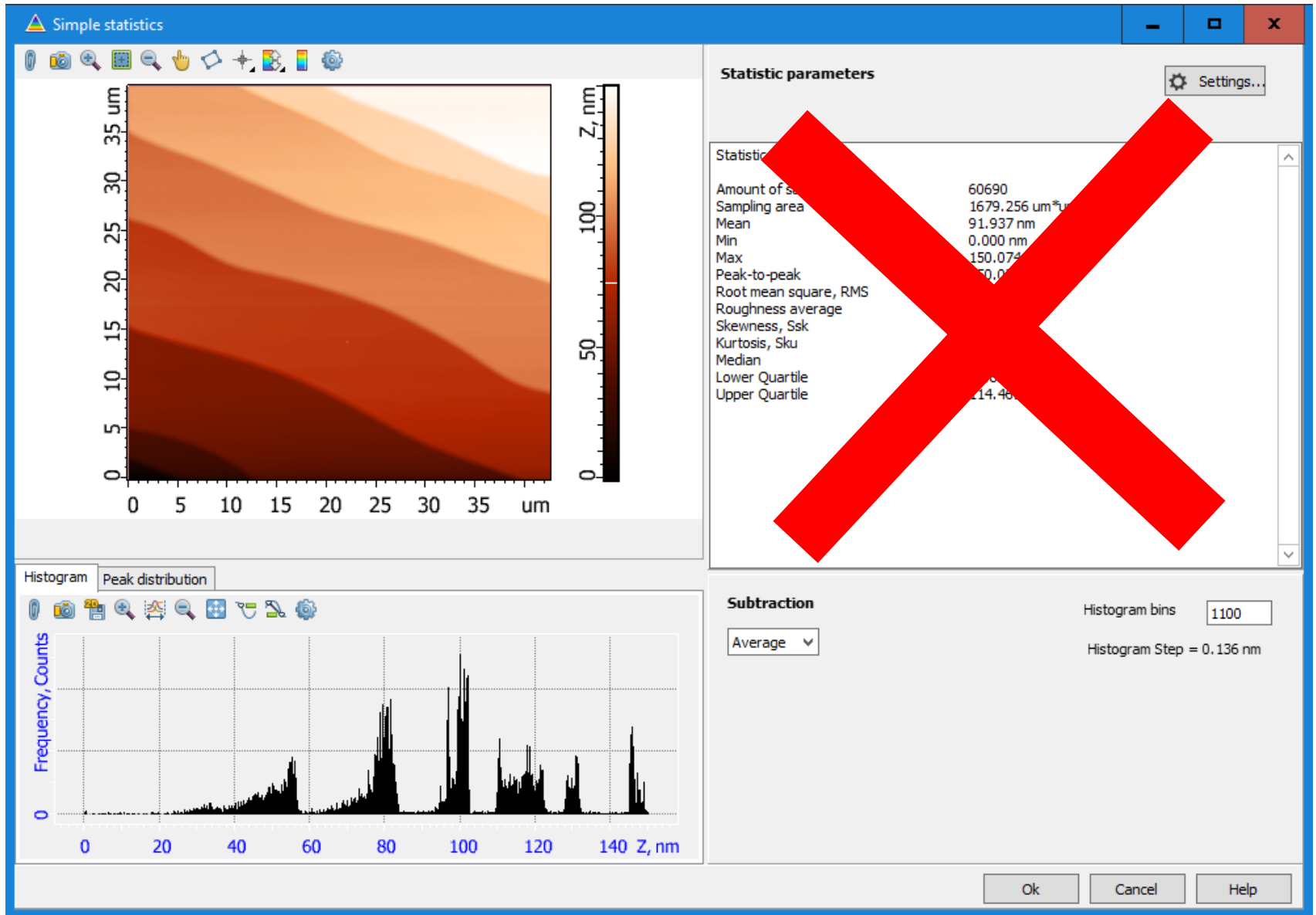
2D:
ГОСТ 25142
ASME B46.1
ISO 4287

ISO 25178-70 2014 Geometrical product specification (GPS),
Surface texture: Areal, Part 70: Material measures

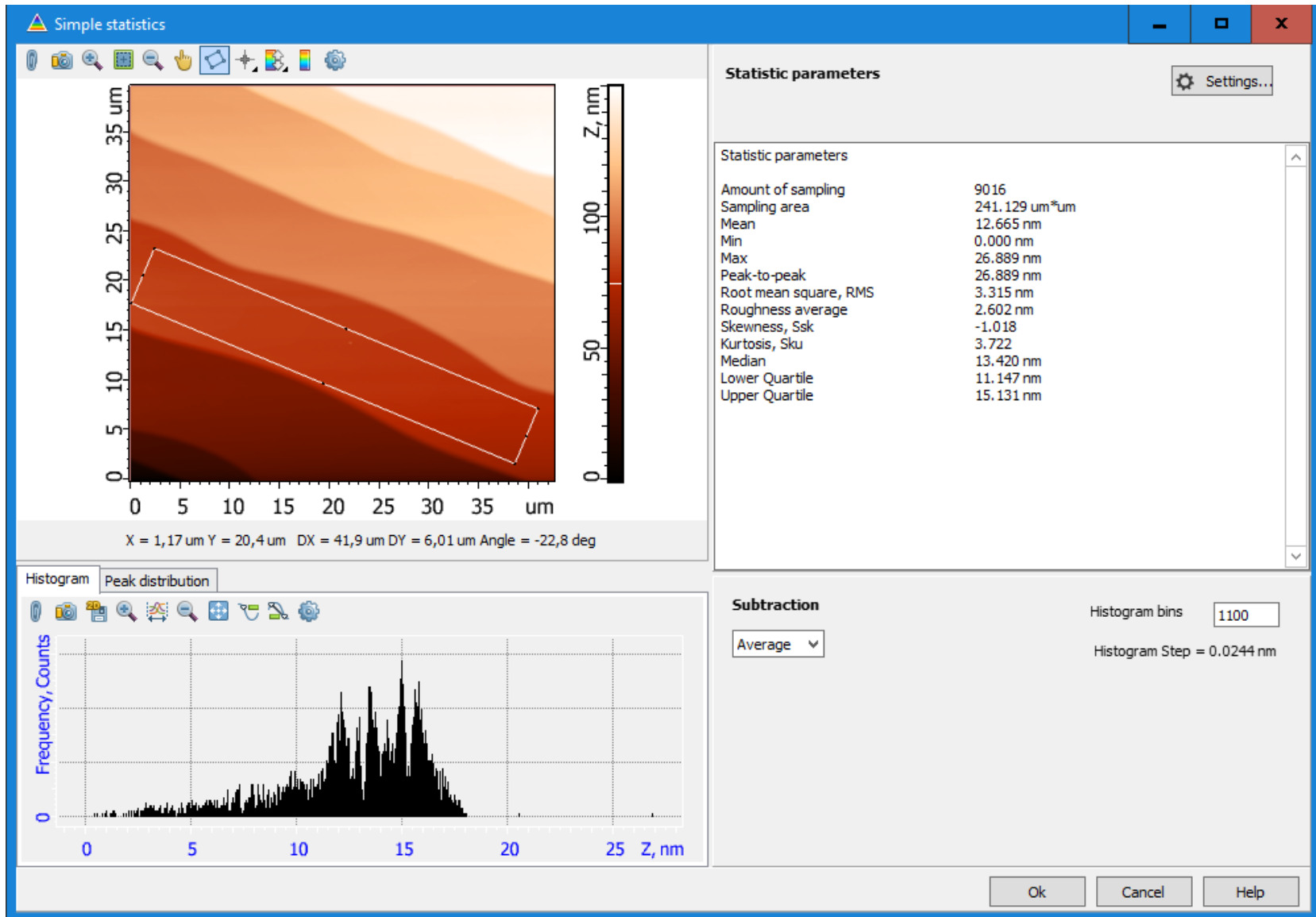
Изображение должно быть корректно подготовлено



Статистика считается корректно для мономодальных распределений

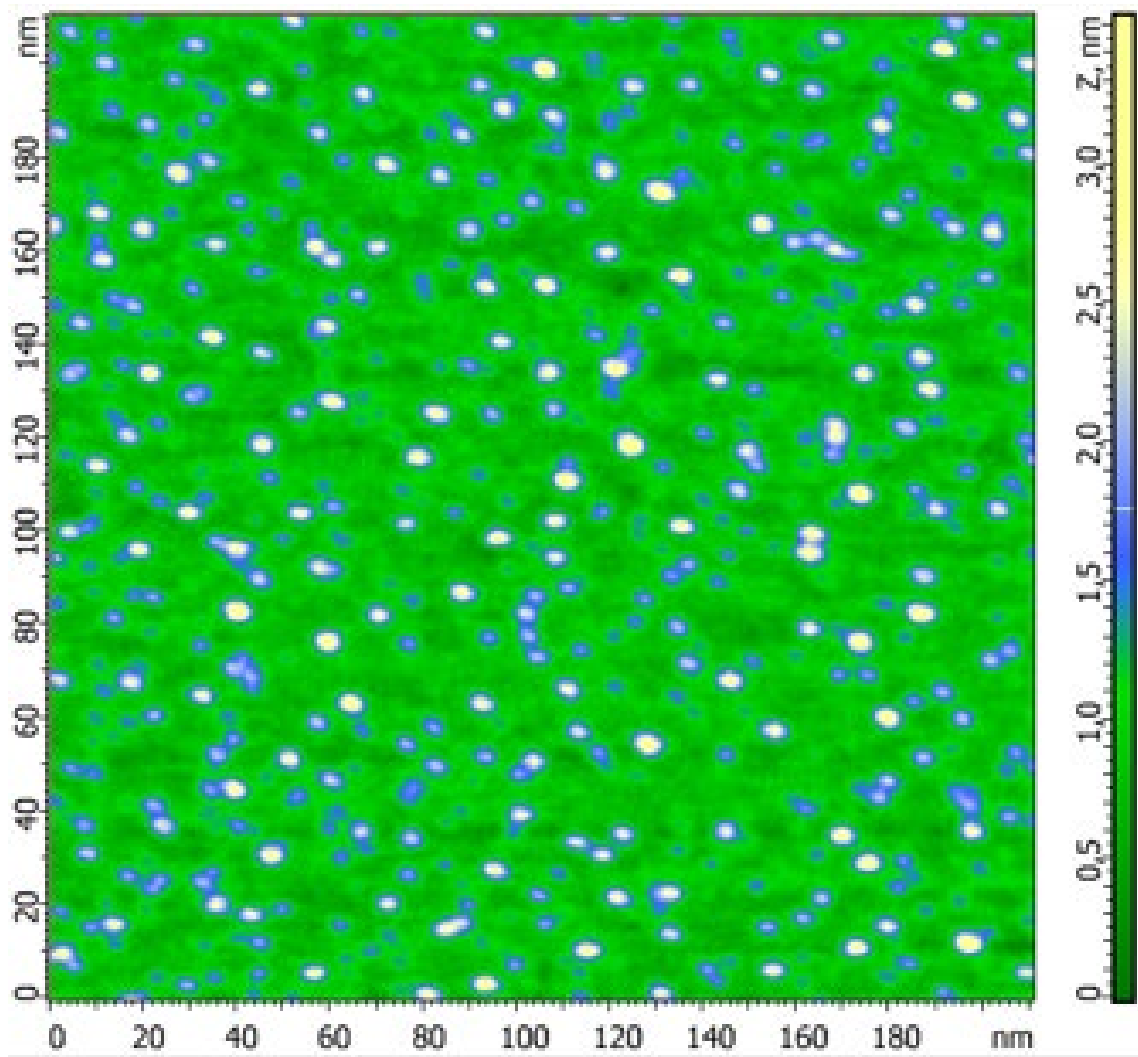


Для расчета параметров можно выбрать область(и)



Анализ частиц

Сколько здесь частиц?



Пороговый метод

Grain Analysis

Grain analysis. Threshold method.

Grains Boundary of grains

Exclude boundary grains

The 286 Grains detected. Section level 1.768 nm.

Control page Preprocessing Grains Sorting

Looking for grains pores

Section Level nm

Find grains

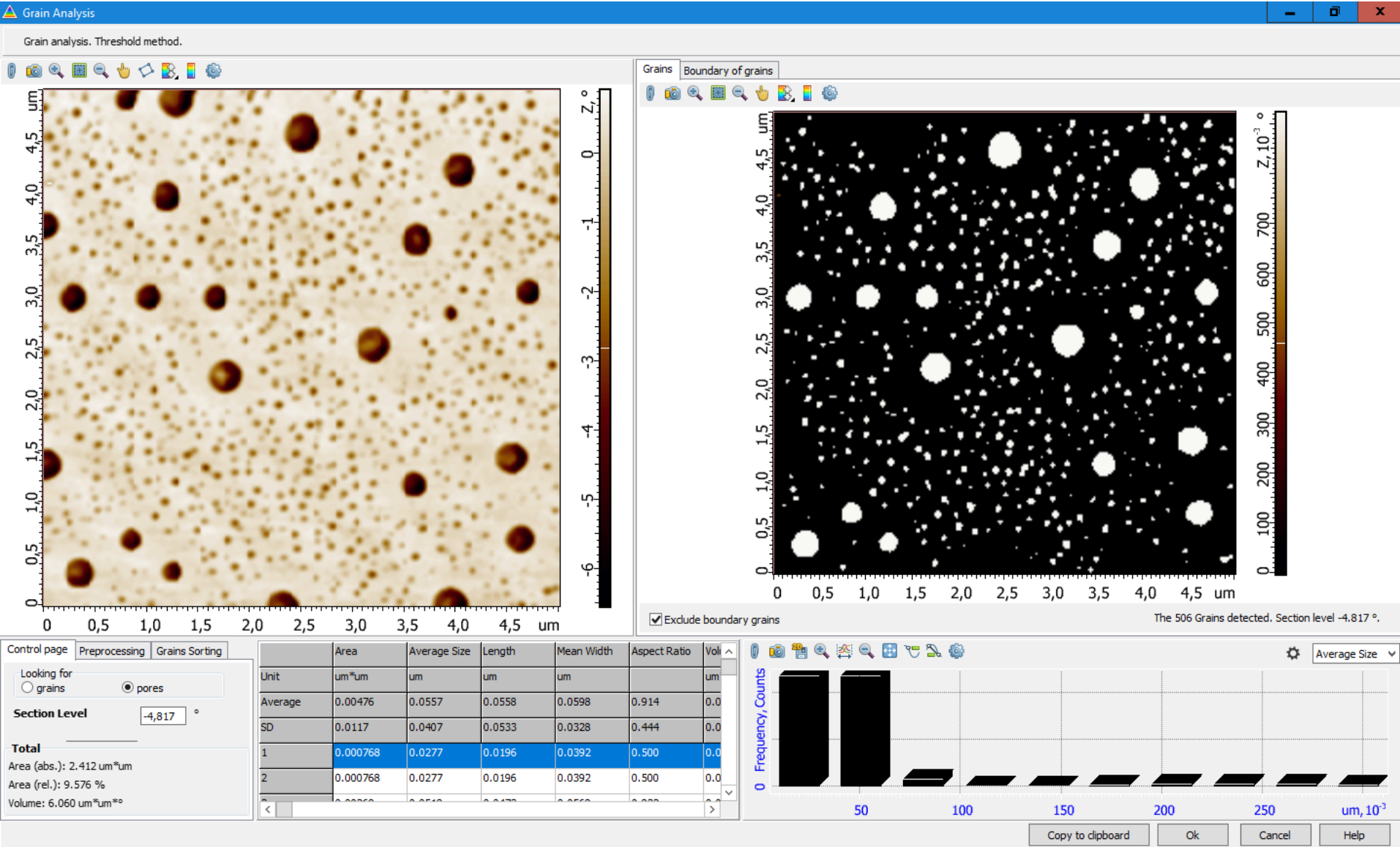
Total
 Area (abs.): 2483.053 nm²
 Area (rel.): 5.587 %
 Volume: 3518.214 nm³

	Area	Average Size	Length	Mean Width	Aspect Ratio	Volume	Zrange
Unit	nm ²	nm	nm	nm		nm ³	nm
Average	8.682	2.653	3.654	1.958	1.784	3.619	-0.761
SD	7.100	1.281	2.015	0.860	0.541	4.308	0.000452
1	0.949	0.974	1.124	0.844	1.332	0.0461	-0.761
2	1.753	1.324	1.979	0.885	2.235	0.0870	-0.761
3	12.563	3.544	7.112	1.766	4.026	3.988	-0.760

Frequency Counts

Copy to clipboard Ok Cancel Help

Анализ пор



Пороговый метод работает хорошо с разделенными частицами на ровной подложке

Grain Analysis

Grain analysis. Threshold method.

Grains Boundary of grains

Exclude boundary grains

The 129 Grains detected. Section level 22.619 nm.

Control page Preprocessing Grains Sorting

Looking for grains pores

Section Level nm

Total
 Area (abs.): 106616.281 nm²
 Area (rel.): 42.480 %
 Volume: 740394.416 nm³

	Area	Average Size	Length	Mean Width	Aspect Ratio	Volume	Zrange	MaxZ
Unit	nm ²	nm	nm	nm		nm ³	nm	nm
Average	826.482	25.684	36.111	18.618	2.027	4913.008	-1.703	31.269
SD	765.110	12.914	20.016	9.288	0.760	6084.029	0.00470	4.705
1	22.020	4.692	7.166	3.072	2.332	8.242	-1.711	23.283
2	27.764	5.269	11.786	2.355	5.003	20.742	-1.710	24.259

Frequency, Counts

0 10 20 30 40 50 60 nm

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Метод Advanced Watershed

Advanced Watershed

This module analyses particles with usage of Advanced Watershed

Image Gradient Image

Grains Grain boundaries

nm 400 300 200 100 0 0 50 100 150 200 250 300 350 400 450 nm

0 5 10 15 20 25 30 35 40 Z, nm

nm 400 300 200 100 0 0 50 100 150 200 250 300 350 400 450 nm

0 5 10 15 20 25 30 35 40 Z, nm

Exclude boundary grains 213 Grains detected.

Ext markers Int markers Result

Looking for grains pores

Add or delete grain 1 -

Histogram bins 10

Total
 Area (abs.): 214015.724 nm²nm
 Area (rel.): 85.272 %
 Volume: 3199107.506 nm³nm

Settings Preprocessing Grains Sorting

Min grain height 7,868 nm 1,000 Sq

Max grain size 62,448 nm 4,000 Lc

Local min threshold 15,735 nm 2,000 Sq

Merge grains

Sq = 7.867 nm

	Area	Average Size	Length	Mean Wid
Unit	nm ² nm	nm	nm	nm
Average	1004.768	29.738	42.926	20.974
SD	667.814	10.973	12.534	9.600
1	133.080	11.536	17.115	7.775
2	180.950	13.451	30.737	5.886
3	179.035	13.380	26.437	6.772
4	351.369	18.744	35.572	9.877

Frequency, Counts

5 10 15 20 25 30 35 40 45 nm

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Выводы

1. Пробуйте разные подходы
2. Используйте априорную оценку (плоское должно быть плоским)
3. Сохраняйте все данные для GTransform
4. Изображение должно быть информативным
5. Бездумное применение методов анализа вредит вашей научной работе

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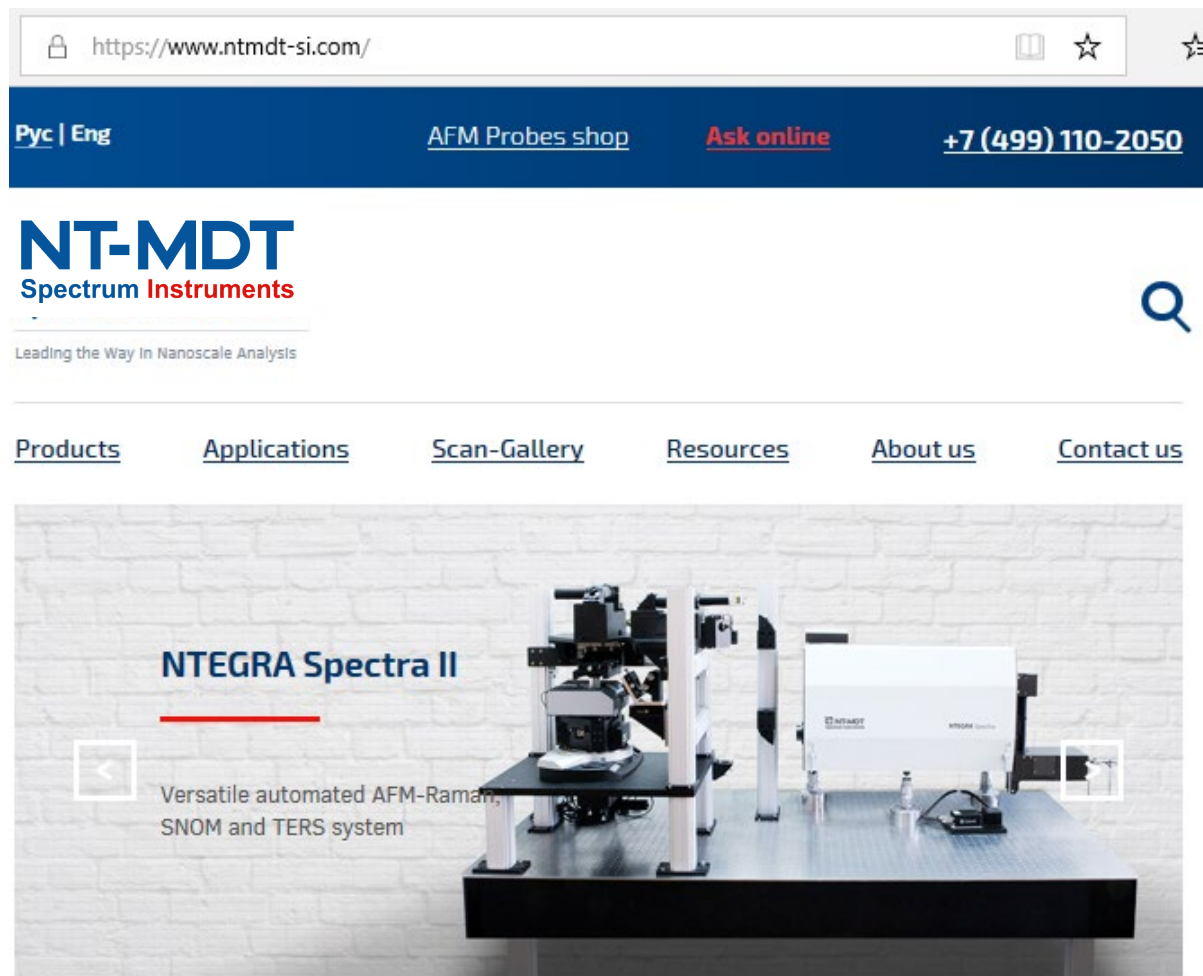
ISO 25178-70 2014 **Geometrical product specification (GPS), Surface texture: Areal**, Part 70: Material measures

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Спасибо за внимание!