

# University of Minnesota Nano Fabrication Center

## Standard Operating Procedure

Equipment Name:

<b>Badger Name:</b>	P4 Scope Confocal	<b>Revision Number:</b>	1.6
<b>Model:</b>	HS200A	<b>Revisionist:</b>	M. Fisher
<b>Location:</b>	PAN Bay 4	<b>Date:</b>	4/20/2020

### 1 Description

The Hyphenated Systems HS200A optical profiler combines Hyphenated systems Advanced Confocal Microscopy technology with the automation required for high throughput industrial environments. The 200mm platform is extremely versatile and suitable for numerous applications. The nano scale 200A designed for fast and non-invasive inspection and measurement of the 3-dimensional geometry of probe marks, probe cards, MEMS, micro lenses and similar micro and nano engineered or precision-machined structures. Offering Advanced Confocal Microscopy, bright field and dark field imaging on a single platform, the 200A is an exceptionally versatile and powerful analytical platform. In addition to routine measurements, these systems are especially well suited to measurements of high curvature, steep slope, rough surfaces and for measurements beneath glass windows or engineered semi-transparent films.

### 2 Safety

- a HS-200 outfitted with an extremely intense white light source, which may cause permanent injury to the eyes if operated incorrectly.
- b Never direct the output of the fiber optic light guides into the eyes or onto the skin.
- c Do not turn on the high pressure mercury arc source on before all fiber optic components have been properly connected.

### 3 Restrictions/Requirements

- a No sample greater in height than 25mm.
- b

### 4 Required Facilities

- a 120 V/20A
- b

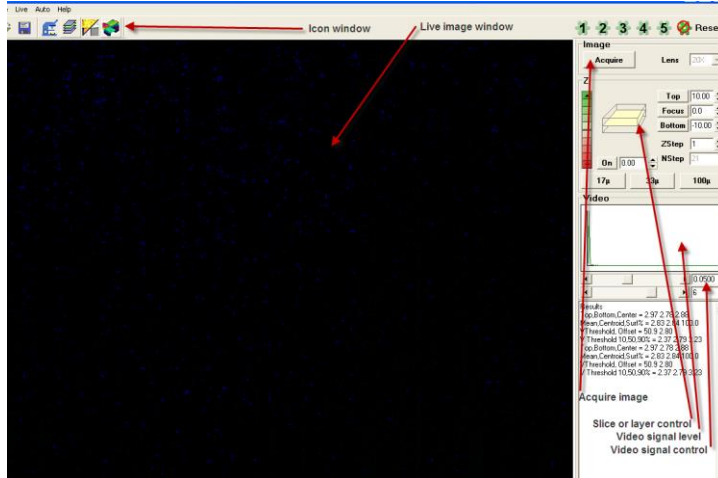
### 5 Operating Instructions


- a Enable Badger. PAN>PAN Bay 4> P4 Scope Confocal HS200A
- b Log in to P4 Scope Confocal. User name **NFC\_users** , Password **user\_1234**
- c Turn on the HS-scope power. The switch is located on the back-right side of the microscope base next to the power cord.
- d **Turn on X-Cite light source.** Wait two or three minutes for the light source to warm up and stabilize, the LED will stop blinking when the light source is stable.
- e **Open the shutter** for the X-Cite light source and push the start/stop button.
- f Press the mode button to display intensity. Intensity will display either 0, 12, 25, 50, and 100). There 3 modes for the light source and they are hours, timed exposure, and intensity.
- g **Press the confocal button** on the top right side of the scope, the yellow confocal LED should light.
- h Double click on **Nas\_V3\_2.exe** icon.
- i Click on **Yes** for stage to initialize or if you say **Cancel** you will be able to move the stage manually with the x and y knobs on the stage.

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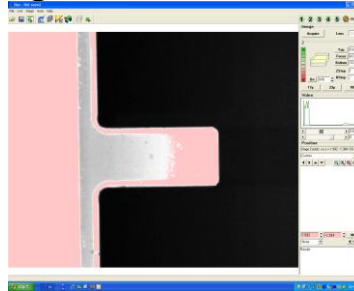
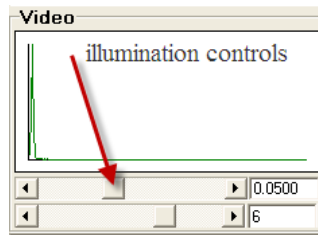
- j This is the correct position of the following components-Analyzer (out), Polarizer(out), DF lever (out), DIC (out), White light lamp (off), white light aperture (closed), Optical path lever (out).
- k Screen is divided into four areas-Live image of the surface, icons across the top, top right hand panel (scan and illumination controls), lower right hand panel.



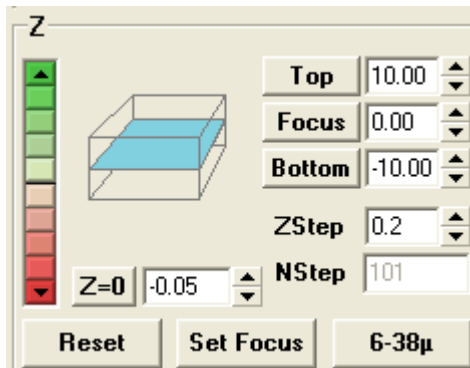
- l Manual data acquisition involves five basic steps.
- Define an area of interest.
  - Adjust light source intensity and CCD integration time.
  - Define a z-scan range and resolution.
  - Click the Acquire button.
  - Data analysis
- m Position sample on stage under the objectives, using the joy stick or the knobs in manual mode.
- n Define an area of interest using the binocular microscope eye pieces.
- o Select the desired magnification.
- 2.5x- numerical aperture 0.075, WD-8.8mm
  - 5x- numerical aperture 0.15, WD-18mm
  - 10x- numerical aperture 0.30, WD-15mm
  - 20x- numerical aperture 0.40, WD-13mm
  - 50x- numerical aperture 0.55, WD-9.8mm
  - 100x- numerical aperture 0.90, WD-1mm
- p Pull the **optical path selection lever** out to directing light into the CCD camera.
- q Click on the microscope icon to obtain a live view. 
- r Using the scan and illumination controls in the image section of the right hand panel to adjust the illumination should be set to maximize the signal while avoiding saturation of the CCD camera. Saturation is present when there are pink pixels in the live image and graph is off scale to right side of the video image. The two slide bars below control the illumination intensity, the upper bar is fine control the lower is coarse control. The signal intensity adjusted using these two slide controls: CCD integration time (directly below the histogram in the video section in the right hand panel, which should be at least 0.05 seconds and preferably between 0.1-0.2 seconds). The lower slide control can manually be set on the front of the EXFO light source with up down buttons.

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- s A good strategy is to focus on the “brightest” layer in the field of view, adjust the illumination intensity, keeping an eye on the image and the intensity histogram as the z-scan range is set.
- t Set the z-scan range with either by using the z bar or by using the microscope fine focus knob. Using the Z control bar in the scan and illumination control panel adjust the top of the scan range by click on the green arrow button until the image goes out of focus (dark). Then click the top button. This will set the upper limit for the scan range. Then click on the red arrow button until the image goes out of focus (dark). Then click the bottom button. This will set the lower limit for the scan range. Once these settings have been performed, the top, middle, and bottom position should be checked for saturation.



- u Click the Acquire button. If image is dark, there are four components to check. 1. Optical path selection lever out. 2. Push confocal light button on the microscope (yellow LED will light up). 3. Pull the Dark field selection lever out. 4. Open the shutter on the EXFO light source.
- v Data analysis can be performed on active data or stored data. To open stored data, click on File>open>browse to the file you would like to open. (Note: If the files are contained on rewritable CDs or DVDs, you must first store the data to a local hard disk for the files to be opened.) The main part of the screen will display false color rendering of the surface with a color wedge which serves as a key, translating color to height. (See 2D analysis for more details)
- w Saving Data: Click on the save icon this will bring up a windows dialogue box. Save data only under user's data section.
- x Transfer data using the usb port on the front right side of the table.
- y After you have completed your measurements, please reduce the EXFO light source to 0 and close the shutter. If you are the last person of the day (after 5pm) please turn off the

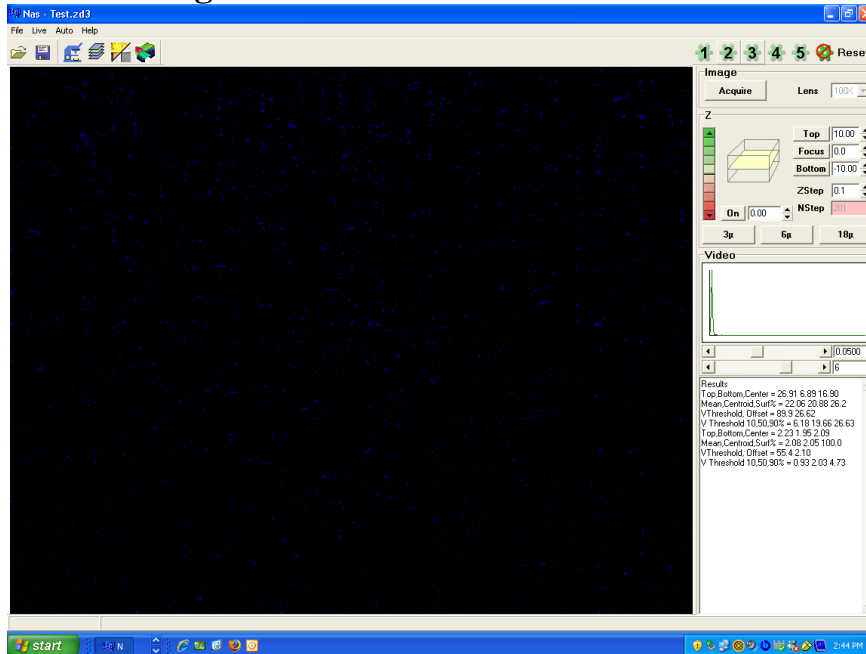
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EXFO light source. A good rule of thumb, if some is going to use the HS-scope within four hours do not shut off the light source, if not, please shut off the light source.



- z Turn off the HS-scope power. The switch is located on the back-right side of the microscope base next to the power cord.
- aa Log out of the HS-scope computer.
- bb Log out of Badger.

## 6 Live image screen



### A Pull down menus

- **File**

1. Open-  To open existing \*.zd3 file.
2. Save as-  To save your \*.zd3 file. Please save your \*.zd3 file to your directory.
3. Show debug window-Shows debug window lower right hand corner.
4. Open surface\*.BMP : Opens surface \*.BMP.
5. Open intensity \*.BMP: Not functional.
6. Save surface \*.BMP: Saves surface \*.BMP.
7. Save intensity \*.BMP : Saves intensity \*.BMP

- **Live**

1. Camera Live: Toggles live camera on/off.
2. Show Debug: Not functional.
3. Bin 1 (1280x1024): Standard setting. Resolution of live image (1280 x 1024).
4. Bin 2 (640x512): Resolution of live image (640 x 512), smaller data file.
5. Bin 3 (320x256): Resolution of live image (320 x 256), smallest data file.
6. Clear volume

- **Auto**

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1. Auto Level: Toggles automatic leveling on/off.
2. Auto Reference: Toggles automatic reference on/off.
3. Auto Interpolation: Toggles automatic interpolation on/off.
4. Keep Tools: Saves tool set to a file.

- **Help**

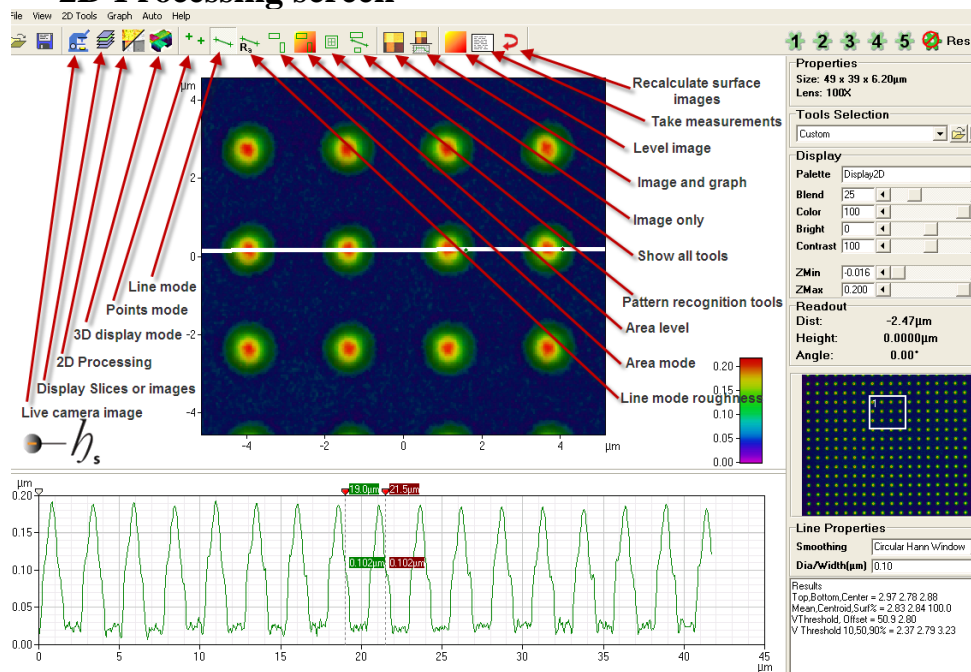
1. About: Hyphenated Systems.

## B Icon below pull down menus.

•

1. Open File 
2. Save as 
3. Live image 
4. Display slices- The displays the images taken.
5. 2D Processing 
6. 3D Display 

## 7 2D Processing screen



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### A Pull down menus

- **File**

1. Open-To open existing \*.zd3 file.
2. Save as- To save your \*.zd3 file. Please save your \*.zd3 file to your directory.
3. Show debug window-
4. Open surface\*.BMP
5. Open intensity \*.BMP
6. Save surface \*.BMP
7. Save intensity \*.BMP

- **View**

1. Properties: Toggles right hand properties panel on/off.
2. Tool Selection: Toggles right hand tool selection panel on/off.
3. Display-Toggles right hand display panel on/off.
4. Readout: Toggles right hand readout panel on/off.
5. Roughness: Toggles right hand roughness panel on/off.
6. Threshold: Toggles right hand threshold panel on/off.
7. Zoom: Toggles right hand zoom panel on/off.
8. Calculation: Toggles right calculation panel on/off.
9. Default: Toggles on default panel settings.
10. Show Invalid Data: Dark green/ black/ interpolated
11. Do interpolation- Does interpolation on data set.

- **2D Tools**

1. Points: Points mode Icon



Click on the “Points Mode” icon to evaluate the quality of the scan data. This will bring up a graph of gray scale intensity of the selected pixel on the vertical axis, against scan position along the horizontal axis. Holding down the left mouse button as the cursor is moved over the surface, the graph will be continuously updated with the contrast curve for the pixel designated – also indicated by a cross displayed on the surface. Releasing the mouse button will freeze the cross and the data for that pixel. The red lines on the following graph represent the algorithm output of surface position at that pixel in the z direction (vertical line) and the maximum gray level at that surface (when it was exactly in focus).







2. Line: Line mode.



Display height profile for current cross section. Clicking on the Line Mode icon enables cross sectional analysis of the data. Line properties: **None**: No averaging is performed. **Circular window**: An unweighted average of a circular area defined by the line width is used **Circular Hann window**: A center-weighted circular average is used. **Wide line**: An unweighted lateral average is used across the line width. **Wide line Hann window**: A center-weighted lateral average is used

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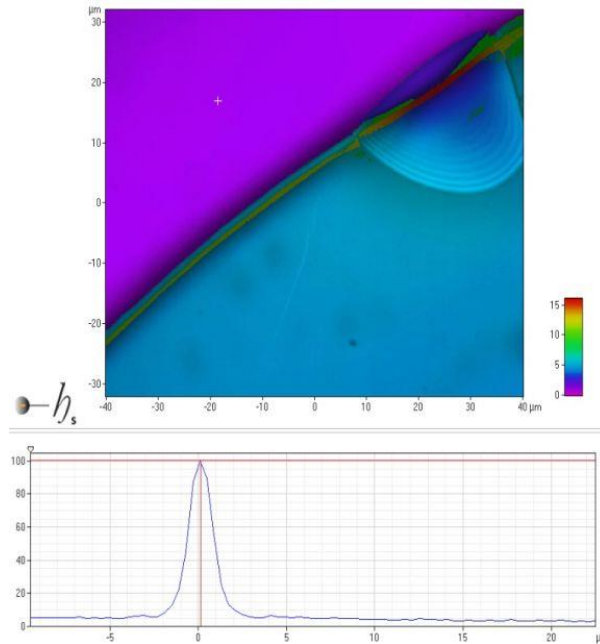
3. Line Roughness:  Display line roughness parameters for current cross section.
  4. Area:  Shows all measurement areas and allows creation of new ones.
  5. Level:  Shows all leveling areas and allows creation of new ones.
  6. Pattern recognition:  Shows all pattern recognition tools and allows creation of new ones.
  7. All Tools:  Show all area tools, pattern recognition tools and line tools on the screen at one time. In this mode, all tools can be moved as a unit, maintaining their relative positions.
  8. Roughness options: Roughness and waviness parameters may be changed.
  9. Do reference:
  10. Do level:
  11. Do interpolation:
  12. Do manual level:
  13. Measure:  Record current measurements in the results text box.
  14. Recalc Z: Recalculate surface with current algorithm settings.
  15. Clear all tools: Deletes all tools.
- **Graph**
    1. Copy as text: Copies a data set a file. First, a line must be made in line mode, then using copy as text, paste the data set into a notepad document, save document in your folder.
    2. Copy as graph: Function does not work.
    3. Display: Display has two modes, image only and image and graph.
    4. Show wedge: Displays color wedges in the lower right hand corner of the image window.
    5. Show Axes: Displays X and Y axes on the image window.
  - **Auto**
    1. Auto level: Enables automatic leveling.
    2. Auto Reference: Subtracts stored reference data from acquired data.
    3. Auto Interpolation: Enables automatic interpolation.
    4. Keep Tools: When this function is enabled it will save your tool set with the \*.zd3 file.
  - **Adjusting Surface Calculations (from Hyphenated Systems manual)**
    1. By default, the surface calculation algorithm finds the surface that shows the largest contrast response with height. For a single opaque, surface this allows the surface to be accurately rendered. In the case of transparent films, however, the surface of interest may not be the one with the largest contrast response.



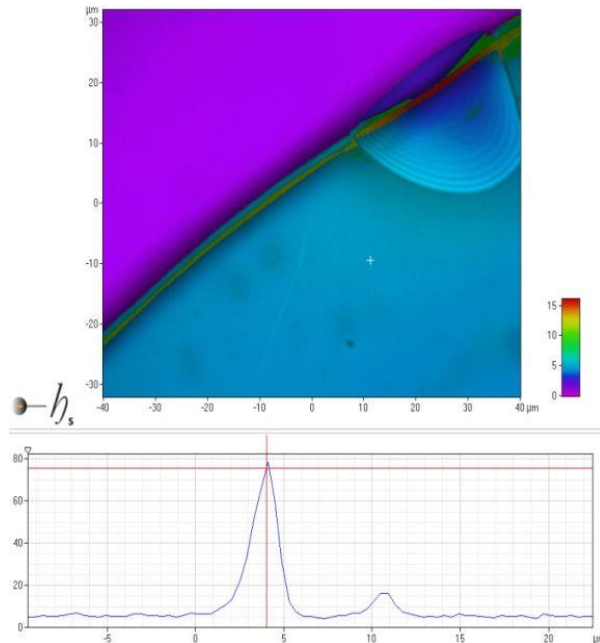
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Consider, for instance the case of an isolated photoresist feature on silicon.  
In the bare silicon region, there is a single contrast response:



In the region of the photoresist, however, there are two responses. Some light is scattered from the surface of the photoresist and some from the silicon surface:

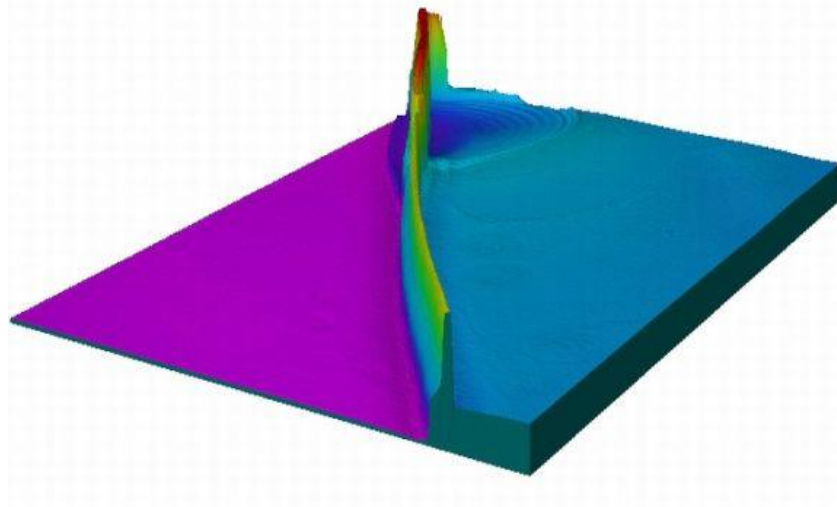


Since the silicon surface shows a greater response than the photoresist surface, this signal is the one traced by the default algorithm. Of course, the silicon seen through the photoresist appears to be at a higher level than the bare silicon because of the refractive index of the photoresist:

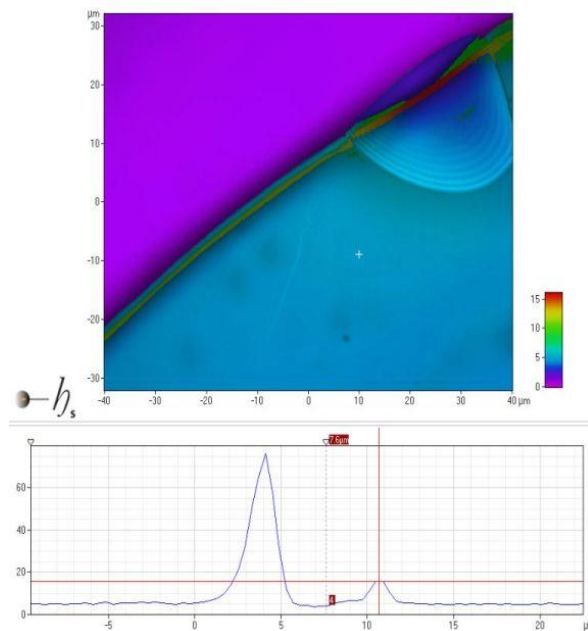


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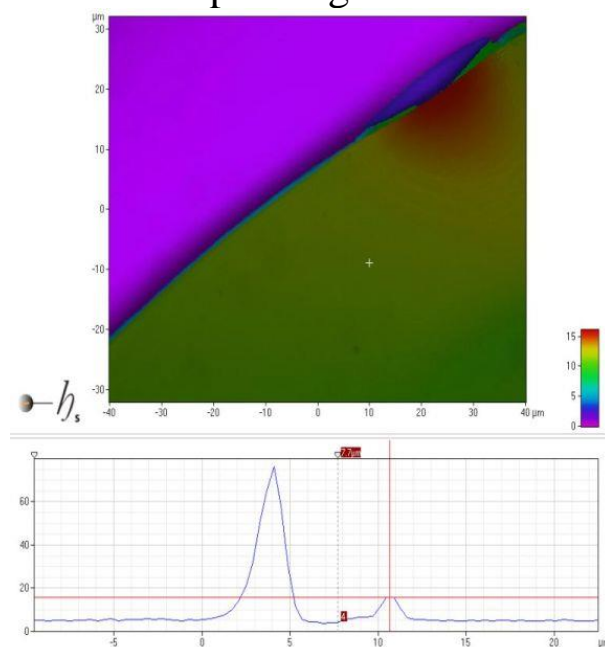
The interface to be rendered may be controlled by adjusting the parameters of the [Surface Calculation](#). Here, for example we can click on the tab icon at the top left hand corner of the chart and drag out a cursor, placing it between the two peaks. Now, selecting Above Cursor in the "Surface" pull-down in the Surface Calculation box the detected surface switches to the upper, photoresist, peak.



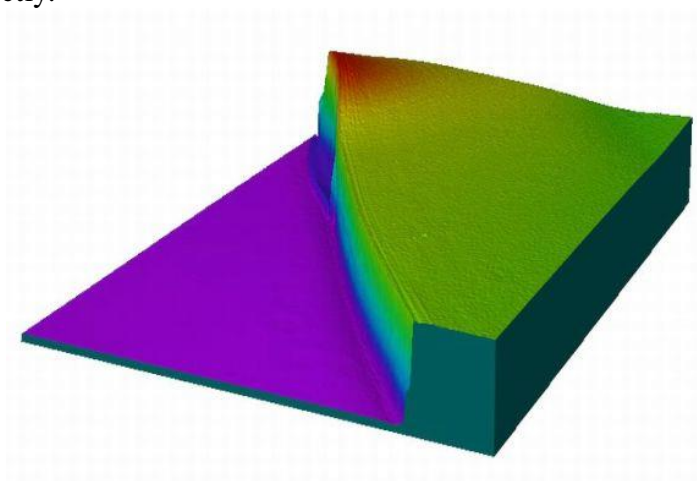
Clicking the "Calculate" button re-calculates the entire surface with this new algorithm setting.

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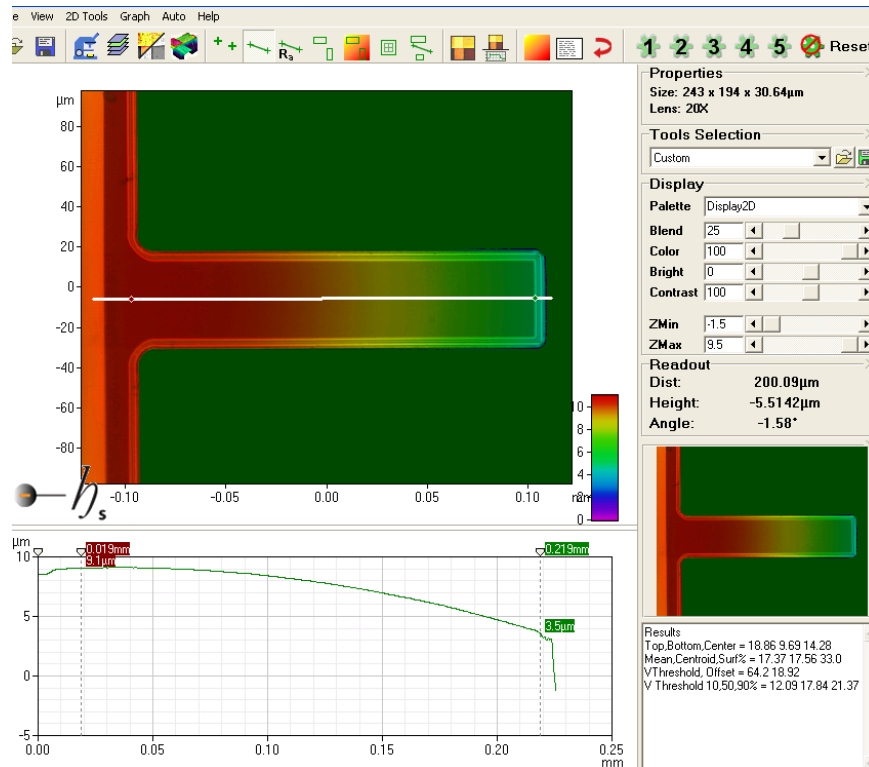
Now the algorithm traces the upper surface and renders the photoresist step correctly.



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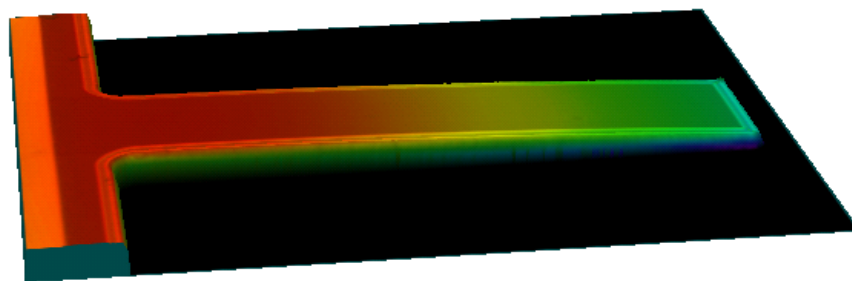
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- Silicon Nitride Cantilever Beam Surface Calculations**



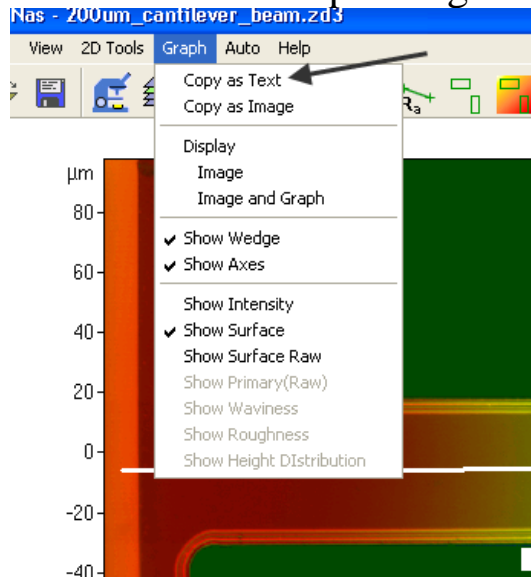
The above image is a silicon nitride cantilever beam that is 200μm long by 50μm wide. The white line at the center of the beam is measuring the deflection of the beam along the length. The above graph gives the deflect vs length for the beam. In graph above the deflection of the beam can be measured at 5.5μm at the tip. Below is a 3D image of the beam, to get this

image for your data please click the following icon



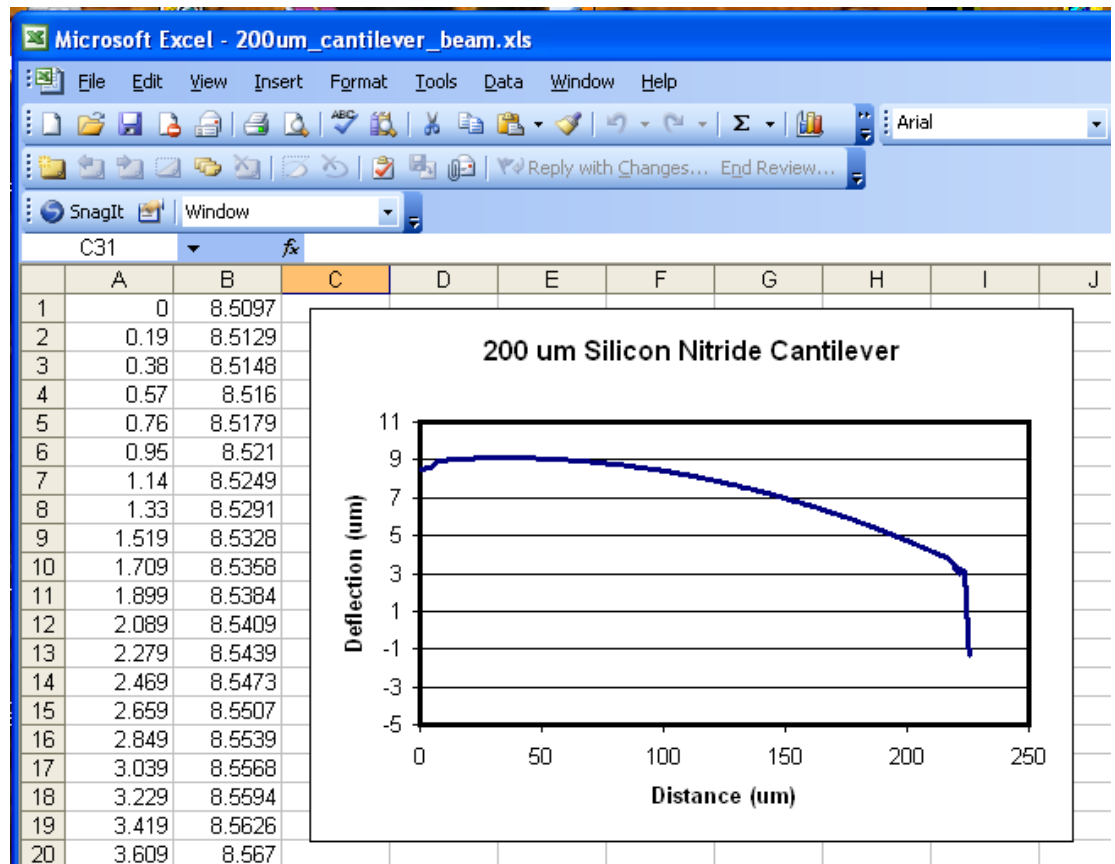
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To port this data to an excel file. To the following:

1. Graph>copy as Text.
2. Open excel and import your data.

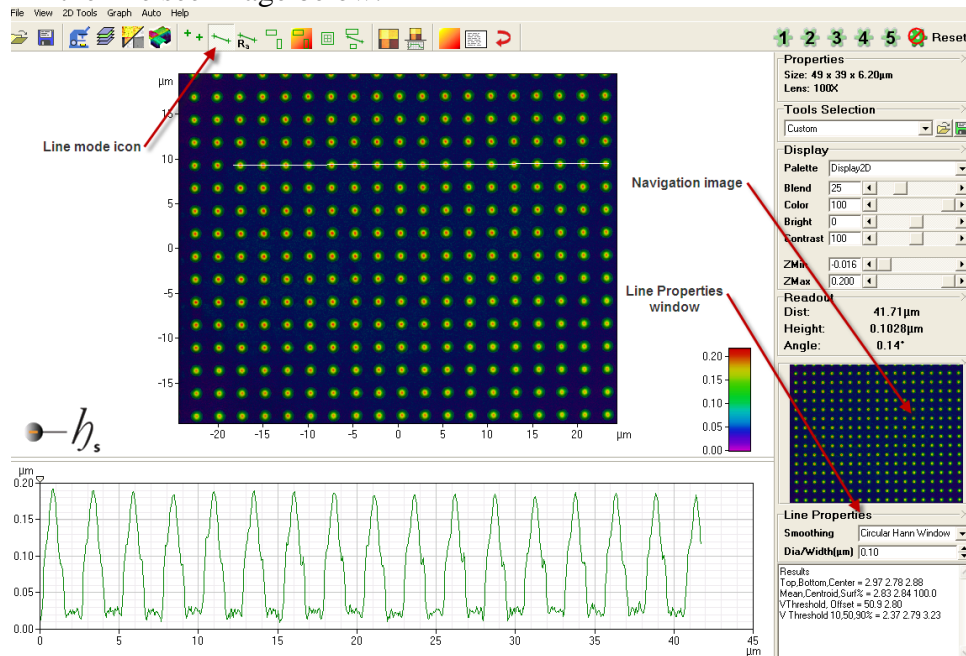


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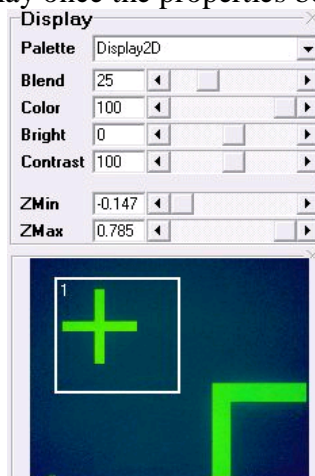
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### 8 To make measurement on your sample.

- After you have acquired an image use points mode to check the signal strength.
- Using line mode, draw a line from the left side to the right side of your screen. To start the line left click and drag your mouse to the second location and double left mouse button to end the line. If you would like to change the line properties double click on the line mode icon in the tool bar. This will bring up a Line Properties window in the lower right side of you screen. To change the wide of the line see image below.



- Navigation image-Provides a means to zoom in on areas within the field-of-view by clicking and dragging to create a zoom box. The main display is zoomed in real time. Any tools present remain in their set positions with their set sizes. Zoom box properties may be accessed by right-clicking the box. Changes to the tool size and position made in the properties box and applied to the navigation image transfer to the main display once the properties box is closed.

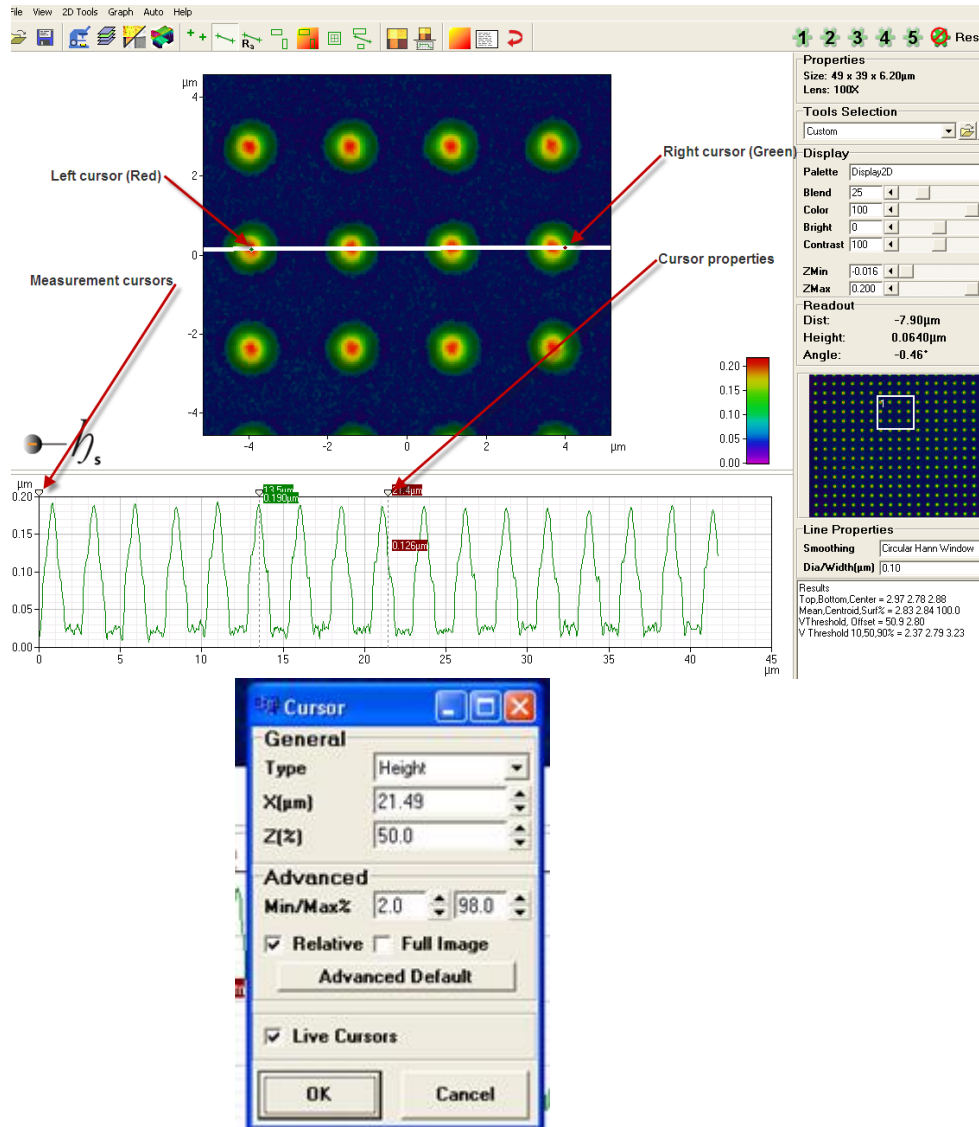


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- **Measurement cursors-**

The location of the measurement cursor can be seen below. If you place the mouse cursor over the measure cursor and right click, you will bring a window to define the measurement cursors. See below.



Measurement cursor properties can be modified in this window. To make a line measurement you would use 50% height as the edge of the line. To set the cursors to snap to these positions, set the type to height, z(%) to 50, click relative and live cursors, then click ok. This sets your cursors to snap to the 50% height of lines or dots.

- **Stitching Overview**

Stitching allows multiple fields of view (FoV's) to be assembled, and displayed and analyzed as a single surface, just like any other surface in our software.

\* Defaults assemble FoV's according to stage read-back

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coordinates, adjusting the height of each FoV by aligning intensity and height information in the overlap region (20%, by default)

- \* Note that stitching assembles all FoV's in the target directory--therefore, the target directory should be empty (or please create a new one) at the start of each stitching acquisition
- \* FoV's may be more accurately placed by allowing them to "float" in X/Y (allowing for variations due to stage read-back repeatability)--for this to be successful there needs to be significant contrast variation (height and/or intensity) in the overlap region for the algorithm to operate upon
- \* Be sure to set up the acquisition conditions to allow for any variations in the surface within the area to be stitched--e.g., Top must be set above the highest point, bottom must be set below the lowest point, illumination should allow the brightest and darkest areas to be imaged well.

### Simple Stitching Operation

- \* In Live Mode, click on the Stitching Mode icon--a new control pane will open at the right of the screen
- \* Select an empty directory or create a new directory, using the Disc icon to the right of the Run button--all data for the stitched set will be placed in this directory
- \* Position the sample to view the area to be imaged
- \* There are several ways of defining the area to image, for instance:
  - \* The entire feature can be seen in the 5X FoV (say)
    - \* Center of the area to be imaged at 5X
    - \* Click the Centre Stitching Area icon
    - \* Click top left button then the bottom right button of the stitch array control
    - \* Change the lens to the analytical magnification--a stitching array will be calculated and displayed
    - \* Click Run
  - \* The dimensions of the area to be imaged are known
    - \* Center the view on the area to be imaged
    - \* Enter the X and Y dimensions in the Size boxes in the stitching controls--a stitching array will be calculated and displayed
    - \* Click Run
  - \* The area to be imaged can only be seen at the analytical magnification
    - \* Position the analytical FoV at the top (or bottom) left of the area to be imaged, click the top (or bottom) left button



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- \* Position the analytical FoV at the bottom (or top) right of the area to be imaged, click the bottom (or top) right button--a stitching array will be calculated and displayed
- \* Click Run
- \* The defined area will be imaged one FoV at a time and the data saved in the target directory
- \* After acquisition is complete, the FoV's will be stitched, starting in the centre of the composite FoV and spiraling outwards
- \* After stitching is complete, the surface may be saved in the usual way
- \* The resulting surface may be analyzed with any of the usual tools, just as for a single FoV

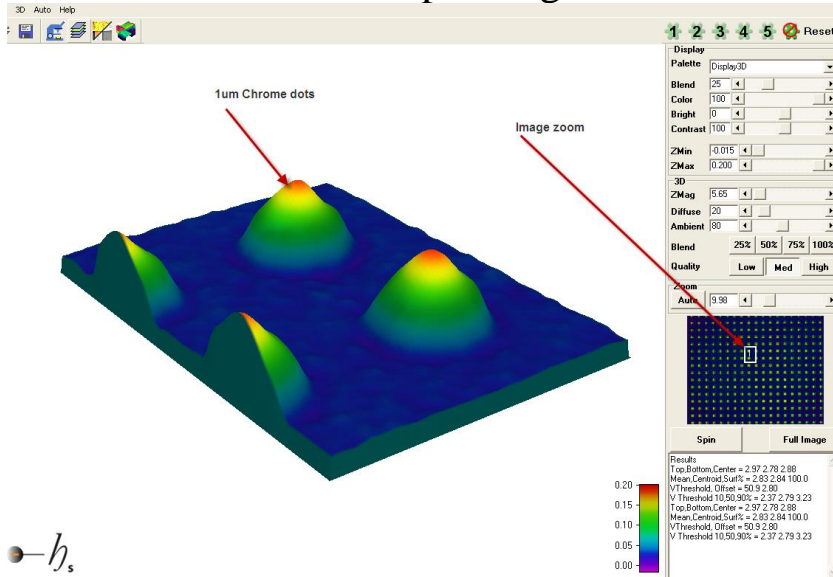
### Advanced Stitching Operation

- \* The Points tab in Script Controls now has a button to transfer the stitching array from the Stitching Mode acquisition controls, described above
  - \* Once the coordinates are in a script, stitching acquisition may be controlled in much more detail--recipe need not be the same for each point, for instance
- \* Stitched arrays may have any aspect ratio and need not be complete--e.g., for circular features FoV's at the corners of the array may be omitted to speed total acquisition
- \* Data to be assembled need not be continuous--if there is no overlap, however, stage read-back accuracy cannot be compensated
- \* Although there is a stitch after measure button, this does not work at present, stitching must be started manually in 2D mode

- **Below are some examples.**
- **3D Display mode- 1um Chrome dots**

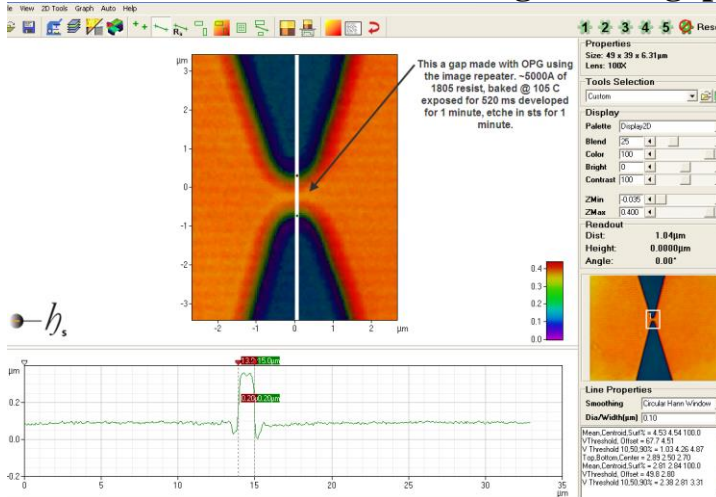
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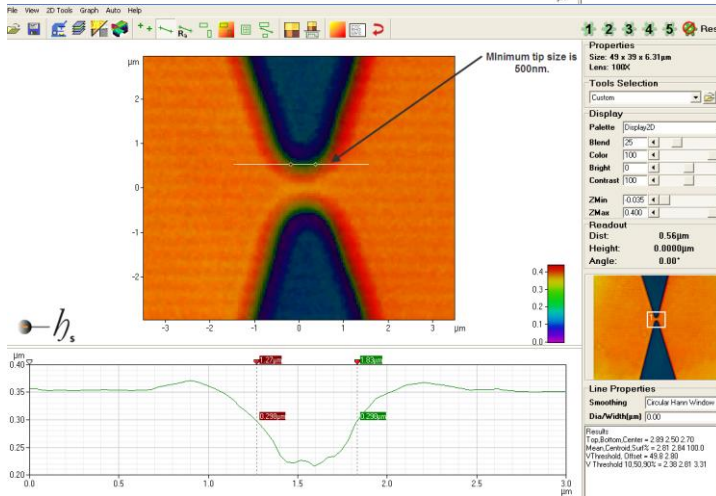


•  $h_s$

- Photoresist on silicon showing a small gap (0.5um)



•  $h_s$

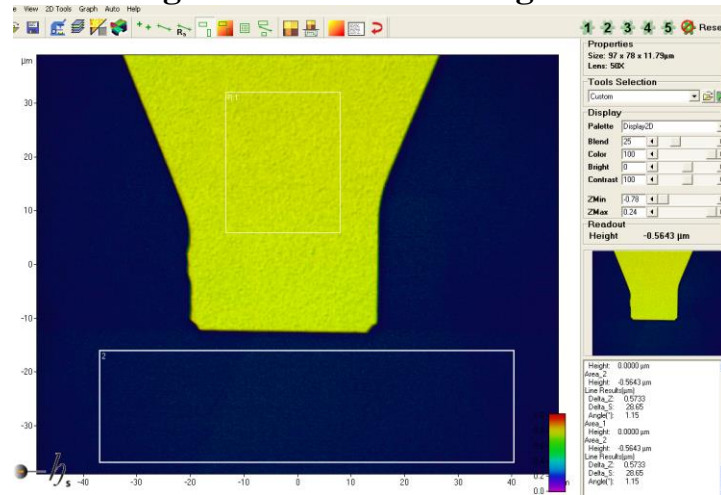


•  $h_s$

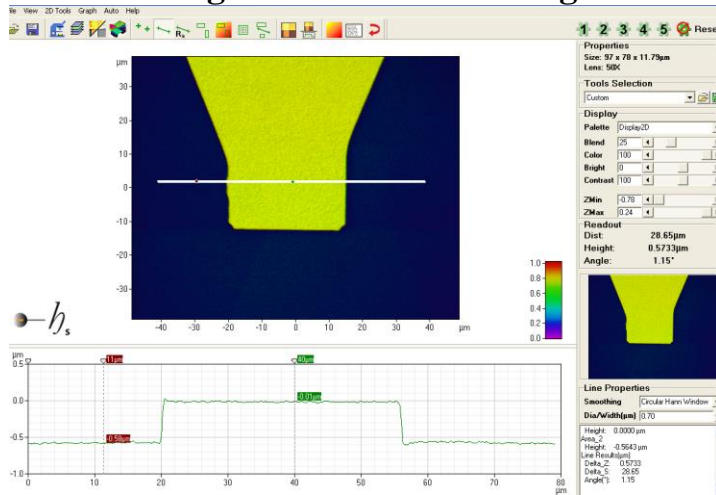
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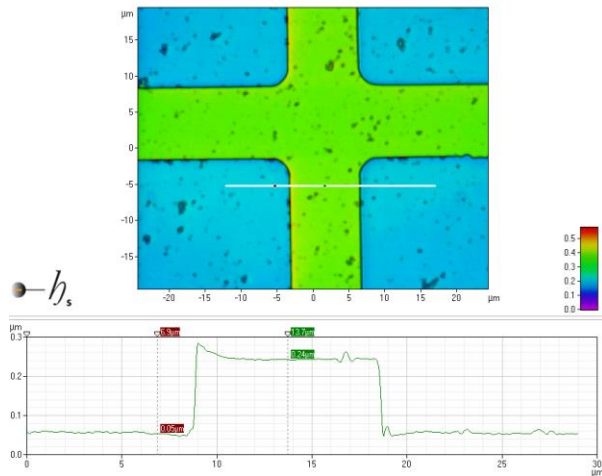
- Metal height measurement using area mode.**



- Metal height measurement using line mode.**



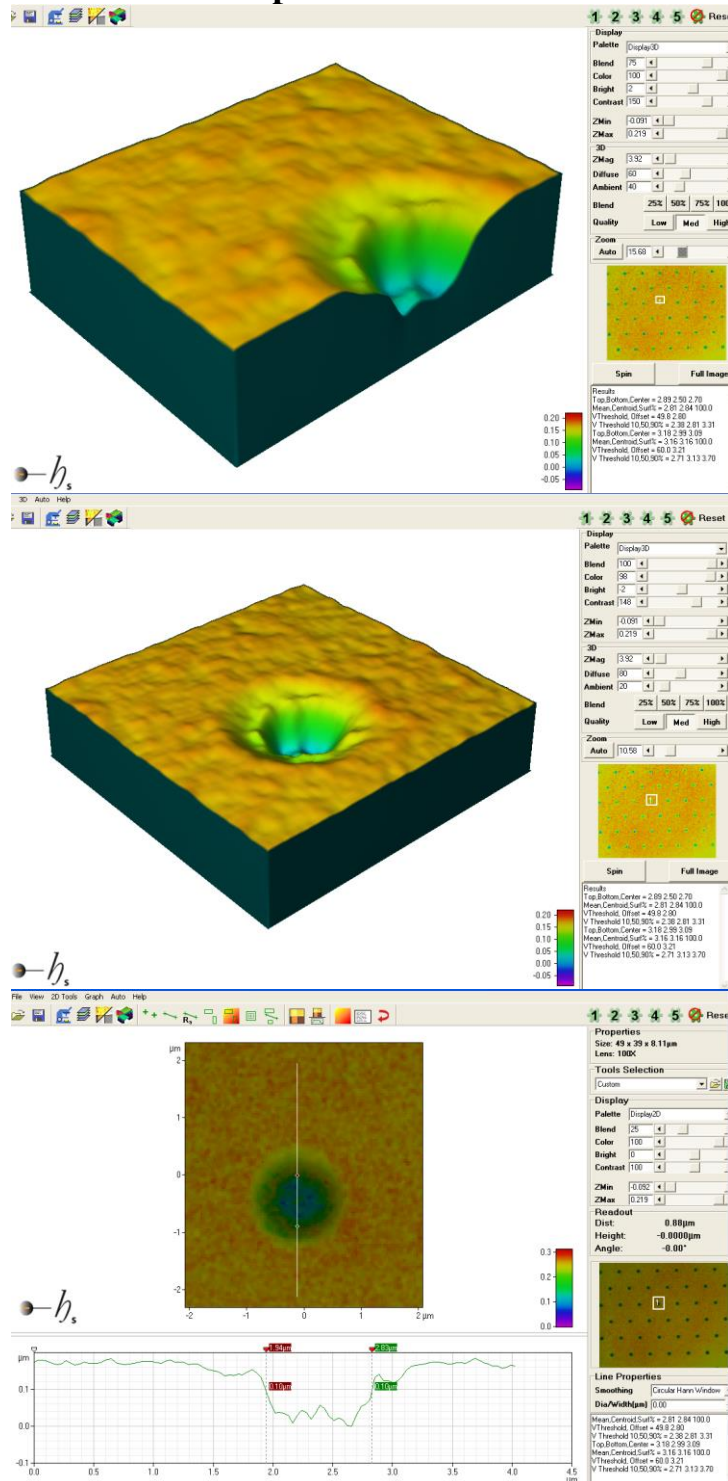
- Silicon etch**



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### 0.9 $\mu\text{m}$ hole in a photomask



## 9 Problems/Troubleshooting