OXFORD INSTRUMENTS ASYLUM RESEARCH

Tutorial

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Introduction to AFM Image Processing for Asylum Research AFMs

Why Use AFM??

Because we want to make a measurement:

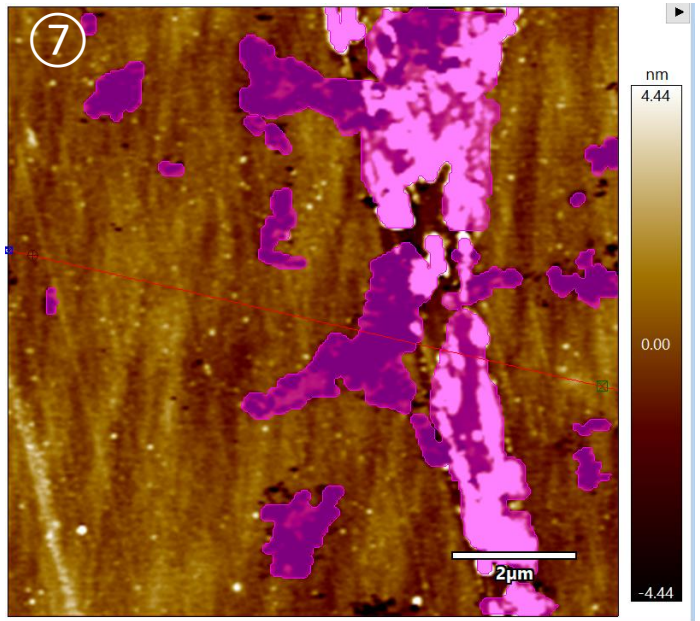
- Image analysis for three types of measurements
  - Critical dimension in XY
  - Step height
  - Roughness
- Image processing
  - It's a necessary evil
  - Principle of least damage
  - Alternatives to processing
  - Polynomial subtraction
    - Planefit
    - Flatten

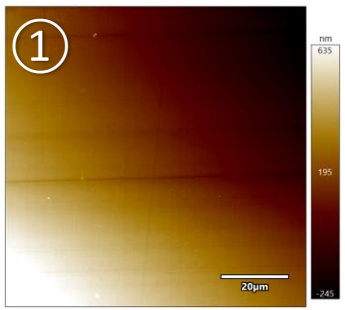
Outline

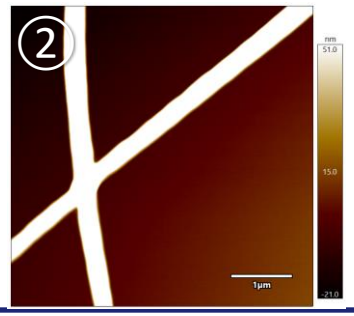
- Opening files
- Introduction to Display Window
- Processing Considerations
- The **Analysis Panel** (Line sections, Roughness, Histograms
- The **Modify Panel** (Flatten, PlaneFit, Mask, Erase)
- Argyle **3D/4D rendering**

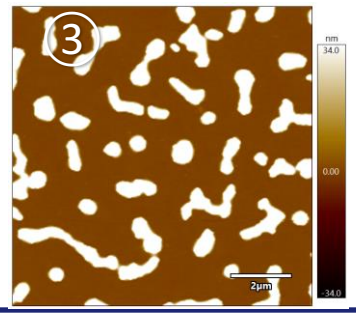
Examples:

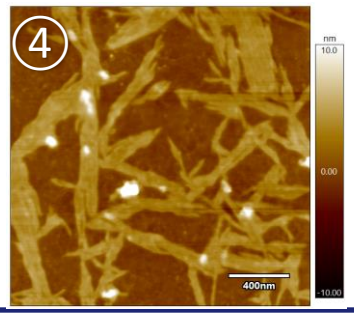
1) Tilted Plane (Planefit, Flatten, line section, Roughness)
2) Al2O3 Fibers (Masking, Flattening, Line section, Roughness,)
3) Molla's Sample (Masking, Flattening)
4) MoS2 (iterative masking, Histogram)
5) Calibration Grating (magic Mask Pits)
6) Polymer Step edge (Planefitting, Line section)
7) RF Challenge Sample (Masking Challenge)

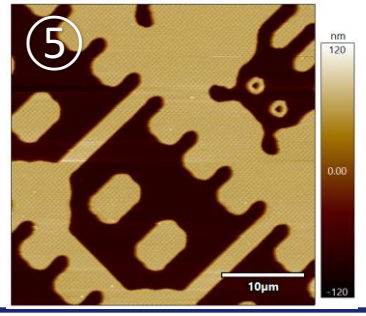


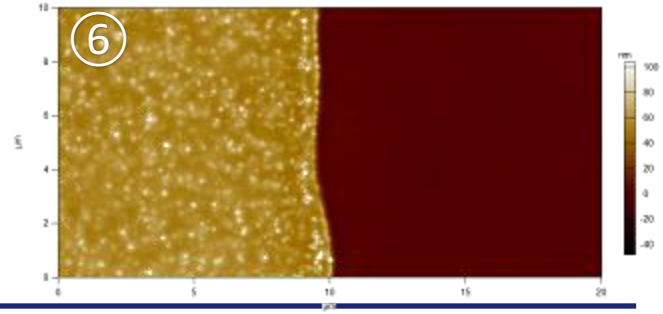












Available Resources

Manuals

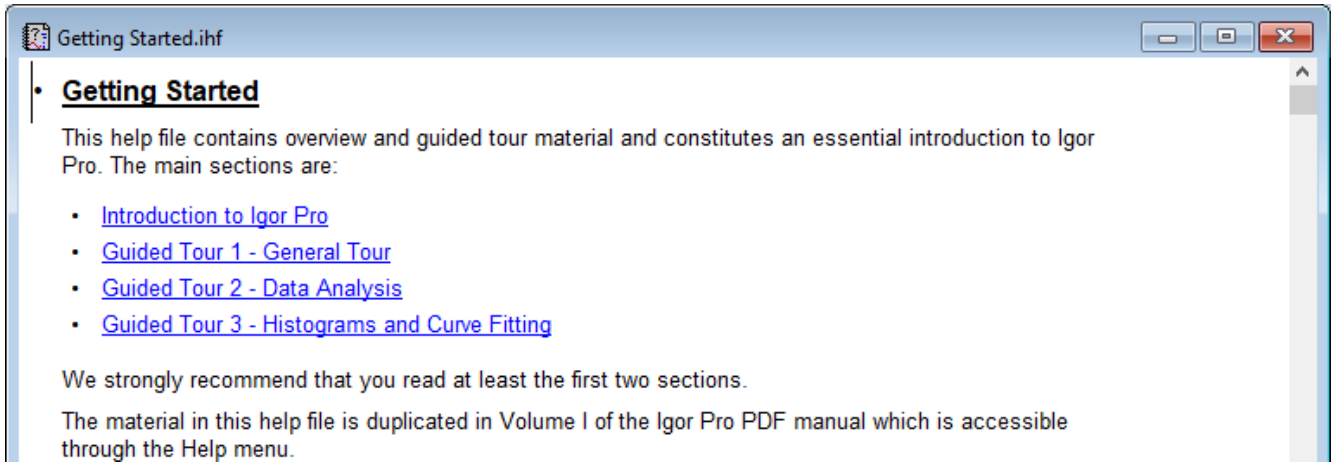
https://oxinst.sharepoint.com/sites/OIARServices

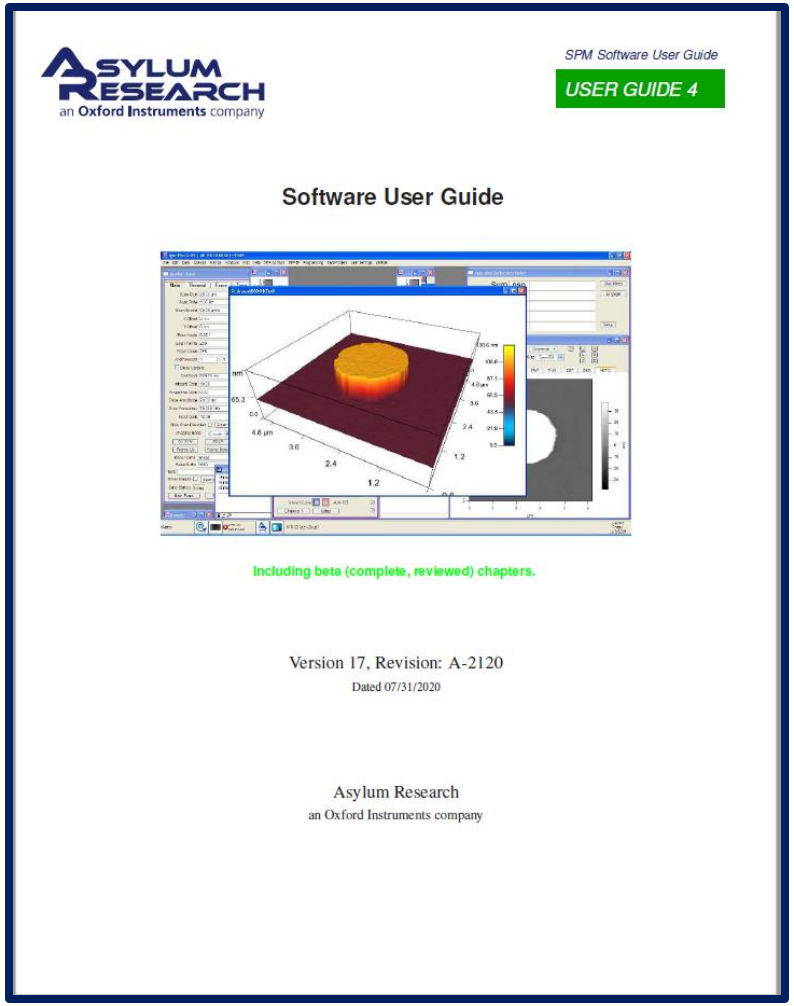
Use Help Menus to Right of parameter setvars/ buttons

Igor Getting Started Tutorial (Help → Getting Started)

Ctrl A- return to full view
Ctrl I – brings up cursors
Ctrl T- brings up tool box

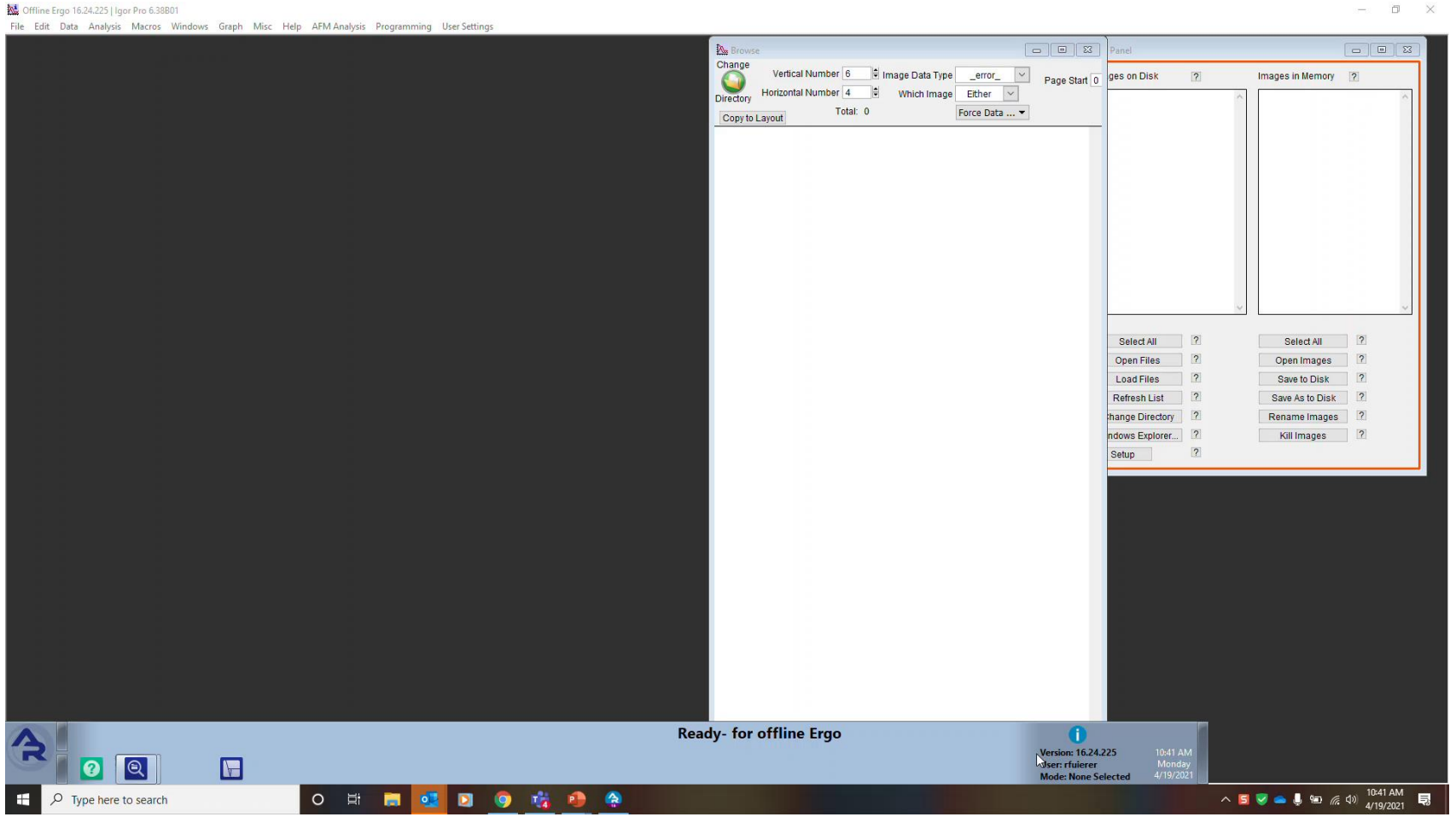
Argyle Lite: Stand alone 3D&4D viewer
https://support.asylumresearch.com/filedata/fetch?id=19894





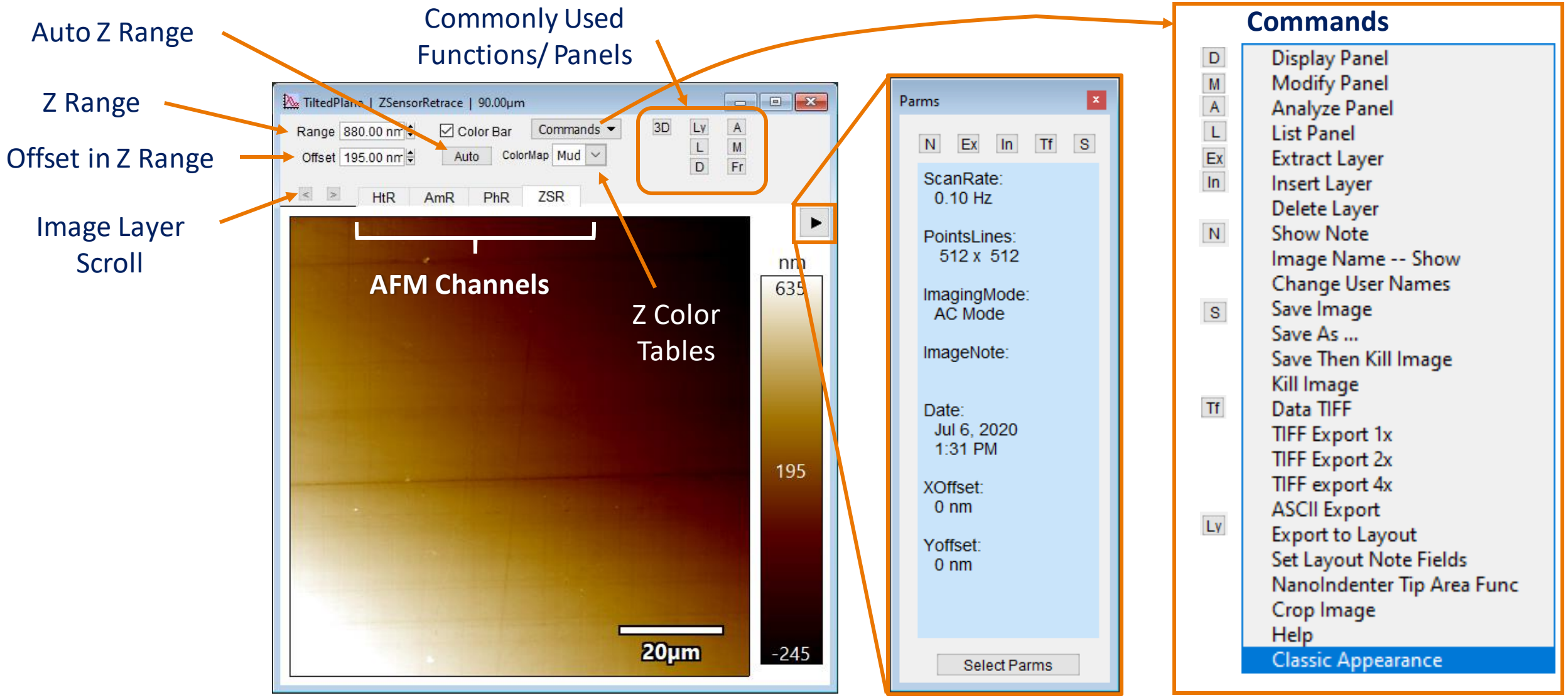
Opening a File:

AFM Analysis→ Browse Saved Data (Brings UP Browse Panel)
Brings up **Browse** & **List** Panels

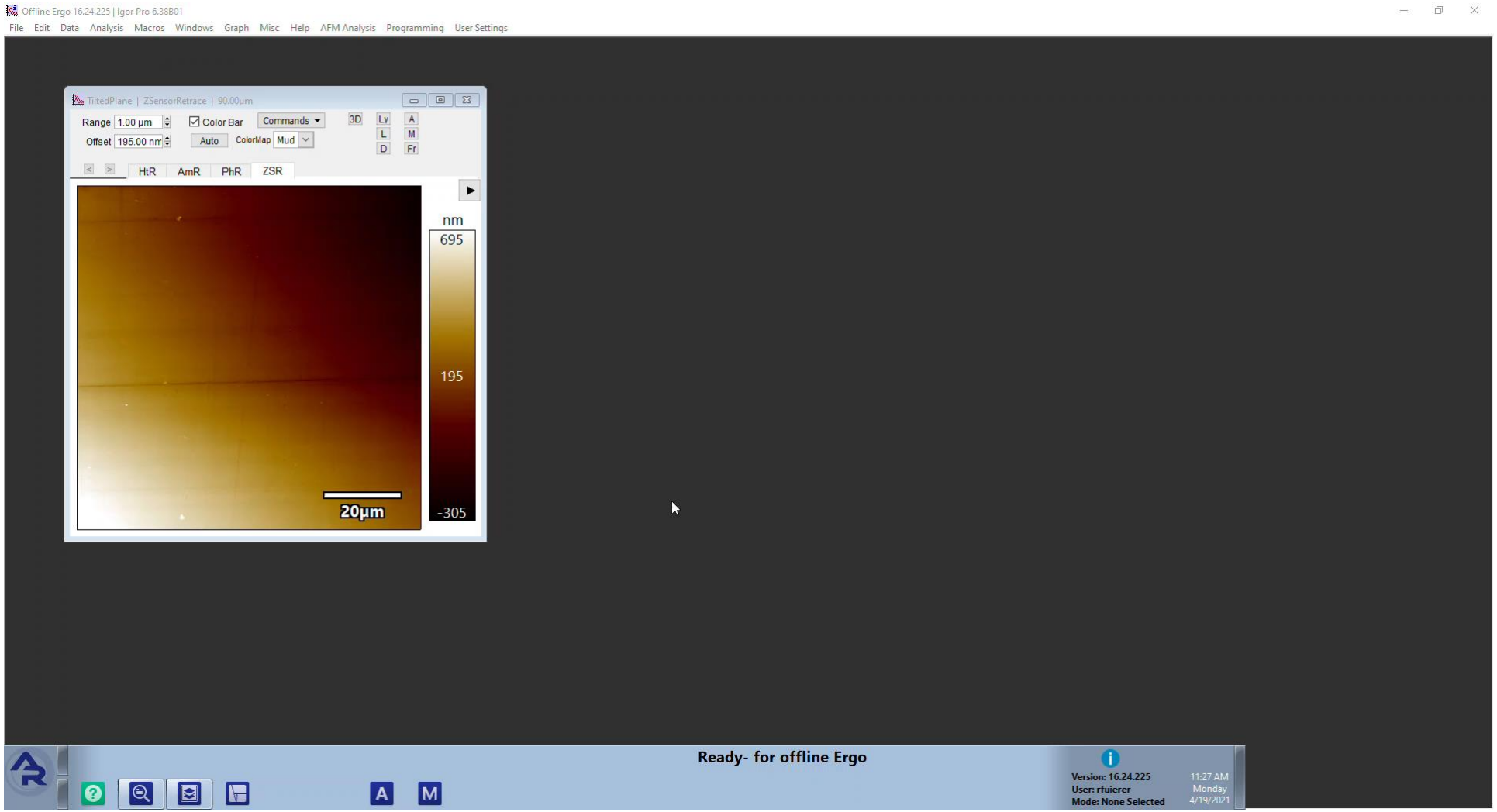


Play Movie

The Display Window Anatomy



The Display Window Anatomy



Play Movie

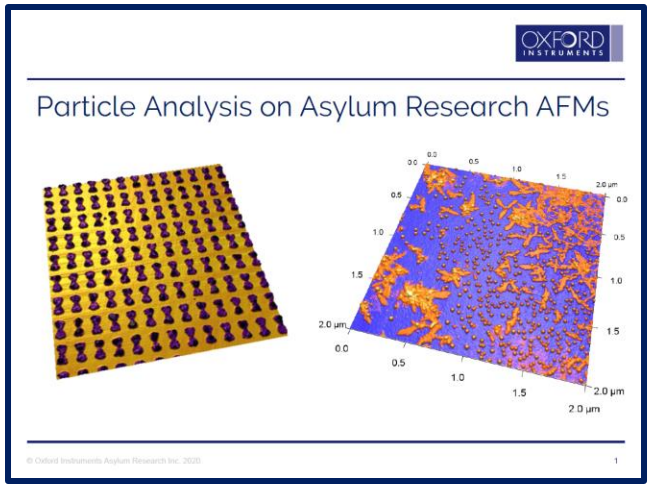
The Analysis Panel

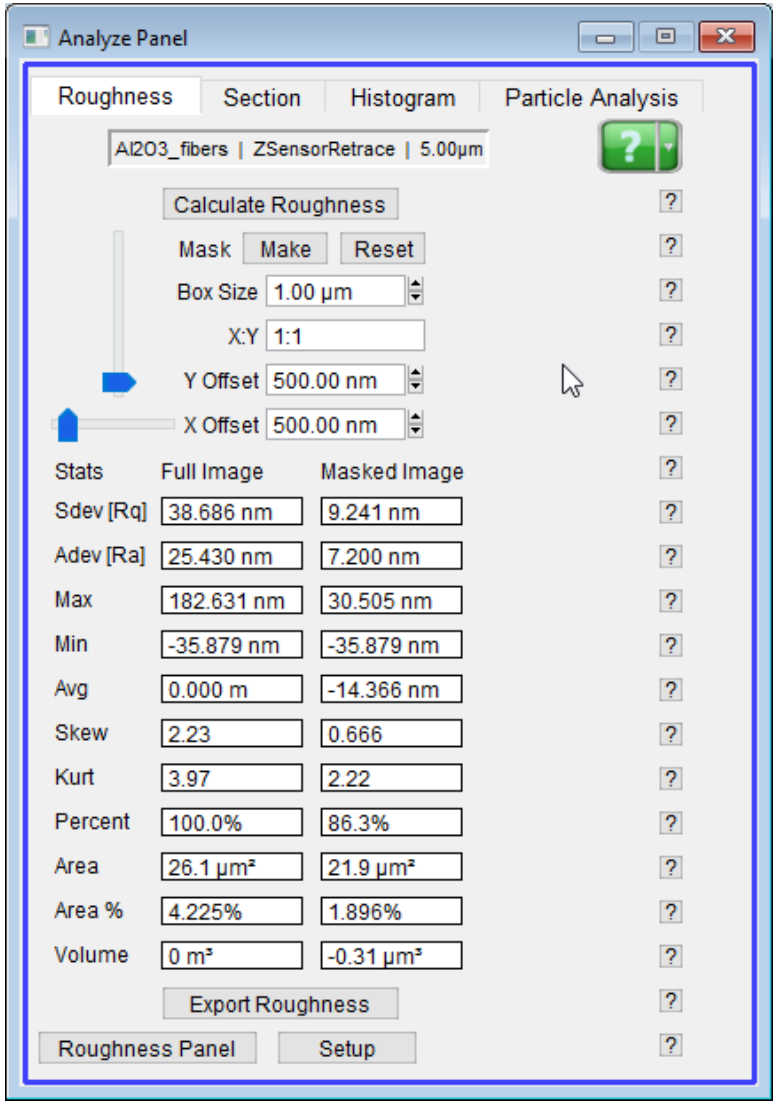
Roughness SubTab- Stats on Roughness values

Section SubTab- all things Line Sections

Histogram Sub tab- creates histograms of data pixels

Particle Analysis- counts shapes relative to a threshold masking plane.
-Author File upon request
- https://youtu.be/SJbj7pical0





The Analysis Panel

Section SubTab:

-**Linear Line** sections (offline & *real time*)

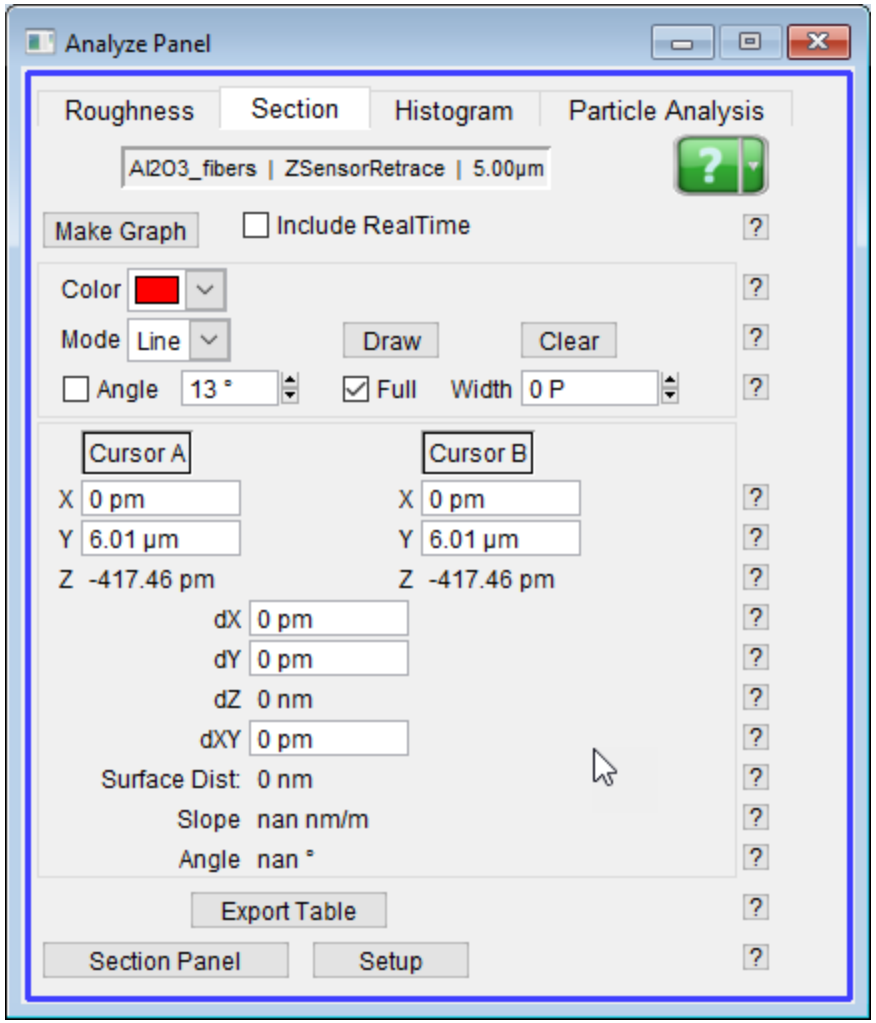
-**Free Hand Line** Sections (Offline only)

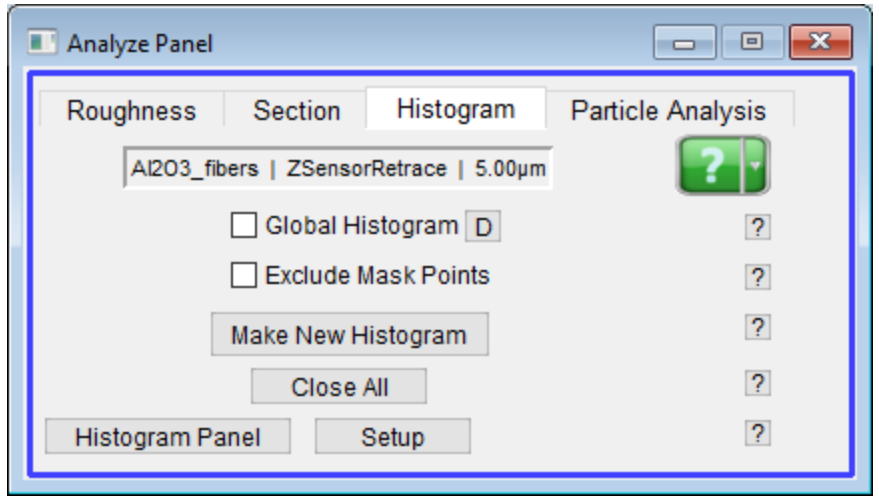
-**Averaging** lines

-Defined angle sections

-Display multiple sections

-Calculates line cursor differentials





Histogram SubTab:

-Display histogram data channel

-Overlay multiple histograms

-Simple binning & fitting

The Modify Panel

Flatten SubTab- Controls all flattening

Planefit SubTab- Controls all Planefitting

Erase Sub tab- Erase lines here.

Mask SubTab- mask layers to include or exclude data in some processing calculation

General Precautions:

Try to keep modifications to lower order processes (0,1st).

Masking features will be the differentiator

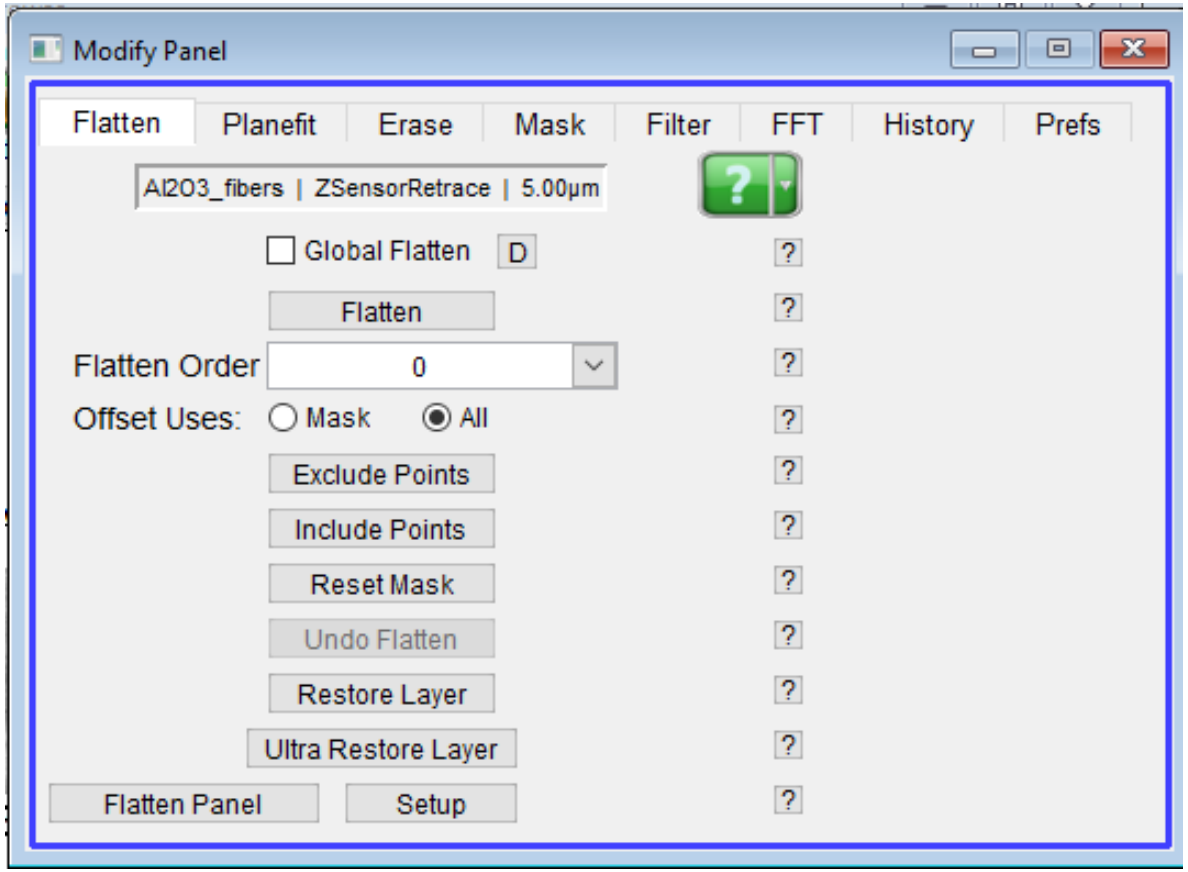
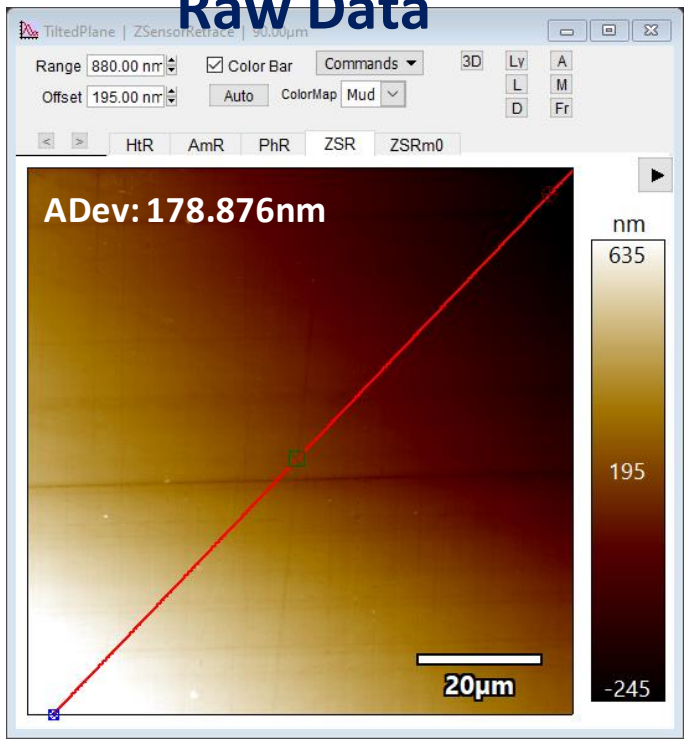
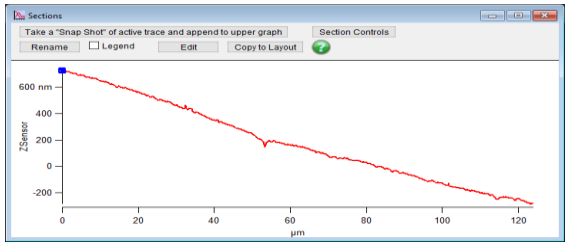


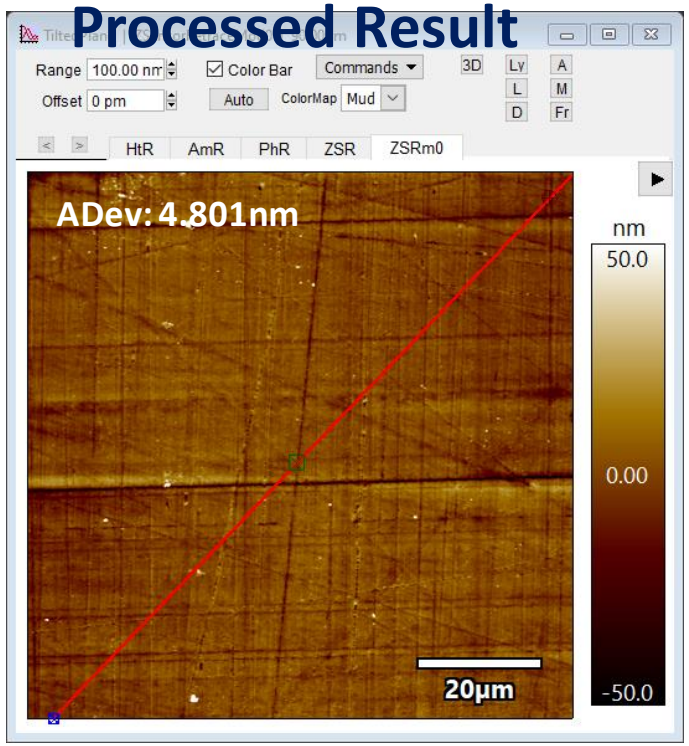
Image 1: Flattening & PlaneFit

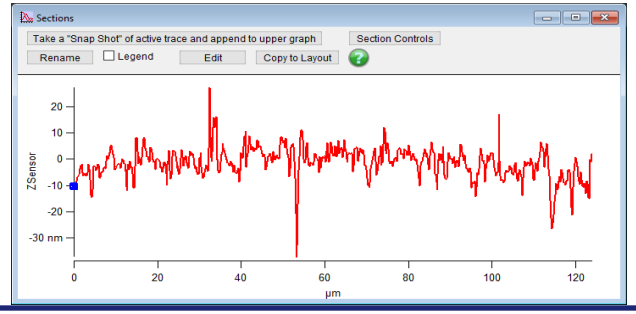
Raw Data





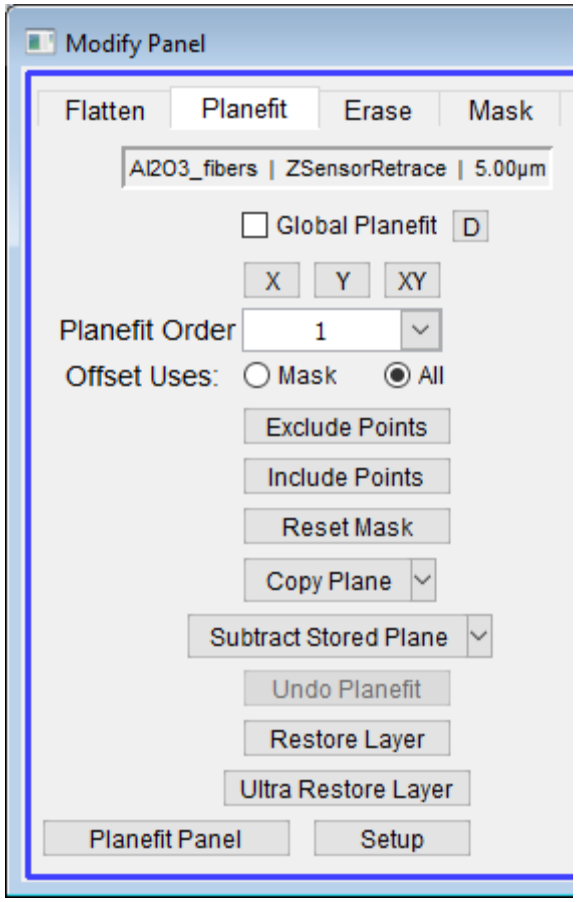
Processed Result





File: TiltedPlane
DataType: ZSensorRetrace
Date: 2020-07-06
ImageNote:
ImagingMode: AC Mode
ScanLines: 512
ScanPoints: 512
ScanRate: 0.10 Hz
ScanSize: 90.00 µm
Time: 1:31:27 PM

The Modify Panel



Plane Fitting-

0,1st order.

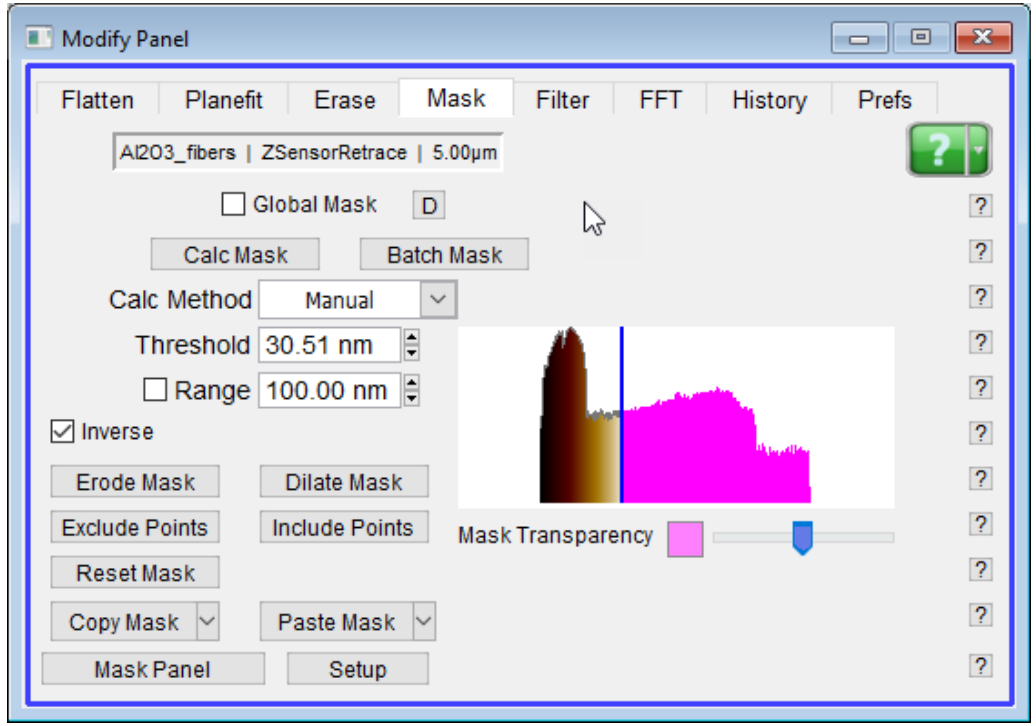
Mask or full image

Masking-

-Many approaches

-Erode/ Dilate Mask

-Copy/ paste Masks



Inverse Mask

This flips the mask so that excluded points become the included points.

Processing Considerations

Keep processing to minimum

Sometimes Image Processing is a necessary evil

Offers more variables and potential artifacts into image *after processing*

Why Use it?- sometimes need to isolate part of image

-Planefitting less invasive than Flatten
-Try to keep processing orders ‘smaller’- 0 & 1 order
-Use masking for excluding processing artifacts
-Avoid filtering and erasing lines
-only use processing when it makes your measurement better

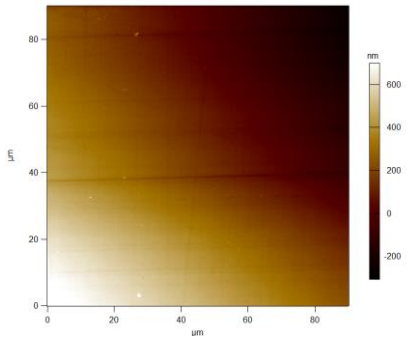
Some things you could do instead of image processing

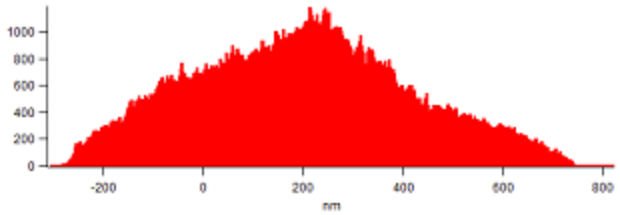
- Select a different image from your imaging session
- Make sure your sample is free of particles to avoid transients
- Try a different scan rate; tap harder (amplitude)
- Thermally equilibrate the AFM after loading the sample;
- Protect the tip and sample from air currents inside the acoustic hood
- Avoid using the first image after engaging on the surface (particularly bad for the Height channel)
- Consider using the most stable AFM you can

Not always possible! Sometimes the cost in time and/or money is too great.

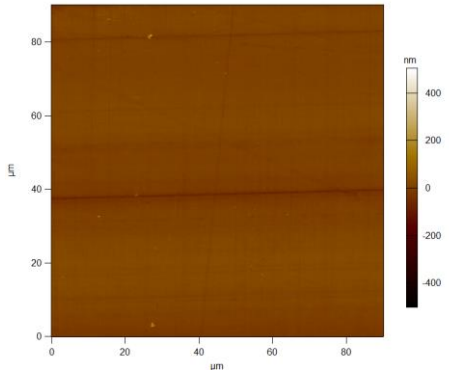
PlaneFitting (XY): Order Examples

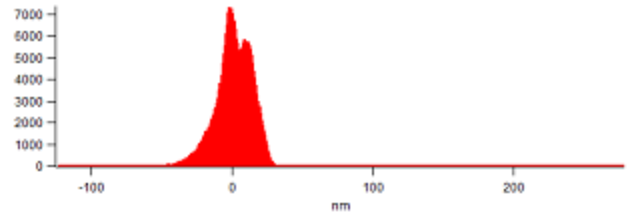
RAW



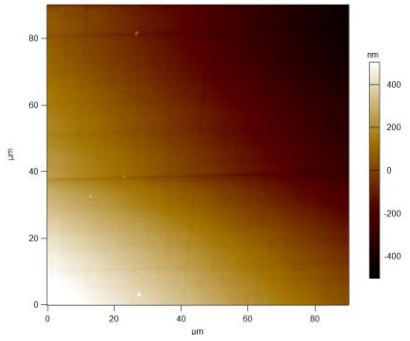


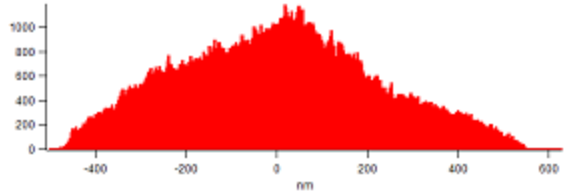
2ND





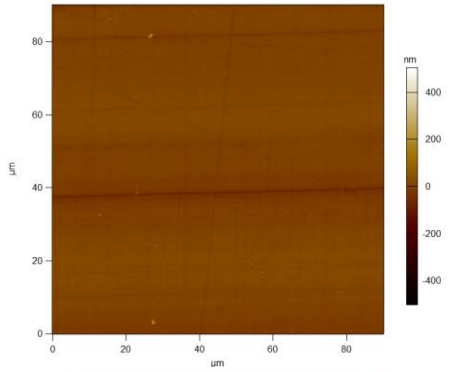
ZERO

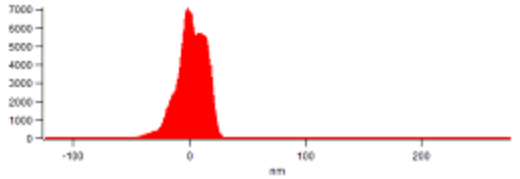




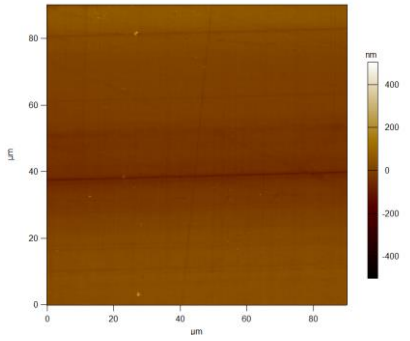
3RD

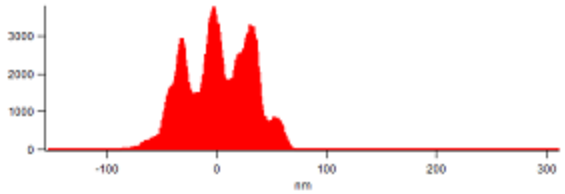
THIRD



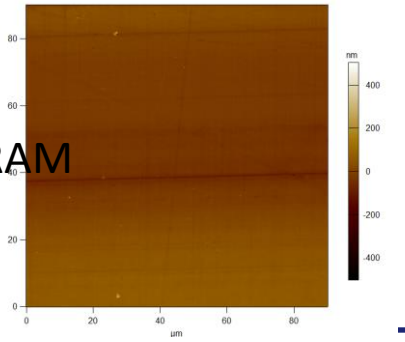


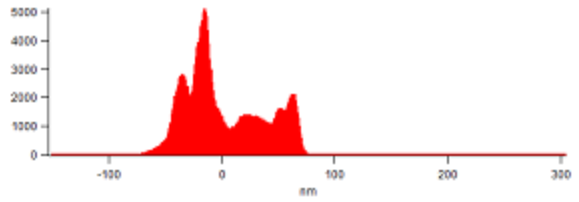
FIRST





HISTOGRAM





PlaneFitting (XY): Order Examples

Y X

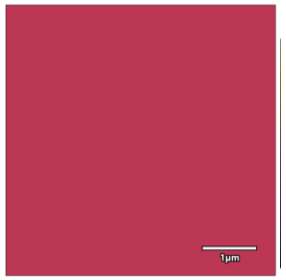
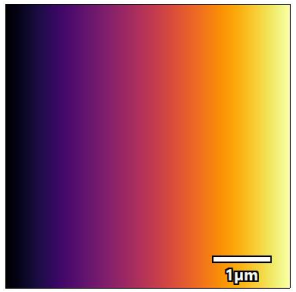
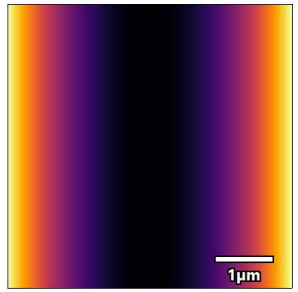
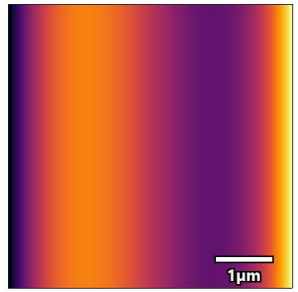
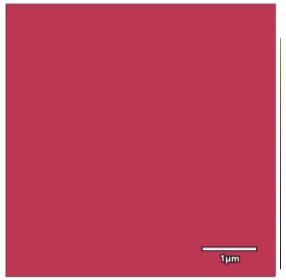
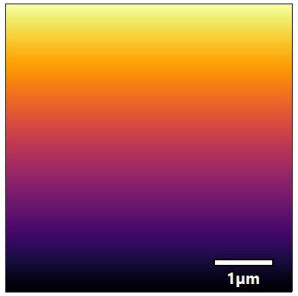
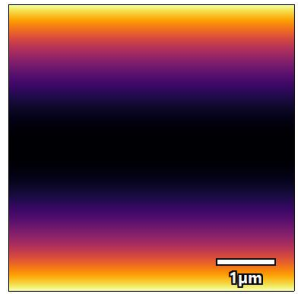
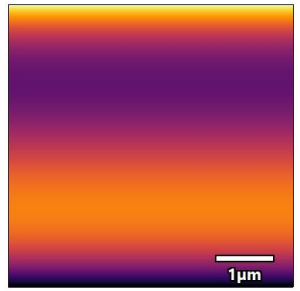
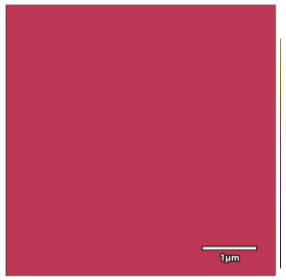
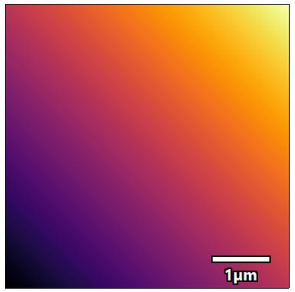
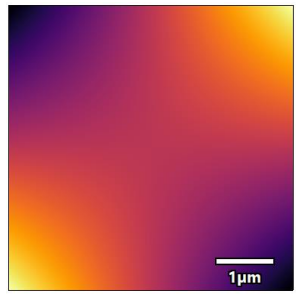
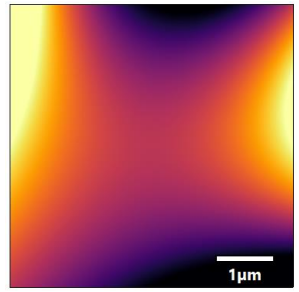
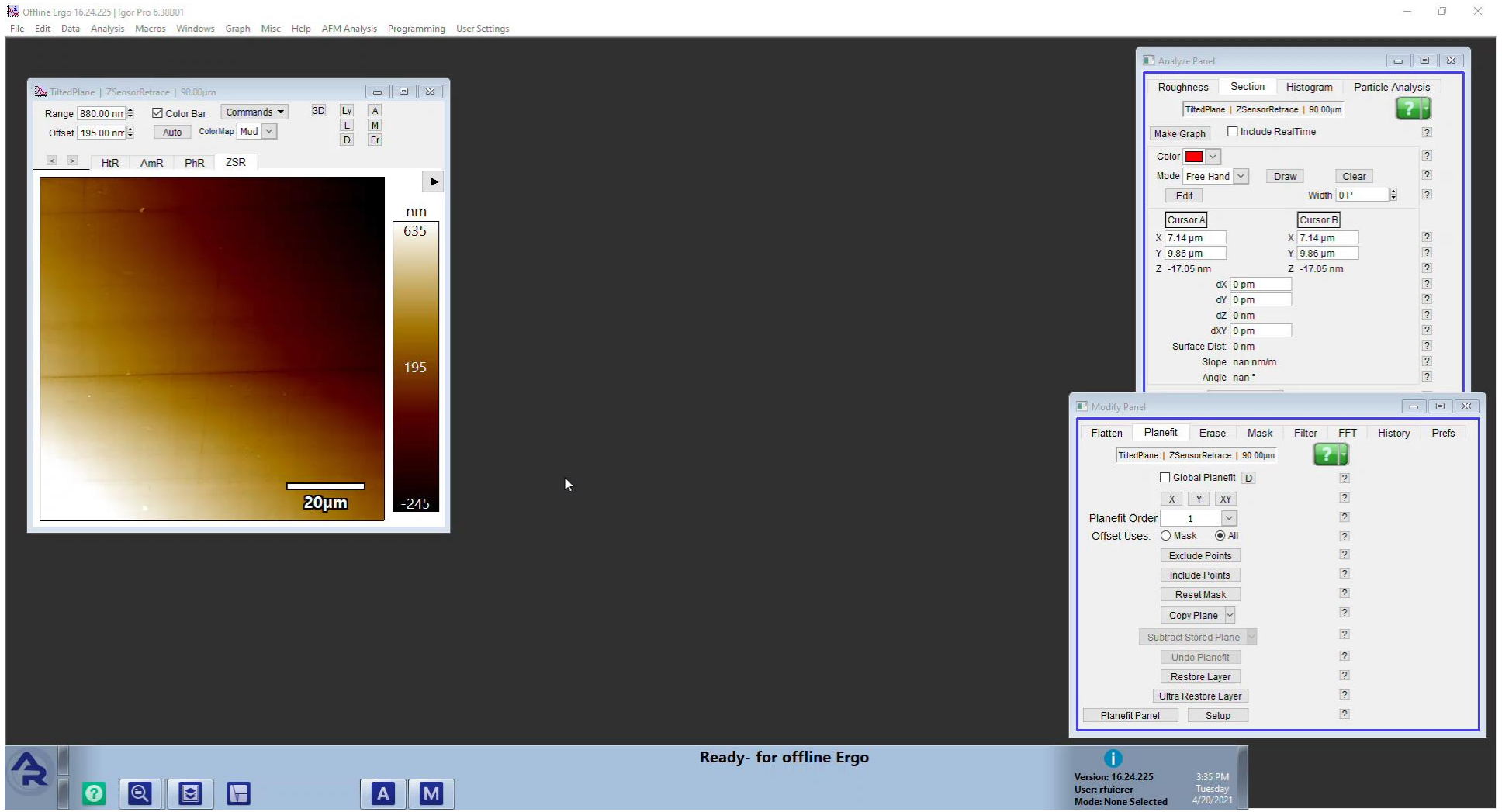
		0 order	1st order	2nd Order	3rd Order
X					
Y					
XY					

Image 1: Flattening & PlaneFit

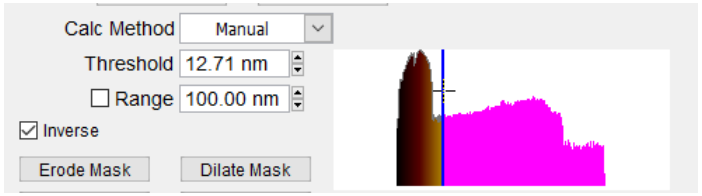


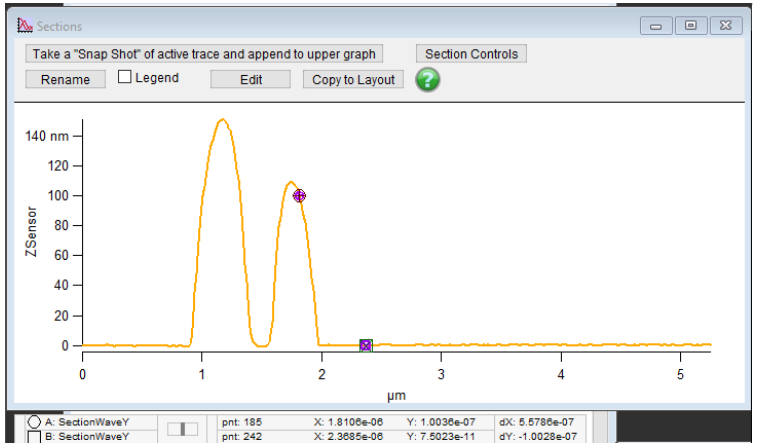
Play Movie

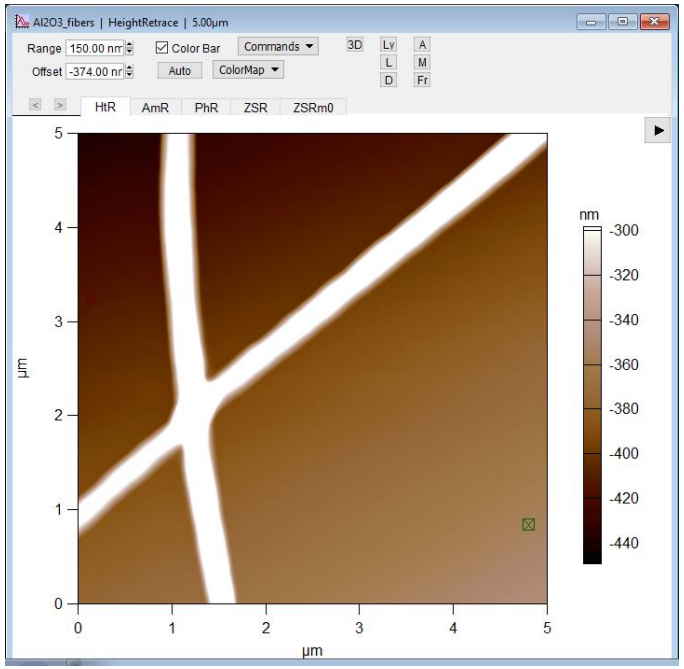
Image 2: Al2O3 Fibers

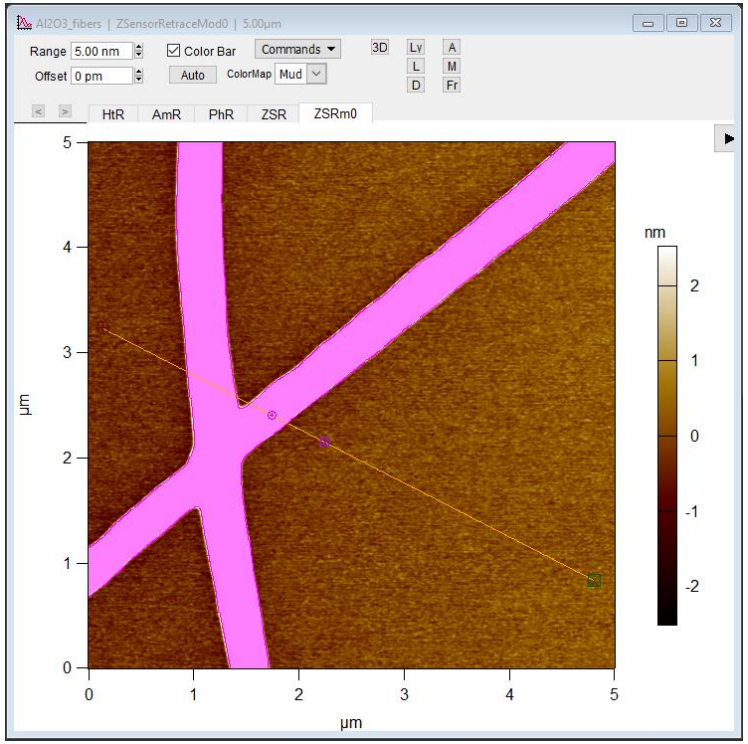
Recipe:

1) **Manual Mask** (12.71nm)
2) Dilate (1x)
3) 1st order ⊙Mask Planefit
4) 0 or 1st order ⊙ Mask flatten



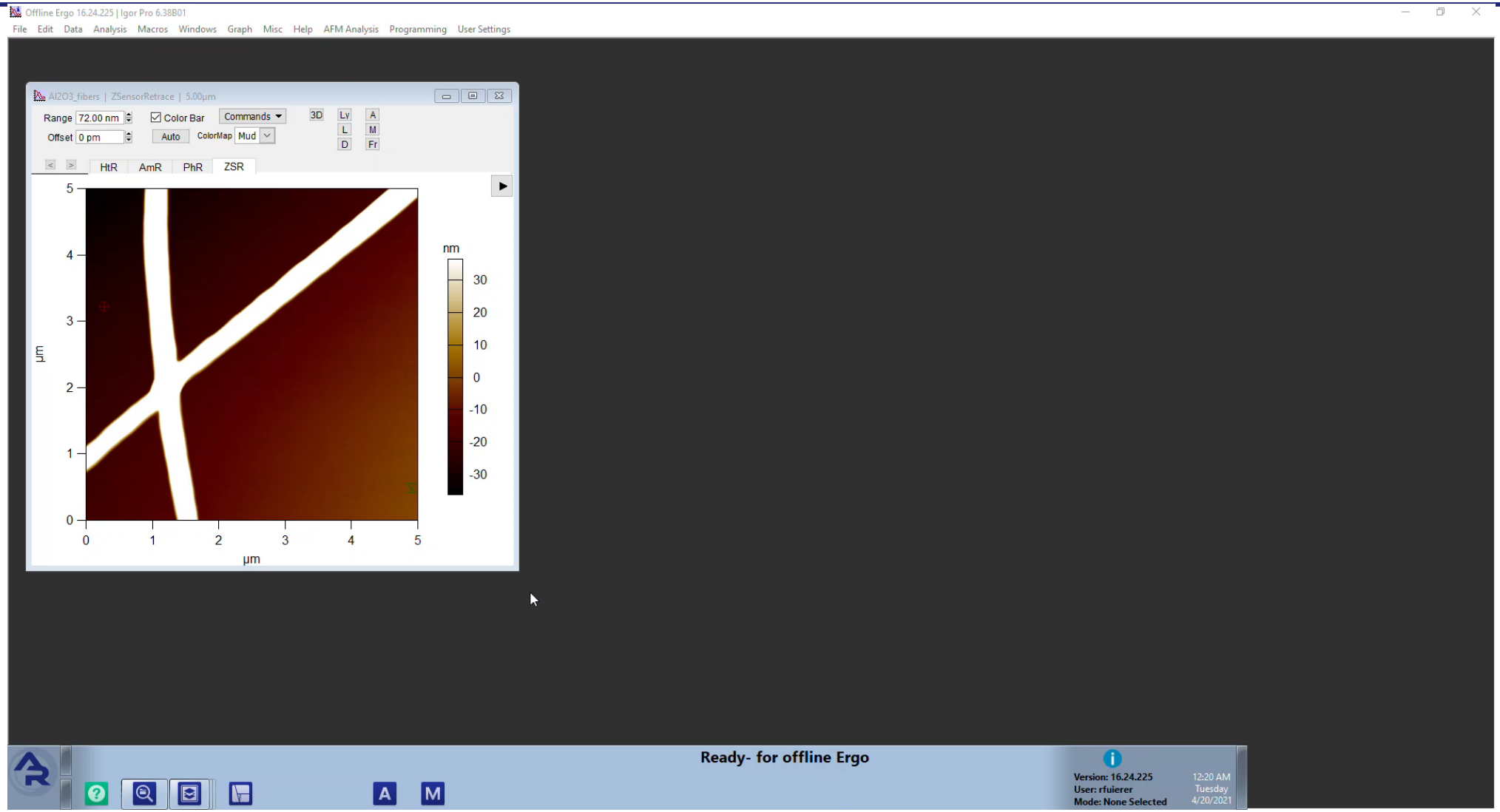






Stats	Full Image	Masked Image
Sdev [Rq]	39.366 nm	374.052 pm
Adev [Ra]	26.450 nm	273.351 pm
Max	201.104 nm	3.714 nm
Min	-1.537 nm	-1.537 nm
Avg	15.846 nm	318.889 zm
Skew	2.39	1.56
Kurt	4.34	10.7
Percent	100.0%	82.9%
Area	26.1 µm²	20.6 µm²
Area %	4.224%	0.07547%
Volume	0.4 µm³	0.0066 nm³

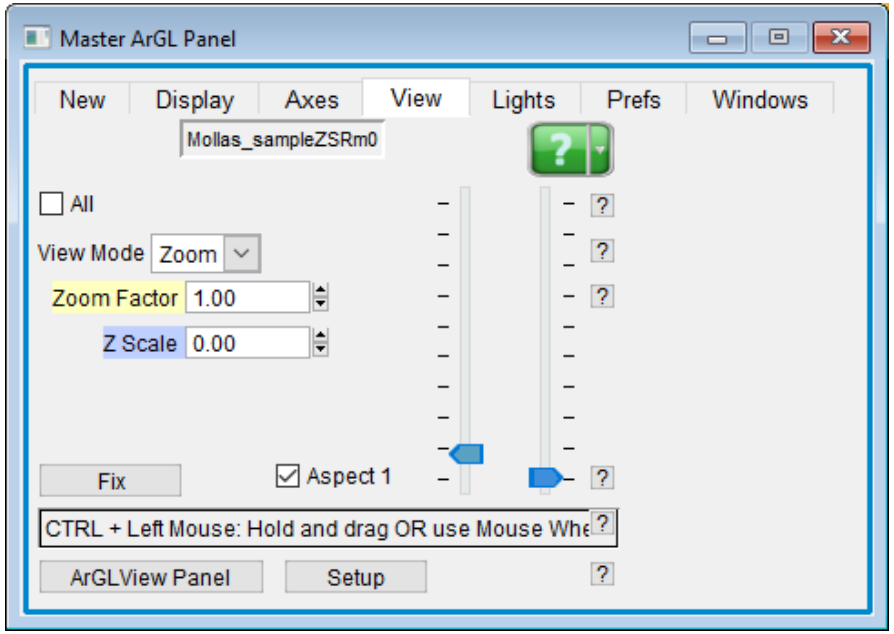
Image 2: Al2O3 Fibers



Play Movie

ARgyle 3D Rendering

Use specular lighting to monitor processing changes



HotKeys:

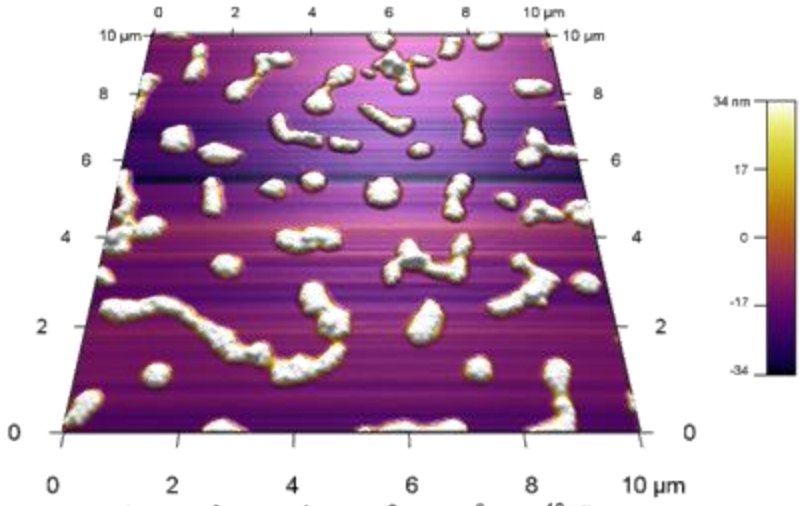
Left Mouse + Cursor- rotate light

Right Mouse + Cursor: rotate sample

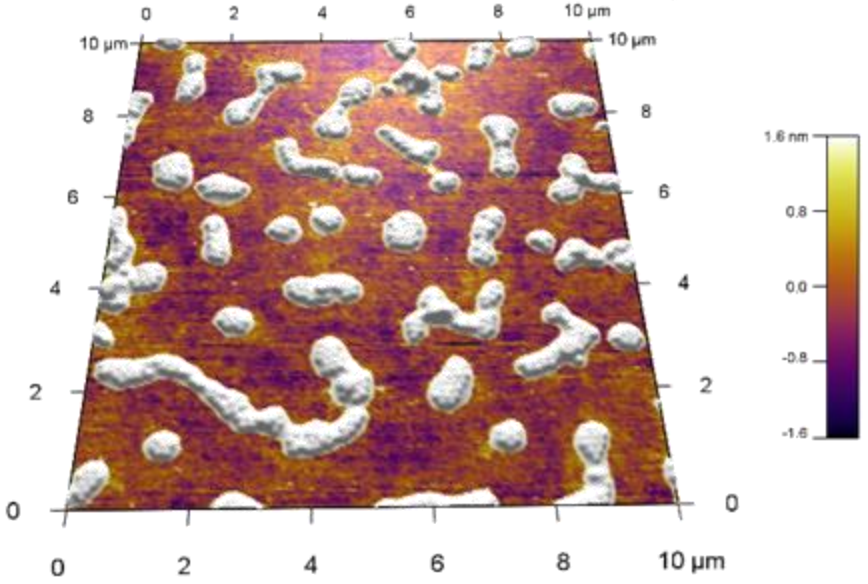
Ctrl+cursor: Zoom

Shift + cursor: Move image around

Before

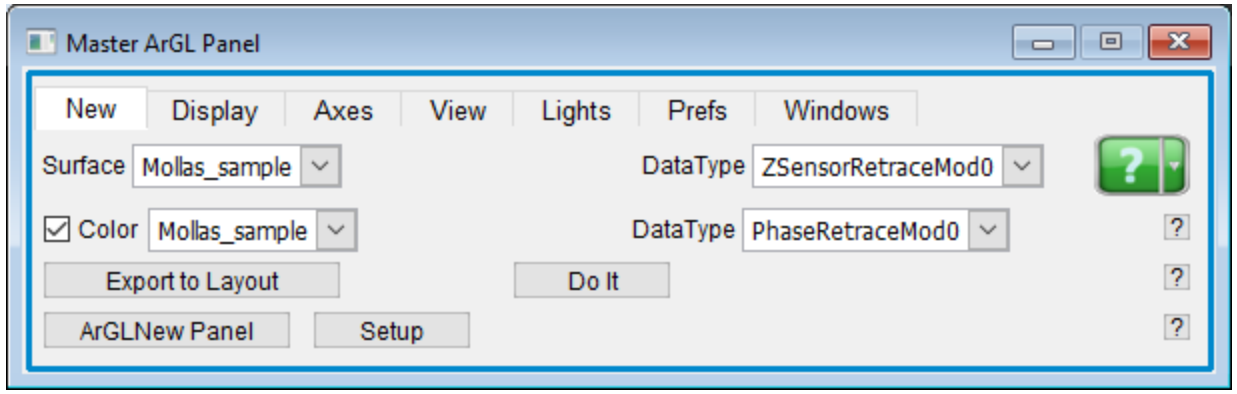


After

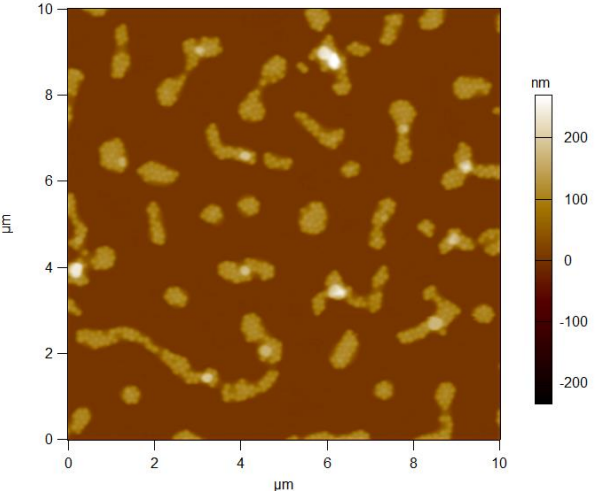


ARgyle 4D Rendering

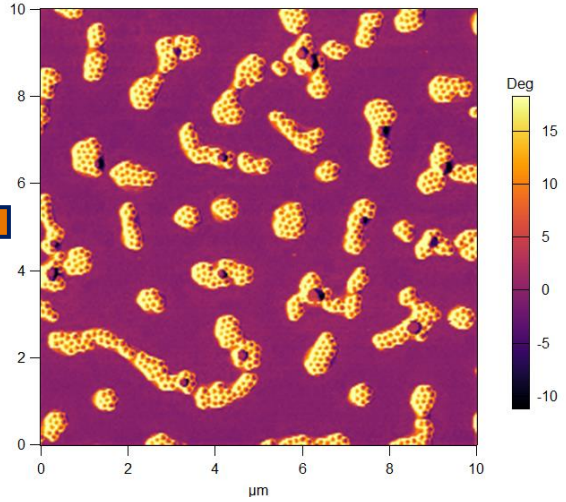
Menu: AFM Analysis → 3D Surface Plots

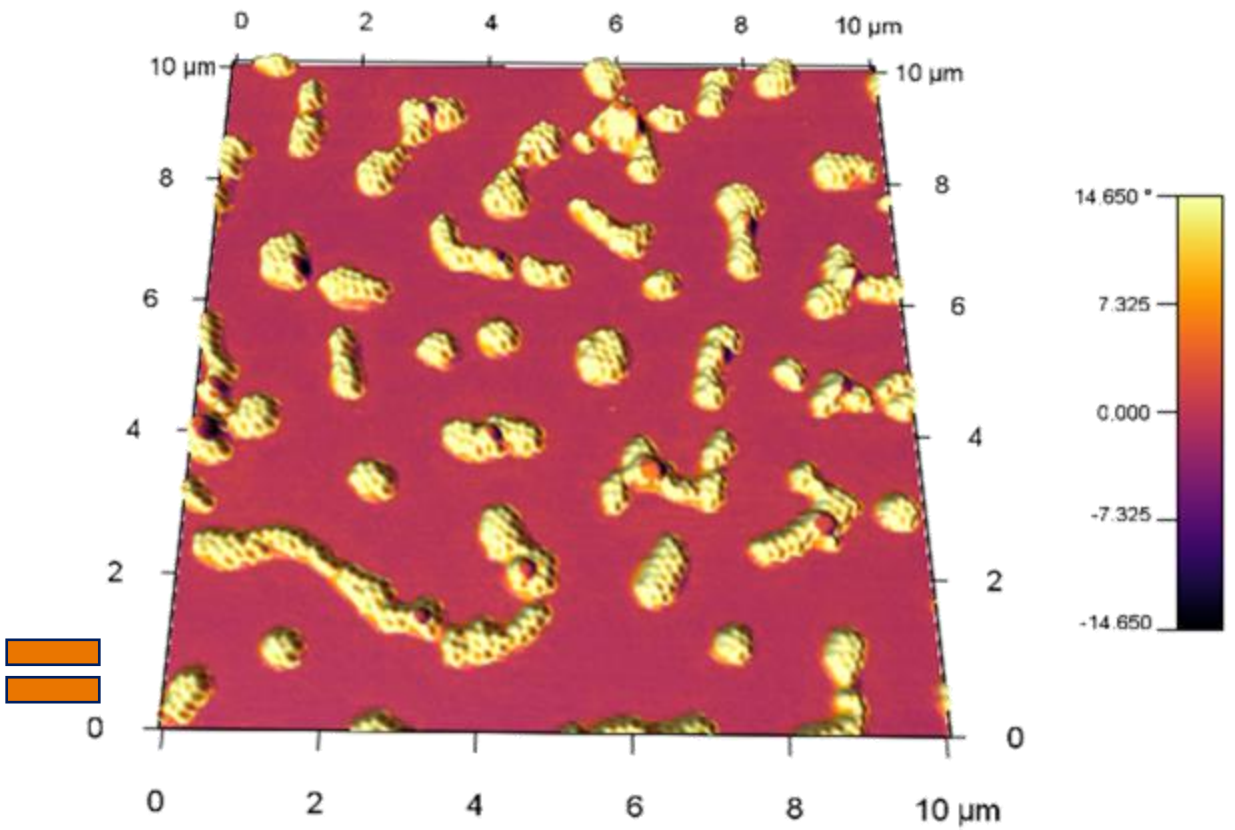


Topography



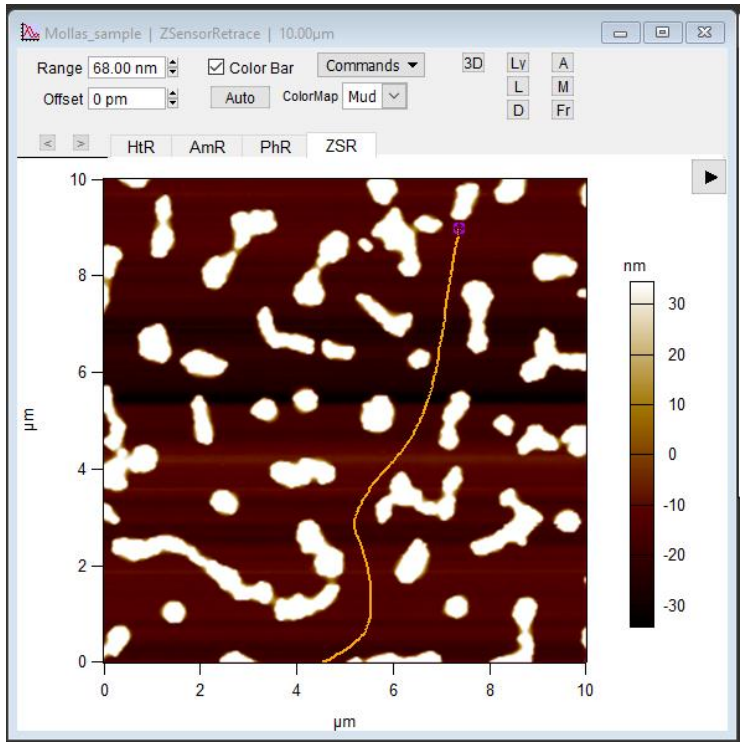
AC Phase





https://www.youtube.com/watch?v=s3B_vOEij70

Image 3: Molla's Sample



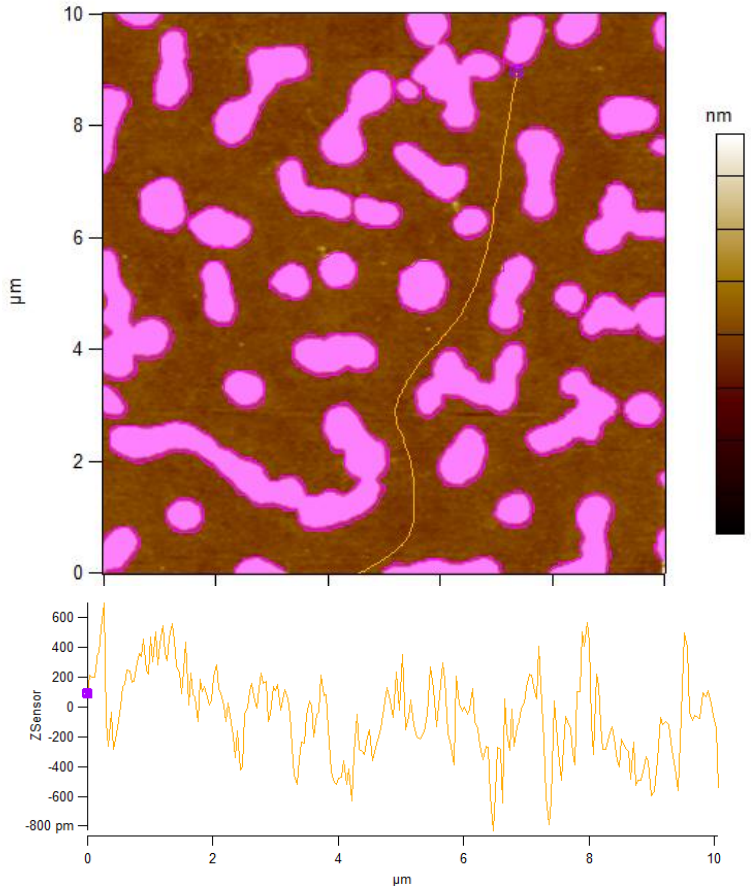
Free Hand Section

Recipe:

1)Magic Mask (2.66nm)

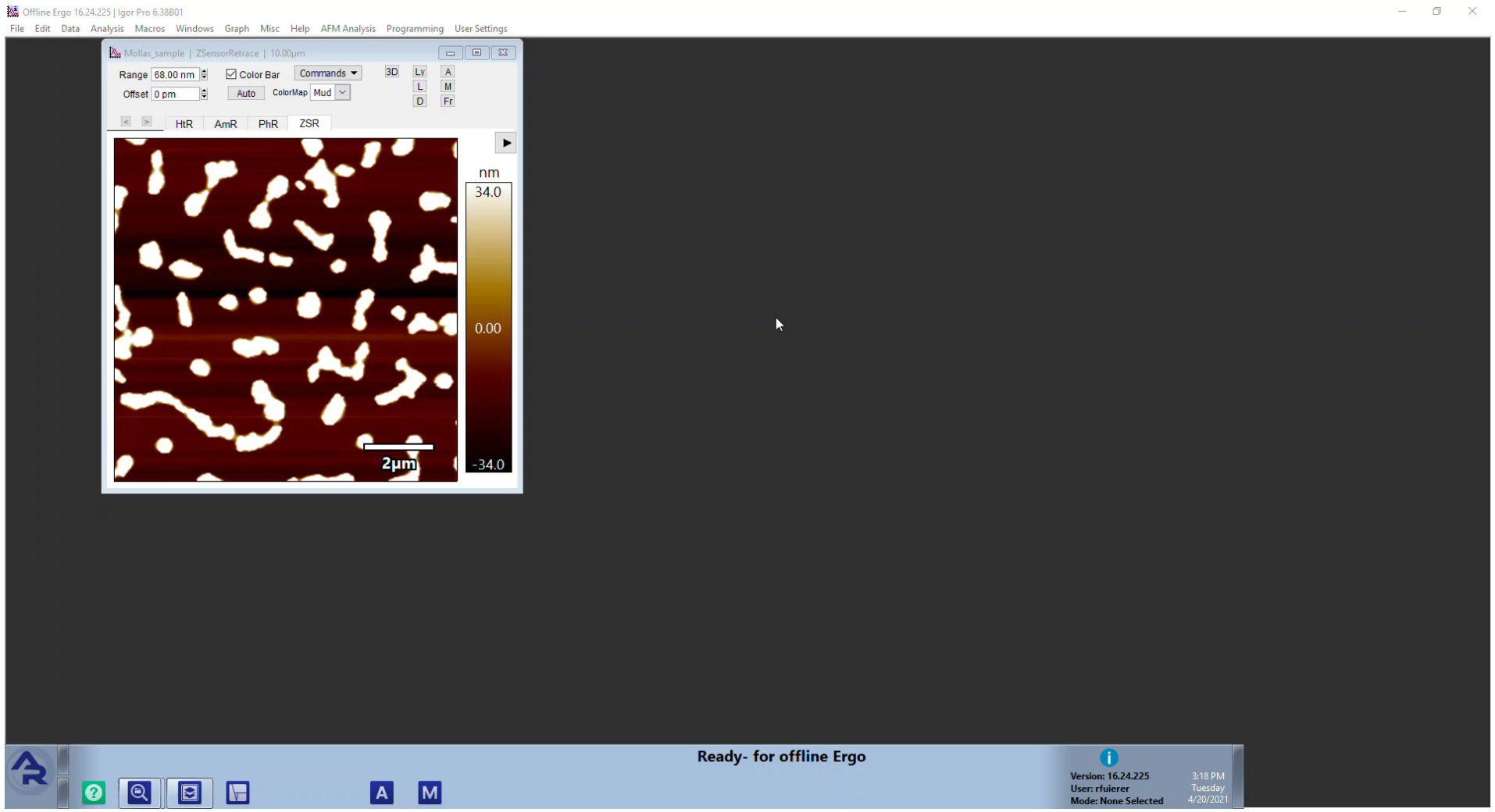
2) Dilate Mask

3) 1st Order Flat



Stats	Full Image	Masked Image
Sdev [Rq]	37.236 nm	346.147 pm
Adev [Ra]	26.513 nm	255.217 pm
Max	280.413 nm	11.896 nm
Min	-1.826 nm	-1.826 nm
Avg	17.201 nm	71.053 zm
Skew	2.28	2.67
Kurt	5.01	59.2
Percent	100.0%	69.1%
Area	104.8 µm²	67.3 µm²
Area %	4.758%	0.005431%
Volume	1.7 µm³	0.005 nm³

Image 3: Molla Sample



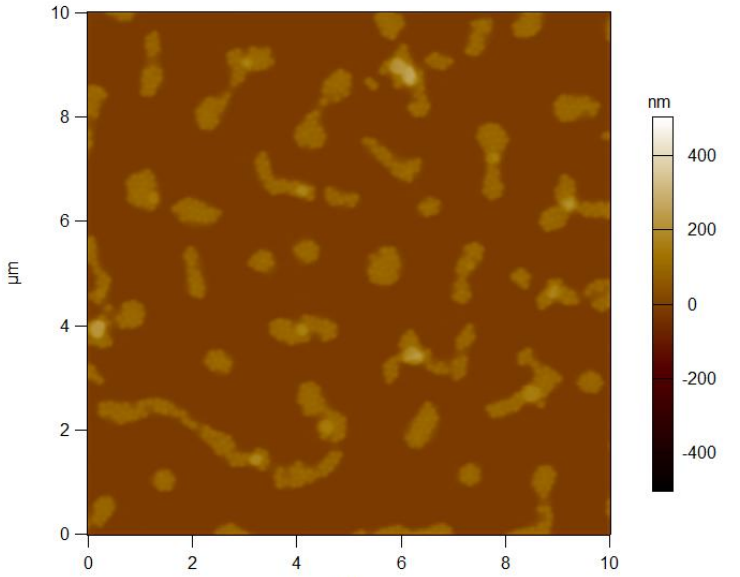
Play Movie

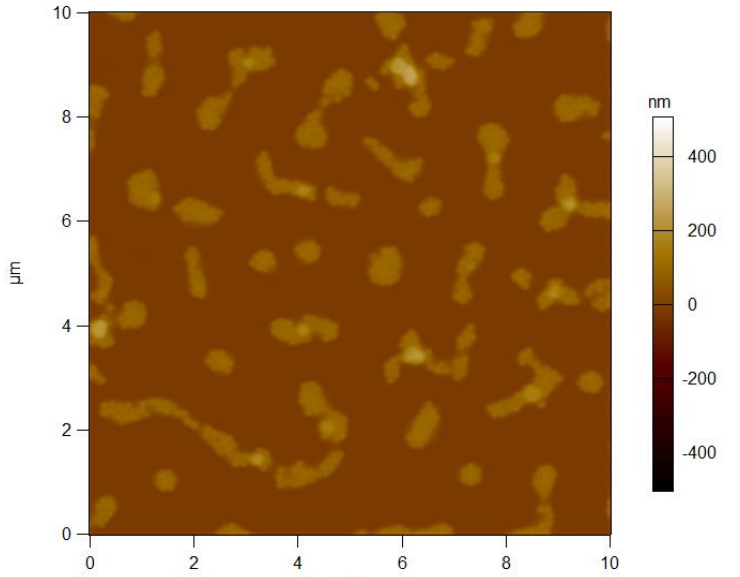
Flattening Conveniences

Magic Mask Flatten Only

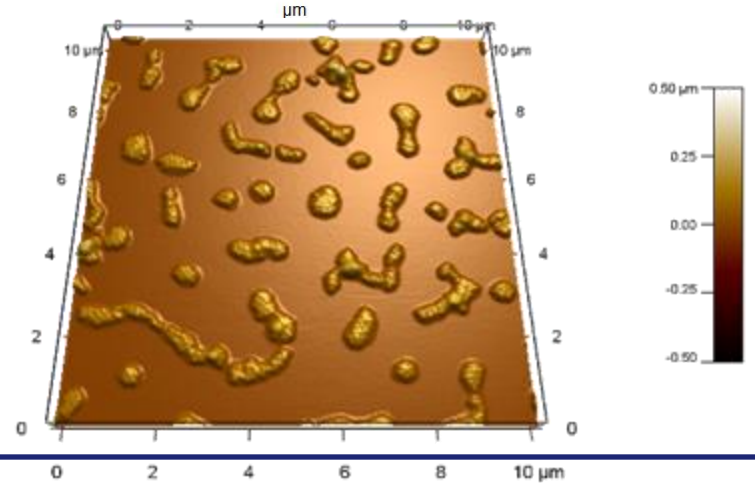
Histogram Flatten Only

2D Z Sensor
Retrace image





Argyle 3D
Rendering



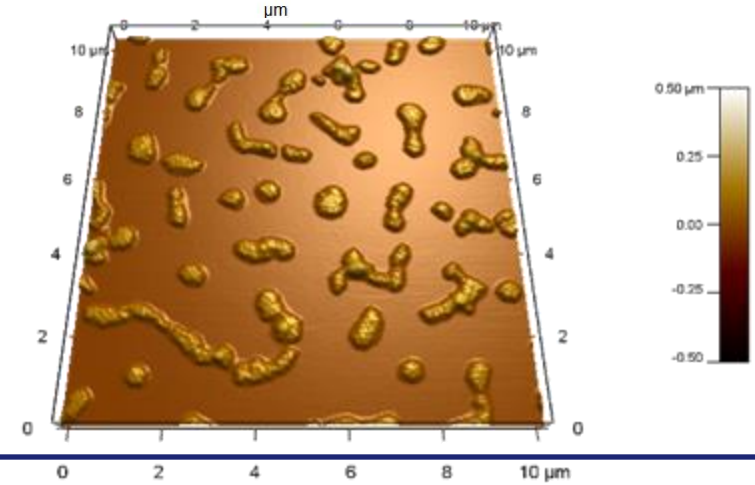
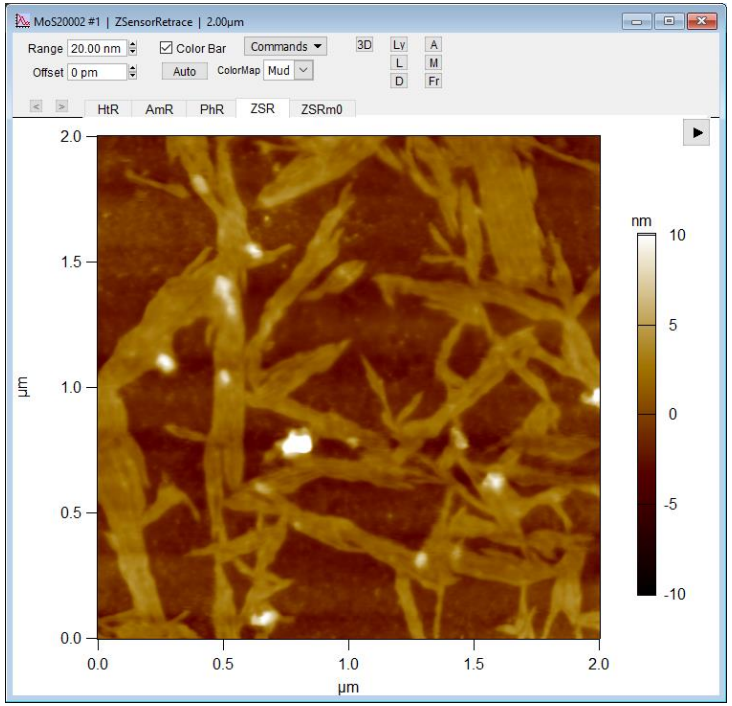
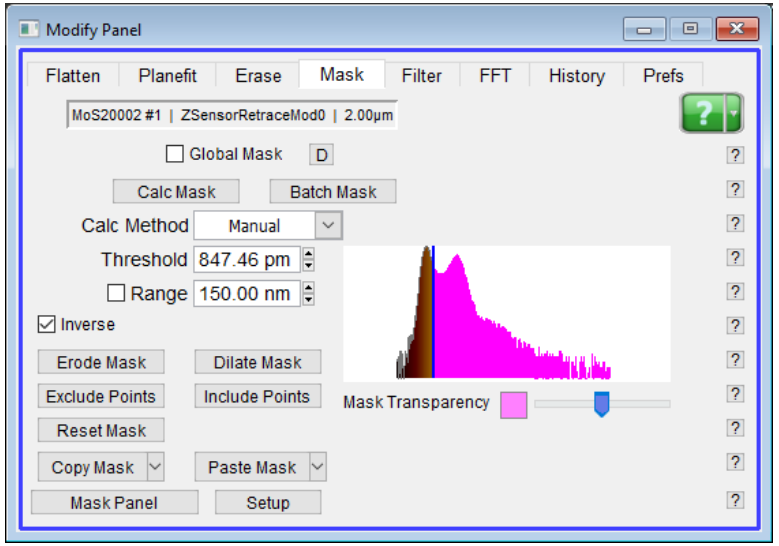


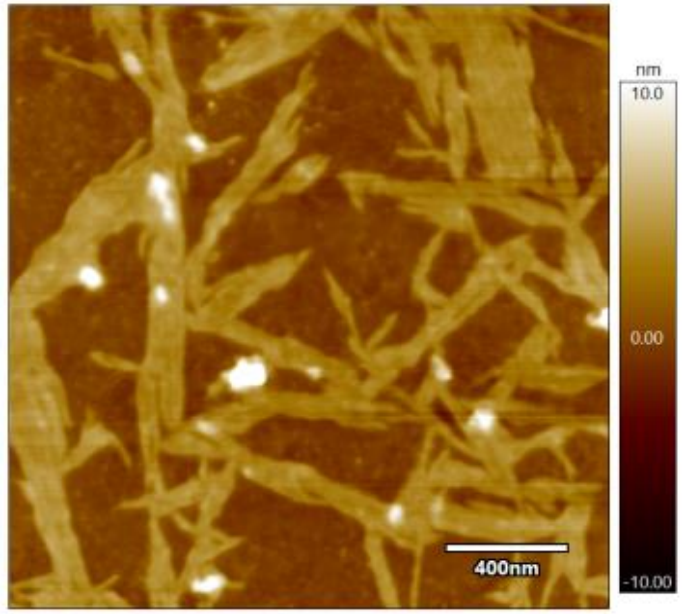
Image 4: MoS2

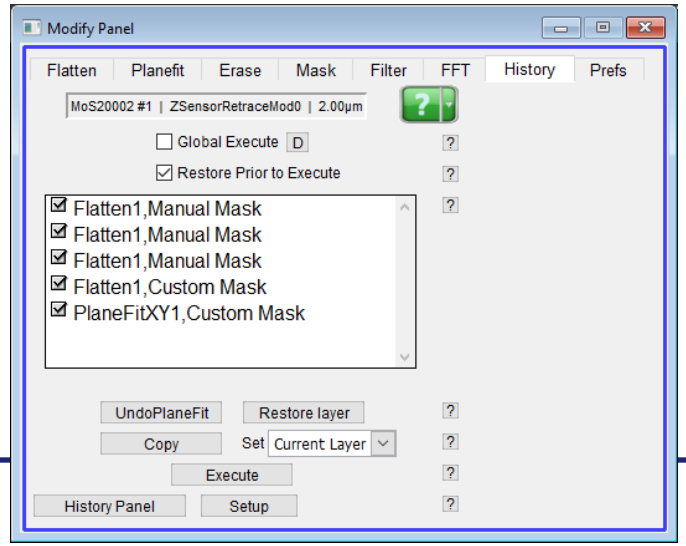
Iterative Manual Masking/ 1st Order Flat cycle (3)



Raw Z Topo







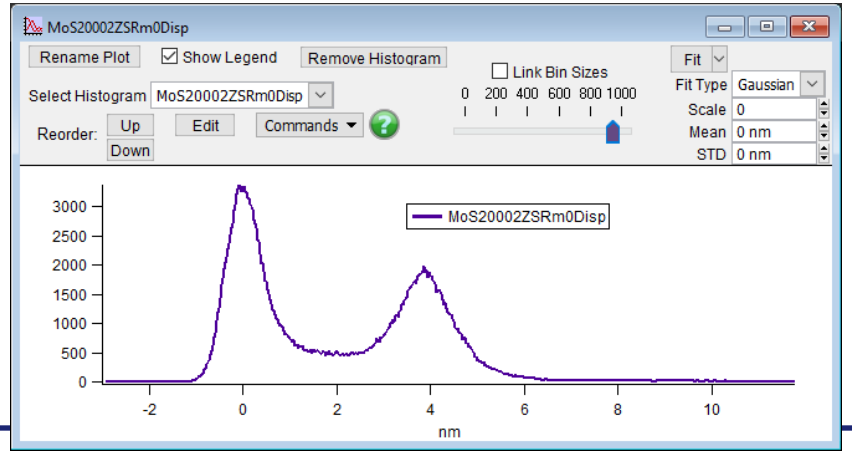
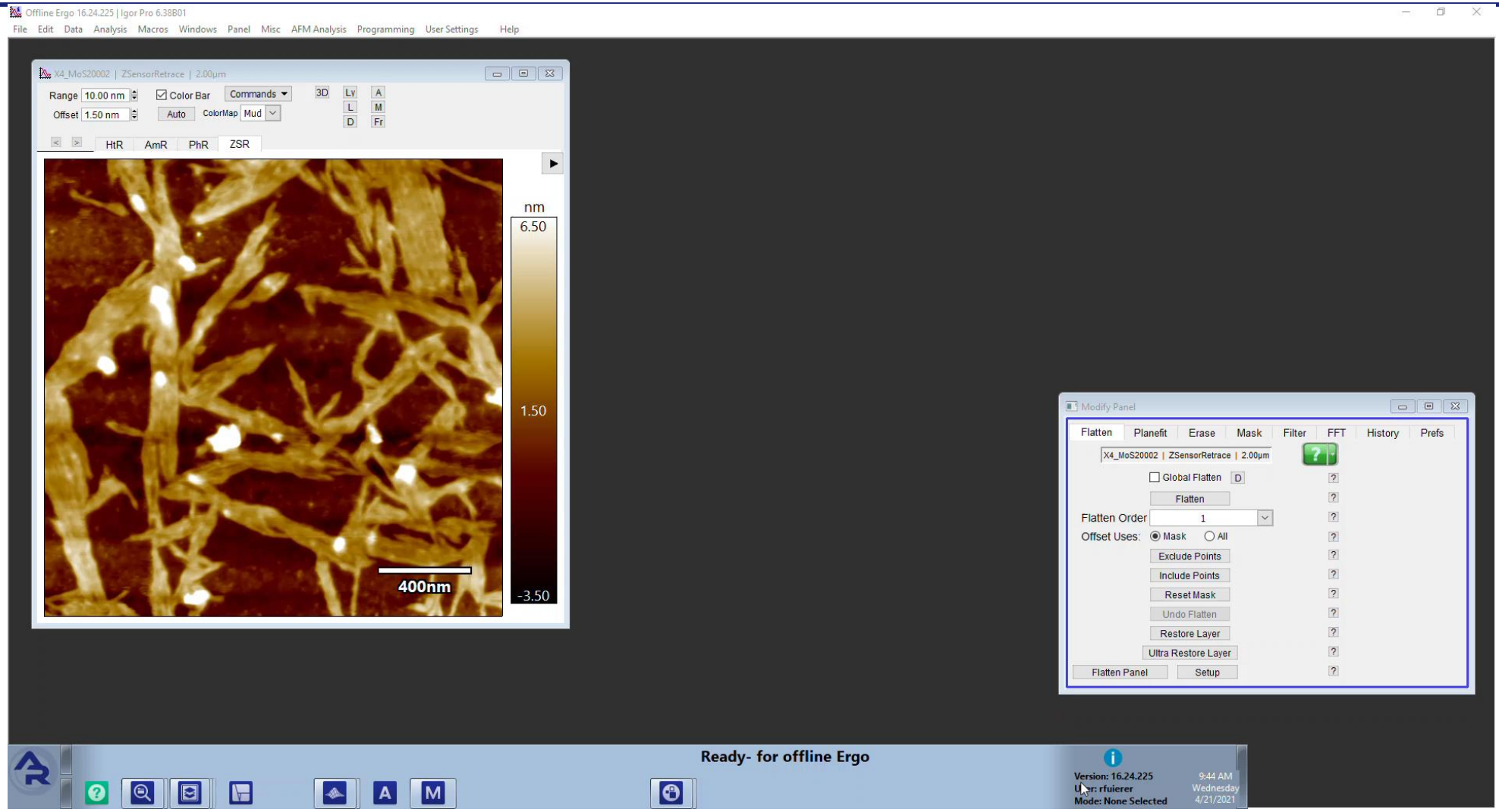
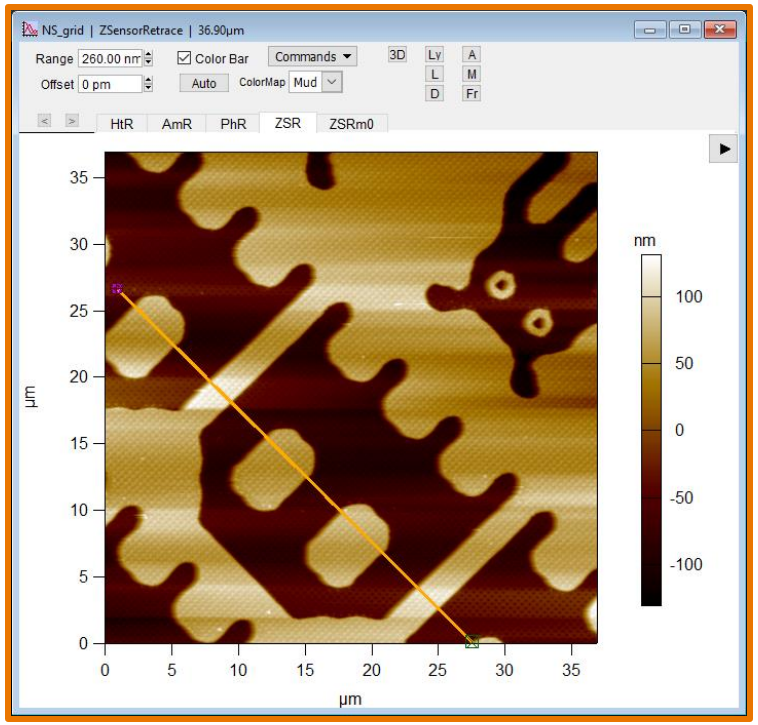


Image 4: MoS2

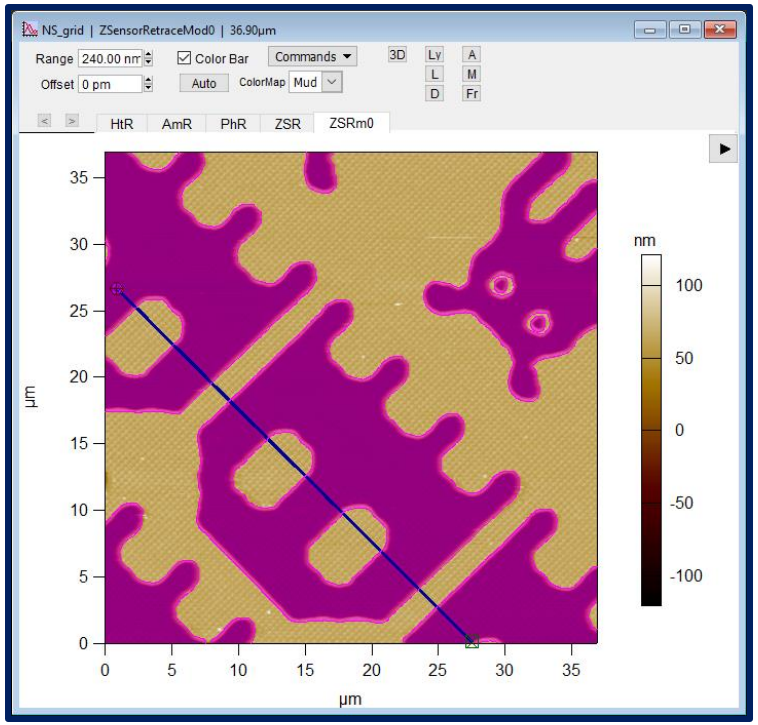


Play Movie

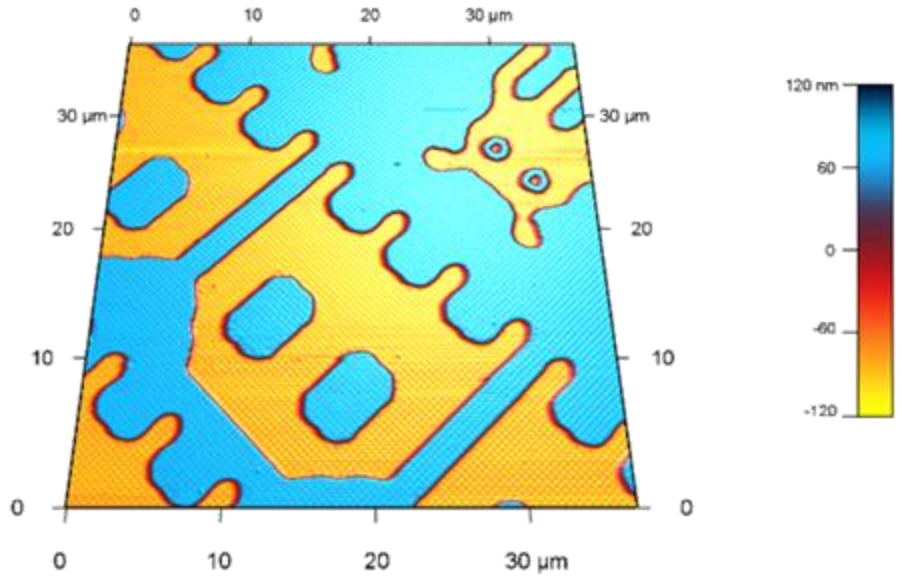
Image 5: Calibration Grating



Before



After



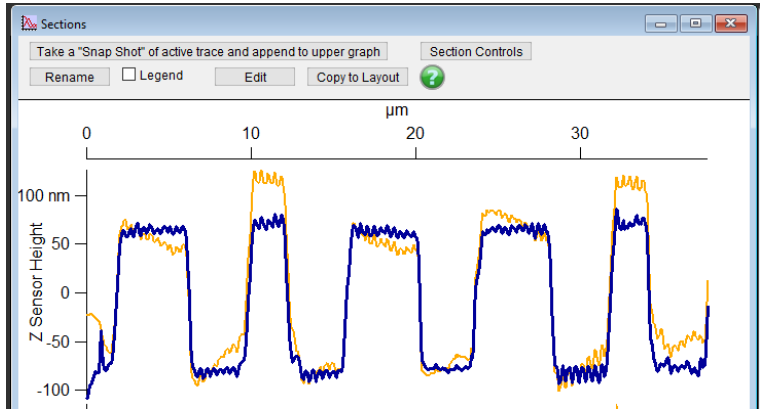
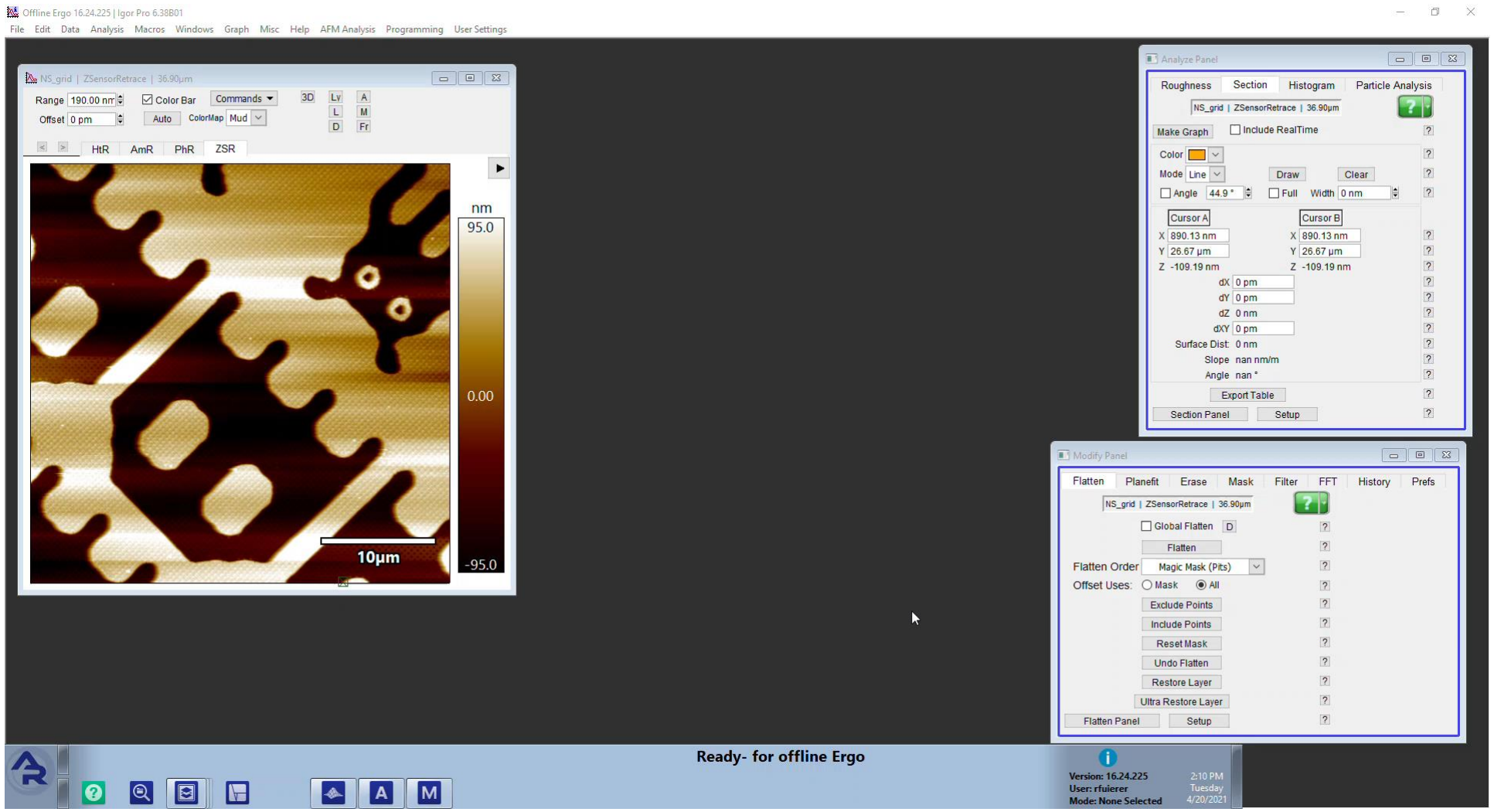
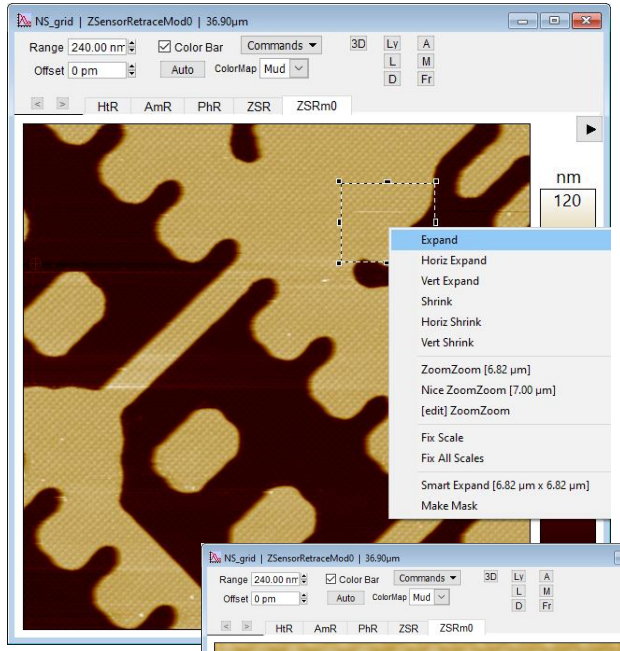


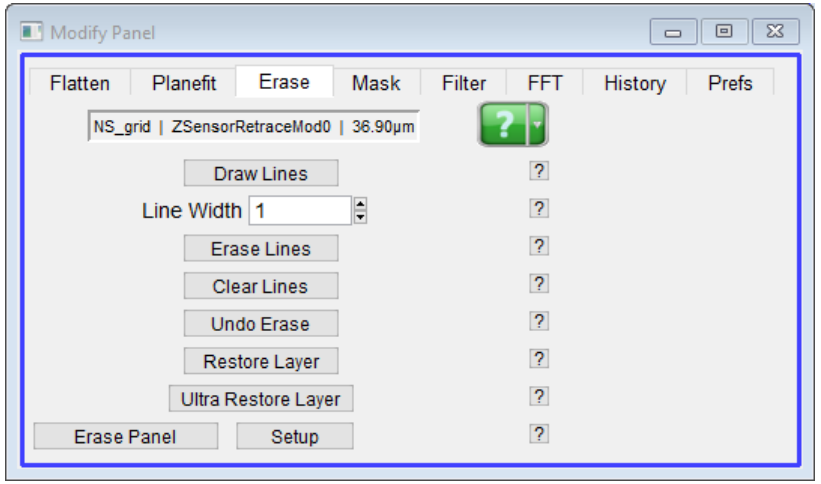
Image 5: Calibration Grating

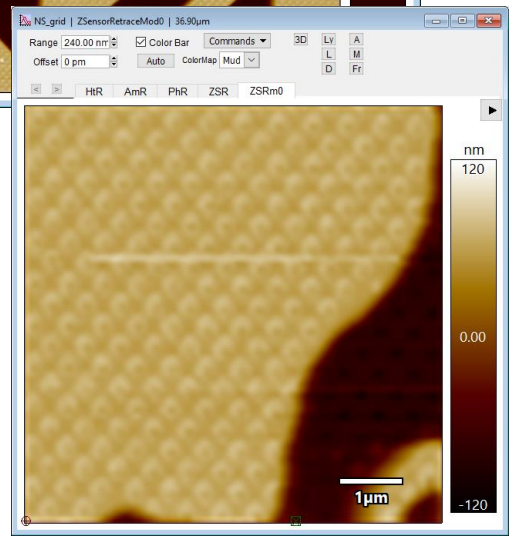


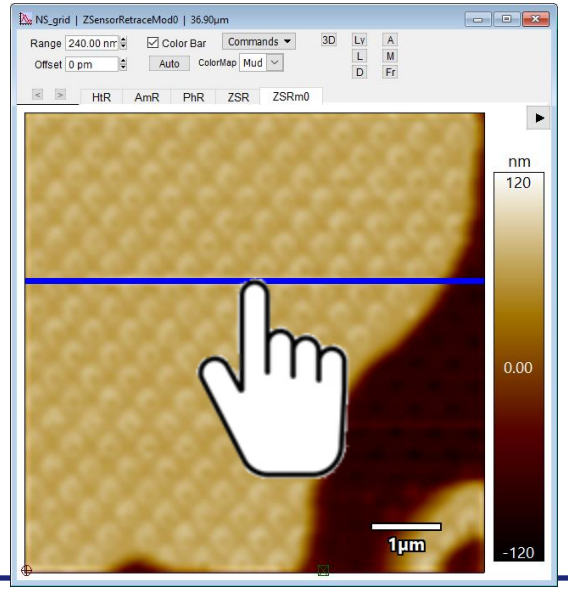
Play Movie

Image 5: Erasing lines









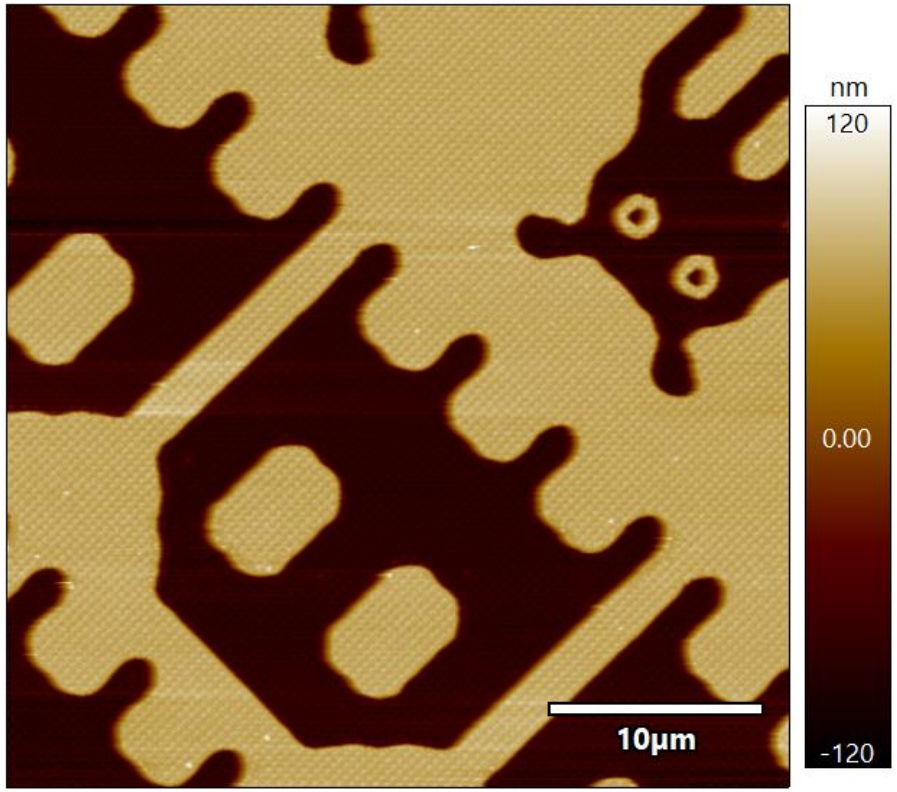
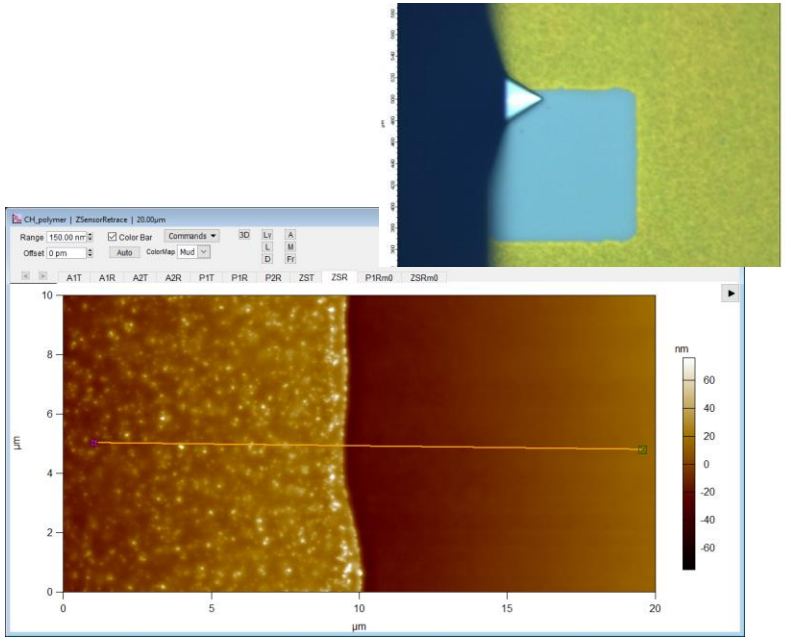
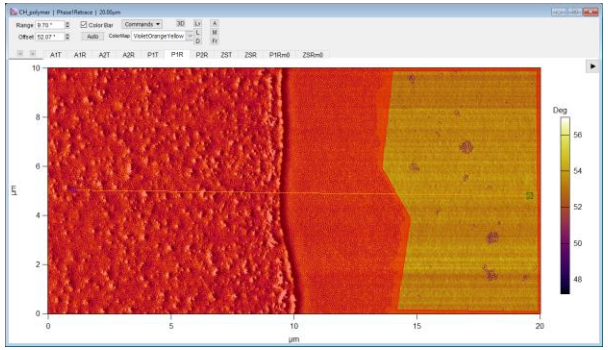
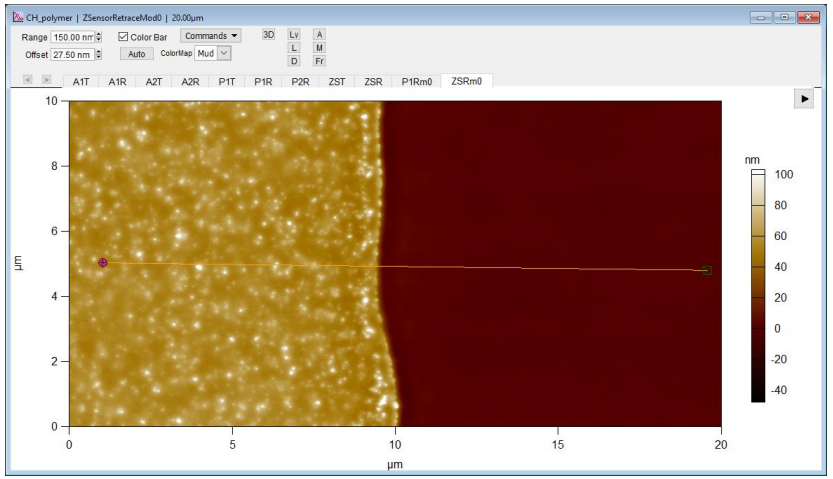


Image 6: PMMA on Au Step Height

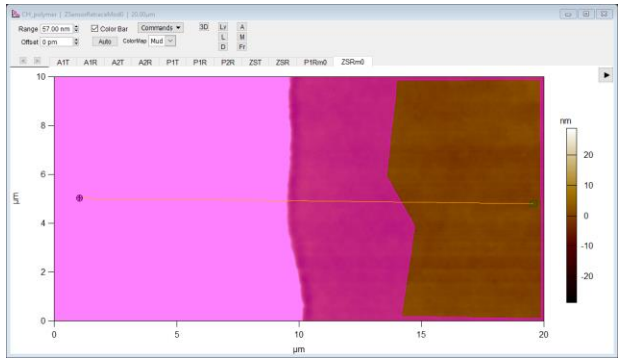


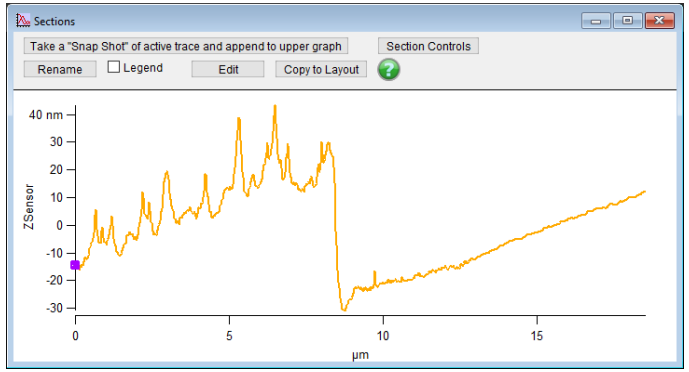
Build Include Points Mask on Phase; Copy Mask





Paste Mask on ZSR, 1st order Planefit XY.





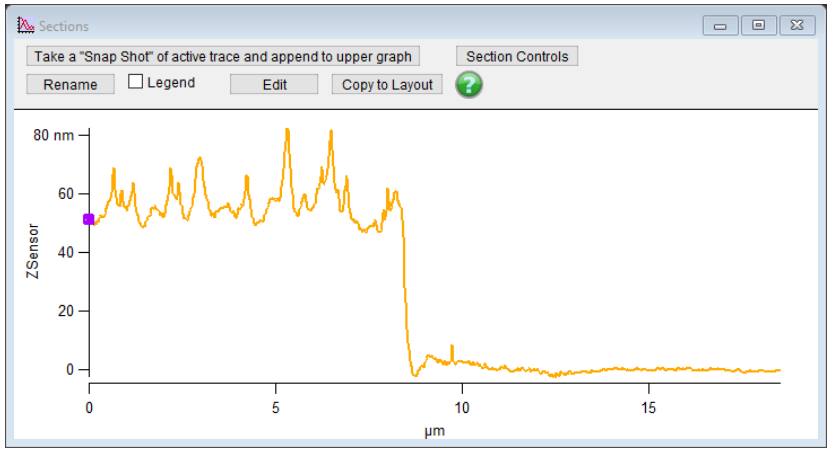
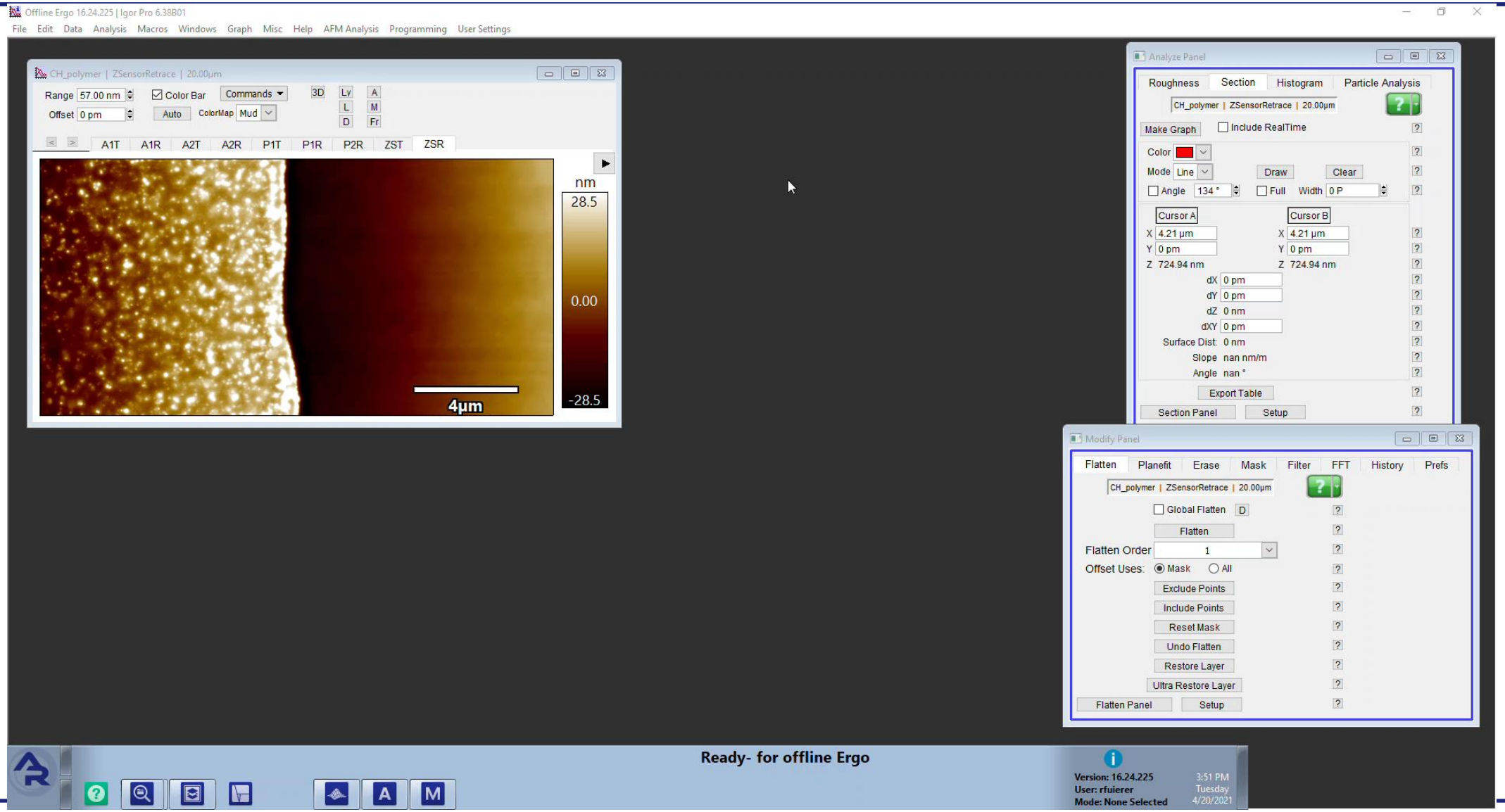


Image 6: PMMA on Au Step Height



Play Movie

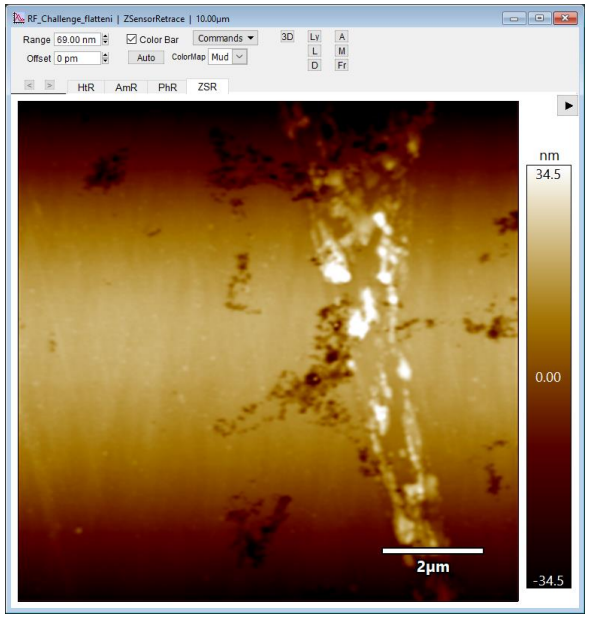
Image 7: RF's Challenge Sample

No idea what the Challenge samples material.

-'Magic Mask Flatten' ***fails***

-Above & below substrate features give standard processing some artefacts.

-Make (subjective) mask with slider bar to include the higher features, then iteratively exclude areas created with freehand tool under 'exclude points' operation.



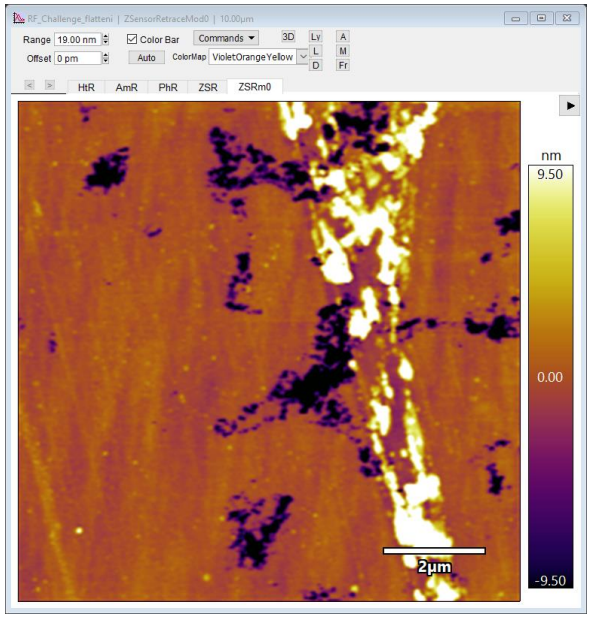
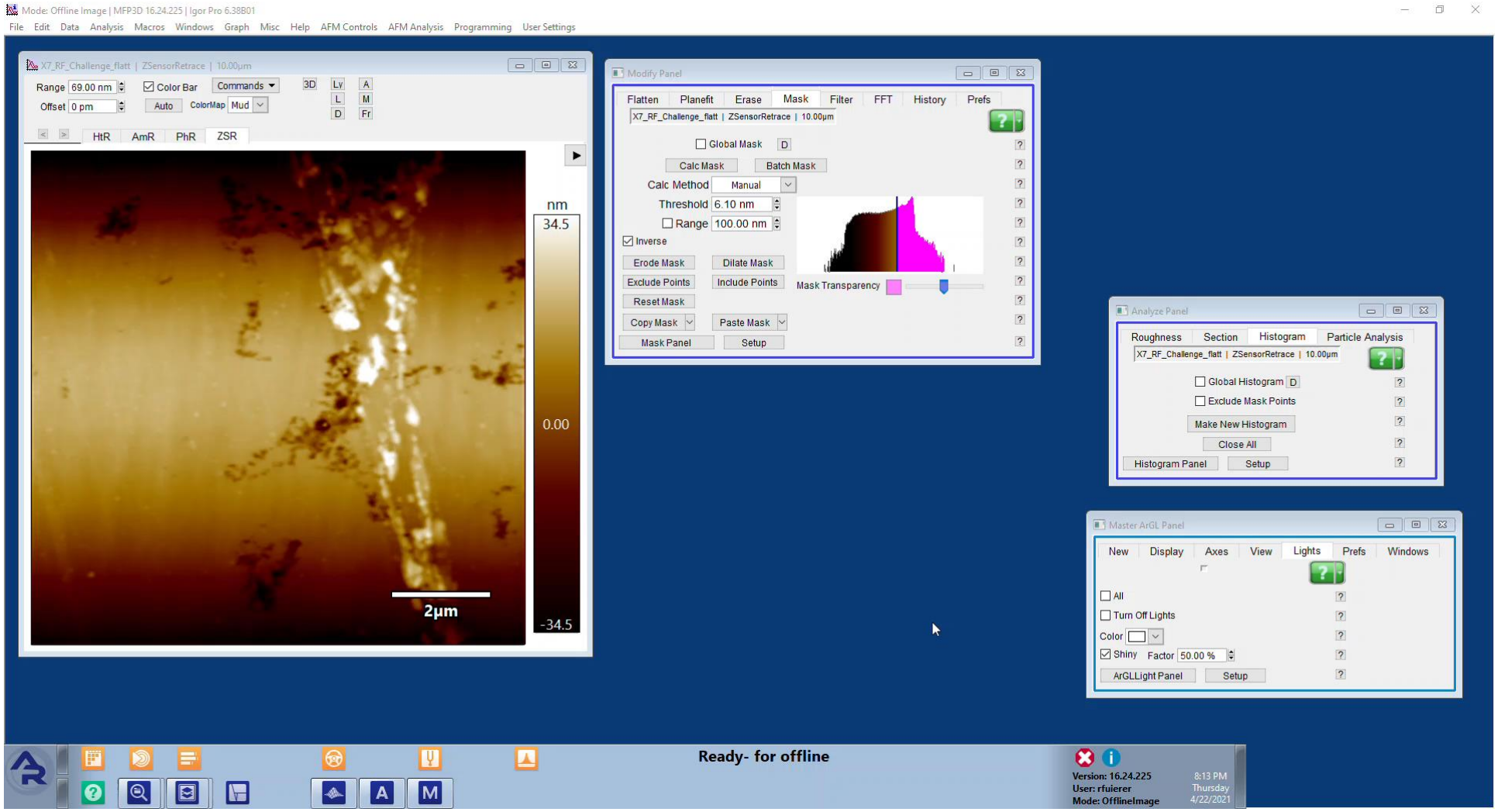


Image 7: RF's Challenge Sample



Play Movie

Take-home messages

- AFM is for measurements
- Think about what measurement you want to make
  - Have you defined completely what the measurement is?
  - Have you considered the factors that affect it?
- **Use ZSensor, not Height, for Z in most cases**
- Be aware of how processing affects your measurement
- Do the least damage possible to your data
- Planefit modifies the whole image at once
  - Good for slope, form, bow
- Flatten modifies each line separately
  - More destructive than planefit
  - Sometimes necessary to correct stuff that happened in the time-domain

•When comparing two images, use the same processing.