Focused ion beam

Introduction

Version 7 – May 2023

PART II – BASIC MILLING CONCEPTS

Universal rules

Rule 1: don't touch a control if you are not sure of the outcome of that action

Rule 2: never, ever force anything beyond finger strength

Rule 3: wear gloves when touching anything that goes into the chamber

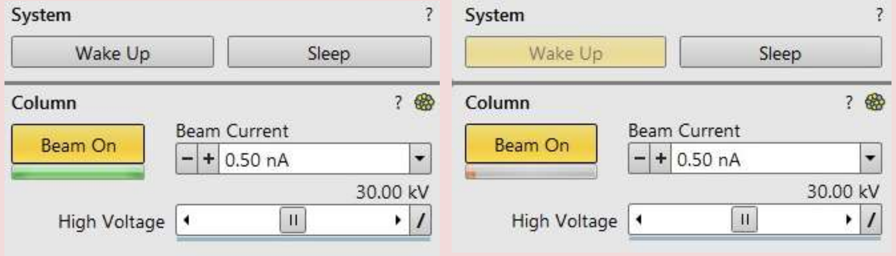
Rule 4: if in doubt, ask for help

Experiment: Shutdown

1. Electron beam and ion beam: same procedure as standby (see above)

2. Sleep

Click the sleep button in the System menu, just above the Column window.



The green bar below the Beam On button of the ion beam turns yellow, then red and reduces in size.

Demonstration: Finishing your session

Prerequisites:

Data recorded

Concepts of shutdown and standby

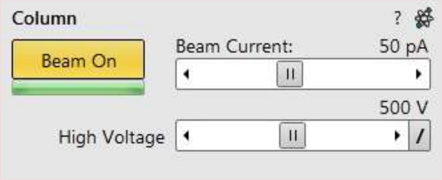
As a rule of thumb SHUTDOWN: when FIB is not in use for 2 nights or more (36h)
STANDBY: when the FIB will be used again within 36h

Experiment: Standby

1. Electron beam

Select the electron beam quadrant (top left)

In the Beam control > Column. Click the yellow button "Beam On"



Beam Current: 50 pA

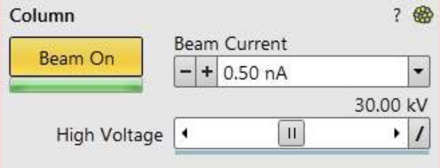
High Voltage 500 V

← This icon symbolizes electrons

2. Ion beam

Select the ion beam quadrant (top right)

In the Beam control > Column. Click the yellow button "Beam On"



Beam Current 0.50 nA

High Voltage 30.00 kV

← This icon symbolizes ions

Demonstration: Login onto the FIB software

Prerequisites:

Running xT server
Running UI

Action:

Login using your FIB account

Load the personal settings and history of the user

Experiment

After startup of the UI, a username and password are requested.

vanhecke

Username: your last name, no capitals, no accents, umlauts, etc.
Password: your first name (no capitals, accents, umlauts, etc.)

Click logon

For the training with the FIB:
Training2, training

Demonstration: Making a cross section using EDX

Prerequisites:

Eucentric height, beam focused, 7mm working distance
Coincidence point set
Ion beam and e-beam aligned

Produce a cross section

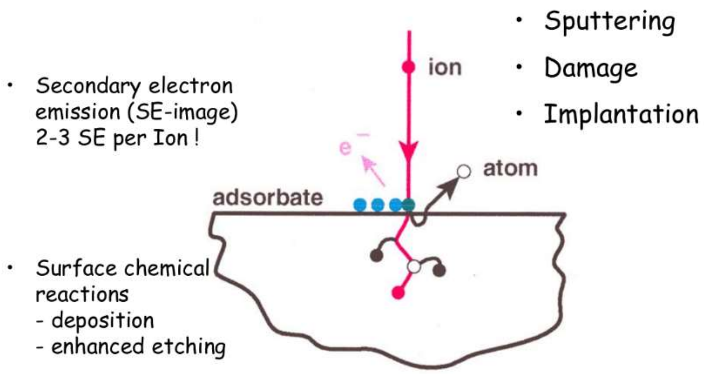
Experiment: EDX on a cross section

- Adjust the formula for Y: $Y > 3 \times Z$ (or more). Because BSEs produce X rays in the gap.
- make a second bulk milling on the right side of your ROI to avoid shadowing. You will end up with an L-shaped gap (below and on the right of the ROI).
- Be careful with the interpretation: the imaging is from under an angle, which means that shallow layers may overlap.

Experiment: Imaging

- Go to a very low ion beam current (10 pA)
- Switch to OptiTilt and use T1 and T2.
- Press F9
- Curtaining issues: Do not use the ETD, since curtaining is the strongest in that detector.
- Lower beam currents: more focused Beam, but more curtaining.
- To image the object:
    * Go to 0° tilt
    * rotate the stage 180°
    * scan rotate 180° (use SHIFT F12)

Material	Sputterrate [µm³/nC]
Si	0.27
Thermal Oxide	0.24
TEOS	0.24
Al	0.3
Al2O3	0.08
GaAs	0.61
InP	1.2
Au	1.5
TiN	0.15
Si3N4	0.2
C	0.18
Ti	0.37
Cr	0.1
Fe	0.29
Ni	0.14
Cu	0.25
Mo	0.12
Ta	0.32
W	0.12
MgO	0.15
TiO	0.15
Fe2O3	0.25
Pt	0.23
PMMA	0.4

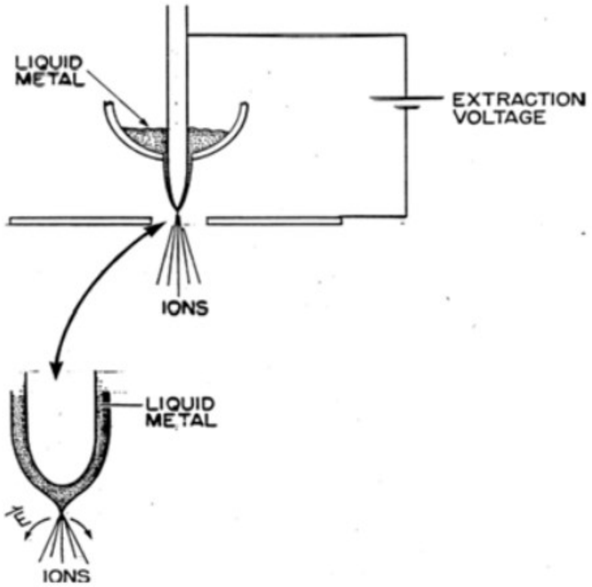


Demonstration: The LMIS (liquid metal ion source)

Prerequisites:

Running xT server
Running UI

Background on the ion beam

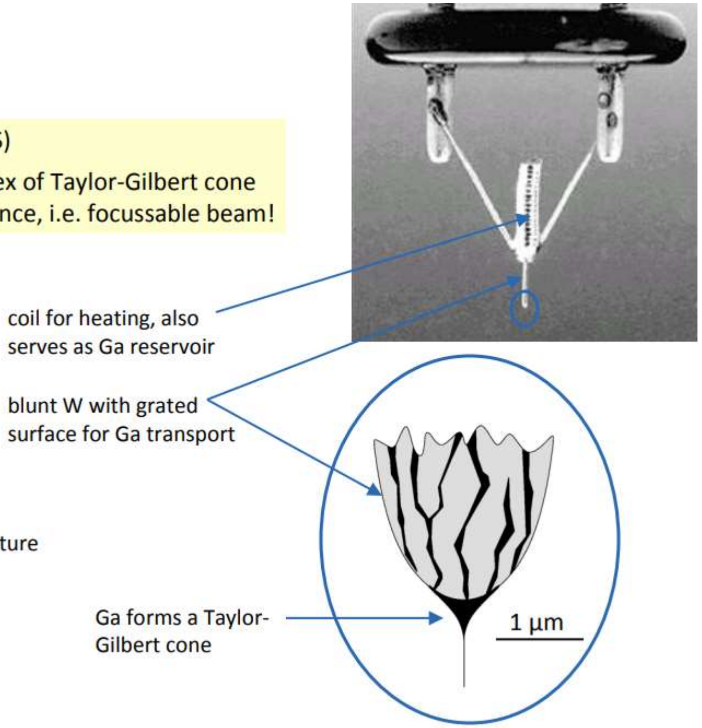


Electrons	Ions
very small	Big ->outer shell reactions (no x-rays)
inner shell reactions	High interaction probability
High penetration depth	less penetration depth
Low mass -> higher speed for given energy	High mass -> slow speed but high Momentum -> milling !!! Ions can remain trapped -> doping
Negatively charged	Positively charged
Magnetic lens (Lorentz force)	Electrostatic lenses

1. Ga⁺ source: LMIS

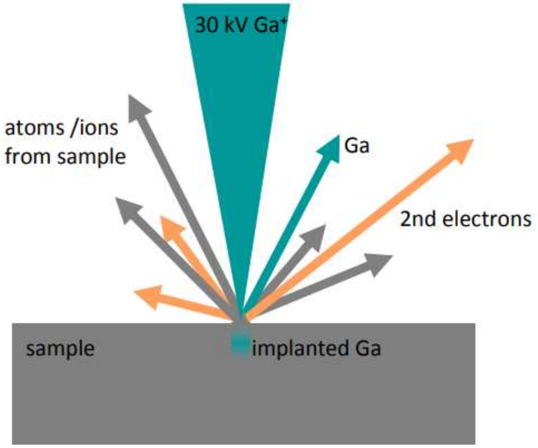
Liquid Metal Ion Source (LMIS)

- Ga beam formed at the apex of Taylor-Gilbert cone
  → very high spacial coherence, i.e. focussable beam!



Why Ga?

- melting point at 30 °C
  → liquid around room temperature
- low steam pressure
  → applicable in HV
- $[Ga^{2+}]/[Ga^{+}] \sim 10^{-4}$ at 10 µm
  → narrow energy distribution



Ga⁺ beam hits substrate and yields

- secondary electrons
- sputterd atoms and ions
- implantation of Ga
- amorphisation /recrystallization

3 FIBing "modes":

- imaging, milling and deposition happen simultaneously
- ion current + atmosphere
  → pronounce one aspect!

Remarks.

i) Implantation and amorphisation also occur at grazing incidence.
ii) Depth of damage layer depends also on energy of Ga⁺.

- Impinging Ga⁺ always mill a little bit and produce secondary electrons
- Sample surface is damaged more with increasing Ga⁺ exposure

Experiment: Polishing

- Set a tilt angle to correct for the beam shape: somewhere back 0.5-1.5° (i.e. between 50.5° and 51.5° absolute angle). The higher the current, the higher the correction angle
- refresh the ion beam image (F9)
- place a **cleaning cross section** between the Pt deposition and the edge (or a little bit over it) of the hole the step before made. place is just a little bit into to Pt (is this correct?). Width of the section: about as wide as the Pt deposition
- go two steps back in beam current (in the list)
- Z: 1/4 of the previous setting. If it was 1000 nm in the regular CS, set it to 250 nm now.
- You can use the iSPY: this will stop the patterning temporarily, make a SEM image and continue

This is important!

too much current and you will mill instead of deposit

Too less current will destroy your vacuum

- You should get a time round 3-5 minutes
- Insert the Pt GIS
- Press F9 in the ion image (this will contrast/brightness correct and take a snapshot). Make sure you have the ETD selected
- Check the position of the rectangle, overlay the e-beam deposited marker.
- Run the deposition
- retract the GIS needle

Experiment: Bulk mill

- Use the **regular cross section** (RCS) pattern (not a cleaning cross section). Position it just below the Pt deposition you just made with the Ga beam
- Place the RCS pattern a bit wider than the Pt deposition marker (about 10-20%) and not exactly touching the Pt above it. The pattern is yellow
- Is the application: Si multipass
- determine / decide on the depth (e.g. 5 µm)
- calculate the Y, with at least Y > 2 times Z. If you intend to do EDX, a factor of 3 is at least needed.
- Pick a Ga ion beam current to mill between 2-5 minutes (rule of thumb, no calculation needed).
- iSPI is possible. Use the brightness / contrast buttons on the physical control panel to adjust B/C, not F9

Demonstration: Switch the beams on

Prerequisites:

Sample loaded

Learn to switch e-beam and ion beam on

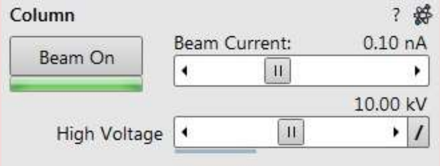
If the system is in standby, you will find the bar under the “Beam On” button green

Experiment

Select the electron beam quadrant (top left)

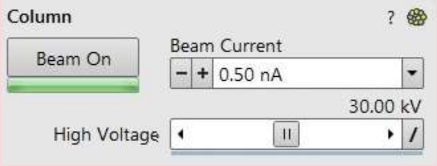
In the Beam control > Column. Check the bar under the button “Beam On”.

Repeat for the ion beam: first click on the ion beam quadrant (top right)



Beam Current: 0.10 nA

10.00 kV



Beam Current 0.50 nA

30.00 kV

Electron beam and ion beam both with green progress bars: **standby**.

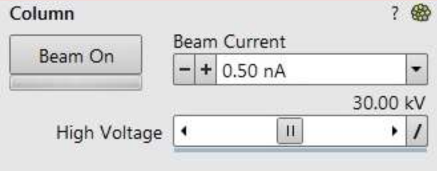
Click both Beam On to start the FIB

If the system is shut down, you will find the bar under the ion “Beam On” button Gray

Experiment

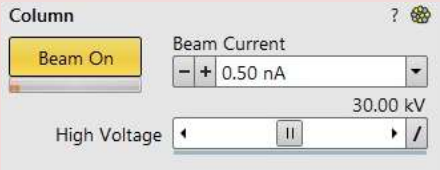
Electron beam: same as standby

Ion beam: the progress bar will be gray. Click the Beam On.



Beam Current 0.50 nA

30.00 kV



Beam Current 0.50 nA

30.00 kV

The gray progress bar will turn red then orange then yellow, while progressing.

It will take about 15 minutes to startup the ion beam.

Demonstration: e-beam Pt deposition

Prerequisites:
Sample loaded
Electron beam on
Eucentric height, focused, WD=7mm

Learn to deposit Pt using the e-beam

Pt deposition using the e-beam marks is used to ensure a proper beam coincidence point setting if no landmarks are available.

IT IS CRITICAL TO BE AT 7 mm WD, IN FOCUS at at eucentric height

Experiment

Make sure your sample is at eucentric height, focused and the WD=7 mm. Hit CTRL+f
Under Patterning > chose a rectangle. Set e.g. 5 µm x 5 µm, deposit using the Pt application (PT_EBID)

Patterning settings
- XYZ: 5µm x 5µm x 0.5µm
- 15 µs dwell time
- Application Pt_EBID (e beam induced deposition)

Microscope settings (might slightly vary on your sample):
- Standard mode
- Magnification: 2000 X or higher
- Acceleration voltage: 5 KV
- Beam current: set until time is 3-5 minutes.

Click start patterning
Note: e- beam deposition is soft and slow, iSPI is not possible
When finished: retract the GIS needle. Hit F9. remove the pattern.

- Patterning settings:
    * set X, Y: 20µm x 2µm
    * Z = 500 nm
    * Set the current to get a estimate time of 5-7 minutes
- Click start patterning

Note: e- beam deposition is slow, iSPI is not possible

- retract the GIS needle. Hit F9. remove the pattern.

Experiment: setup beam-coincidence point

Set the BCP. You may use the deposition from the step before as a marker.
CTRL + i (will tilt to 52° – ion beam)
CTRL + e (will tilt to 0° – electron beam)
Align the e-beam to the ion beam precisely.

Experiment: ion beam Pt deposition (NOT OPTIONAL)

Pt deposition with the Ga ion beam (in the **Ga ion image**)

- First glance: Do not make an image with the Ga ion beam!
- Draw a rectangle in the Ga ion image with the patterning tool (e.g. 20µm x 2µm)
- z= about 1 µm
- select Pt dep (not Si) in the application
- calculate the Ga current required using the magic number 6 (pA/µm2).

$$Current\ (pA) = X(\mu m) \cdot Y(\mu m) \cdot 6\ (\frac{pA}{\mu m^2})$$

* e.g. 10 µm x 4 µm x 6 = 240 pA

* Use this value and chose the closest current for the Ga beam

Demonstration: Making a cross section

Prerequisites:

Eucentric height, beam focused, 7mm working distance
Coincidence point set
Ion beam and e-beam aligned

Produce a cross section

Experiment: preparation

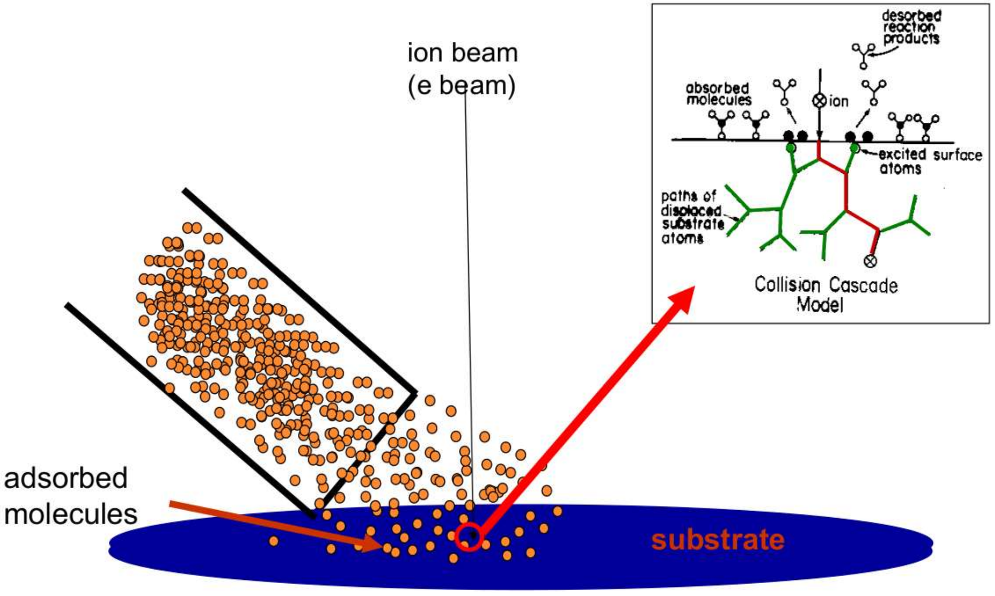
In the electron beam (0°)

- Proper imaging setting, magnification: sufficient (1500+ X)
- Focus the region
- Link the stage
- Go to 7 mm WD (at 0 degree)
- Set eucentric (CTRL+F)

Make 100% sure you are in focus, eucentric and at 7mm. Incorrect settings will damage the instrument

(Optional) experiment: protect the ROI using e-beam Pt deposition

- Insert the GIS needle
    - * If it drops a shadow on your image: Press F9
    - * If the needle is visible: increase magnification
- Select a rectangle and draw a pattern in the e-beam quadrant.
- As application, choose Pt_EBID (E beam induced deposition). The rectangle should be green
- Microscope settings (will obviously vary depending on the sample)
    - * Standard mode
    - * 2000 X (or higher)
    - * 2 KV
    - * 1.6 nA beam current (to start with, see below)



Demonstration: Beam coincidence point

Prerequisites:

Sample loaded
Electron beam on
Eucentric height, focused, WD=7mm

Set the beam coincidence point

A proper beam coincidence point is crucial to use the FIB beam. A proper beam coincidence point assures that the FIB beam is focussed on the SEM image.

Experiment

Reset beam shift

- Beam > beam shift > right click > reset

Landmark definition

Search for a landmark in your SEM image and center it at the yellow cross (if there is none, get one in the overlay)

- Focus if needed
- Link the SEM image
- CTRL + f to set to eucentric height
- Update the working distance to 7 mm

- Magnification: around 5000 X, 5 kV, 0.4 nA

Activate the overlay crosshair

- View > center cross (or shift + F5)

Tilt the stage

- Tilt the stage about 5°. Move your landmark back to the middle:

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2. Insert the STEM detector

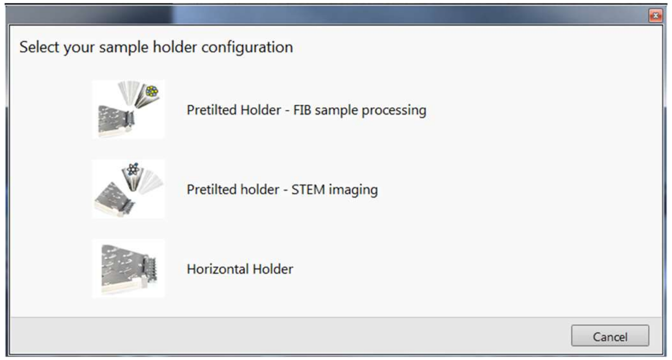
Doublecheck in the chamber view if the path below the stage is free.
Doublecheck you are in focus, at 7mm

Experiment: insert the STEM detector

In the menu Detectors:

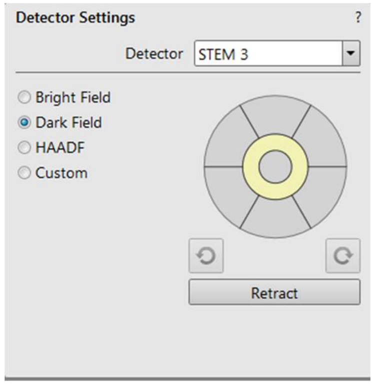
- Select the STEM3 detector from the dropdown list
- Click 'Insert”

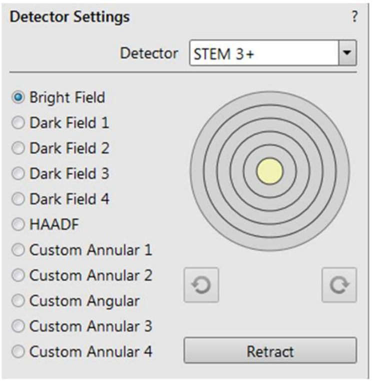
A window will appear:



Select the relevant option, i.e. the situation which describes the stage and the rowbar.

STEM 3 and STE3M+ allow to select different prats of the detector be active.





Demonstration: STEM imaging Demonstration

Prerequisites:

Eucentric height, beam focused, 7mm working distance
Coincidence point set
Stage tilt: 52°
Ion beam and e-beam aligned

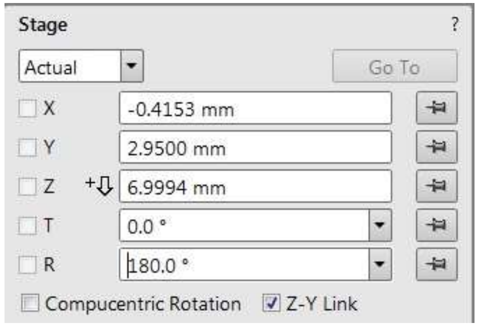
Use the STEM detector

Experiment: Link the stage (CRUCIAL)

In the electron beam (0°)

- Proper imaging setting, magnification: sufficient (>1500 X)
- Focus an area of interest
- Link the stage
- Go to 7 mm WD (at 0 degree)
- Set eucentric (CTRL+F)

1. Rotate the stage 180 degrees:



Stage

Actual

☐ X -0.4153 mm
☐ Y 2.9500 mm
☐ Z 6.9994 mm
☐ T 0.0 °
☐ R 180.0 °

☐ Compucentric Rotation ☑ Z-Y Link

→ In the CCD quadrant, hold the middle mouse button and move the mouse down to move the landmark down, up to move the landmark up (assure the SEM quadrant is live).

- Go in steps of 5-10° until you reach 52°. Always correct the vertical movements of your landmark as you go. Keep an eye on the stage in the chamber view: **do not touch the pole piece with the sample of the stage!**

Some notes:

- The intensity of the signal will increase as you tilt
- CTRL + e is a shortcut for T=0° (***e***lectron)
- CTRL + i is a shortcut for T=52° (***i***on)

Demonstration: Aligning electron and ion beam

Prerequisites:

Sample loaded
Electron beam on
Eucentric height, beam focused, 7mm working distance
Coincidence point set

Find where the ion beam and the electron beam meet

Important notice:

The ion beam will destroy your sample surface (unless it is protected by layers of Pt).
Do not continuously image with an ion beam!

Use low currents for imaging! (30 pA or lower)

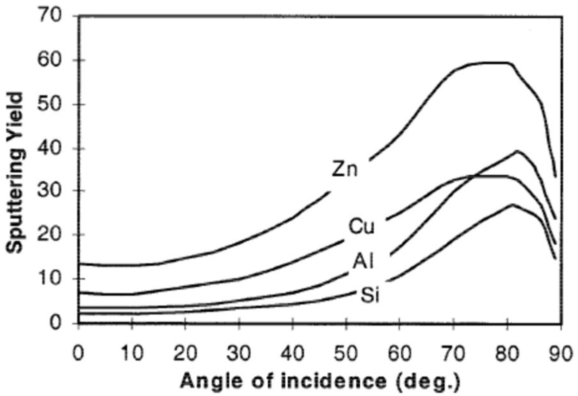
Use single image only

Experiment

Align the FIB image

- Image with the Ga ion beam:
    - use a low beam current (10 pA or about), 30 kV
    - Zoom out to a magnification below what you had in the electron beam.
    - Press CTRL + f. Assure the working distance is 19 mm
    - press F9
    - Assure you have low current, dwell times below 1 µs, live camera settings. Then press F6 and press F6 immediately again (will record 1 image)
    - Find an object that is present in both the electron image and the ion image.

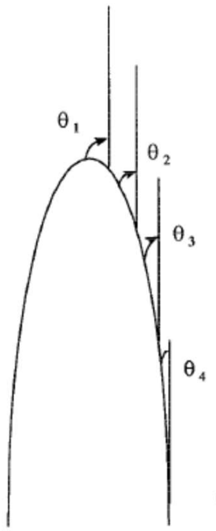
Sputter yield depends on target material



Similar to the Mohs scale of hardness of solids (graphene = soft, diamond is hard), each material has a tendency to get sputtered by the Ga ion beam. The sputter rates are not a function of the Mohs scale.

Crystalline structures will cause channeling of the ions depending on the Bragg conditions. Hence, crystalline structures will not mill to a flat surface.

Notes:



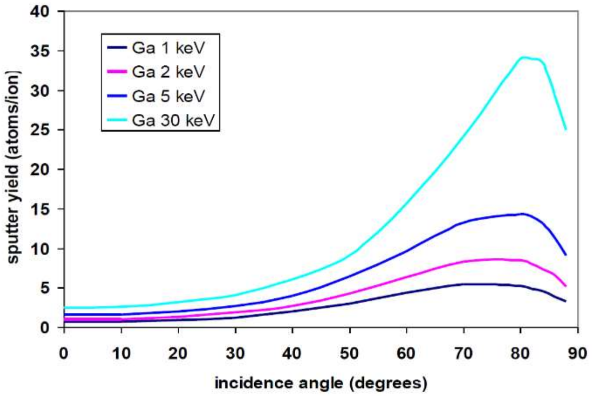
Asperities on a surface will be FIB milled at different rates due to topographic effects on milling

The topographic effects will grow and exacerbate as FIB milling continues

This is why surfacesare "never" FIB milled from top-down, but rather, are created by FIB milling at high incident angles.

$$\theta_1 \neq \theta_2 \neq \theta_2 \neq \theta_4$$

Sputter yield depends on ion acceleration voltage



30 keV is the maximum voltage of the ion gun. Always use 30 kV, unless clearly mentioned otherwise.

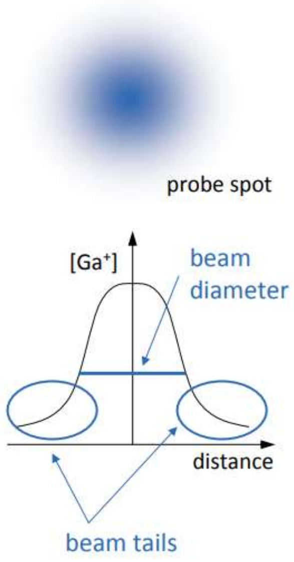
If the same object is not in the middle (use the center cross):

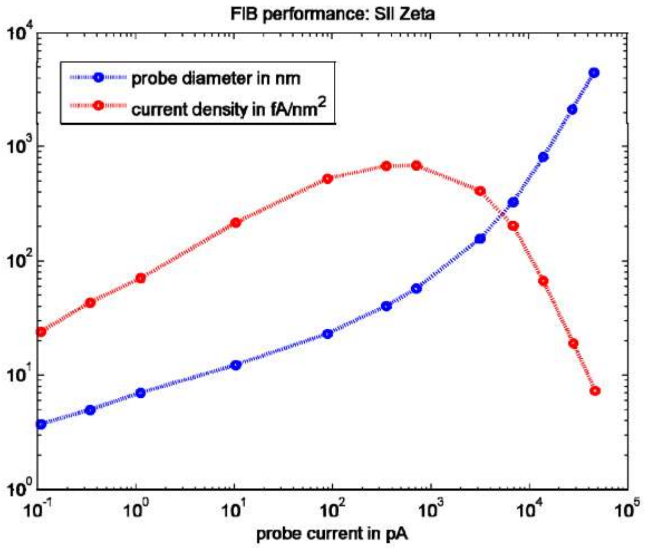
- Use beam shift XY to put it in the middle of the Ion beam image:

1. Open the beam control. Watch the Beam shift module
2. Grab the object / landmark with LMB while holding shift. The mouse icon will change into a hand with a blue sleeve.
3. Move the mouse (holding shift and LMB) to the center cross. The marker in the beam shift module should not reach the borders of the control. The image will not change.
4. release the mouse

Alternatively, use the shift XY buttons are on the physical control panel below the central screen. Note that here you will need a live ion image. switch off the FIB imaging as soon as the landmark is aligned (you are milling away your sample).

Setting: couple magnifications to OFF





- SMALL CURRENT → NARROW BEAM
- Beam tails can extend up to some µm

Demonstration: Pt deposition with the ion beam

Prerequisites:

Sample loaded
Electron beam on
Eucentric height, beam focused, 7mm working distance
Coincidence point set
Stage tilt: 52°

Deposit Pt with the ion beam

Experiment

Patterning settings
- Choose a rectangle (easiest)
- XYZ: XY, usually < 20, Z usually between 0.1 and 1 µm
- Application: Pt dep

Microscope settings:
- Magnification: 2000 X or higher (Standard mode, ETD detector)
- Ion acceleration voltage: 30 KV
- Beam current: CALCULATE! Using this formula:

$$Current\ (pA) = X(\mu m) \cdot Y(\mu m) \cdot 6\ (\frac{pA}{\mu m^2})$$

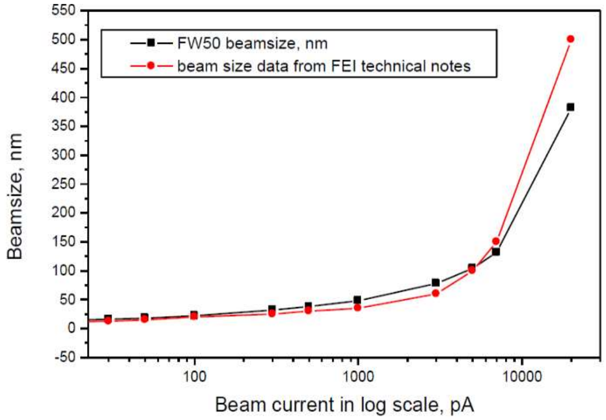
Where X = width of the pattern in µm, Y = height of the pattern in µm. Choose the ion beam current to be as close as possible to the calculated value

Example: a 20 µm x 20 µm rectangle → 6 x 20 x 20 = 2400 pA (actual value: 3 nA)

Example: a 2 µm x 3 µm rectangle → 6 x 2 x 3 = 36 pA (actual value: 30 pA)

Failing to choose the correct beam current will either ruin your vacuum or create a hole in your object.

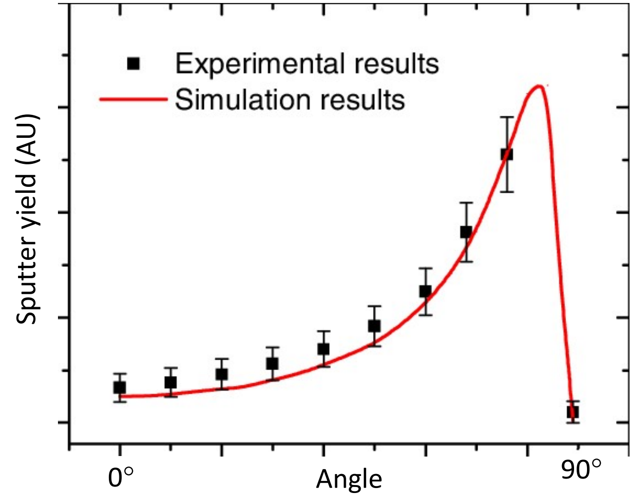
Ion beam morphology



The higher the ion current, the wider, larger the ion beam.

Index	Beam current	Aperture diameter (um)	Beam diameter
0	1.5	0.008	7.0
1	10	0.016	13.0
2	30	0.025	17.0
3	50	0.032	19.0
4	**100**	0.042	24.0
5	300	0.068	31.0
6	500	0.087	35.0
7	**1000**	0.118	44.0
8	3000	0.198	66.0
9	5000	0.250	85.0
10	7000	0.294	102.0
11	15000	0.420	182.0
12	30000	0.600	210.0
13	50000	0.750	300.0
14	maxmium	1000.000	400.0

Sputter yield depends on sputter angle



The milling efficiency is a function of the local curvature of the sample. Milling works most efficiently between 75-85°. At 90° the sputter yield is near zero. Hence, do not mill samples that are not flat: you will end up with a preferentially milled object.

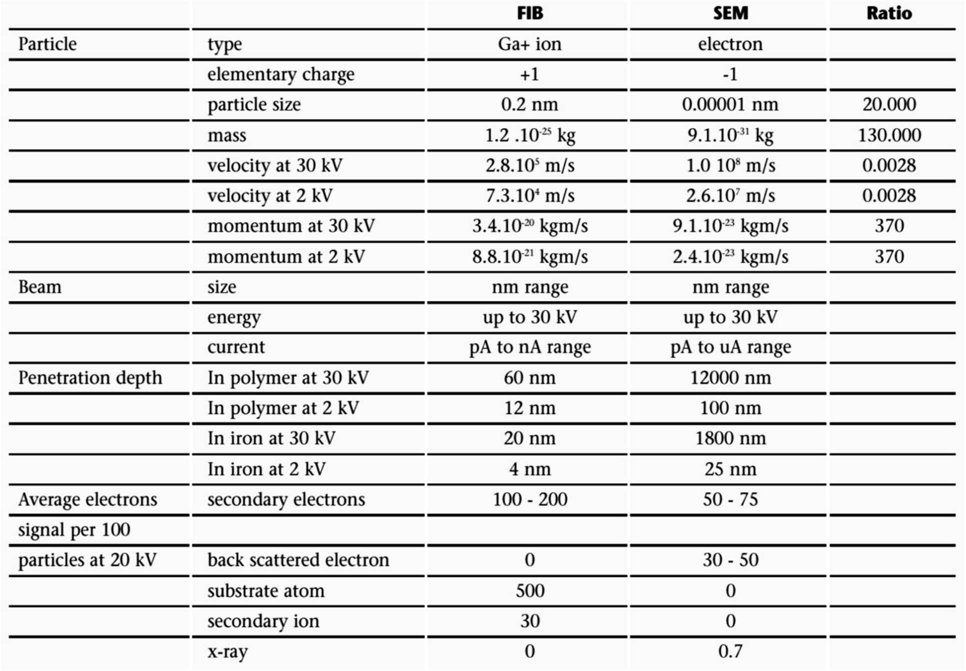
Demonstration: Basic milling concepts

Prerequisites:

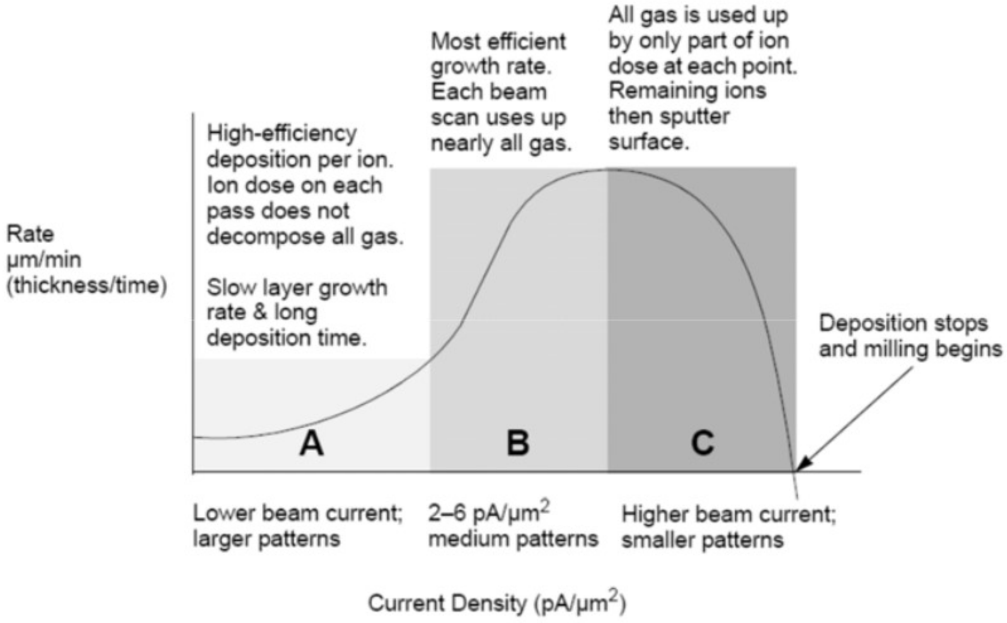
Sample loaded
Electron beam on
Eucentric height, focused, WD=7mm
Beam coincidence point set

Milling practicalities

Ions version electrons



		FIB	SEM	Ratio
Particle	type	Ga+ ion	electron	
	elementary charge	+1	-1	
	particle size	0.2 nm	0.00001 nm	20.000
	mass	$1.2\ .10^{-25}$ kg	$9.1.10^{-31}$ kg	130.000
	velocity at 30 kV	$2.8.10^{5}$ m/s	$1.0\ 10^{8}$ m/s	0.0028
	velocity at 2 kV	$7.3.10^{4}$ m/s	$2.6.10^{7}$ m/s	0.0028
	momentum at 30 kV	$3.4.10^{-20}$ kgm/s	$9.1.10^{-23}$ kgm/s	370
	momentum at 2 kV	$8.8.10^{-21}$ kgm/s	$2.4.10^{-23}$ kgm/s	370
Beam	size	nm range	nm range	
	energy	up to 30 kV	up to 30 kV	
	current	pA to nA range	pA to uA range	
Penetration depth	In polymer at 30 kV	60 nm	12000 nm	
	In polymer at 2 kV	12 nm	100 nm	
	In iron at 30 kV	20 nm	1800 nm	
	In iron at 2 kV	4 nm	25 nm	
Average electrons	secondary electrons	100 - 200	50 - 75	
signal per 100				
particles at 20 kV	back scattered electron	0	30 - 50	
	substrate atom	500	0	
	secondary ion	30	0	
	x-ray	0	0.7	

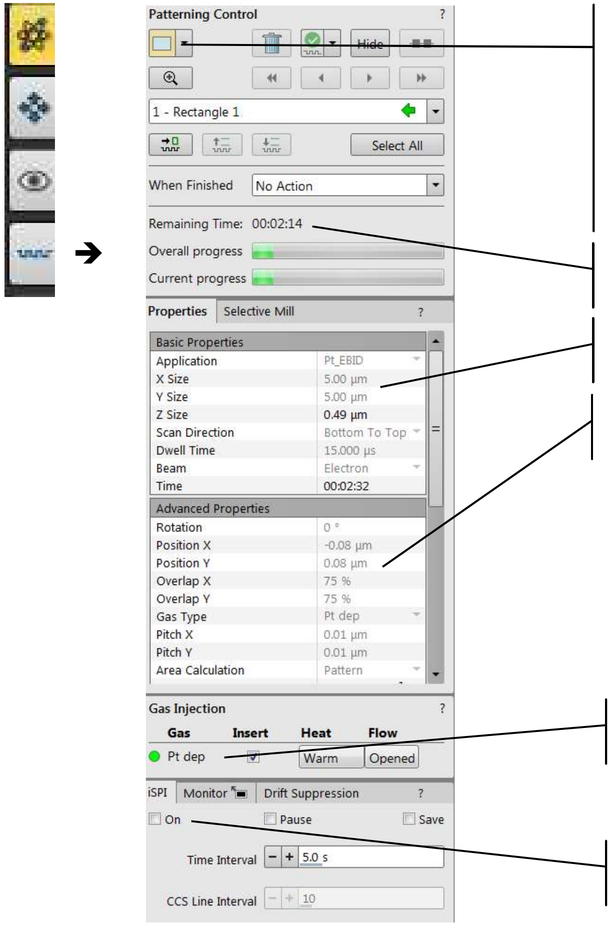


Demonstration: Patterning types

Prerequisites:

Sample loaded
Electron beam on
Eucentric height, focused, WD=7mm, either at 0° or 52°

Information of the different pattering types



1 - Rectangle 1
When Finished: No Action
Remaining Time: 00:02:14

Basic Properties	
Application	Pt_EBID
X Size	5.00 µm
Y Size	5.00 µm
Z Size	0.49 µm
Scan Direction	Bottom To Top
Dwell Time	15.000 µs
Beam	Electron
Time	00:02:32

Advanced Properties	
Rotation	0 °
Position X	-0.08 µm
Position Y	0.08 µm
Overlap X	75 %
Overlap Y	75 %
Gas Type	Pt dep
Pitch X	0.01 µm
Pitch Y	0.01 µm
Area Calculation	Pattern

Pt dep ☑
☐ On ☐ Pause ☐ Save
Time Interval 5.0 s
CCS Line Interval 10

Pattern type selector (see Toolbar icons also): Rectangle / Line / Circle / Cleaning Cross Section / Regular Cross Section / Polygon / Bitmap / Stream File

Time indicator

Pattern size settings

Array settings, passes, …

Pt Deposition

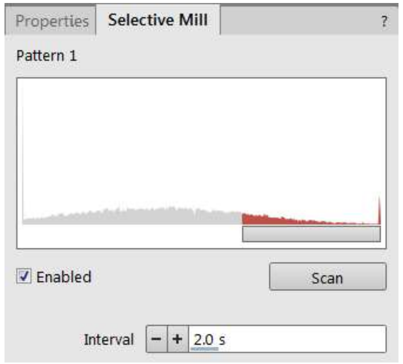
iSPI: imaging during deposition

The current at which 63% of the saturation sputter rate is reached (actually not used)

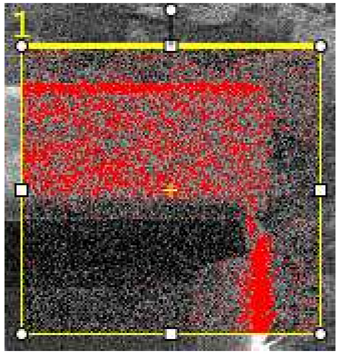
Total Volume Sputter Rate – the speed at which material is removed or deposited (actually not used)

Selective Milling Enabled / Selective Milling Time Interval / Min Contrast Threshold / Max Contrast Threshold items
Correspond to the Selective Mill tab module elements: Enabled check box / Interval adjuster / left / right border of the grey level to be processed for the selected pattern.

Selective milling



Pattern 1
☑ Enabled
Interval 2.0 s



It is possible to set a given grey level range to be processed in the extent of the selected pattern area. The scan button reads the pattern area grey level histogram (only ion image). Move the vertical black line to a desired grey level position and also move the red rectangle edges to set the grey level extent.

Area
The surface area of the pattern (read only)

ScanType
the Serpentine means the beam proceeds from left to right and back from right to left, while the Raster scans from left to right, then the beam returns to the left starting point

Fill Style
One can choose either to mill a solid (area) or just a frame (box and circular types only)

Passes
The number of the beam scans over the pattern

Defocus of the beam (WD change)
Influences the Total Diameter and Area Calculation. It allows focusing above / below (negative / positive value) the sample surface

Blur
Like Defocus, but specifying the (additional) diameter of the blurred spot

Interaction Diameter for an infinitely small beam
Influences the Total diameter

Total Diameter
the combination of the beam diameter and interaction diameter influences the OverlapX/Y and PitchX/Y values (read only)

Maximum Dose per Area
describes the adsorbed gas layer, allowing a certain dose to be deposited at a higher rate than the saturation current density, allowing a temporary higher rate (actually not used)

Saturation Current Density

Pattern types

Patterns are automatically assigned to one or more particular processes, distinguishable by a different cross-hatch.

- Rectangle / Line / Circle / Polygon pattern: both milling and deposition.
- Cleaning Cross Section: milling line by line (each line with set number of passes).
- Regular Cross Section: has two possibilities selectable in the Property editor:
    - Multipass – processes entire pattern and starts again (with set number of passes)
    - Stairstep – the pattern is created as a compilation of five rectangles with specified overlap between them. Each one is processed with the set number of passes.
- The Bitmap pattern enables importing bitmaps as a pattern. It must be 24 bit RGB bitmap, each pixel consists of:
    - Red component – actually not used
    - Green component – determines if the beam is blanked.
    - Any value other then 0 activates the beam
    - Blue component – determines the dwell time per pixel:

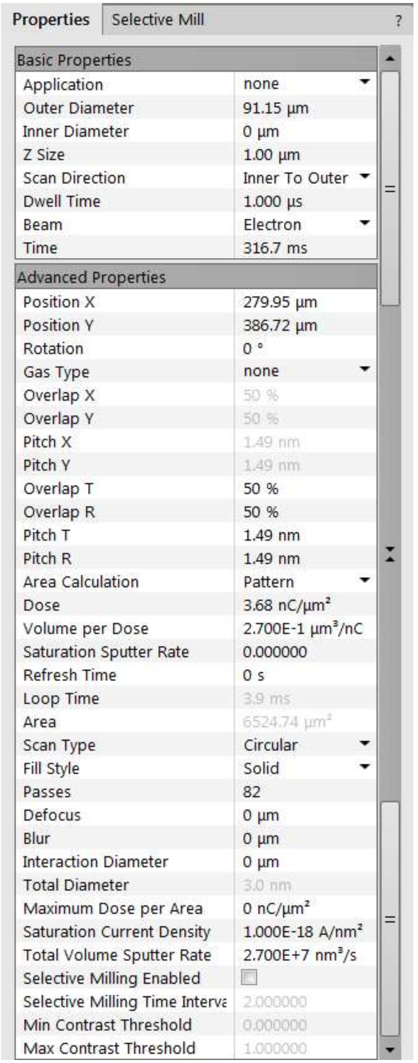
Serial vs parallel patterning

This is the default patterning mode. All patterns defined on the screen are processed consecutively; milling / deposition is completed on one pattern before moving to the next one. Serial patterning is always used with cleaning cross section milling.

All patterns defined on the screen are processed concurrently, one pass of the beam is completed on all patterns before moving to the second pass. Parallel patterning is typically used to avoid a redeposition of material on the adjacent areas.

Pattern properties

A pattern can have many associated parameters, which can be set via the Property module:



Basic Properties	
Application	none
Outer Diameter	91.15 µm
Inner Diameter	0 µm
Z Size	1.00 µm
Scan Direction	Inner To Outer
Dwell Time	1.000 µs
Beam	Electron
Time	316.7 ms
Advanced Properties	
Position X	279.95 µm
Position Y	386.72 µm
Rotation	0 °
Gas Type	none
Overlap X	50 %
Overlap Y	50 %
Pitch X	1.49 nm
Pitch Y	1.49 nm
Overlap T	50 %
Overlap R	50 %
Pitch T	1.49 nm
Pitch R	1.49 nm
Area Calculation	Pattern
Dose	3.68 nC/µm²
Volume per Dose	2.700E-1 µm³/nC
Saturation Sputter Rate	0.000000
Refresh Time	0 s
Loop Time	3.9 ms
Area	6524.74 µm²
Scan Type	Circular
Fill Style	Solid
Passes	82
Defocus	0 µm
Blur	0 µm
Interaction Diameter	0 µm
Total Diameter	3.0 nm
Maximum Dose per Area	0 nC/µm²
Saturation Current Density	1.000E-18 A/nm²
Total Volume Sputter Rate	2.700E+7 nm³/s
Selective Milling Enabled	☐
Selective Milling Time Interva	2.000000
Min Contrast Threshold	0.000000
Max Contrast Threshold	1.000000

Application
clicking on the value slot enables a down arrow bringing a drop down list of applications. Choosing the required one sets the subsequent properties.

X / Y / Z size
Dimensions of the pattern

Scan Direction
Scan movement direction (Bottom to Top; Top to Bottom)

Dwell Time
A time the beam spends on a single pixel per pass (rounded to a multiple of 25 ns).

Beam
The beam used for patterning

Time
required to process this pattern. Calculated from the different parameters

Rotation
Rotation of the patterns (the positive direction is clockwise)

Position X / Y
Position of the pattern relative to the origin (the display center)

Overlap X / Y
Sets the beam diameter overlap. The value of the overlap can be positive (=array) or negative (=overlapping) depending on a particular application. The overlap parameter influences the Area Calculation and the Dose.

Gas Type
the gas to be used to process the pattern (or None if no gas is to be used). This determines the pattern color onscreen (yellow for milling, green for Pt deposition).

Pitch X / Y
Sets the pitch between two spots. Alternative to overlap.

Area Calculation
Defines how the patterning area will be calculated in order to get the most accurate value of the Dose. This value is related with the OverlapX/Y. The Pattern (default) / Array are set for positive / negative overlaps.

Volume per Dose
The volume of material that is removed per charge

Saturation Sputter Rate
The maximum linear sputter rate for a given gas. For Gas = None this is 0 (actually not used).

Refresh Time
The minimum loop time that must at least elapse before the next pass, so that the adsorbed gas can be refreshed

Loop Time
The time required for a single pass (read only)