NACK NETWORK

Building College-University Partnerships for Nanotechnology Workforce Development

Focused Ion Beam (FIB): "Seeing" and "Processing" at the Nano-Scale

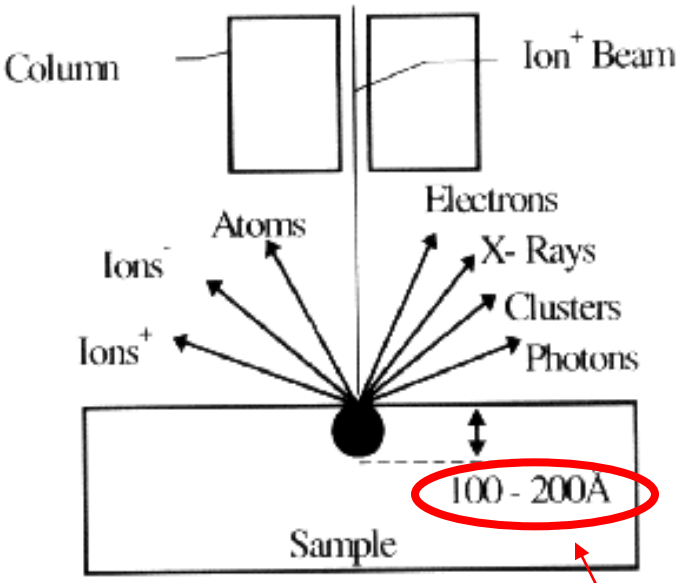
Outline

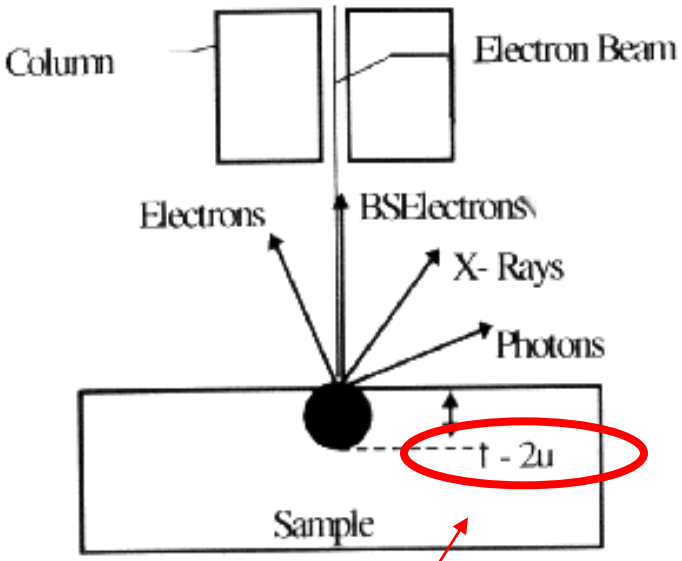
- FIB Overview
- FIB Operation
- FIB Applications

FIB overview

Ebeam vs. Ion Beam

- Beam Interactions





Milling as it scans sample surface

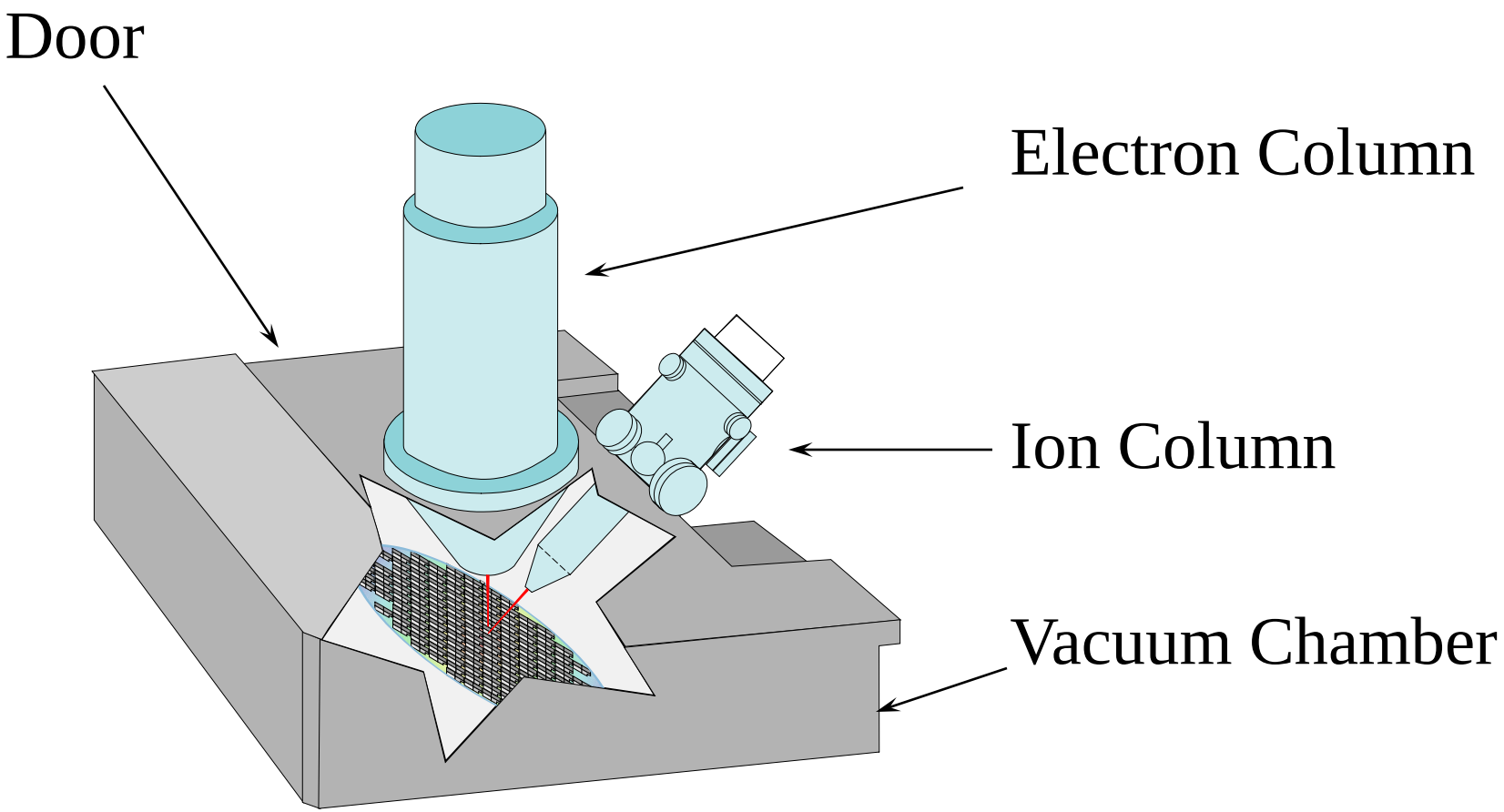
No damage as it scans sample surface

Note difference in interaction volume

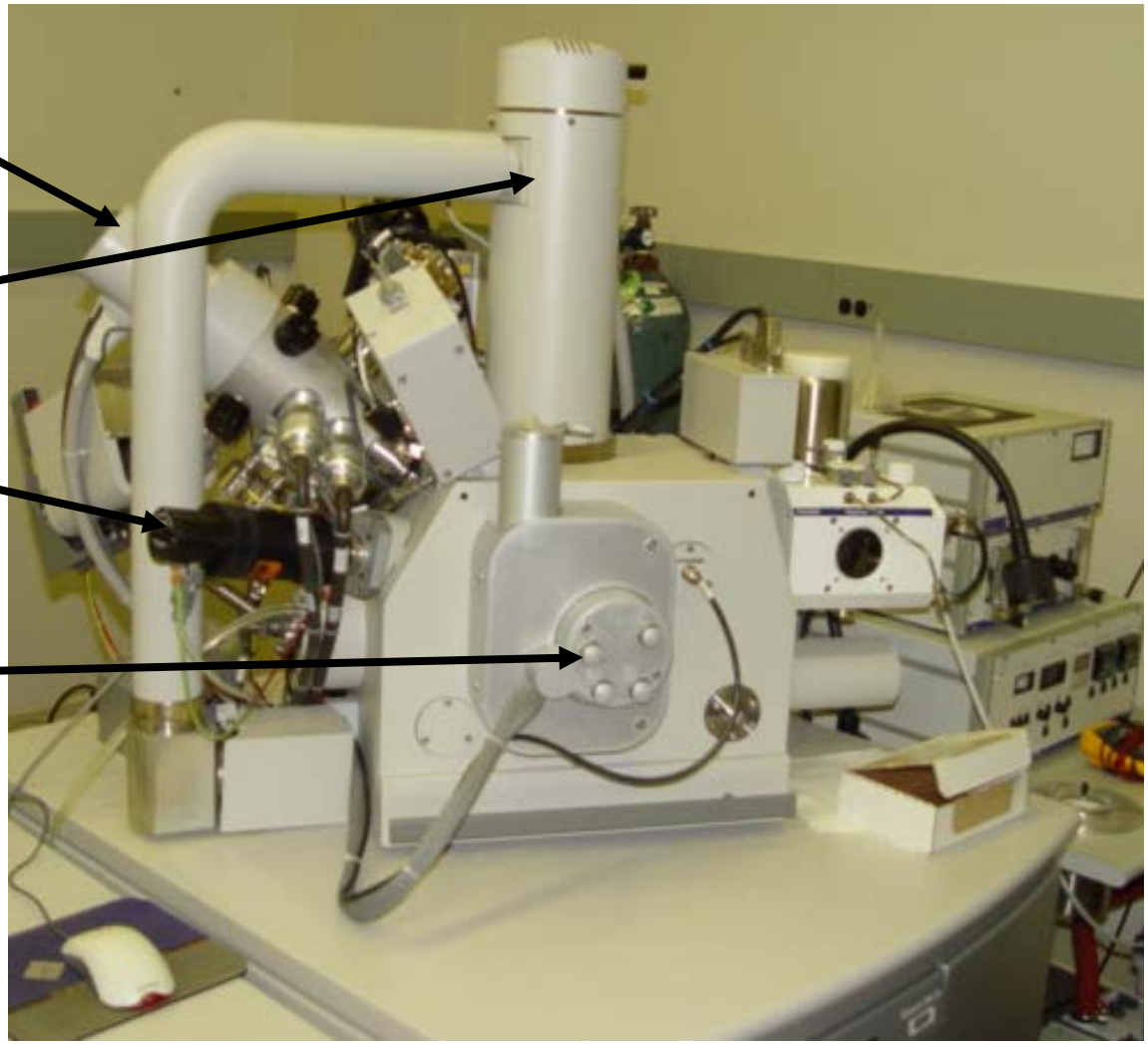
Applications of Focused Ion Beam (FIB)

1. Ion beam lithography
2. Image Analysis
3. Film Deposition
4. Ion Milling (Dry Etching)

Typical Configuration of FIB



Typical Configuration of FIB (continued)

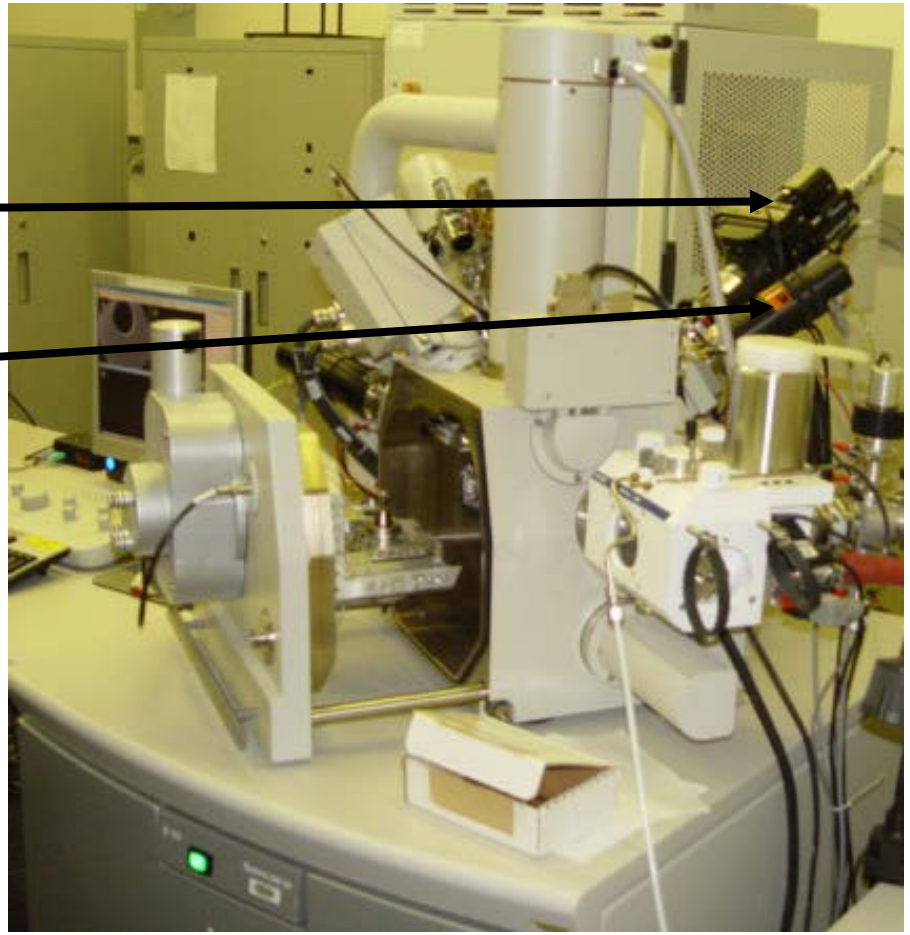


FEI Quanta 3D system

Typical Configuration of FIB (continued)

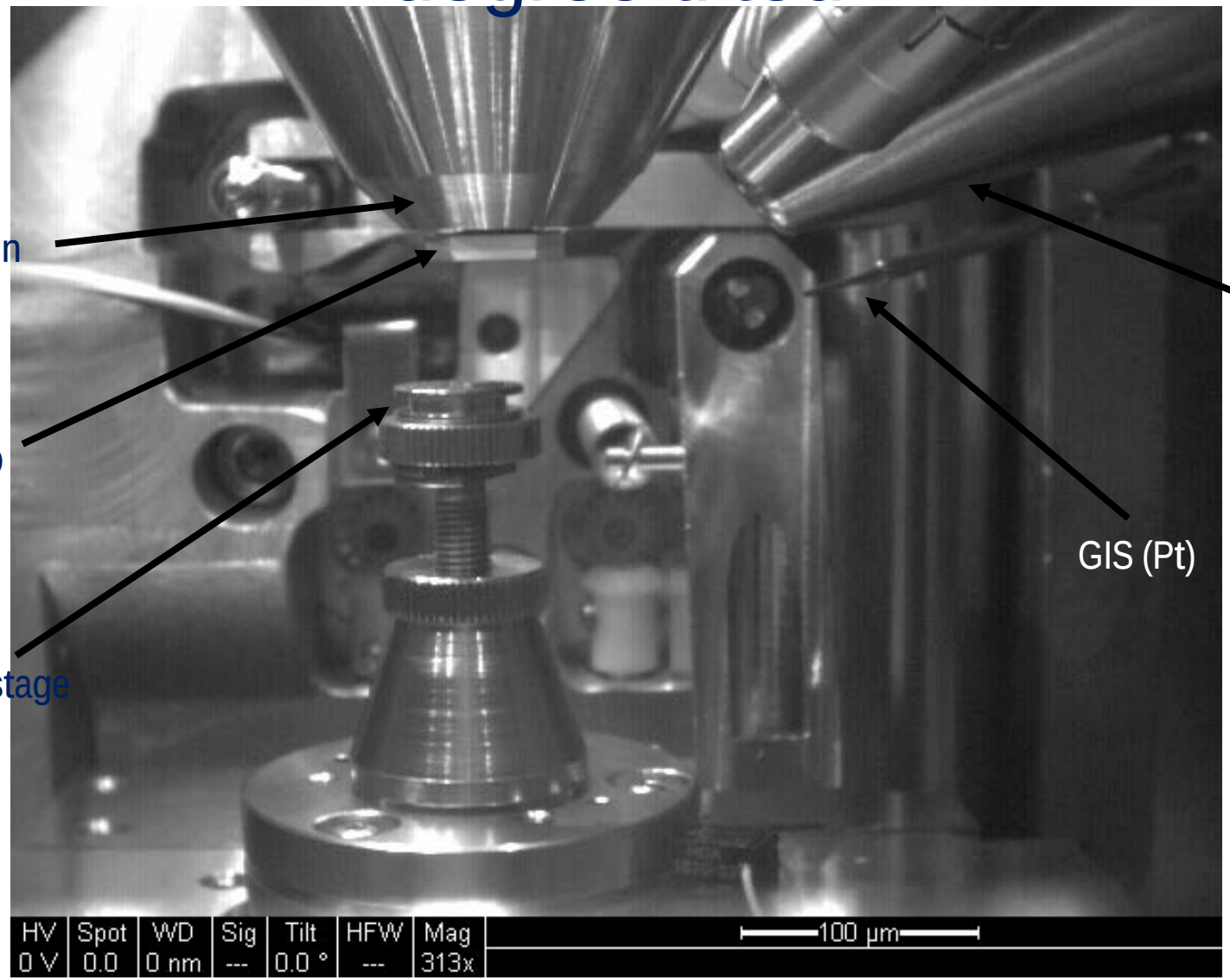
Omniprobe

Tungsten Gas Injection System (GIS)



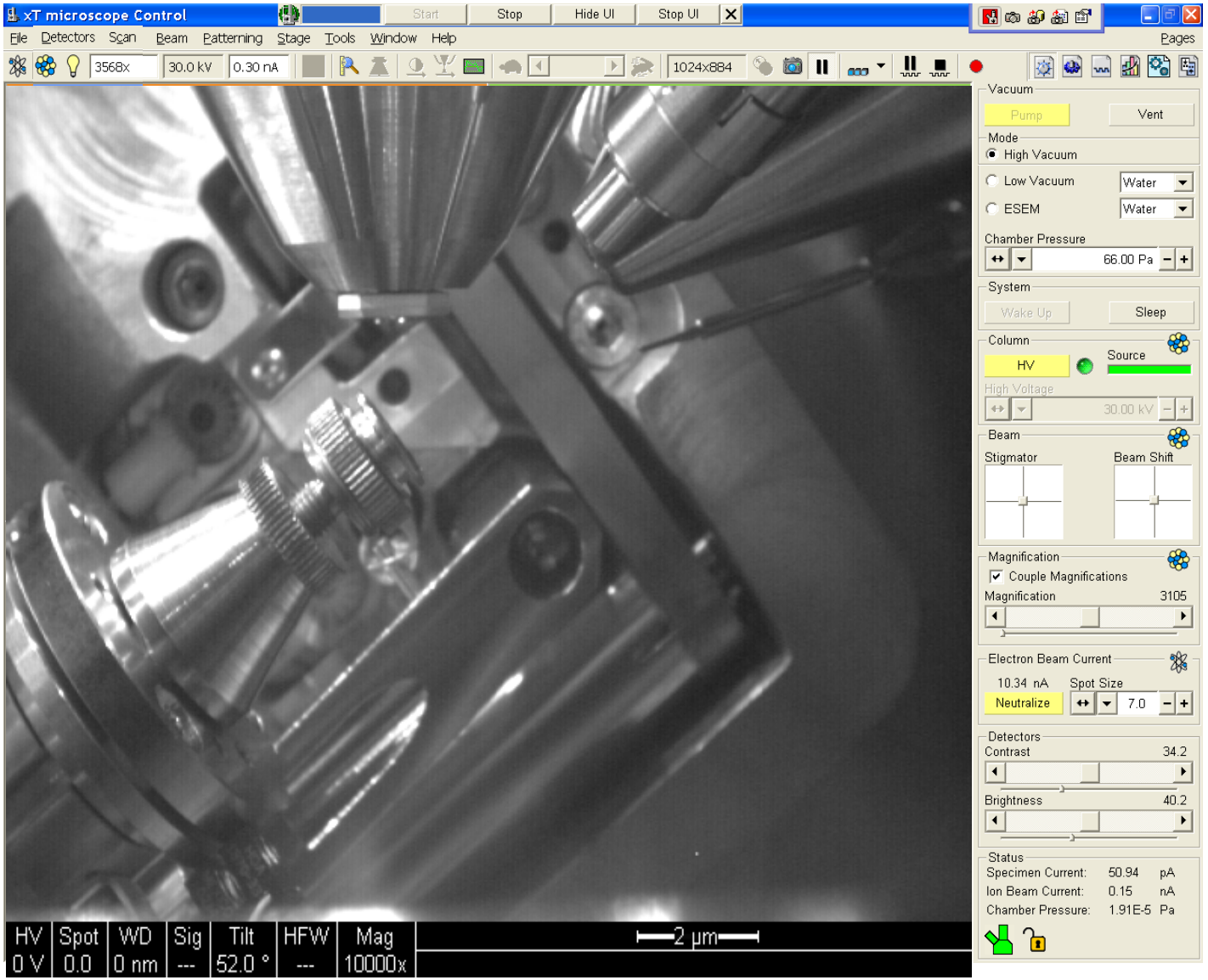
FEI Quanta 3D system

Typical Configuration of FIB (continued): 0 degree tilted

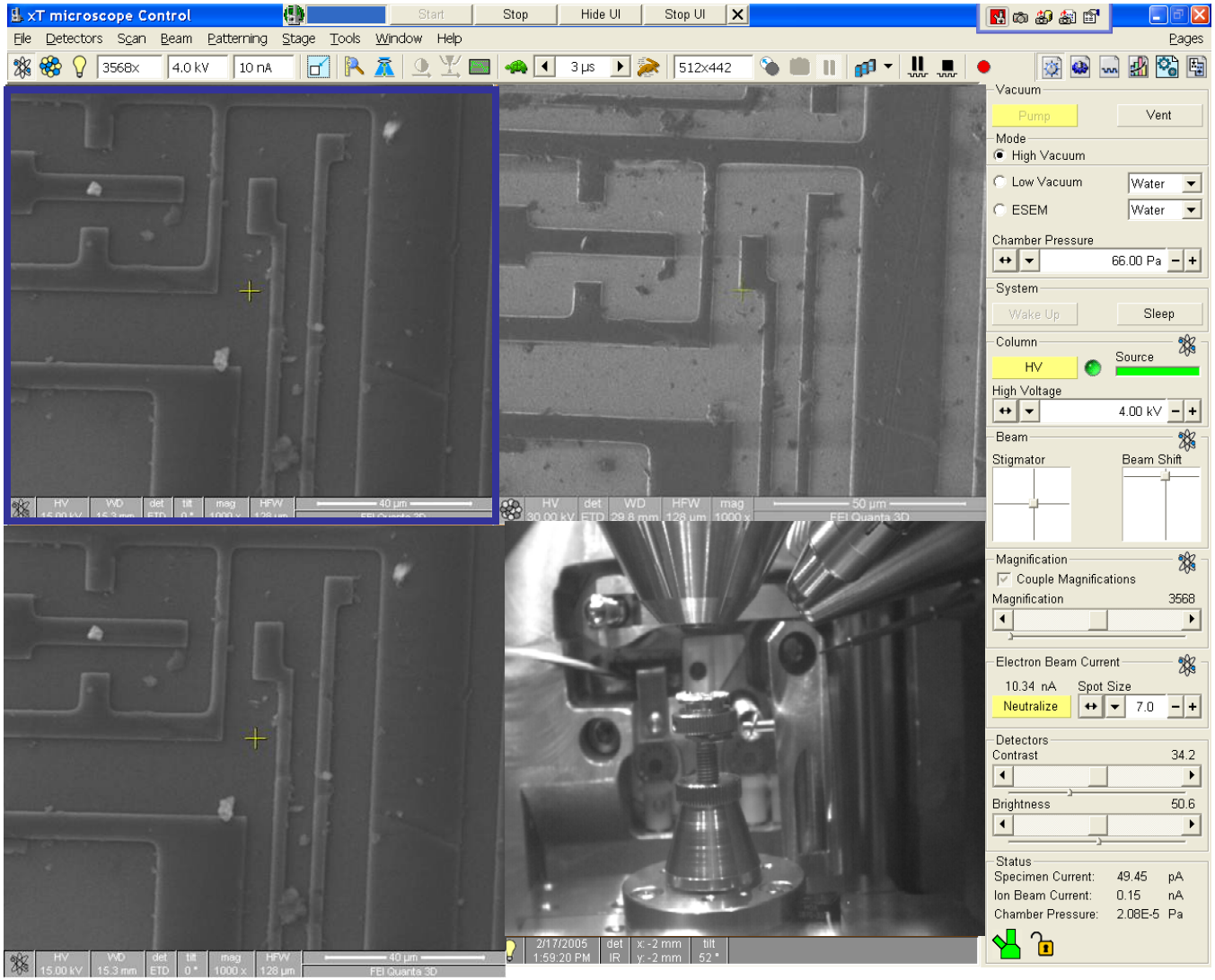


FEI Quanta 3D system

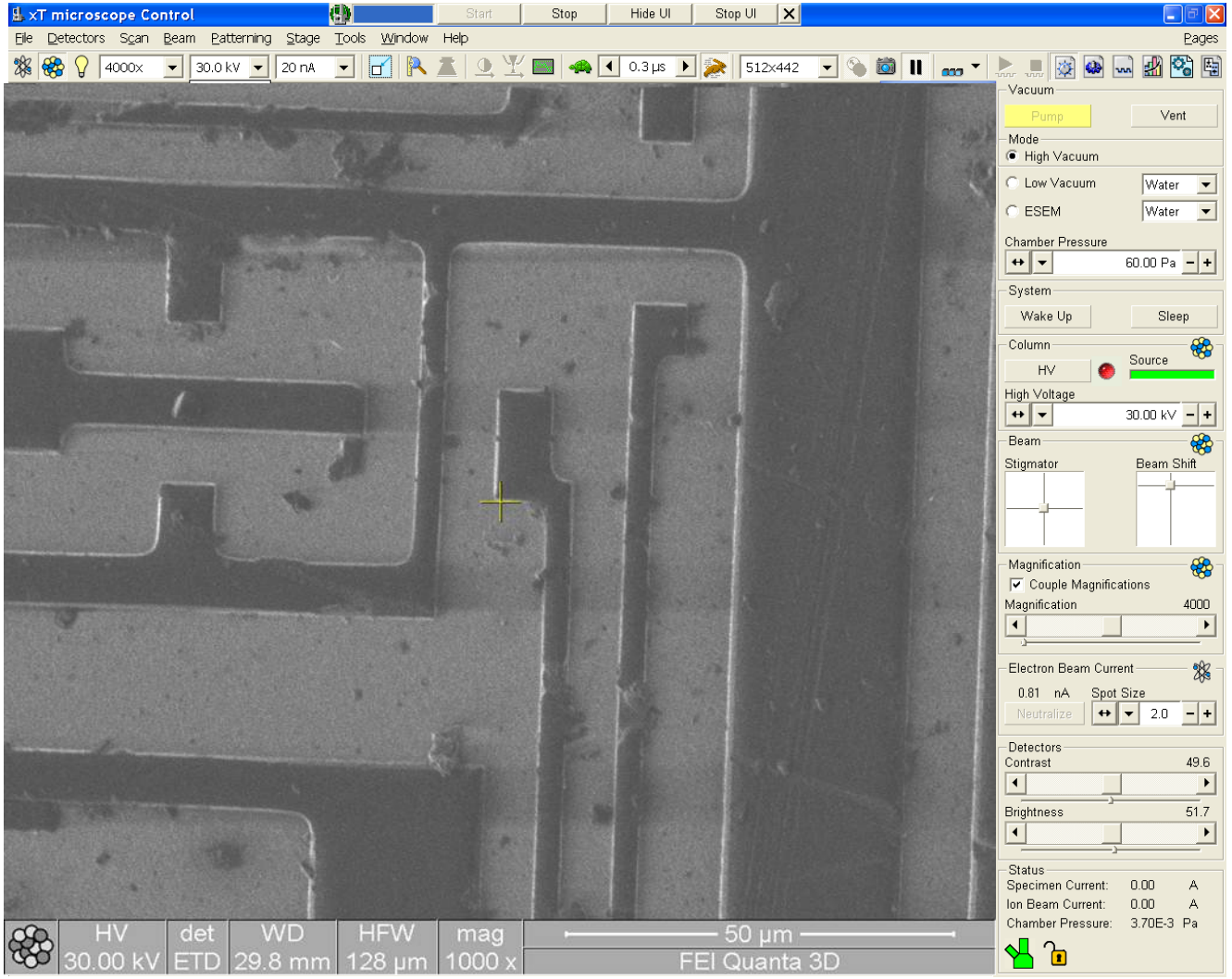
Typical Configuration of FIB (continued): 52 degree tilted



Typical Configuration of FIB (continued): User Interface

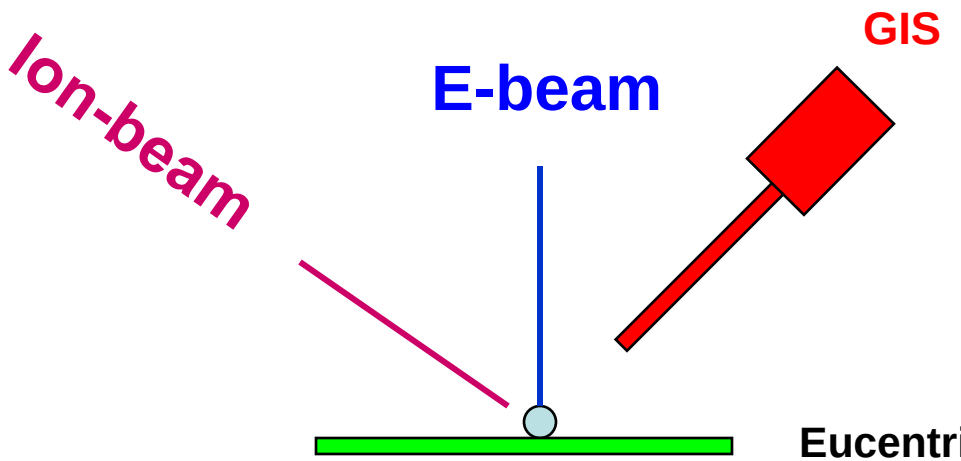


Typical Configuration of FIB (continued): User Interface



FIB operation

What is Eucentric Point ?

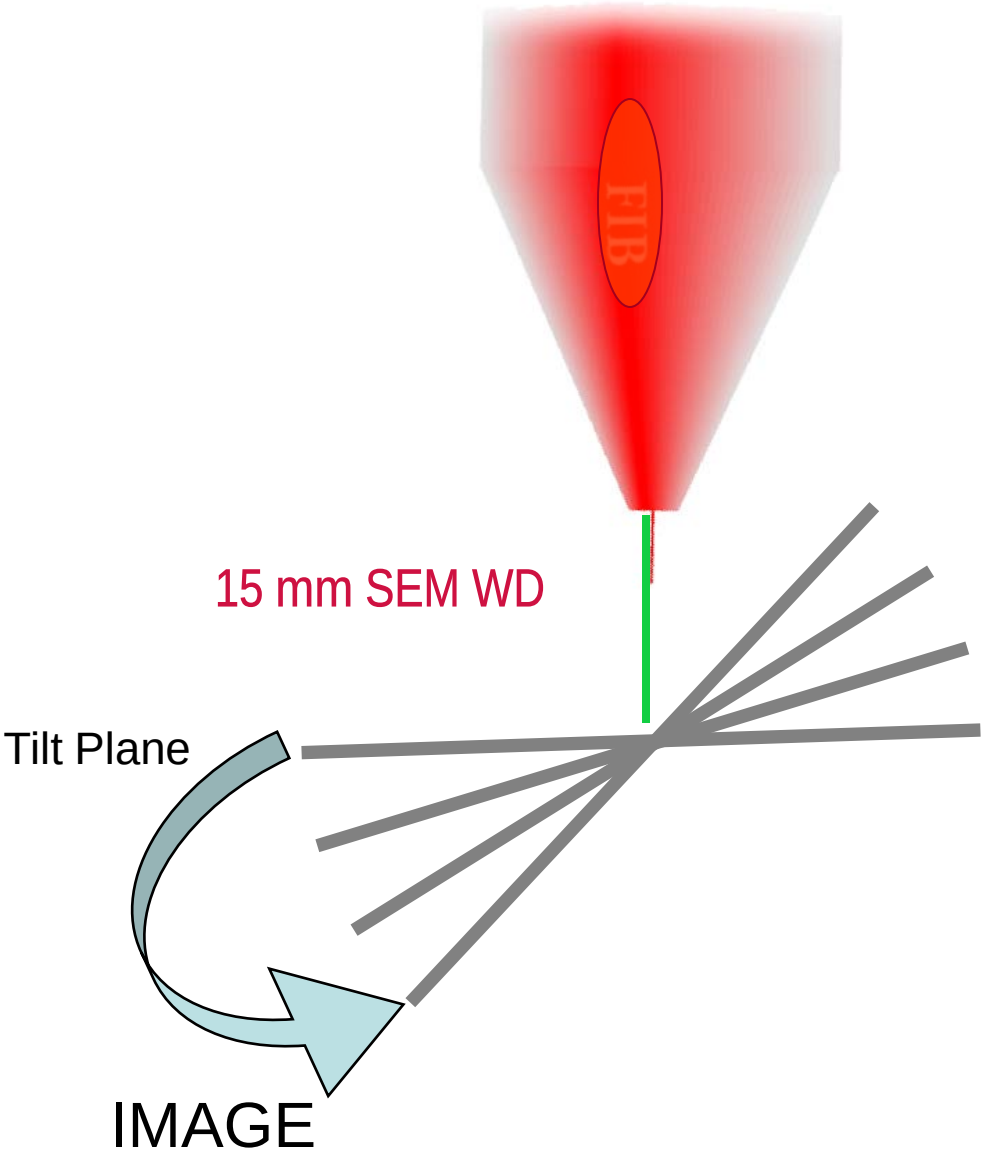


Eucentric height =15mm WD below e-column pole piece and 30mm from I column

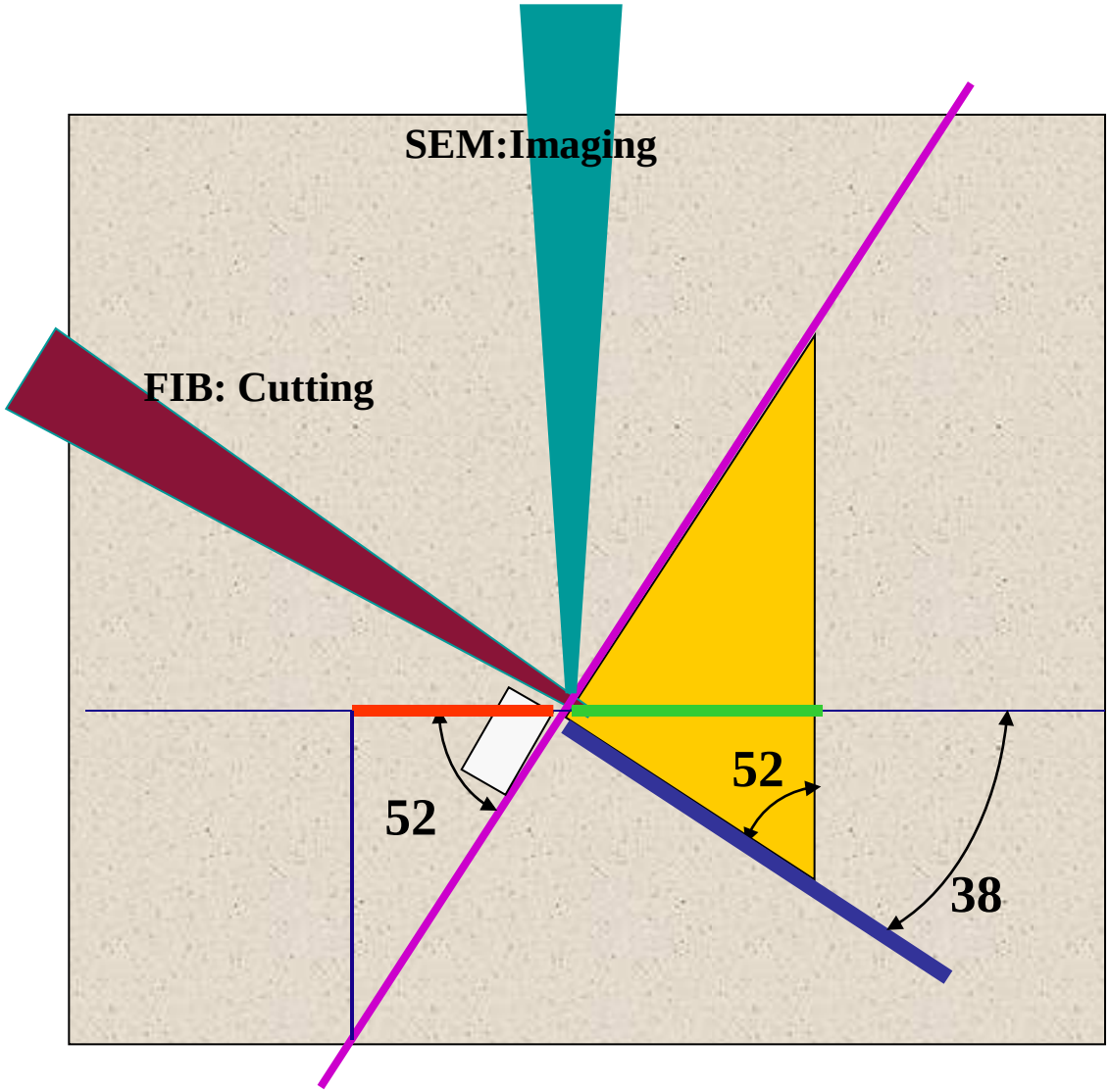
All equipment is pointed to one central spot !!

What is Eucentric Point ? (continued)

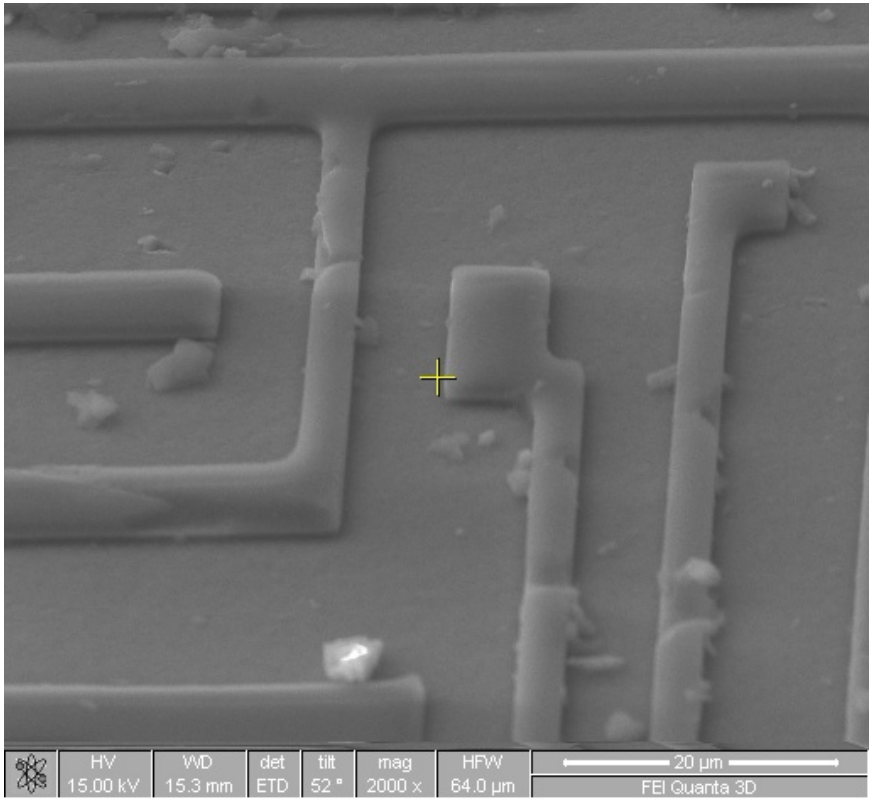
- All aligned:
  - "Eucentric" is a point in the stage height control ("Z") where the sample's image does not move when the sample is tilted.
  - SEM imaging is used to find the physical point.

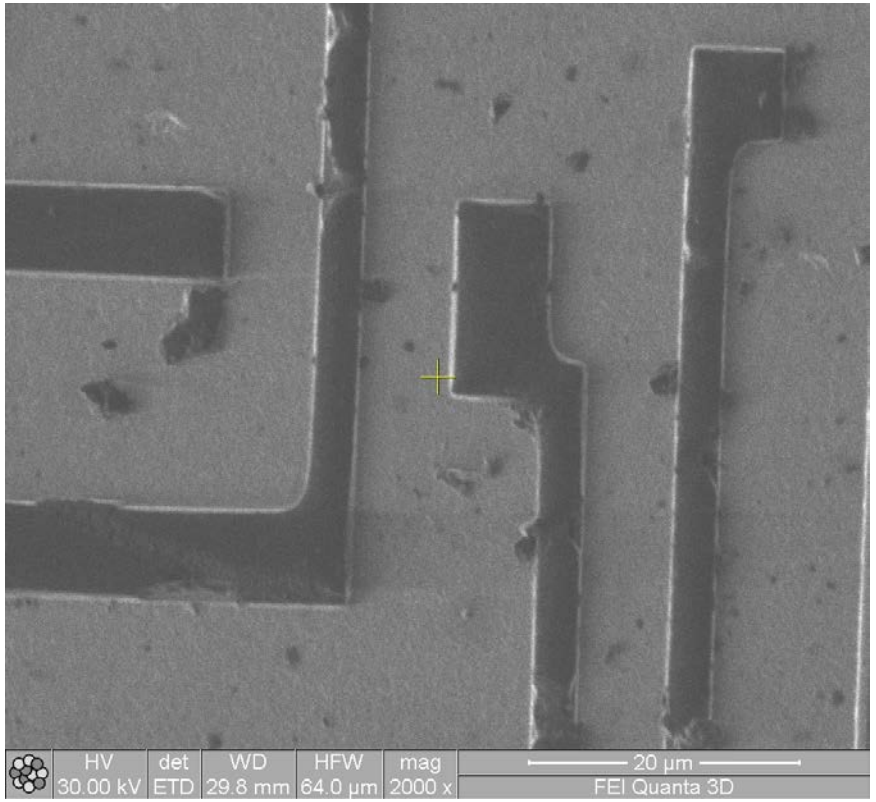


Eucentric Point (continued)

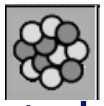


Eucentric Point (continued) – 52 degree tilted Images

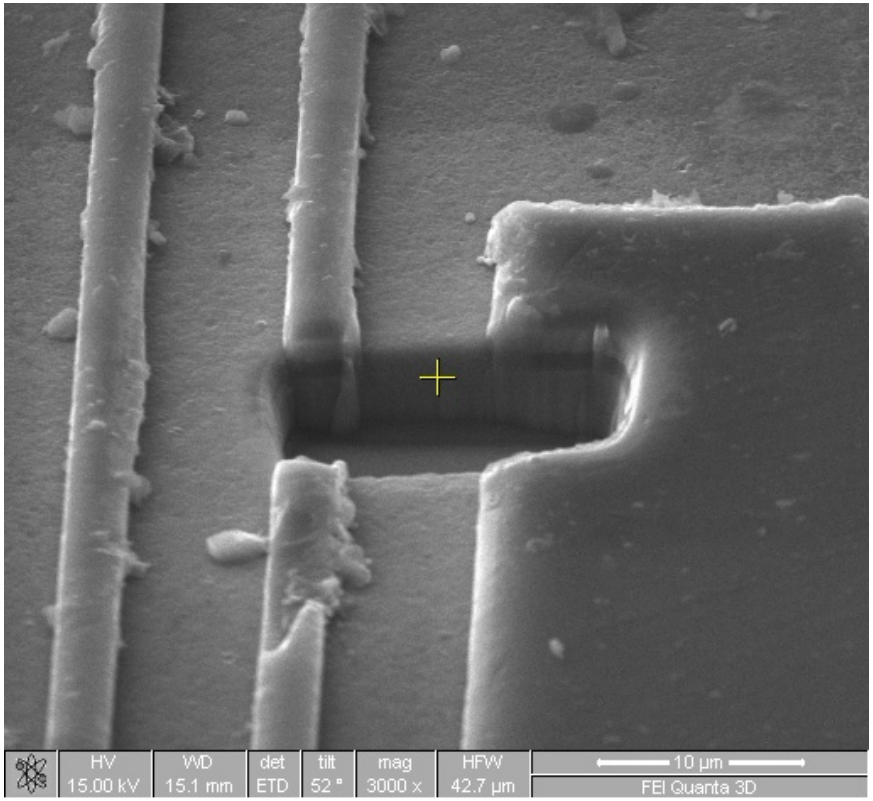


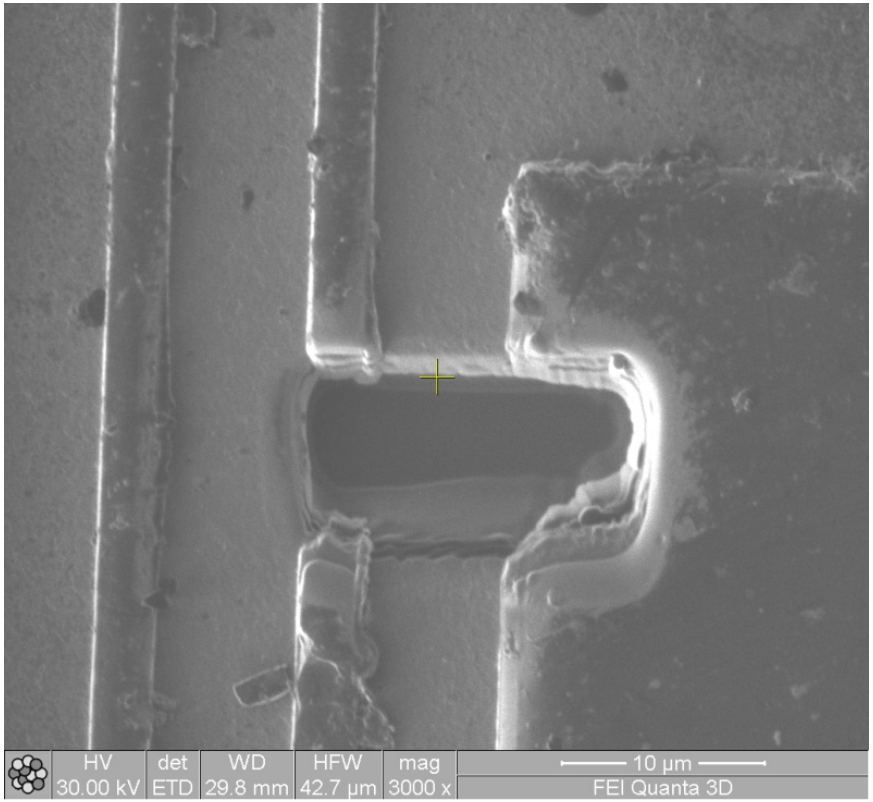


SE image  is foreshortened. The upper part of the image is at a longer WD than the lower portion of the image.

Ion mage  - Appears to be looking straight on.

Eucentric Point (continued) – 52 degree tilted Images





SE image can look into the milled area.

Ion image is doing the cutting and “looking” down in the sample.

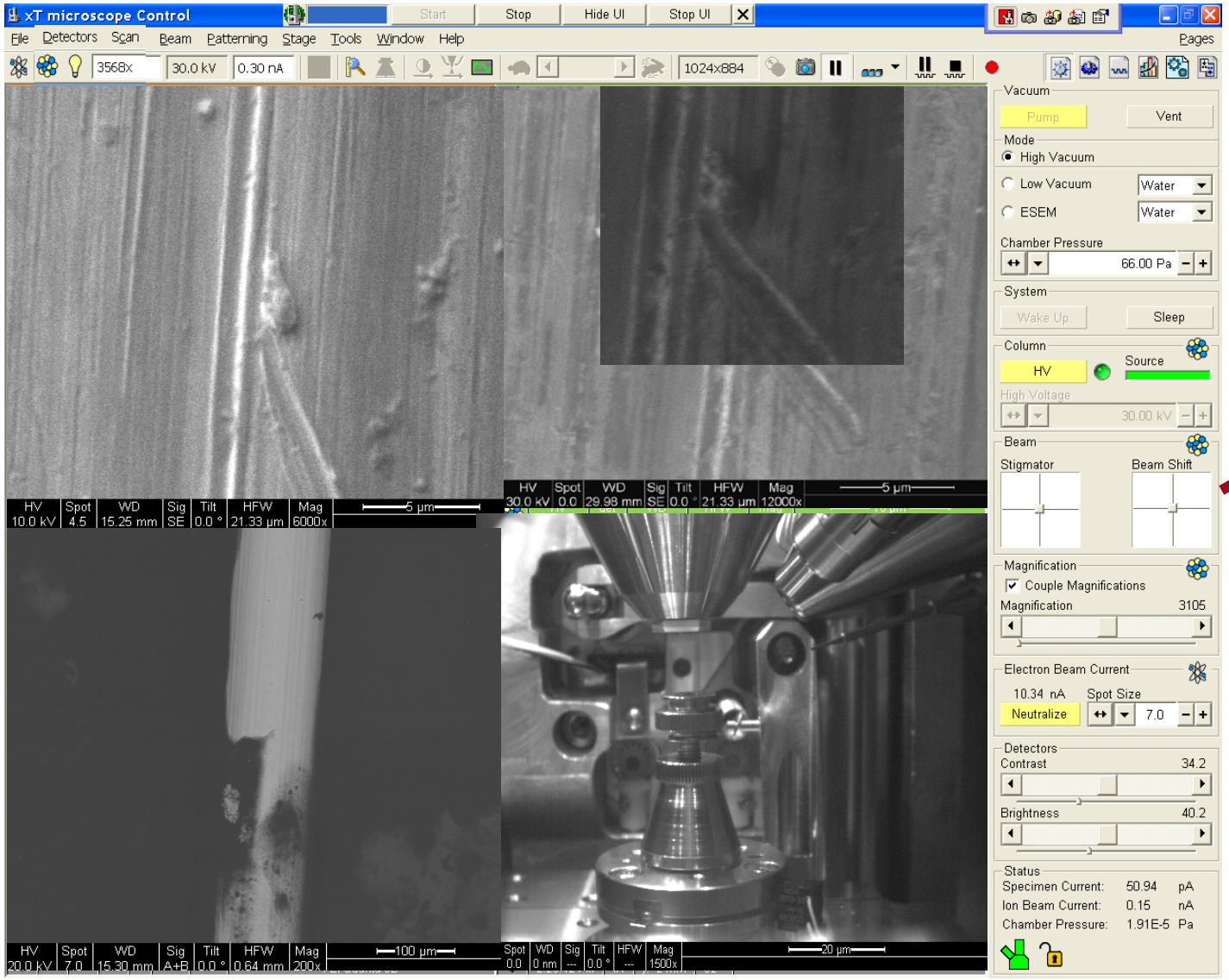
Eucentric Point Finding Steps

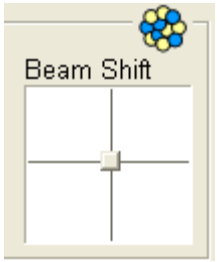
- “Eucentric” is the point on the height of the stage in which the sample stays centered as the stage is tilted.
- It’s assumed you are at about 15 mm WD (having done a Z<>FWD and moved the stage previously)
- Only after finding the eucentric point, you have coincidence alignment of the beams!

Eucentric Point Finding Steps (continued)

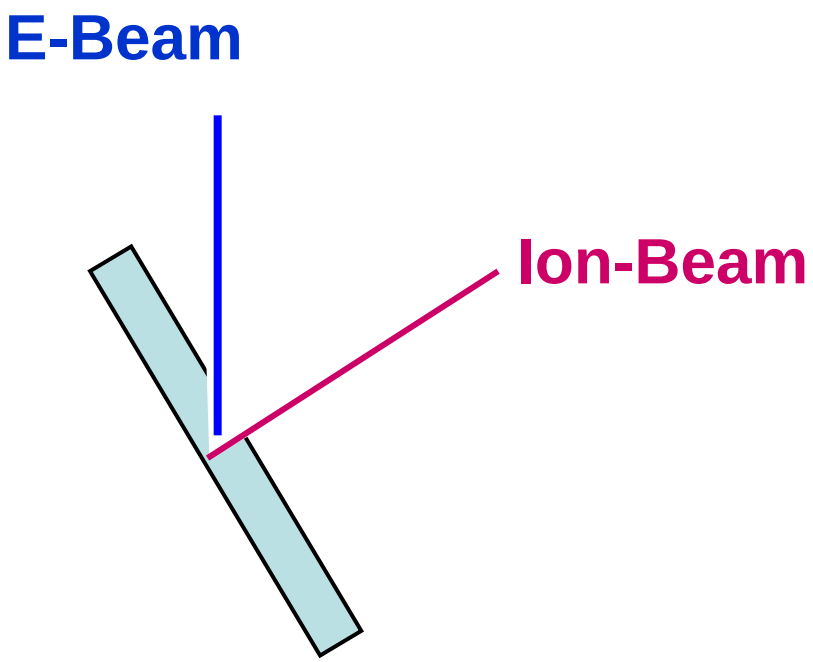
- You will perform the following steps in the upcoming slides:
  - Start at ‘0’ degrees tilt
  - Note a feature of interest and bring to a feature of interest (e.g., center of crosshairs)
  - Tilt the stage to a positive 52 degrees
  - Watch the image move either up or down on the screen
  - Adjust the “Z” height on the specimen door to bring feature back to the center of the screen
  - You may have to do this several times at higher and higher magnifications to get perfect eucentricity

Fine Alignment of Ion Beam





We just set up the sample to face the Ion beam



Ion Beam Operation

- The ion beam will damage your sample when viewing. It is important to use a small beam size when imaging!

- When getting ready to mill with a large beam current, you must focus quickly and in as few of scans as possible!

- While milling or depositing a film, you can highlight Quad 1 (SE column) and take a photo (F2) or click “snapshot.” or. It will pause the Ion beam and grab a quick SE image to see status of the Ion milling operation.

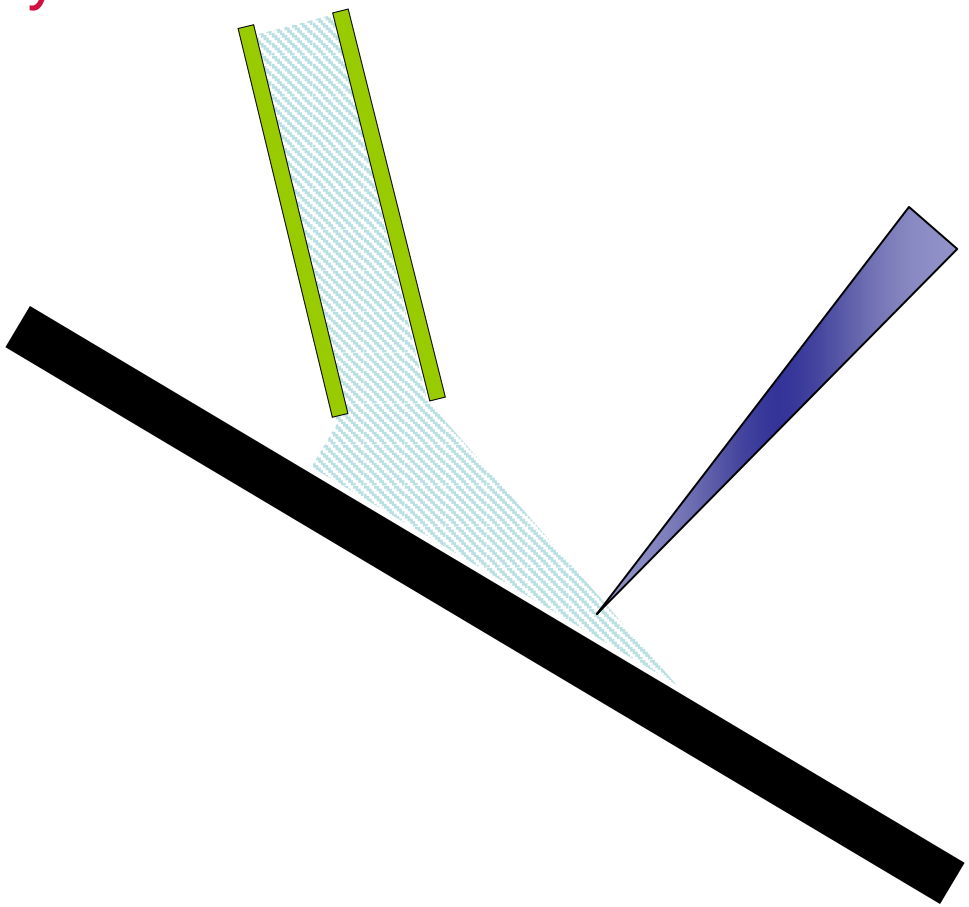
Film Deposition (Pt)

- Pt. deposition can be used for many applications.
  - adding a conductive layer to a non conductive sample
  - setting up a pattern, to prevent “curtaining” with the FIB
  - adhesive attachment for mechanical testing

  - This tutorial will cover the second point: making a protective shield for further processing

Film Deposition (Pt)-continued

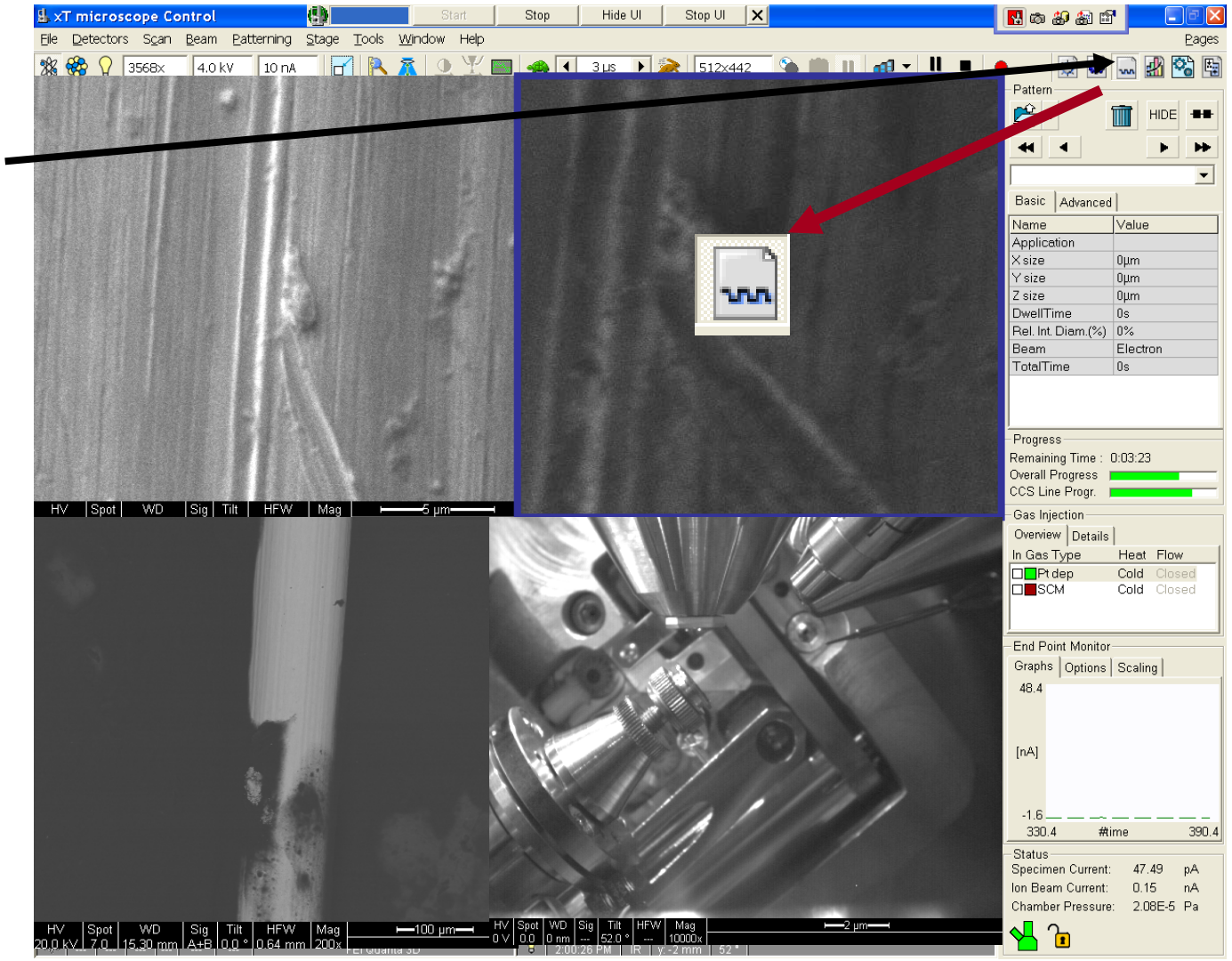
Gas Injection System



Ion Beam

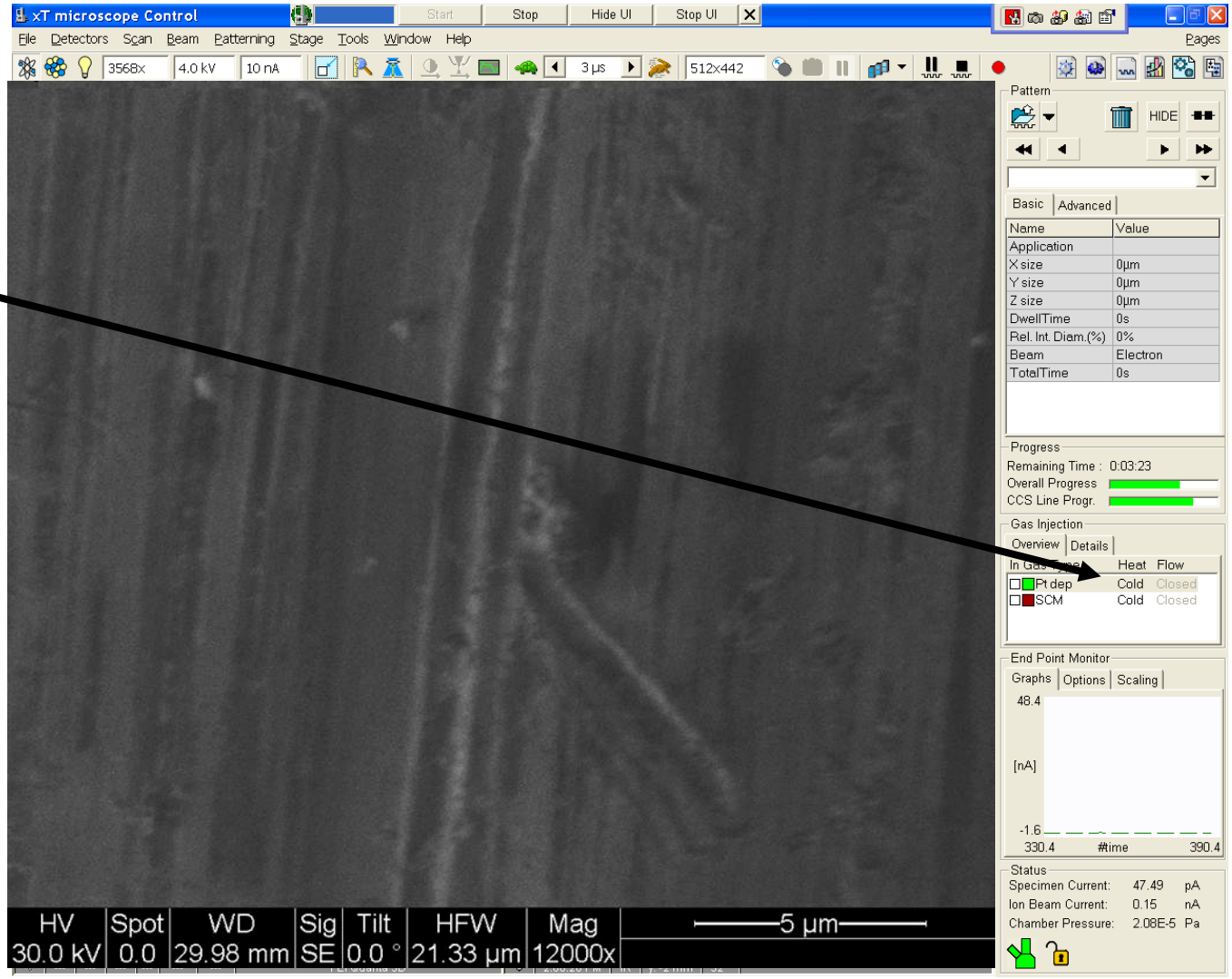
Film Deposition (Pt)- Find Deposition Spot

- Click on the third Icon - the Patterning Page
- This page controls:
- Patterning type including size
- Progress of mill or deposition
- Gas injection
- End Point Monitor



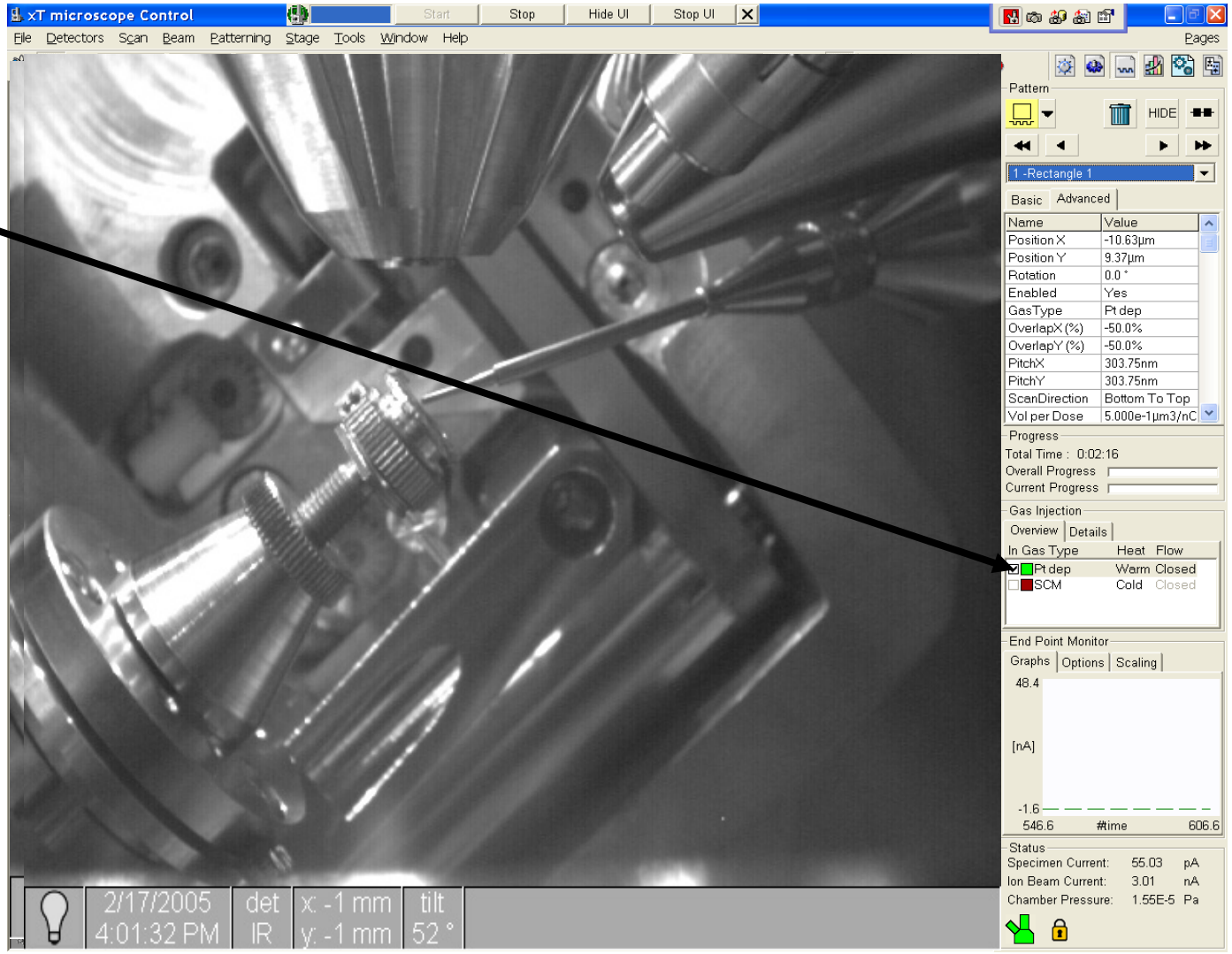
Film Deposition (Pt)-Warm up the Pt Source

- Double click “cold” to toggle on “warm”
- -This heats the Pt. Gas deposition system.



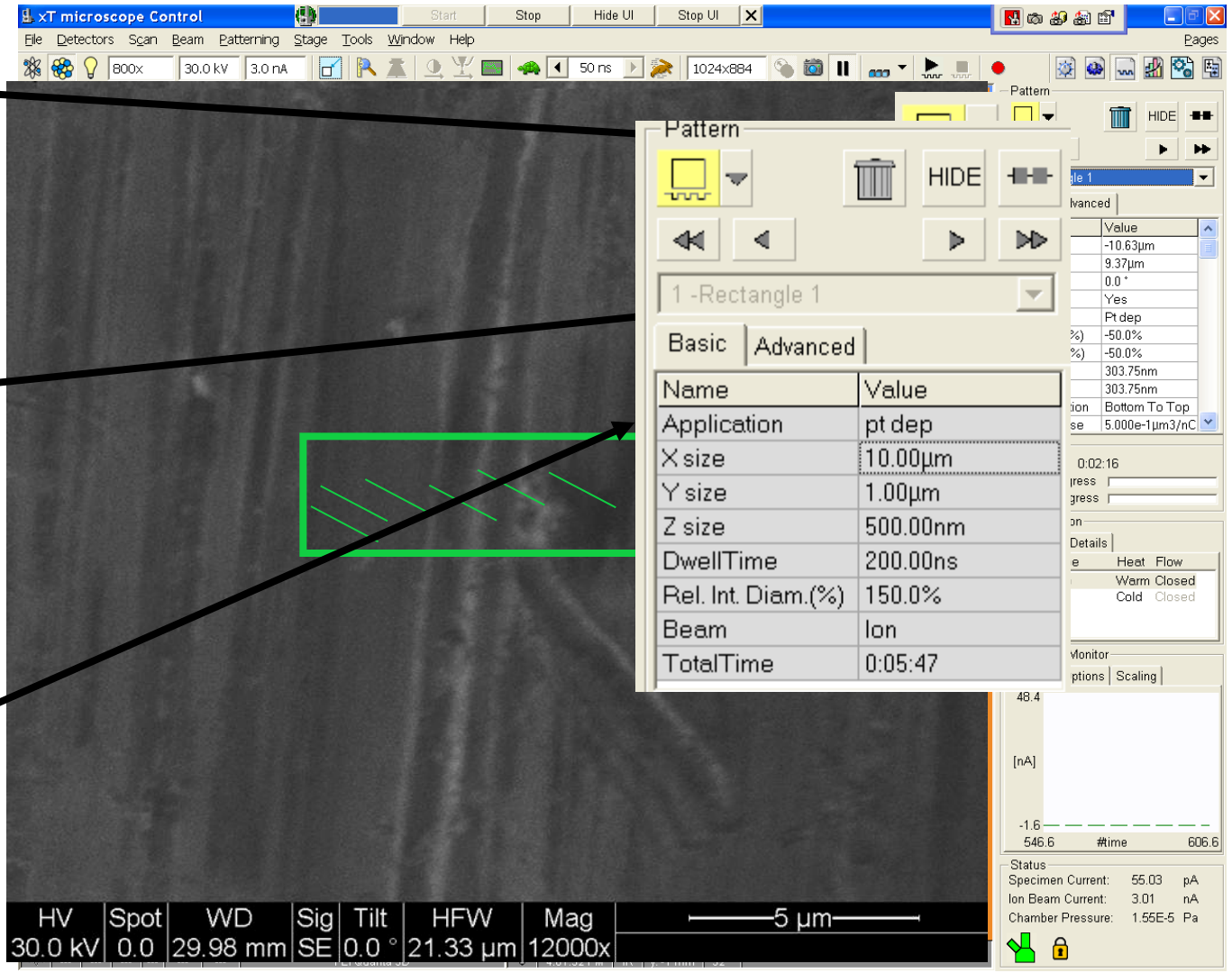
Film Deposition (Pt)-Insert Pt Gas Injector

- Click on click box under “In”, to inject the GIS needle
- Check Quad 4 to see that the needle appears to be inserted properly



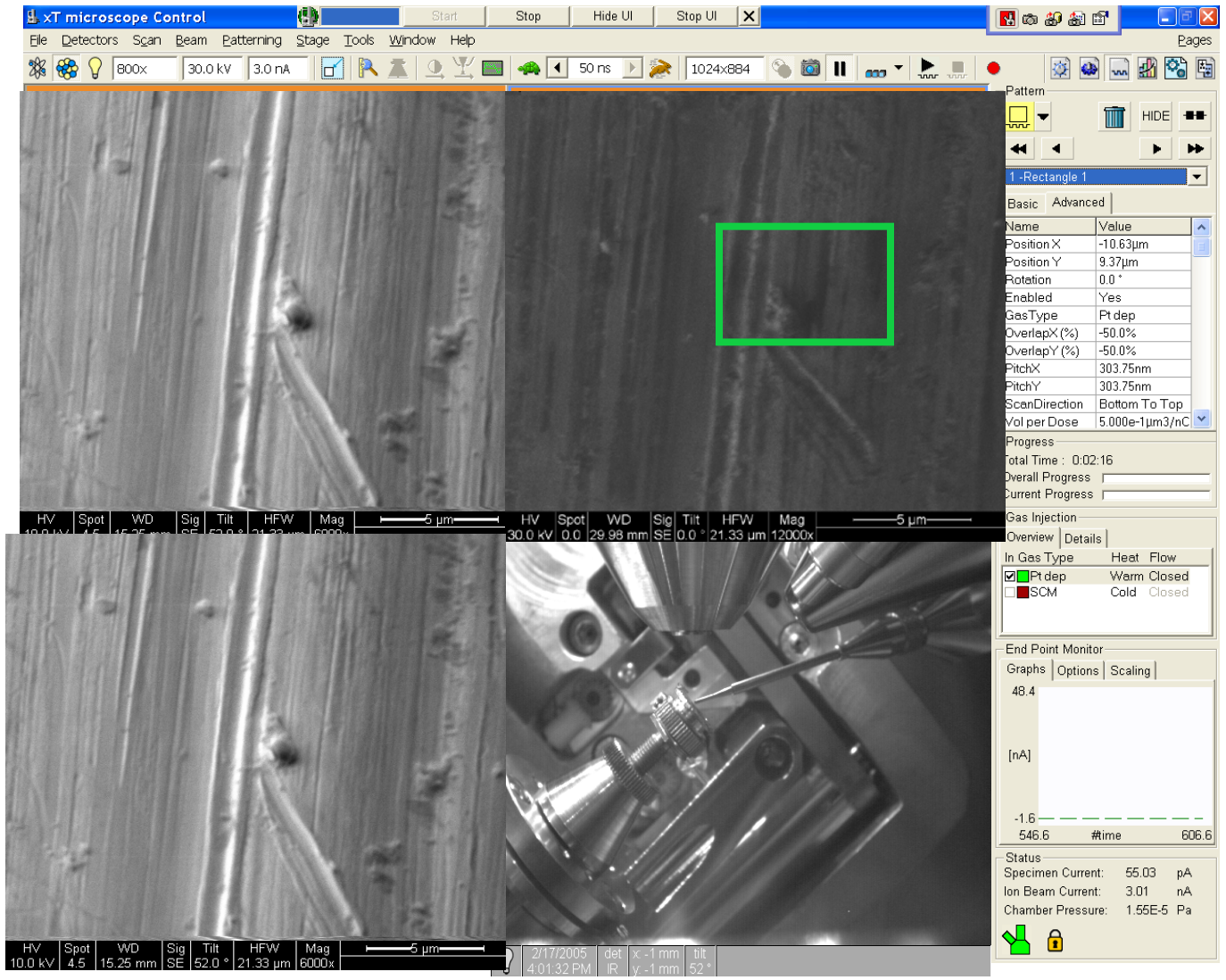
Film Deposition (Pt)-Define the Deposition Area

- Select “Rectangle”.
- Draw a rectangle on the frozen Ion image by clicking and dragging the left mouse button.
- Make the rectangle about 10 X 1 X 1 Micron in X,Y, and Z values.
- Increase mag so rectangle fills large fraction of screen
- Verify “Pt dep” is selected as application on the “basic” tab



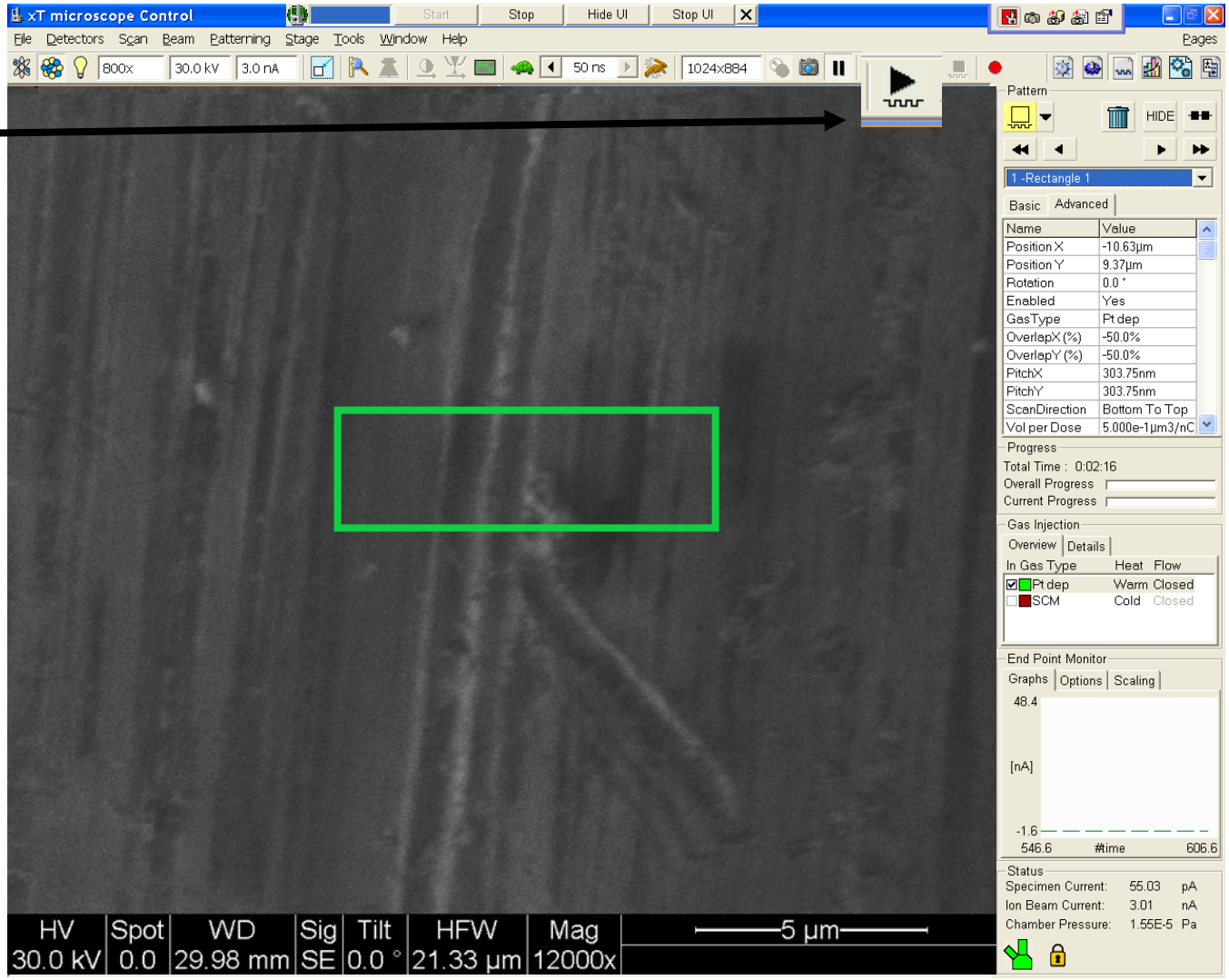
Film Deposition (Pt)- Deposition Condition Setup

- Set Ion current to 0.10 nA for dep.
- Un Pause and quickly focus, if a “Beam Shift” is necessary, move image so that it is still aligned to SEM image.
- Re-alignment of the deposition pattern box may also be necessary.



Film Deposition (Pt)-Start Deposition

- Start the Dep by clicking the “Start” icon
- Note the various parameters in Pattern menu. These will become more important to you later, but its good to get exposed now, while you are waiting for a deposition.

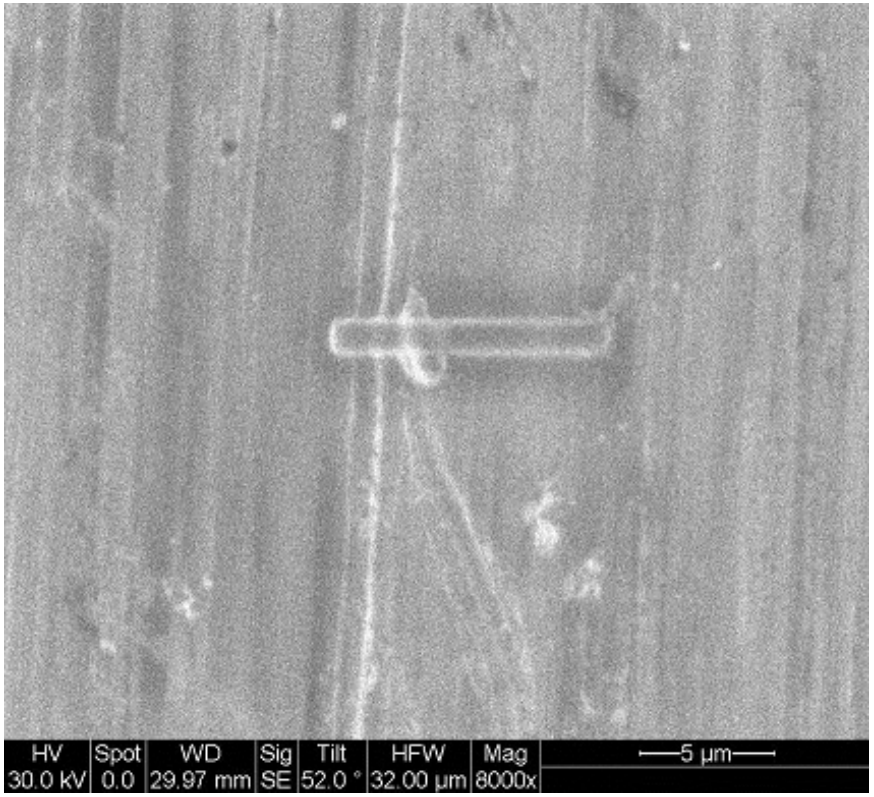


Film Deposition (Pt)- Deposition Progress Check

- You may take a quick peak at the depositions, as it progresses by using the “Snapshot” feature.
- - Enable Quad 1
- - Click on the “SnapShot” icon

Film Deposition (Pt)- Images of Deposited Film

Electron beam image

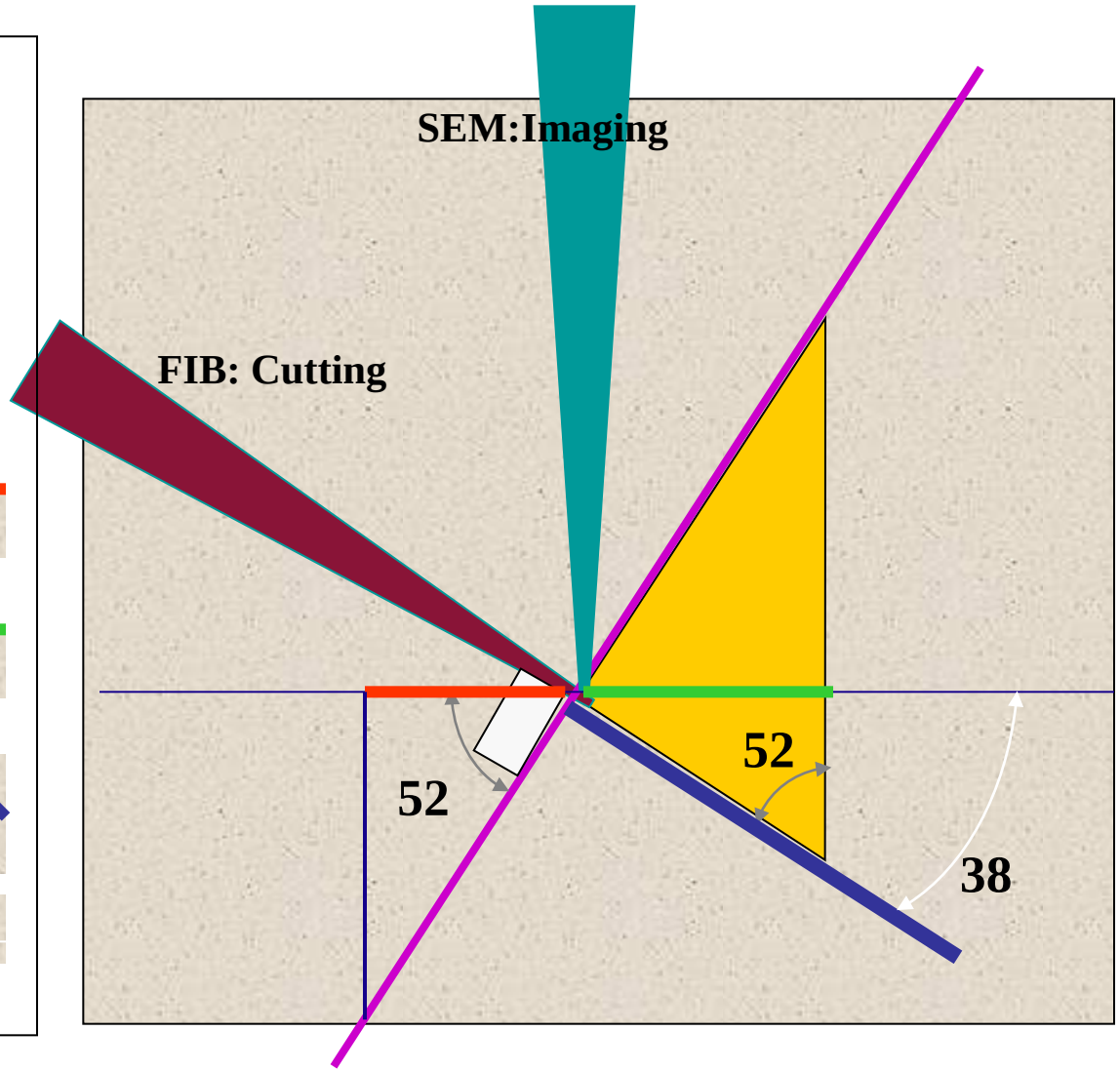


Ion beam image

Ion Milling

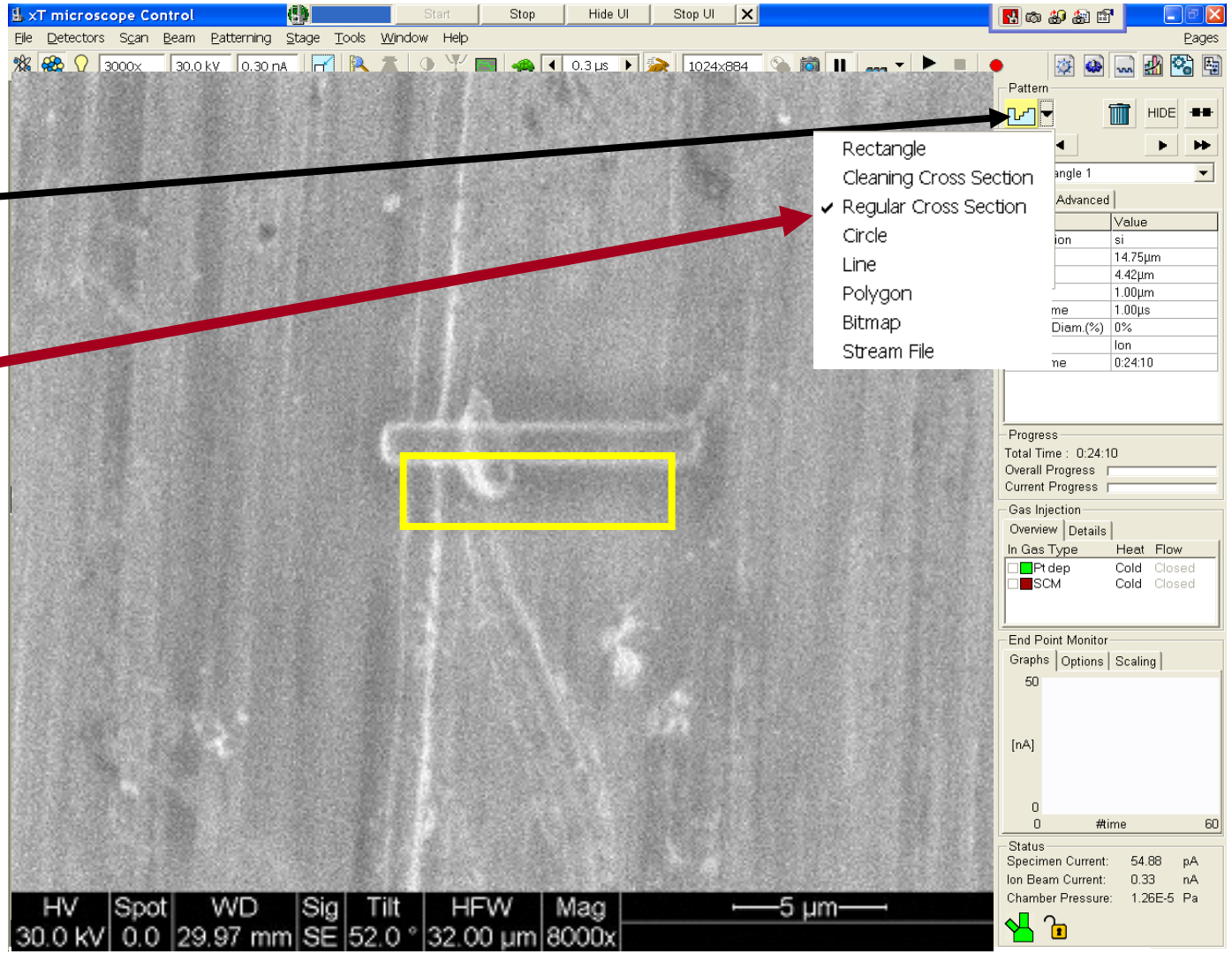
Key

- Metal deposition
- SEM
- FIB
- Sample plane
- Cross section
- Projection of sample plane to SEM image plane
- Projection of cross section plane to SEM plane
- Cross section image surface
- Stage at 0°



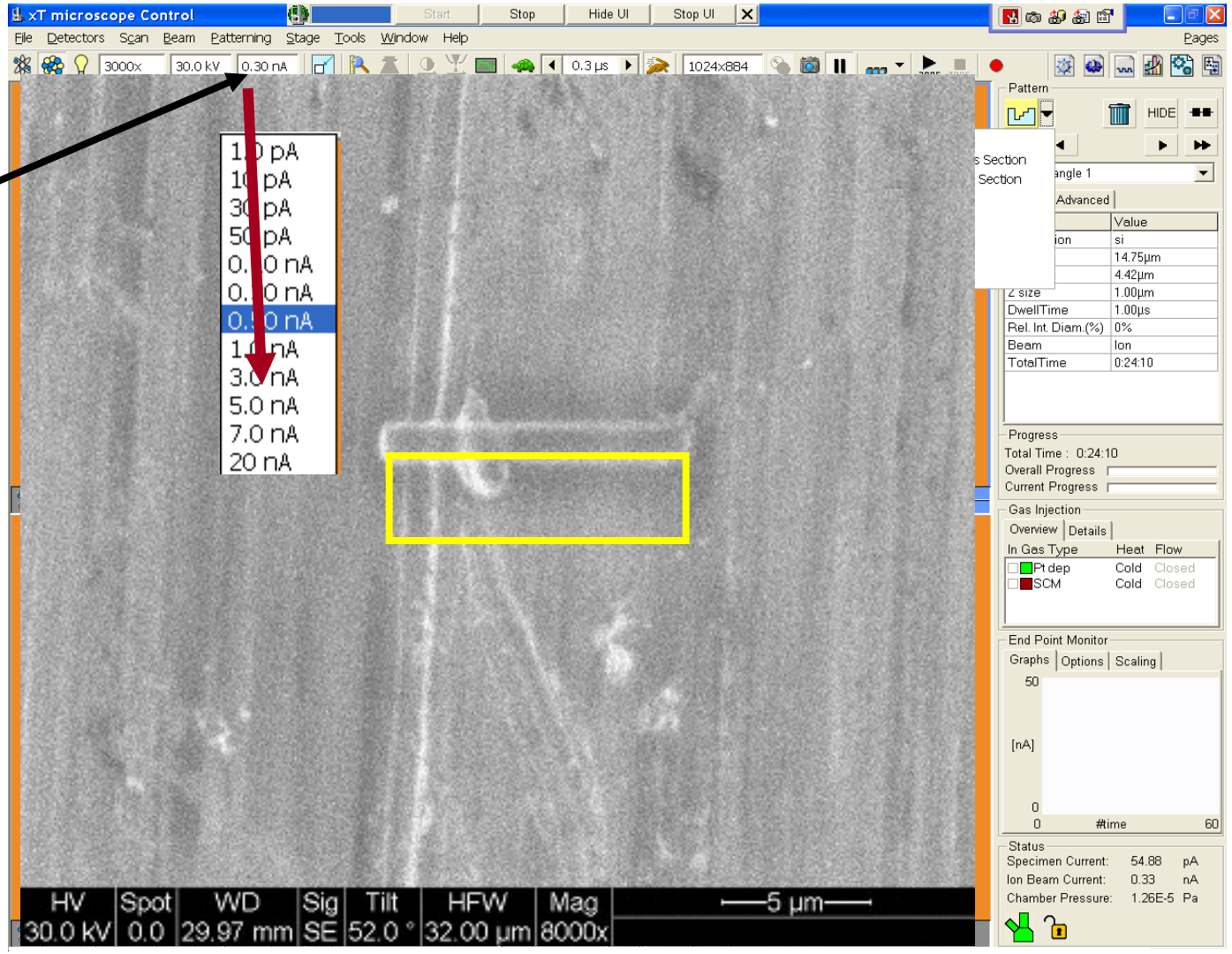
Ion Milling: Basic Step

- Start with “Regular Cross Section”
- Click and draw a rectangular box on the prepared sample
- Align the rectangle just below the Pt.dep area
- Set “Application” to “Si”, as default cutting parameters



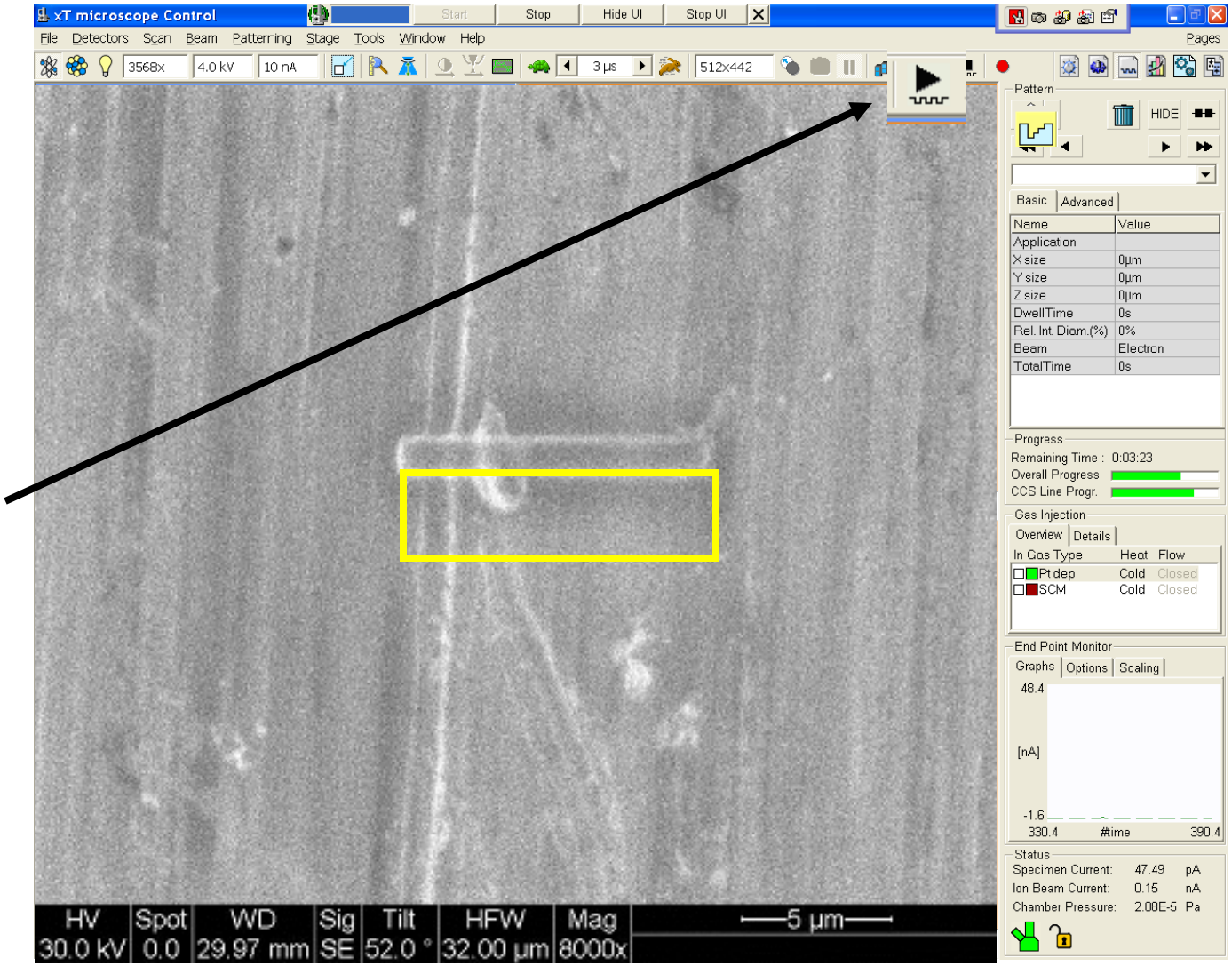
Ion Milling: Ion Beam Setup

- Increase the ion beam current to 5 nA
- Quickly scan and focus (you are milling as you scan)
- Pause as soon as the image is in focus
- Re-align the milling pattern if necessary on the frozen image



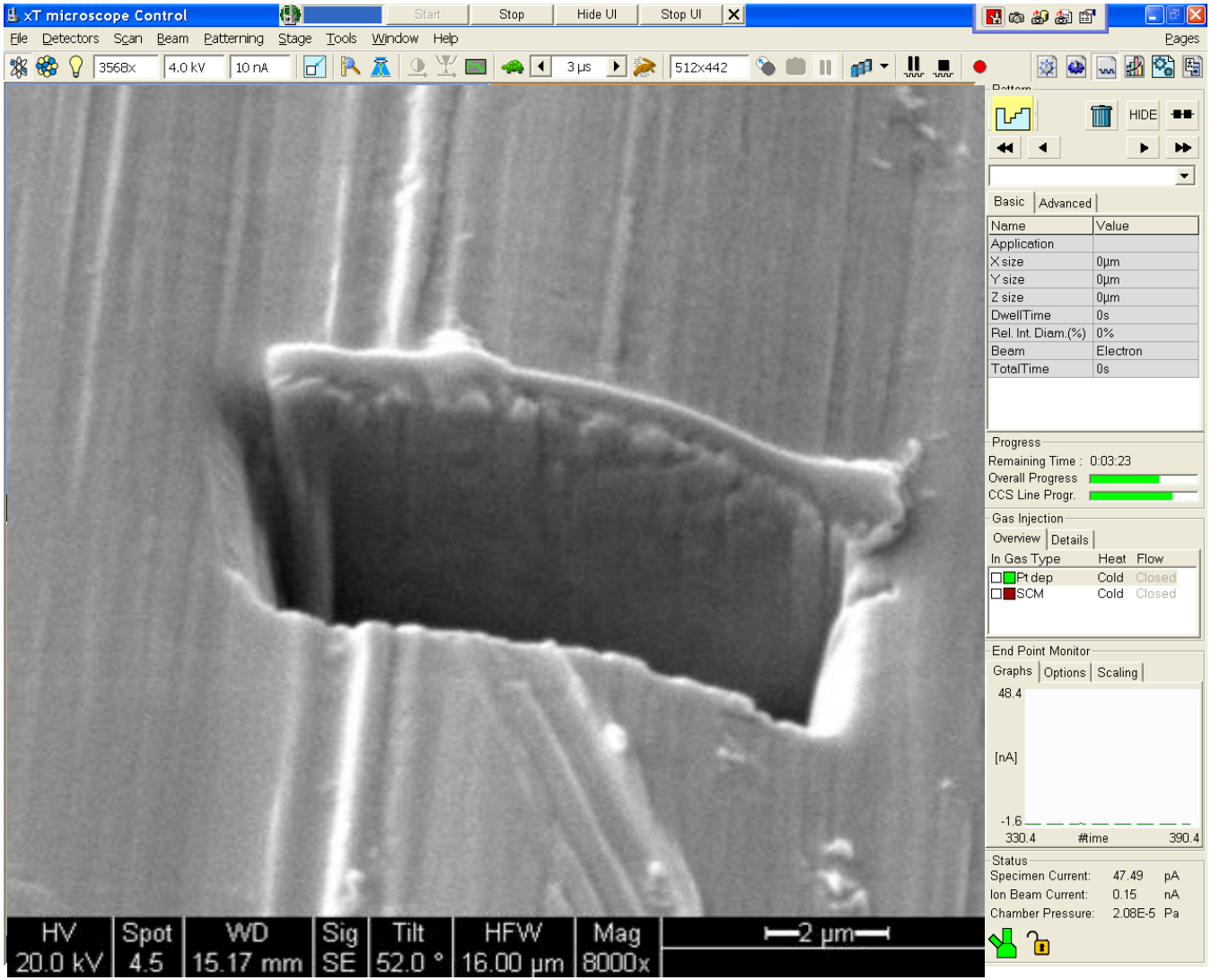
Ion Milling: Milling

- Verify that the rough cross section is 10 X 4.5 X 4 microns deep and aligned just touching the Pt. Dep pattern.
- Start Milling
- If you have a BSD, you may image live in Quad 3 as the sample is milled.



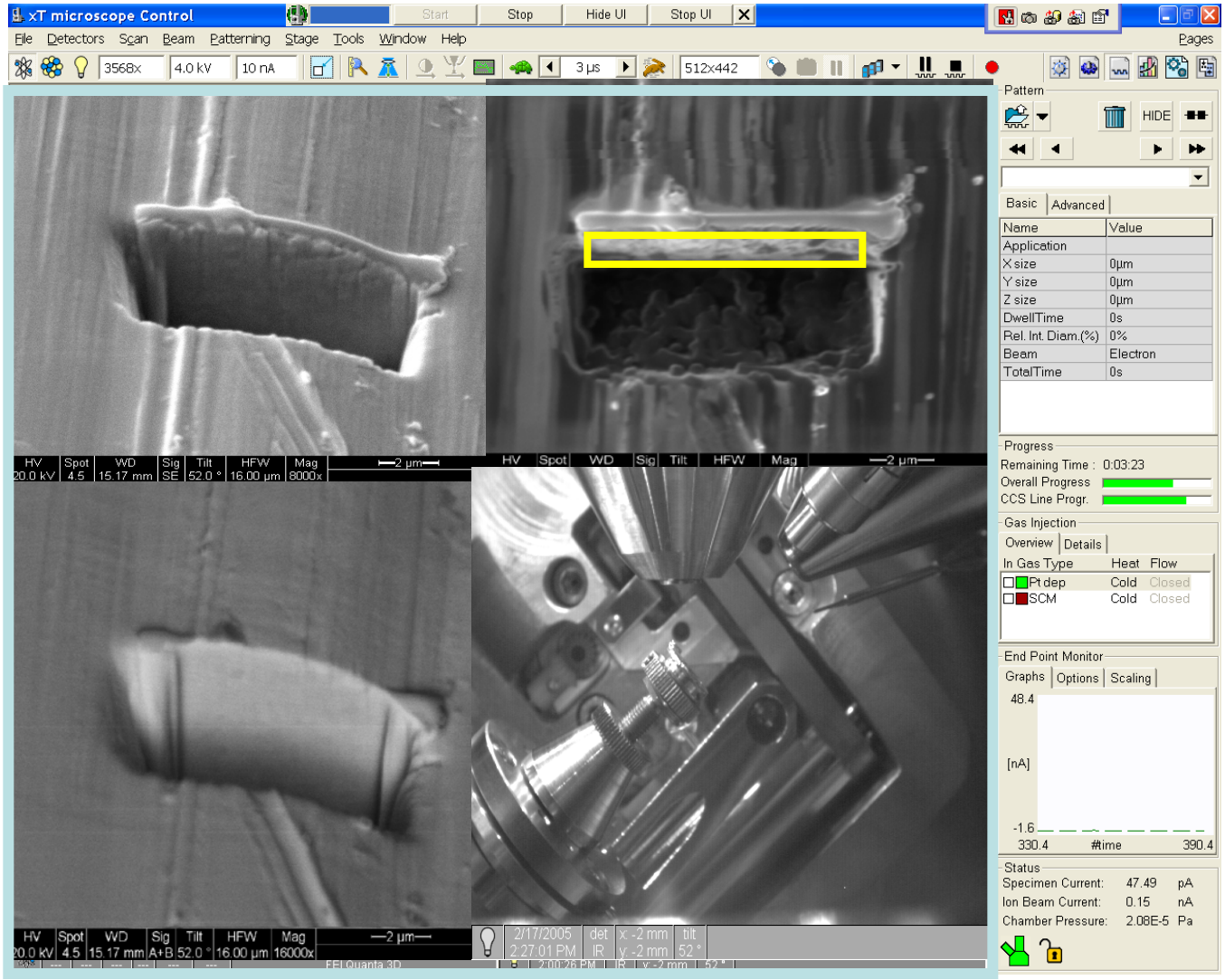
Ion Milling: Progress Check

- Milling has now started
- Note time remaining
- Take a break for that time period (tell your boss its an order)
- If you are curious, click on Quad 1 and then “snapshot”. That will give you a quick SE image of your milling progress



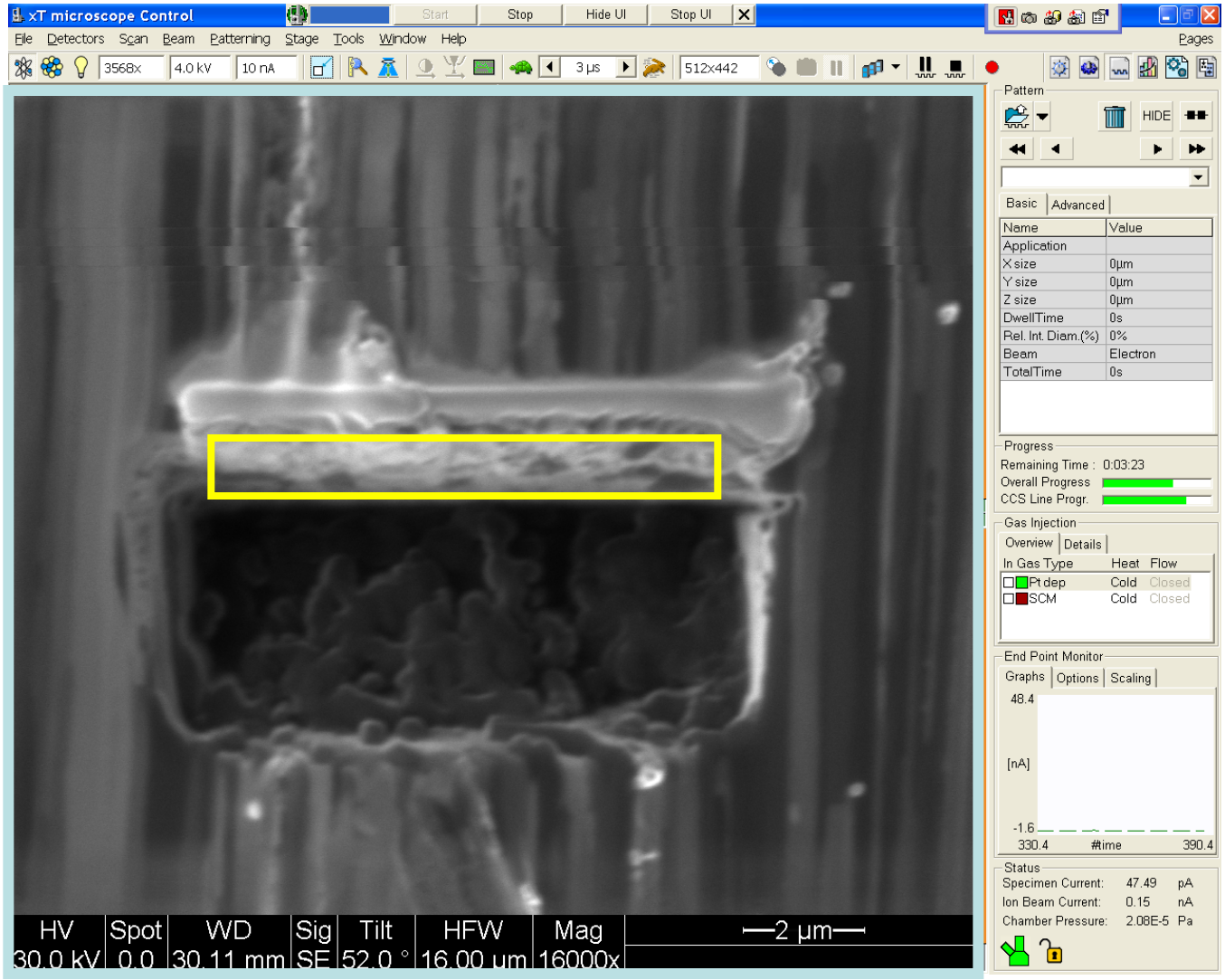
Ion Milling: Cleaning Cut

- View the rough cut with the SEM
- Click on Quad 2 and adjust ion beam current to 0.3 nA
- Select “cleaning cross section” pattern
- Scan and focus with the ion beam and then pause
- Redraw a smaller pattern on the frozen ion beam image
- Use a depth 1/3rd that of the regular cross section
- Start milling

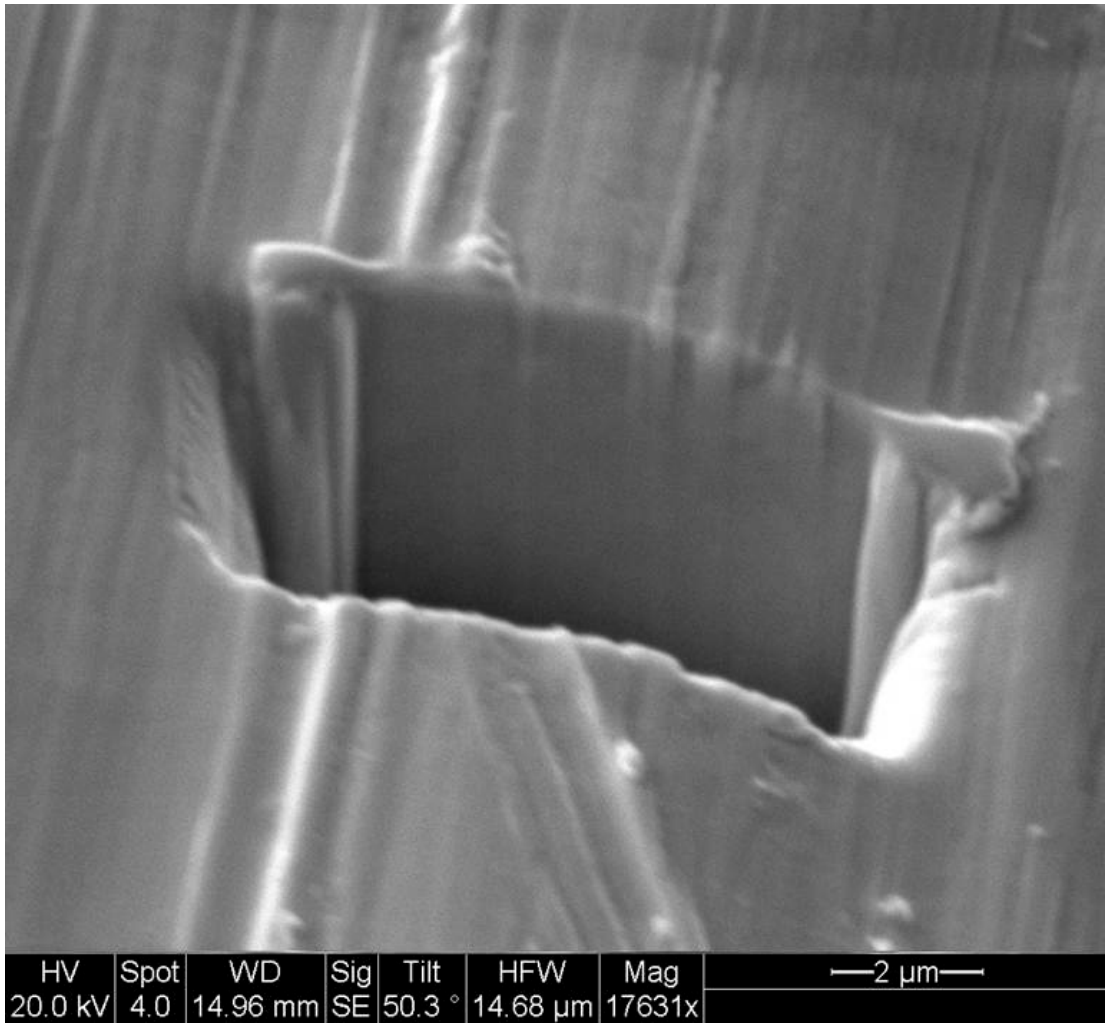


Ion Milling: Cleaning Cut

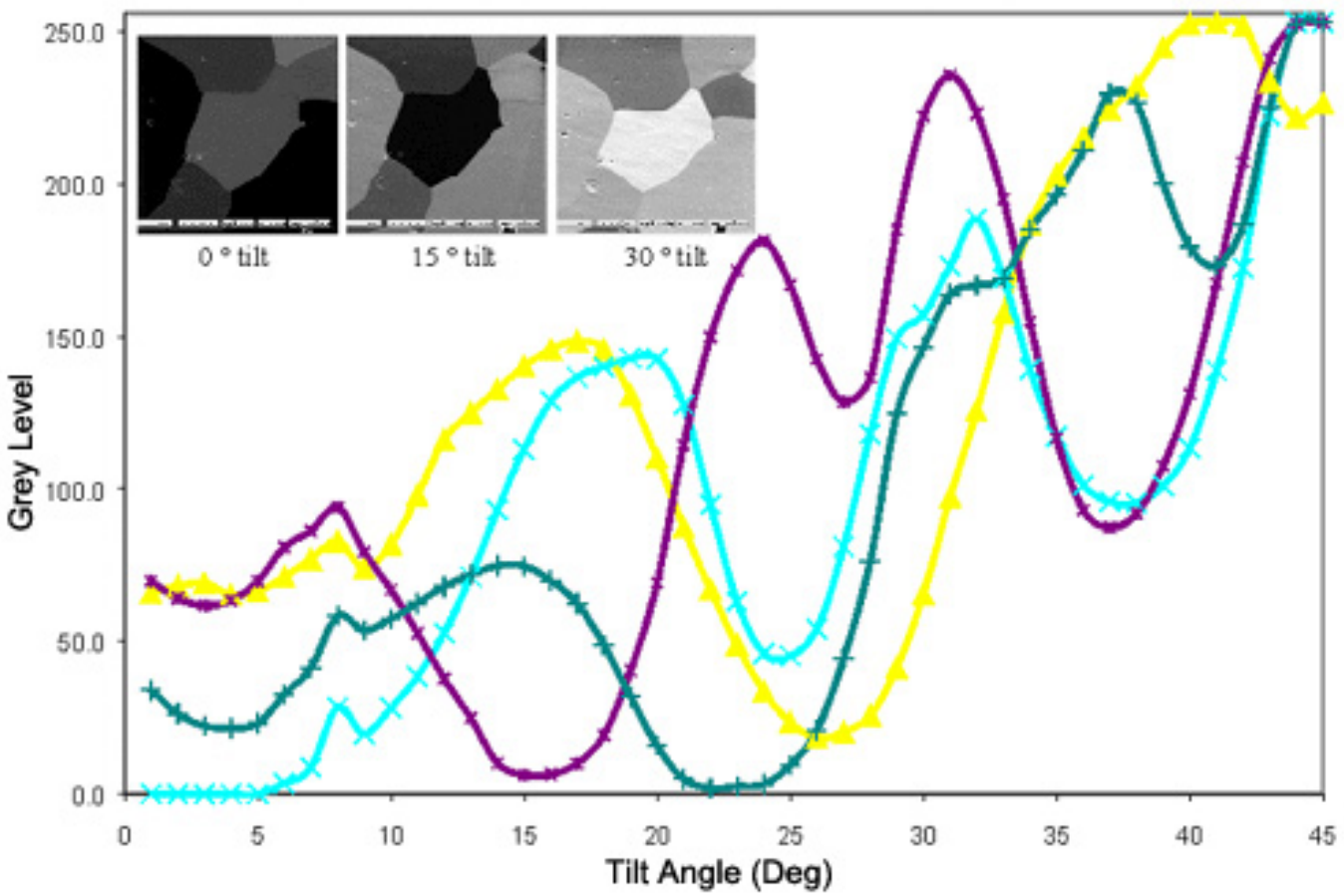
- View the rough cut with the SEM
- Click on Quad 2 and adjust ion beam current down to 50 pA
- Select “cleaning cross section”
- Scan and focus with the ion beam and then pause
- Redraw a smaller pattern on the frozen ion beam image
- Start milling



Ion Milling: SEM Image of the Cut



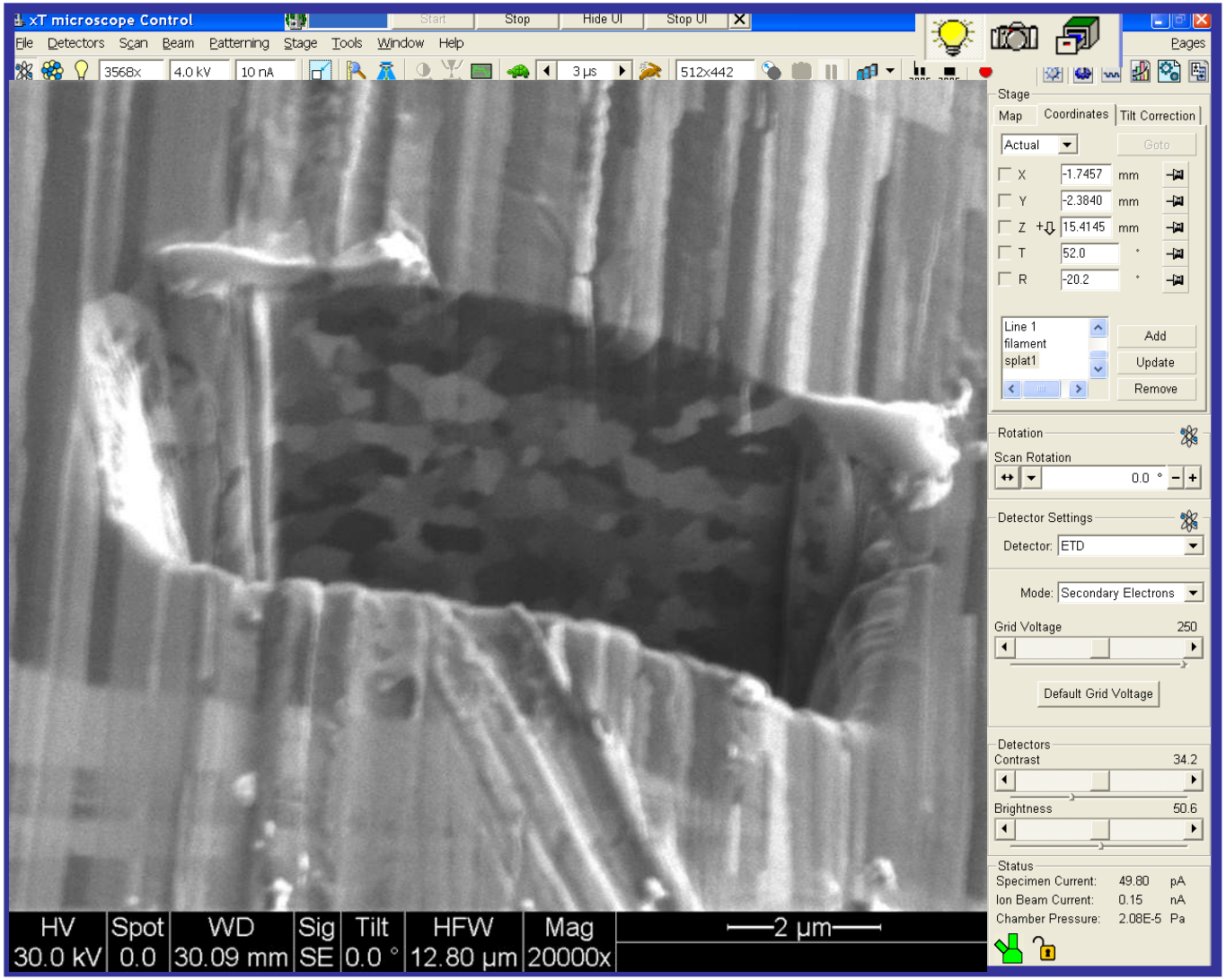
FIB Grain Contrast



FIB is more than four times as intense as that produced by backscattered electrons in the SEM, and results in spectacular grain contrast, as can easily be seen in the FIB image of aluminum grains in the image.

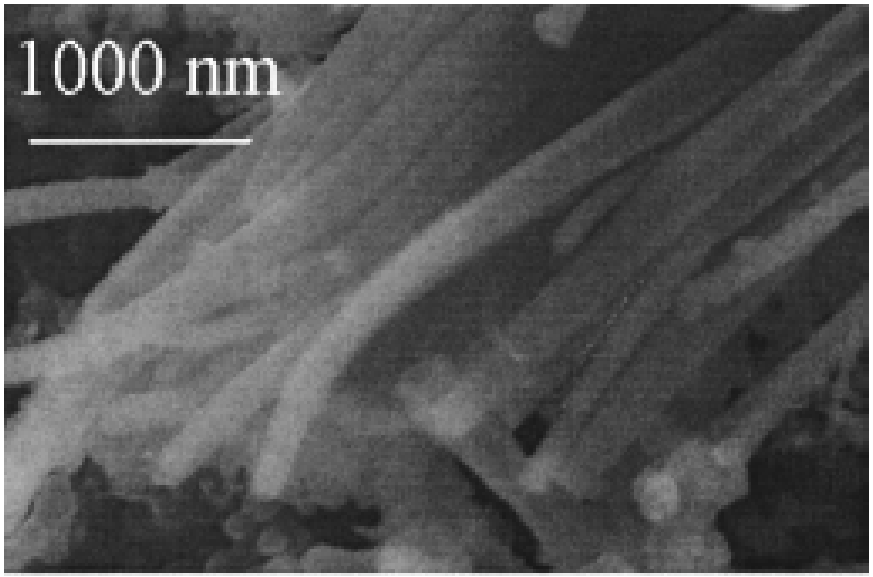
http://www.fibics.com/fib/tutorials/Grain-Orientation-Contrast/6/

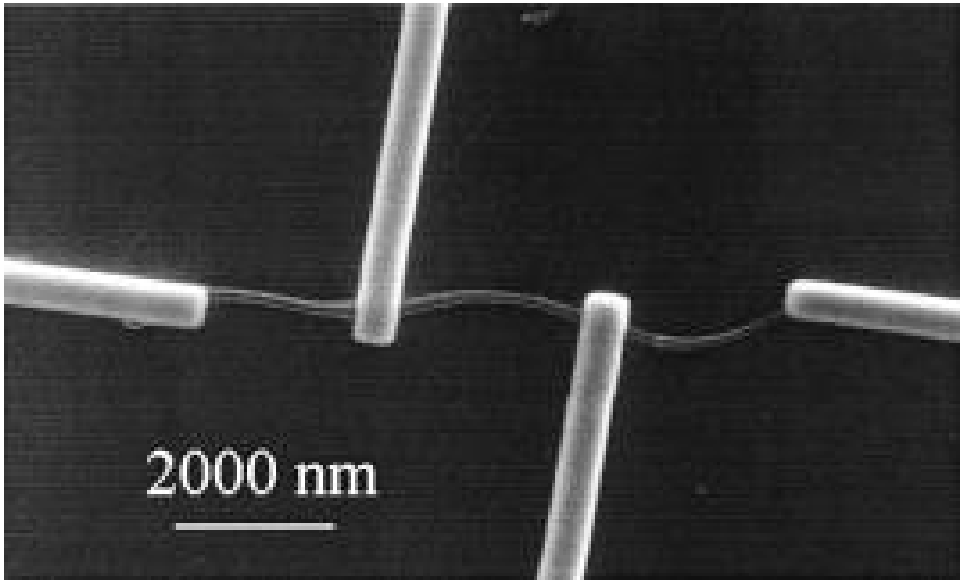
FIB Grain Images: W filament



FIB Applications

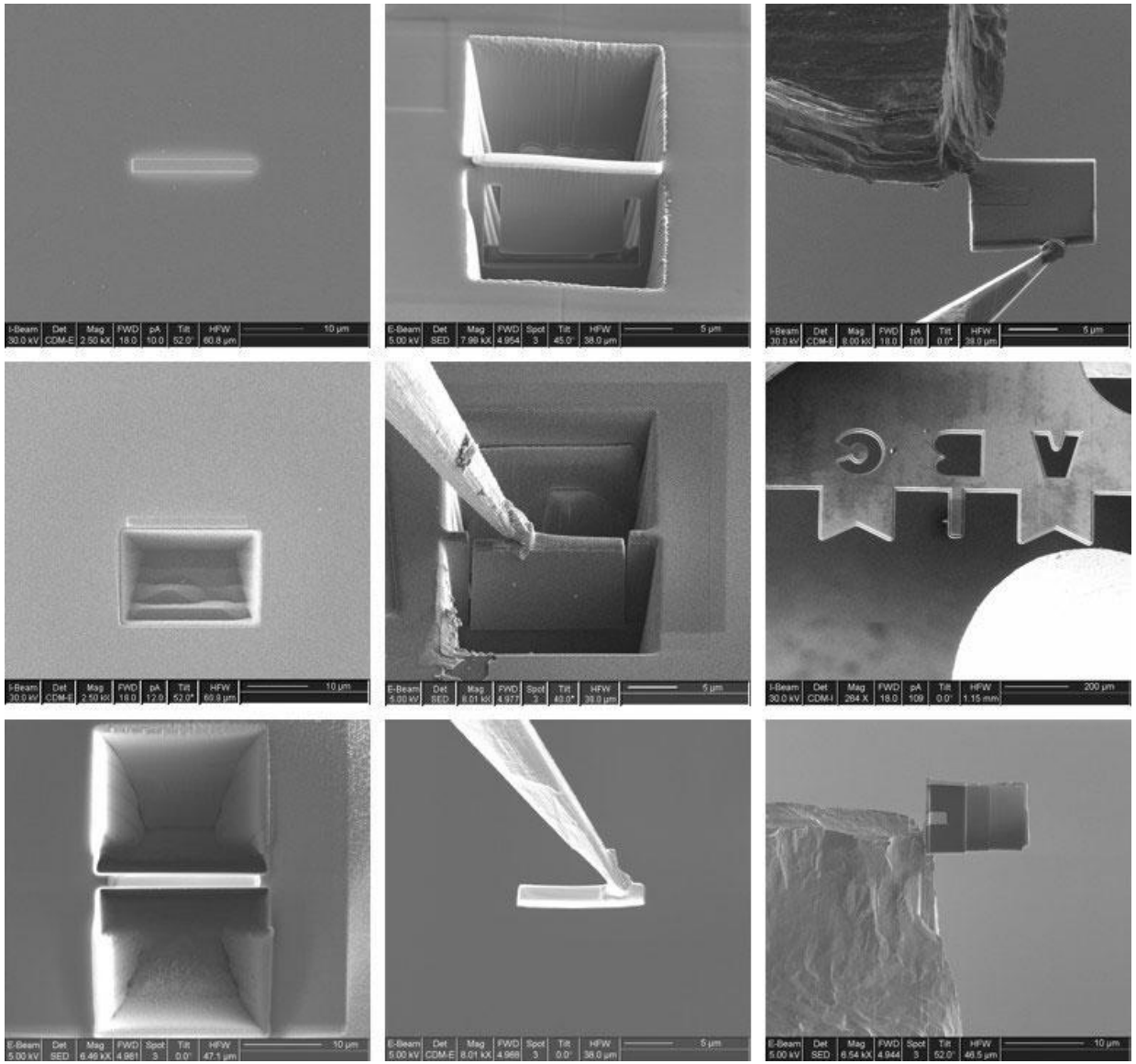
Electrode Formation for Nanowires





Y. Long et. al, Appl. Phys. Lett. (2003)

Cross Sectional TEM Sample Preparation



http://www.pdx.edu/cemn/fib-gallery