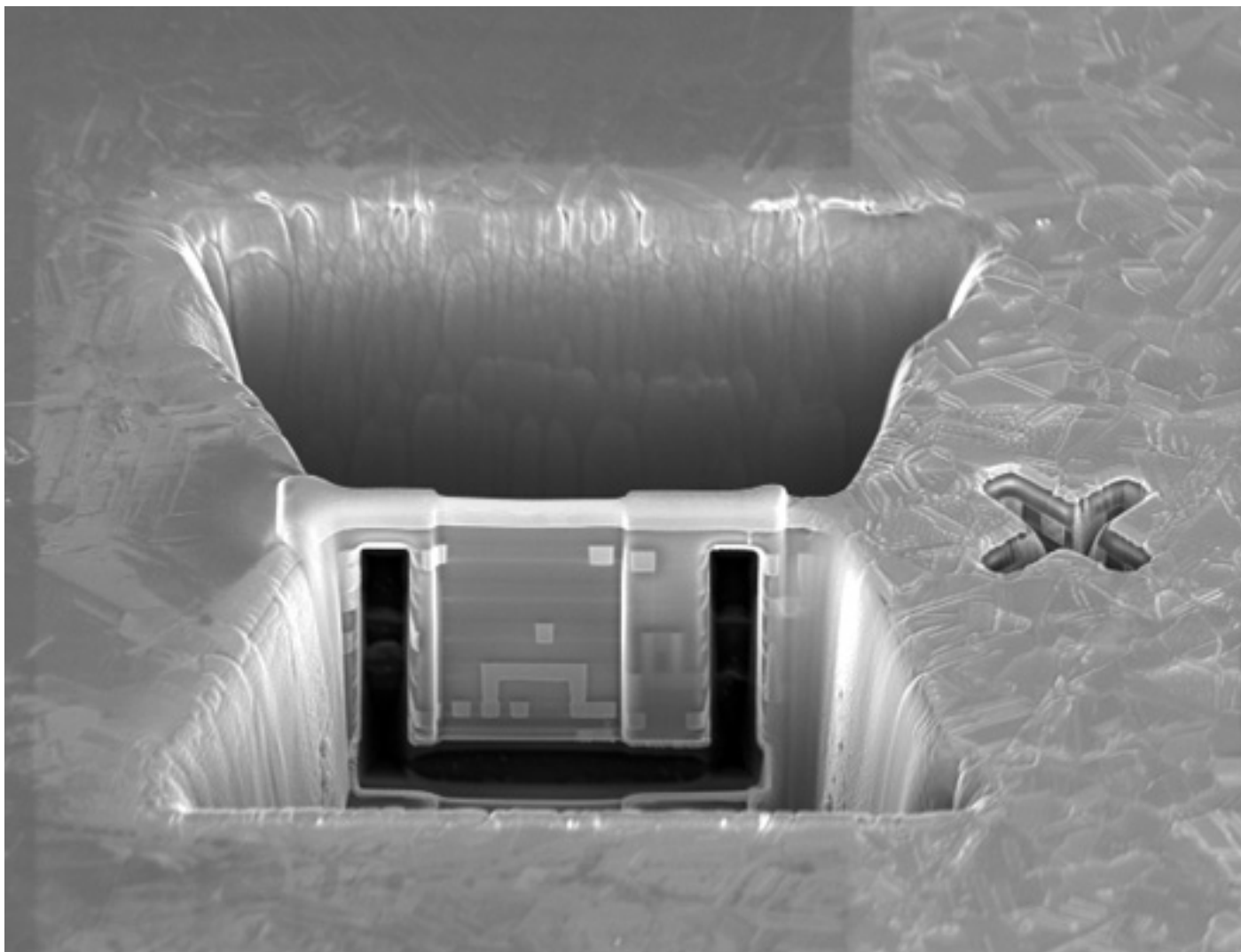




Software Manual

SmartSEM[®] V05.07 XB
Operating software for CrossBeam[®]
workstations



We make it visible.

Software Manual

SmartSEM[®] V05.07

Operating software for Scanning Electron
Microscopes



We make it visible.

Software Manual SmartSEM® V05.07 XB
Operating software for CrossBeam® workstations

Original instructions

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1. Introduction

1.1. For your safety

Read the instructions in this software manual carefully. Keep the software manual nearby the CrossBeam® workstation and hand it over to future owners of the instrument.

1.1.1. Intended use

The SmartSEM® software for CrossBeam® is intended for the operation of ZEISS CrossBeam® workstations of the 15xx series (1540XB, 1540EsB, 1560XB), the NEON® series and the AURIGA® series.

The SmartSEM® software has to be run exclusively on a personal computer delivered by ZEISS. Any other applications are not allowed.

1.2. About this manual

This software manual is designed for operators who have been trained to operate the CrossBeam® workstation by an authorised expert.
It is assumed that the operator is already familiar with general functions of SmartSEM® and the operation of the FESEM, as this software manual only deals with CrossBeam® specific topics.



IMPORTANT

For general information about SmartSEM®, refer to the Software Manual SmartSEM®.



IMPORTANT

For the Capella FIB column, several functions have been moved to the SmartFIB® user interface.

Wherever this is the case, the sections are marked with „If a Capella FIB column is installed, refer to the SmartFIB® Online Help for details.“

Operators of the CrossBeam® workstation must not deviate from the instructions provided in this manual.

This software manual contains the following chapters:

- **1. Introduction**
Includes general safety information and typographical conventions.
- **2. Description**
Describes system requirements, software elements, and operating principles of SmartSEM®.
- **3. First steps**
Summarises briefly how to perform basic operation procedures.
- **4. Operation**
Provides details on software-based operation sequences relevant for the CrossBeam® workstation.
- **5. Applications**
Explains advanced operation sequences for special applications.
- **6. Troubleshooting**
Helps to quickly solve possible problems during operation of the CrossBeam® workstation.
- **7. Summary of software functions**
Lists menus and submenus.
- **8. Abbreviations**
- **9. Glossary**
Alphabetical list and explanation of important technical terms used in this manual.
- **10. Index**

1.2.1. Safety instructions in this manual

The safety instructions in this manual follow a system of risk levels, that are defined as follows:



CAUTION

This safety symbol and signal word indicates a potentially hazardous situation. Disregarding this warning MAY result in minor or moderate injury.

CAUTION

This signal word used without a safety symbol indicates a potentially hazardous situation. Disregarding this warning MAY result in property damage.

Moreover, you will find the following type of hints:



IMPORTANT

This symbol and signal word draws your attention to important and useful information.

1.2.2. Typographical conventions

For the description of software, the following typographical conventions are used:

Typography	Meaning
Push <ENTER>.	Push the ENTER key on the keyboard.
Type <key1, key2>	Type key 1 first, then type key 2 on the keyboard.
Type <Ctrl + Alt + Del>.	Simultaneously type CTRL key, ALT key and DEL key on the keyboard.
Click the High voltage icon. Select Aperture size from the drop down list. Select FIB Mode .	Icons, buttons, menus, and modes are printed in bold.
Select Aperture size <i>30 μm</i> . Set FIB Fil V target to zero.	Values to be selected are printed in italics.

Text	Meaning
Click...	Press the left mouse button.
Right-click...	Press the right mouse button.
Double-click....	Press the left mouse button twice.

1.2.3. Definition of terms

The following terms are used in this software manual:

FESEM	Field emission scanning electron microscope, referred to as FESEM.
XB	CrossBeam [®] product family, including 1540XB, 1540EsB, 1560XB, and NEON [®] series
FIB	Focused ion beam
ZEISS service representative	Specially trained service expert, either ZEISS staff or authorised service partner of ZEISS.
Operator	A trained person, who is assigned to operate the FESEM.
SmartSEM [®] Administrator	Program for user management.
Gas injection system, GIS	Optional gas injection system, required for gas assisted etching and deposition.

2. Description

2.1. System requirements

2.1.1. Operating system

SmartSEM® V05.06 requires the operating system Windows® 7 Ultimate 32 bit.



IMPORTANT

The screenshots shown in this software manual are partly taken from SmartSEM® V05.05 that runs on Windows® XP.

These screenshots are only used for parts of the user interface which can still be operated in exactly the same way as in SmartSEM® V05.05.

CAUTION

The integrated personal computer delivered with the FESEM should mainly be used to control the FESEM and to archive images, because the installation of additional software programs might cause problems.

Before installing additional software programs contact your local ZEISS service representative for his/her recommendation.

2.1.2. Dongles

To operate the software, a SmartSEM® dongle has to be installed.

For using the optional drift correction licence (DRIFT-CORR), an additional dongle (called MIL dongle) is required.



IMPORTANT

If a dongle is lost, contact your local ZEISS service representative to order one. Microscope type and serial number have to be mentioned in the order.

2.2. Installation

SmartSEM® is factory-installed on your CrossBeam® workstation by the factory.

For possible updates or upgrades or licences installations contact your local ZEISS service representative for more information.

2. Description

SmartSEM[®] program suite

2.3. SmartSEM[®] program suite

In addition to the EM server, the FIB server implements the internal communication between control software and microscope hardware.

The SmartSEM[®] programme suite includes the following CrossBeam[®] specific programmes and utilities.

	Program/Utility	Function	Remarks
Select Start/Programs/...			
...SmartSEM	FIB Drift Correction	Drift correction is most useful over especially long milling periods so that the effects of stage drift or thermal effects do not result in damage to the intended milling areas. The drift correction settings determine how and with what frequency drift correction is used.	Requires the licence DRIFT CORR and the MIL dongle.
	FIB Auto Sample Preparation	Allows the automated FIB preparation of cross sections and TEM lamellas.	Requires the licence TEM SAMPLE PREP and the MIL dongle.
	FIB Deposition Materials Editor	Allows you to create material definitions for deposition and gas assisted etching (GAE). These are used by various components in the FIB software.	
	FIB Feature Milling	Allows you to mill any geometrical object, letters (texts) or image files (bmp or dxf)	
	FIB Manual Milling Interface	Allows manual selection of milling parameters.	
	FIB Materials Editor	Allows you to create material definitions. These are used by various components in the FIB software to allow specifying a target depth and slope angle for a milling operation.	
...SmartSEM Service	FIB Calibration Wizard	Service activities	For ZEISS service representative only
	FIB Configurator	Service activities	For ZEISS service representative only
	GIS Configurator	Service activities	For ZEISS service representative only

Table 2.1: Overview of CrossBeam[®] specific programmes and utilities

2.4. Available licences

Software licences are used to enable specific functionality in the SmartSEM[®] software. Some licences are provided as standard with a specific model of FESEM, others are purchased as options. When the FESEM is delivered, the standard and the additionally purchased licences are already installed.

Licence	Sales code	Part no.	Explanation
3D reconstruction	3D_ RECONSTRUCT	348224-6073	Allows creating a 3D visualisation of the bulk structure of a specimen based on a series of cross sections.
Annular Milling	ANNULAR_MILLING	348224-6083	Allows user to use the Annular Milling feature in Feature Mill
End detection	END-DETECTION	348224-6061	This function is used to detect the point at which milling should be paused by detecting the signal changes generated during milling.
Feature Mill	FEATUREMILL	348224-6055	Allows user to use the Feature Mill application
FIB API	FIB-API	351434-6023	Allows user to use the FIB Visual Basic API
FIB low energy mode	FIB-LOW-ENERGY	348224-6060	Allows working with FIB EHT values less than 5 kV.
FIB Tomography	FIBTOMOGRAPHY	351434-6126	Allows user to use the Nano Tomography Wizard
TEM Sample Prep	TEM-PREP	348224-6059	Allows user to use the Auto Sample Prep and associated programs to define automated procedure to create TEM lamellas

2.5. Principle of operation

The CrossBeam[®] workstation is operated by the SmartSEM[®] software: All commands, settings and functions necessary for the handling of the workstation are controlled by the SmartSEM[®] software using keyboard and/or mouse.

The motorised specimen stage can be operated by the dual joystick or by the software.

In most cases, the SmartSEM[®] user interface offers more than one possibility to run a function. For instance, to switch on the EHT you can use

- the menu bar or
- the status bar or
- the MiniBar or

2. Description

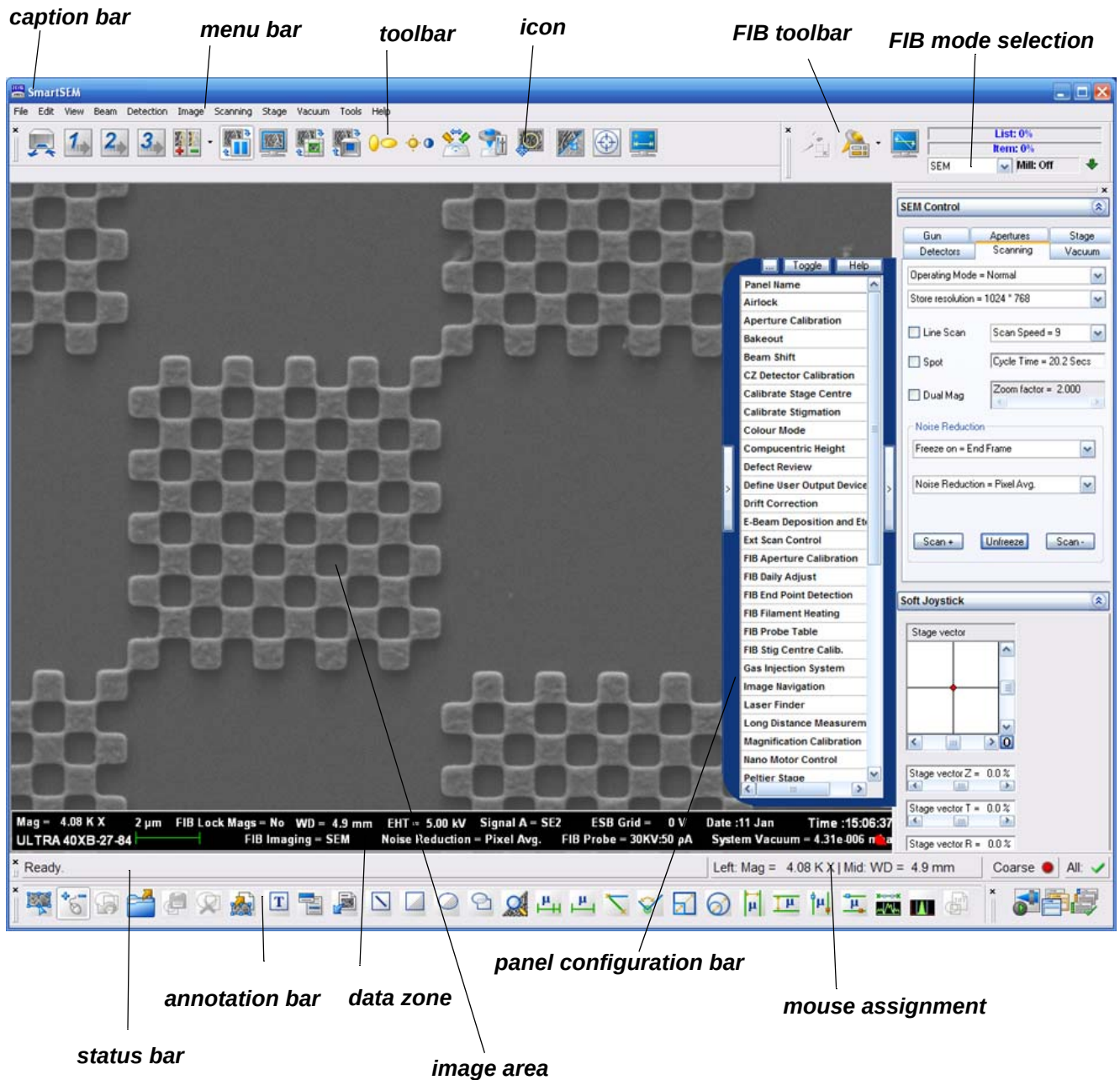
Principle of operation

- the Gun tab in the SEM Control panel.

This allows the user to operate the SmartSEM[®] software according to his/her individual preferences.

2.6. SmartSEM® user interface

The SmartSEM® software is operated via a graphical user interface that can be used intuitively.



2. Description

SmartSEM[®] user interface

Menu bar	When left-clicking a menu, the pull-down menu shows the different submenus.
User toolbar	Most icons in the toolbar are assigned twice. The different functions and parameters can be activated by pressing the left or the middle mouse button. When moving the cursor across the icon, tool tips show the different assignments.
MiniBar	The MiniBar provides quick access to recently used dialogs and to the recipe management.
Status bar	The status bar shows the active mouse assignment: • Left: left mouse button • Right: middle mouse button Moreover, it shows the Coarse/Fine toggle button and allows access to a pop-up menu for quick control of important SEM parameters.
Annotation bar	The annotation bar allows putting additional information on the SEM image. Text, SEM parameter data, and even bitmaps (like logos etc.) can easily be added to the image. Moreover, it provides several measurement functions.
Data zone	The data zone contains important information on the recording parameters of the current image. Each user can design the data zone as desired and store it together with the image.
Panel Configuration Bar	The panel configuration bar allows accessing to several functions which are listed alphabetically.
FIB toolbar	The FIB toolbar allows accessing different panels and dialogs necessary to operate the FIB.
FIB mode selection	The FIB Mode selection allows you to select the imaging mode.

3. First steps

At a glance

This chapter is a quick guide that contains information about:

- Preparing the workstation
 - Getting started
 - Adjusting tilt eucentricity
 - Switching on the ion beam (FIB)
 - Setting the coincidence point
- Operating the workstation
 - Milling for depth
 - Recording images while milling
 - Depositing platinum by using the optional Gas Injections System (GIS)

It is assumed that the operator is already familiar with general functions of SmartSEM[®] and the operation of the FESEM, as this software manual only deals with CrossBeam[®] specific topics.



IMPORTANT

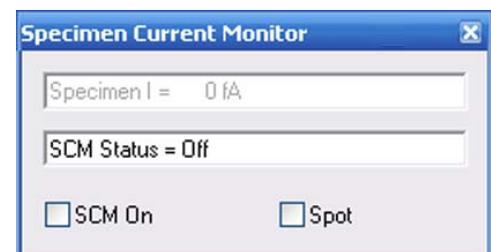
For general information about SmartSEM[®] refer to the Software Manual SmartSEM[®].

3.1. Preparing the workstation

3.1.1. Getting started

- 1 Switch on the workstation.
- 2 Start the SmartSEM[®] user interface and log in.
- 3 Initialise the specimen stage.
- 4 Load the specimen chamber with an appropriate specimen.
- 5 Evacuate the specimen chamber.
- 6 Switch on the SEM:
 - a Switch on the gun.
 - b Switch on the EHT.
- 7 Ensure the **Specimen Current Monitor** is switched off:
 - a Select **Tools/Goto Panel** from the menu.
 - b Double-click **Specimen Current Monitor**.
 - c Untick the **SCM On** checkbox.

This ensures that the touch alarm function is active.



- 8 Bring the image into focus.

How to continue

Continue with adjusting the tilt eucentricity.

3. First steps

Preparing the workstation

3.1.2. Adjusting the tilt eucentricity

Before you can start imaging or milling, it might be necessary to adjust tilt eucentricity. By adjusting the eucentricity, the specimen surface is moved into the tilting plane of the super-eucentric stage. That is why the image does not shift out of the screen when the stage is tilted.

CAUTION

Danger of damaging objective lens or specimen if the specimen is too close to the objective lens.

Since the eucentricity is adjusted by using the M-axis, the working distance will be changed during the eucentricity setup.

Ensure the working distance is 10 mm or more.

- 1 Open the **Panel Configuration Bar**.
- 2 Double-click **Adjust**.

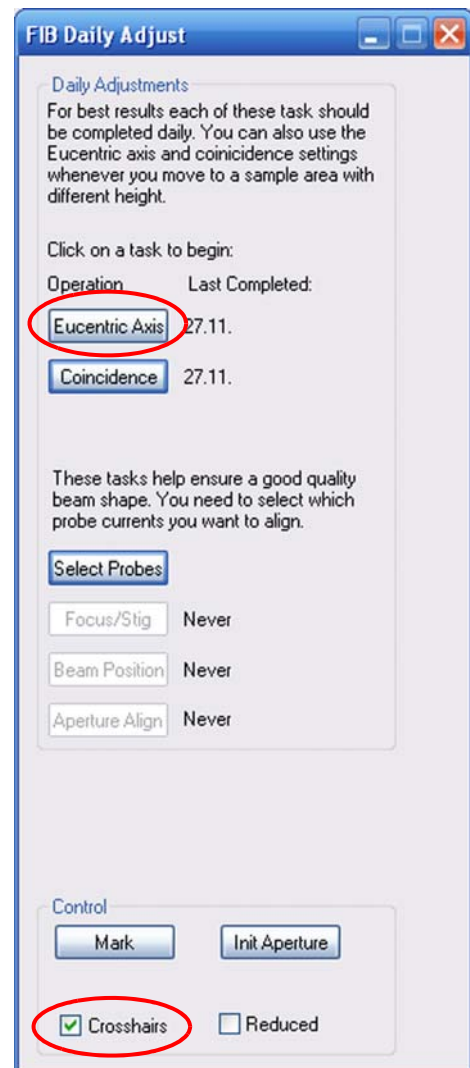
The **FIB Daily Adjust** panel opens.

- 3 Tick the **Crosshairs** checkbox to show the crosshairs.
- 4 Center a characteristic feature in the middle of the screen (i.e. in the middle of the crosshairs).
- 5 Click **Eucentric Axis**.
- 6 Click **Start**.
- 7 Follow the instructions in the wizard.

To re-centre the feature, use the Centre feature function (<Ctrl+Tab>) or change X/Y.

To change the tilt degree of the stage:

- a Go to the **Stage** tab of the **SEM Control** panel.
- b In the **Go To T(ilt)** field, enter the required degree.



How to
continue

Continue with switching on the ion beam (FIB).

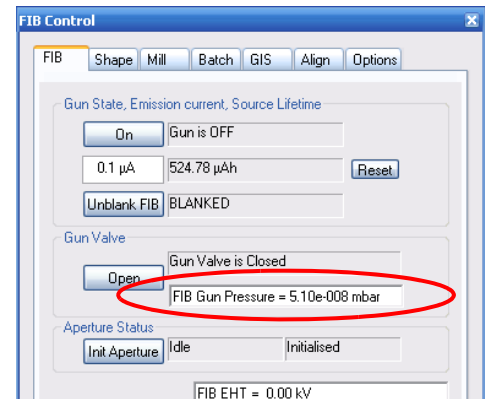
3.1.3. Switching on the ion beam (FIB)

- 1 Click the **FIB** icon.



The **FIB** tab of the **FIB Control** panel opens.

- 2 Ensure the **FIB Gun Pressure** is better than 5×10^{-7} mbar (Canion) or 1×10^{-7} mbar (Cobra).



CAUTION

Danger of arcing. Danger of damaging the ion source.

Before switching on the ion beam, ensure the FIB gun pressure is better than 5×10^{-7} mbar (Canion) or 1×10^{-7} mbar (Cobra).

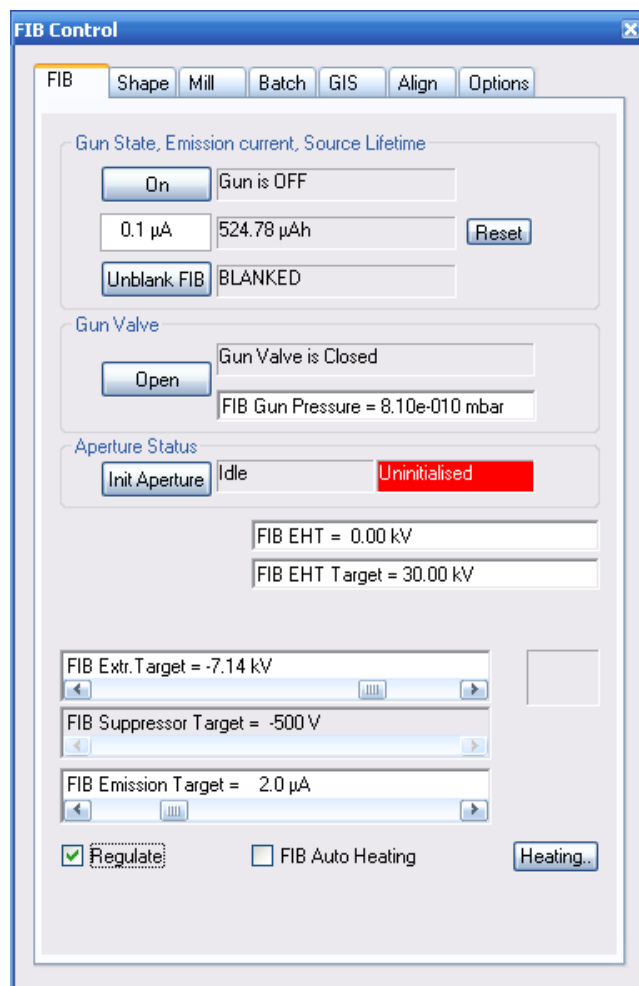
- 3 Go to the **Vacuum** tab of the **SEM Control** panel.
 - a Check the current status of the system vacuum.
 To be able to switch on the ion beam, the system vacuum has to be 5×10^{-5} mbar or better.



3. First steps

Preparing the workstation

- Go to the **FIB** tab of the **FIB Control** panel.



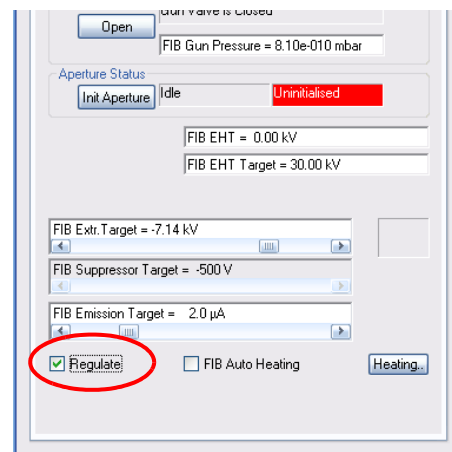
IMPORTANT

*Do not change the FIB Extr. Target value.
Changing this value would require a complete adjustment of the FIB probe currents.*

- Ensure the **Regulate** checkbox is ticked.

This guarantees a stable emission current.

The emission is automatically regulated by changing the **FIB Suppressor Target** which can have values between -2000 V and 0 V.





IMPORTANT

From time to time, the gallium emitter has to be regenerated by heating. The heating procedure removes the gallium oxide which has been created during operation or during longer breaks.

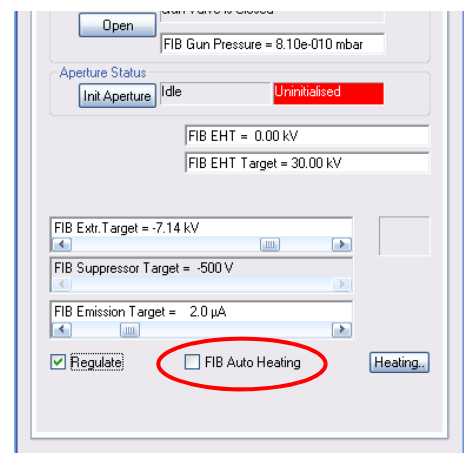
In general, it is recommended that you activate the automatic heating function. This will ensure that the ion source is heated automatically if required.

6 Regenerate the ion source by either:

Heat automatically:

- a Tick the **FIB Auto Heating** checkbox.

Heating
automatically



CAUTION

*Risk of instabilizing the ion source due to incessant automatic heating.
To ensure optimum operation, the ion source must be heated manually at regular intervals.*

Heating
manually

The manual heating will be required after having performed the Auto Heating for about 5 times, i.e. about every 2 - 3 weeks. However, this interval is dependend on the usage of the workstation. All Auto Heating cycles are listed in the log file of the EM Server.

Heat manually:

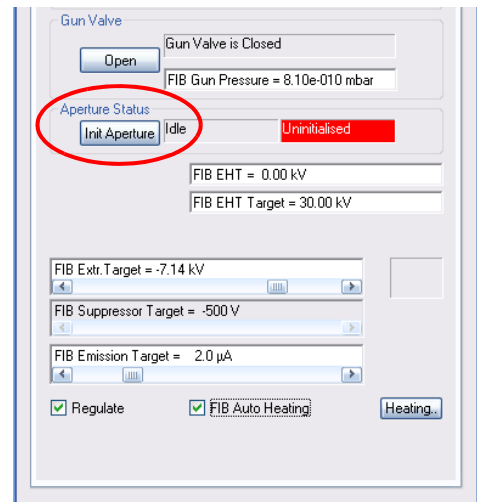
- a Check the number of Auto Heating cycles in the EM Server.
- b After every fifth Auto Heating cycle heat manually (refer to section 6.2.2.).

3. First steps

Preparing the workstation

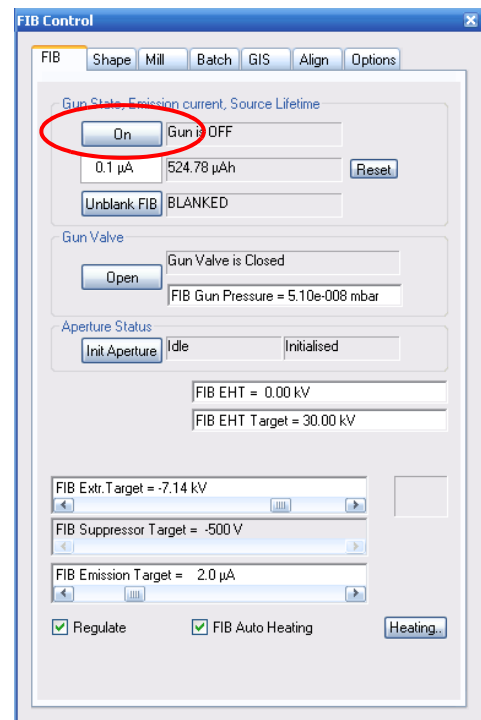
- 7 Initialise the FIB apertures:
Click **Init Aperture**.

The aperture initialisation may require several seconds.



- 8 To switch on the ion beam, click **On**.

The FIB Gun is ramping up.
The gun valve is opened automatically.



Below the **Off** button, the emission current is shown.

The emission current should be about $2\ \mu\text{A}$.

The background of the button can have several colours.

Green background:

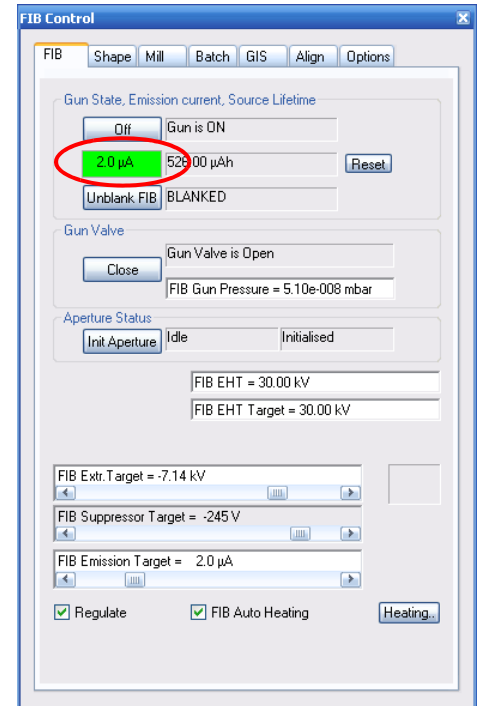
The emission current equals the target ($\pm 0.1\ \mu\text{A}$).

Yellow background:

The emission current differs from the target by more than $0.1\ \mu\text{A}$.

Red background:

The suppressor voltage has almost reached its limit.



IMPORTANT

If you intend to deposit platinum with the optional GIS, you should start heating the platinum precursor now.

Refer to section 3.2.3.1.

**How to
continue**

Continue with setting the coincidence point.

3. First steps

Preparing the workstation

3.1.4. Setting the coincidence point

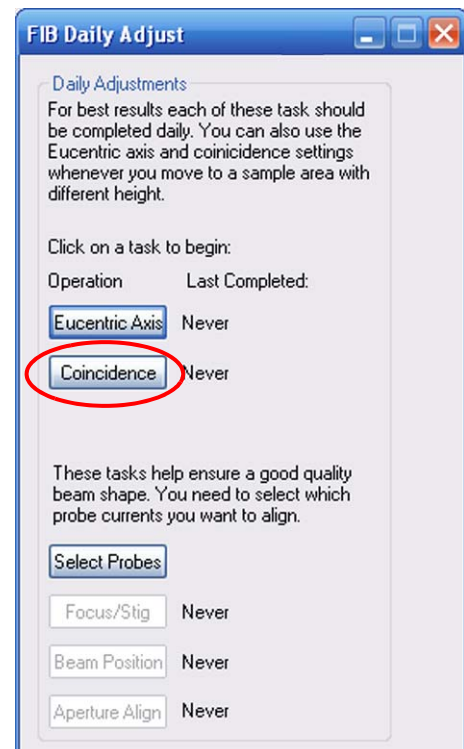
Before you can start imaging or milling, you have to align the specimen to the coincidence point.

The coincidence point is the crossing point of electron beam and ion beam. Only if a specimen feature is located in the coincidence point, it can be imaged simultaneously as well in SEM mode as in FIB mode.

- 1 Position the feature of interest under the SEM.
- 2 Make sure the eucentricity is setup.
- 3 Set a WD of 5 mm.
- 4 Go to SEM view.
- 5 In SEM view, centre the feature.
- 6 Open the **Panel Configuration Bar**.
- 7 Double-click **FIB Daily Adjust**.
- 8 Tilt the stage to 54°.

The **FIB Daily Adjust** panel opens.

- 9 Click **Coincidence**.
- 10 Follow the instructions in the wizard.
- 11 Click **Start**.
- 12 Centre the feature by using the centre point function (<Ctrl + Tab>).
- 13 Move Z.
- 14 Repeat the procedure until the **Finish** button is shown.
- 15 Click **Finish**.



IMPORTANT

In general, the magnifications of SEM image and FIB image are not identical. If you wish both magnifications to be the same, you have to couple them together. Refer to section 4.4.2.

3.2. Operating the workstation



IMPORTANT

If a Capella FIB column is installed, refer to the SmartFIB® Online Help for details.

3.2.1. Milling for depth

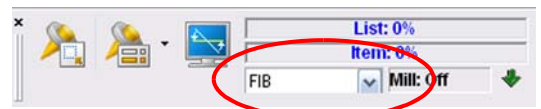
Milling stands for the local removal of surface material by means of the focused ion beam. Milling for depth is a milling mode, which allows removing of material to a specified depth.

Preconditions:

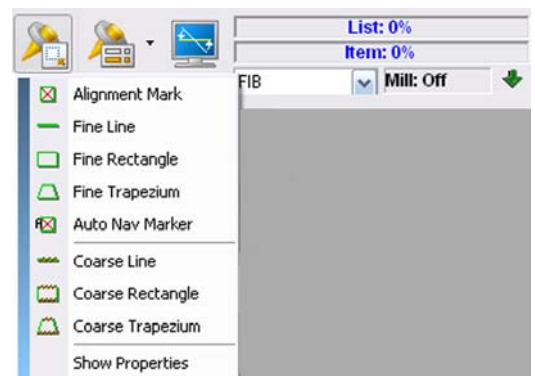
- Electron beam has been switched on
- Ion beam has been switched on
- Tilt eucentricity has been adjusted
- Specimen has been moved to the coincidence point

3.2.1.1. Selecting milling conditions

- 1 Select **FIB** mode from the drop-down list.



- 2 Select a milling object from the drop-down menu, e.g. *Fine Rectangle*.



3. First steps

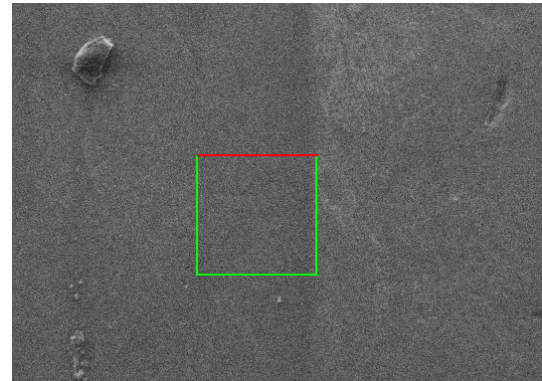
Operating the workstation

- 3 Click into the image area, where you wish to place the milling object.
Hold the left mouse button and drag.

The milling object is displayed on the screen.

The green side of the milling object opposite the red side accentuates the side, where the process will start.

The red side accentuates the side, where the process will end.

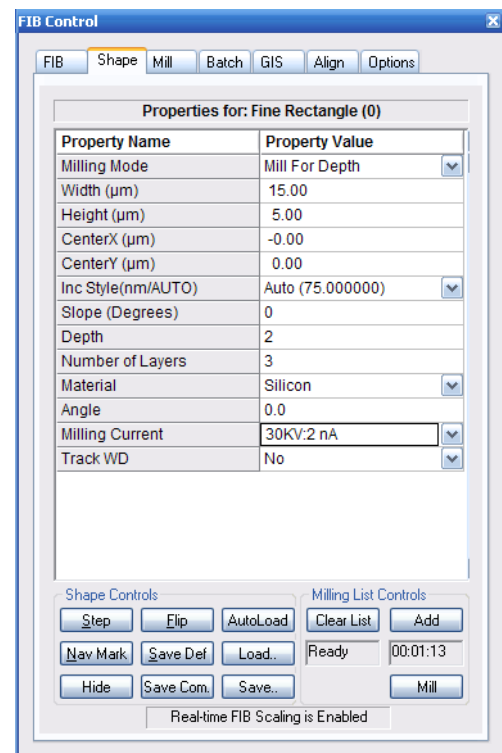


The **Shape** tab opens.

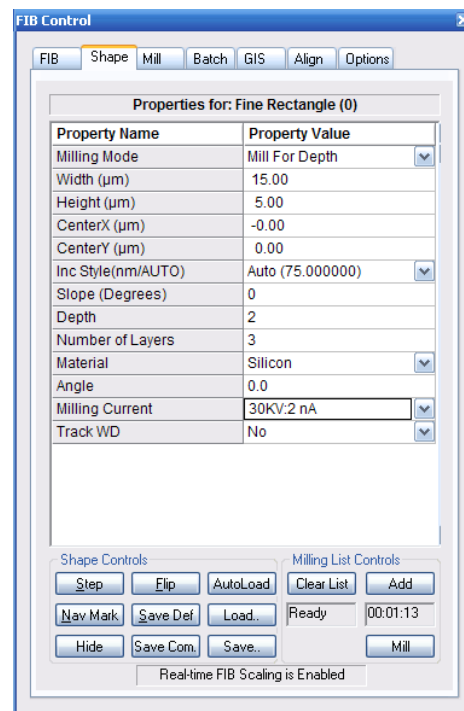
- 4 Enter the required parameters:
 - a Select *Mill For Depth*.
 - b Set the size of the milling object:
Enter values for **Width** and **Height**.
Alternatively, click the markers of the milling object and drag.
 - c Set the position of the milling object:
Enter values for **CentreX** and **CentreY**.

Alternatively, select the milling object.
Click the line between the markers and displace the milling object.

- d Define the step size between each milling element: In the **Inc Style** drop-down list, select *Auto*.
This setting is suitable for most applications.



- e Set the geometrical slope to be milled:
At **Slope (Degrees)** enter 0.
- f Set the **Depth** in μm .
This defines how deep the milling should go at the lamella edges.
- g Set the **Number of Layers**.
The number of layers determines how often a milling element is milled.
- h Select material data from the **Material** drop-down list.
The material data can be edited via the **FIB Materials Editor** (see section 4.6.5.).
- i Select the **Angle** 0.
- j Set the **Milling Current** depending on your application and the size of your milling object:



Examples

Application	Size	Recommended milling current
Coarse milling	large e.g. 10 x 10 μm^2 , 8 μm deep	5 - 10 nA
	medium e.g. 5 x 5 μm^2 , 3 μm deep	2 nA
Medium polish	-	100 - 500 pA
Fine polish	-	10 - 50 pA
Lithography	-	1 - 20 pA

- k In the **Track WD** drop-down list, select Yes or No.
If you select Yes, the working distance and the beam shift will be tracked while milling into the depth.



IMPORTANT

Track WD is only useful if the stage is tilted to 54°.

How to continue

Continue with starting the milling procedure (next section).

3. First steps

Operating the workstation

3.2.1.2. Starting the milling procedure

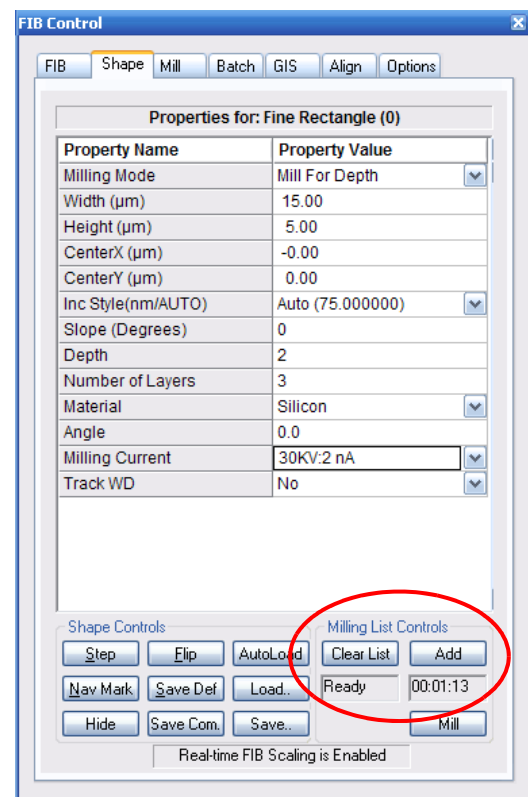
- 1 Click **Clear List**.

All previous milling objects are deleted from the milling list.

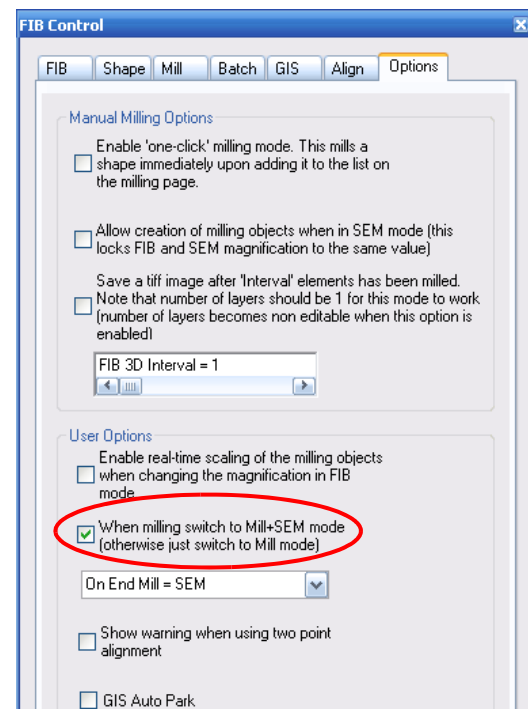
- 2 Click **Add**.

The current milling object is - together with the selected milling conditions - added to the milling list.

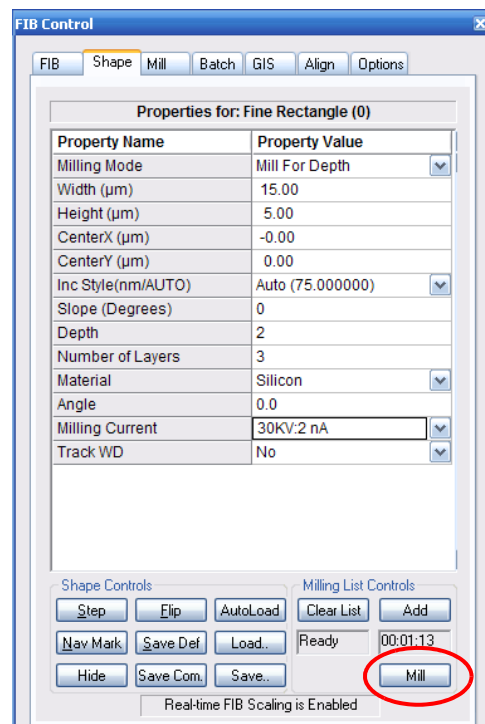
The time needed to process the object is shown under the **Add** button.



- 3 Go to the **Options** tab.
- 4 Tick the **When milling switch to Mill+SEM mode...** checkbox.

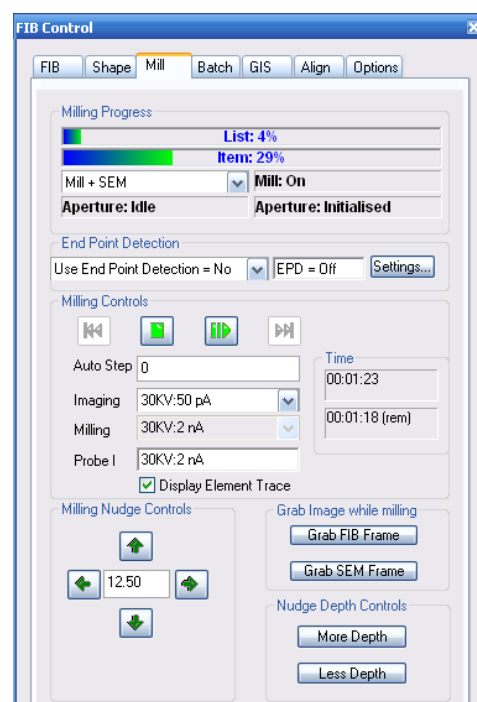


- 5 To start the milling, go to the **Shape** tab and click **Mill**.



The milling process starts.
The progress marker is shown.

The **Mill** tab opens, which allows you to directly control the milling progress.



The milling process ends automatically.

3.2.2. Recording images during milling

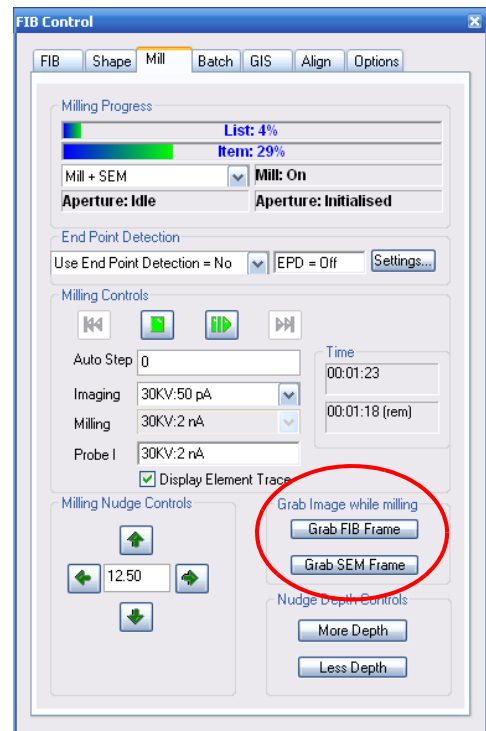
When selecting the imaging mode *Mill+SEM*, images can be saved any time during milling. However, the images may be interfered by the ion beam.

To avoid any interferences, you can pause the milling while you are taking an image.

- 1 To record a FIB image, click **Grab FIB Frame**.
Grabbing a FIB image provides an orthogonal view onto the specimen surface.
- 2 To record a SEM image, click **Grab SEM Frame**.
Grabbing a SEM image provides a sharp image, since the milling is paused.

When clicking one of the **Grab...Frame** buttons, the milling is stopped, while the image is recorded. After having finished the grabbing, the milling continues, but the image remains frozen.

To continue imaging, go to the **Scanning** tab of the **SEM Control** panel and click **Unfreeze**.



3.2.3. Depositing platinum by using the Gas Injection System (optional)

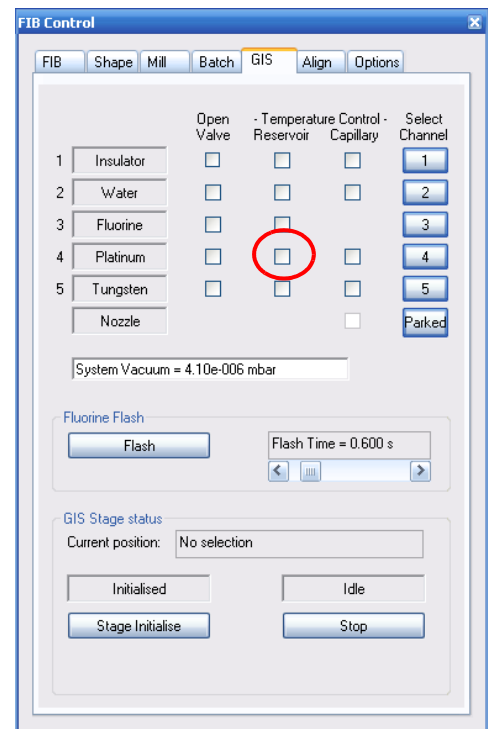
A common ion-beam induced deposition is the deposition of platinum, which serves e.g. as a surface protection layer.

It is assumed that you work at a stage tilt of 54°.

3.2.3.1. Heating the platinum precursor

- 1 Heat the precursor:
 - a Go to the **GIS** tab of the **FIB Control** panel.
 - b Tick the **Reservoir** checkbox of **Platinum**.
The **Capillary** checkbox is ticked automatically.

There is a temperature gradient between reservoir (lowest temperature), capillary and nozzle (highest temperature). This will guarantee that substances will not have the chance to condense in any part of the gas line.



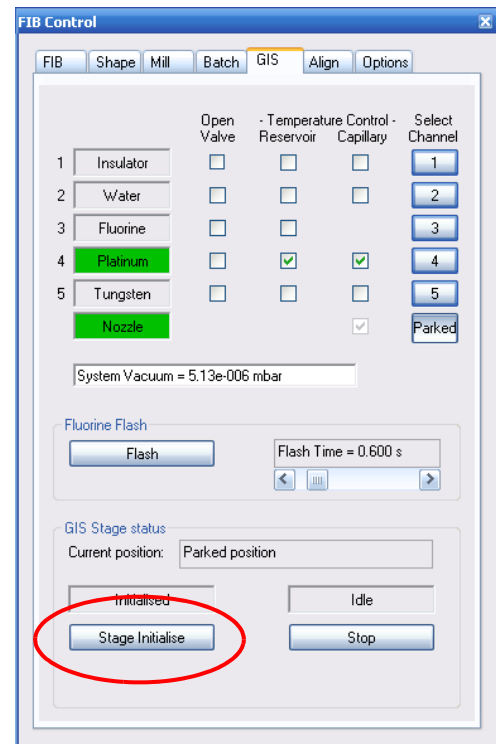
IMPORTANT

It is recommended that you switch on the precursor heating at least two hours before you start the deposition procedure.

3. First steps

Operating the workstation

- 2 If required, initialise the GIS micro stage:
 - a Go to the **GIS** tab.
 - b Click **Stage Initialise**.



How to
continue

Continue with outgassing the platinum precursor.

3.2.3.2. Outgassing the platinum precursor

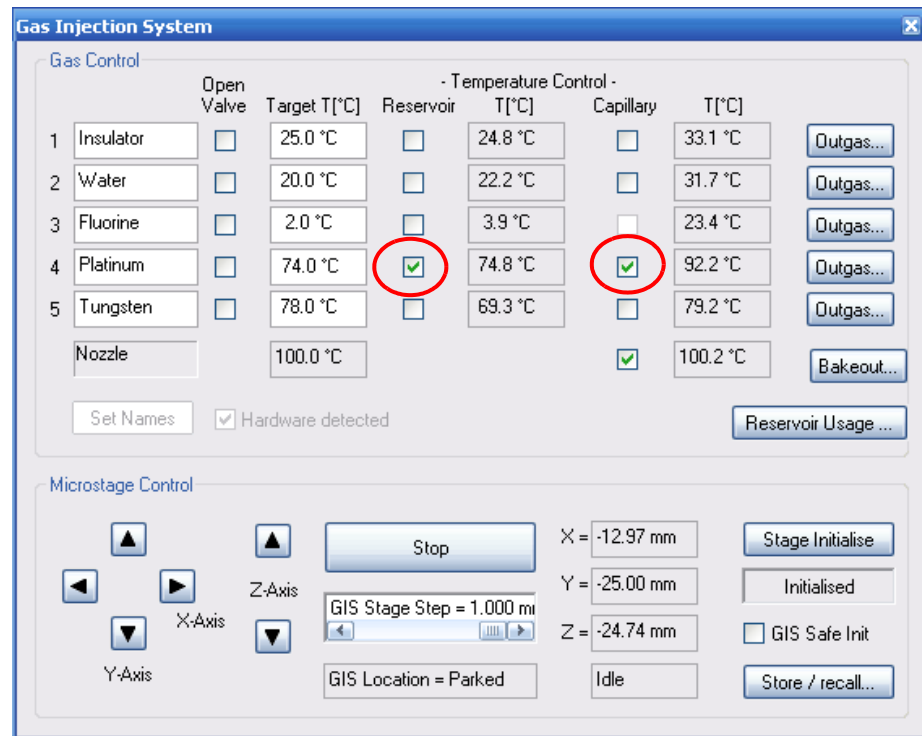
Outgassing is required to remove excess gas from the reservoir. If a channel is not used daily, the gas pressure in the reservoir is built up. Therefore, outgassing is necessary to avoid that the FIB vacuum level exceeds and decreases abruptly when the reservoir valve is opened.

Outgassing basically consists of a series of open and close cycles to let small amounts of gas out of the reservoir.

Procedure:

- 1 Switch off the SEM EHT.
- 2 Switch off the FIB EHT.
- 3 Open the **Panel Configuration Bar**.
- 4 Double-click **Gas Injection System**.

The **Gas Injection System** panel opens.

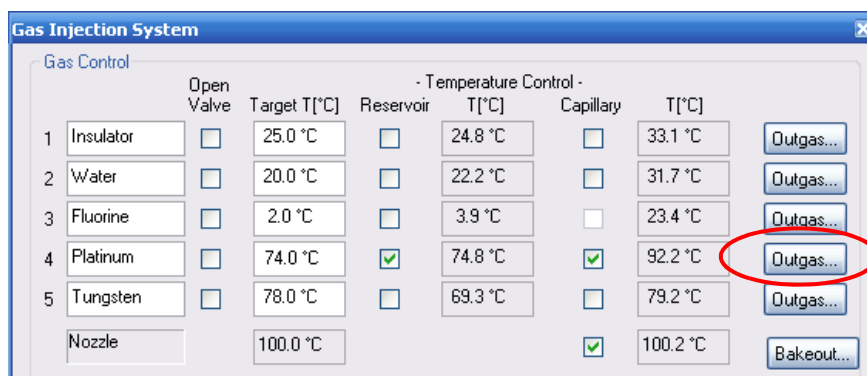


- 5 Ensure that the **Temperature Control** checkboxes for **Reservoir** and **Capillary** of *Platinum* are ticked.

3. First steps

Operating the workstation

- 6 In the **Platinum** row, click **Outgas**.



CAUTION

Danger of damaging electron source and ion source

Before starting the outgassing procedure:

Ensure that EHT and FIB EHT are switched off.

Ensure that "SEM Column Valve" and "FIB Gun Valve" are closed.

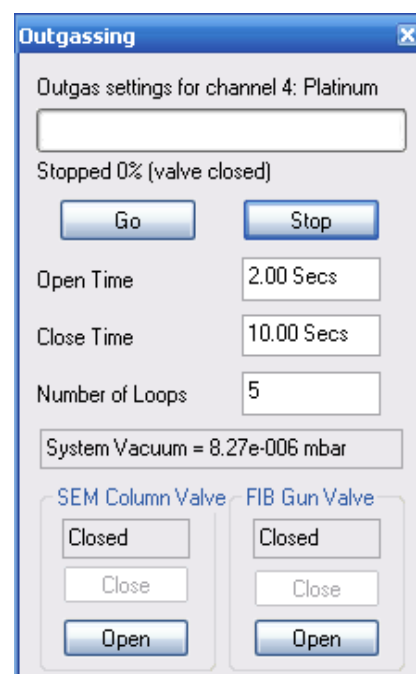
The **Outgassing** panel opens.

- 7 In the **SEM Column Valve** field:

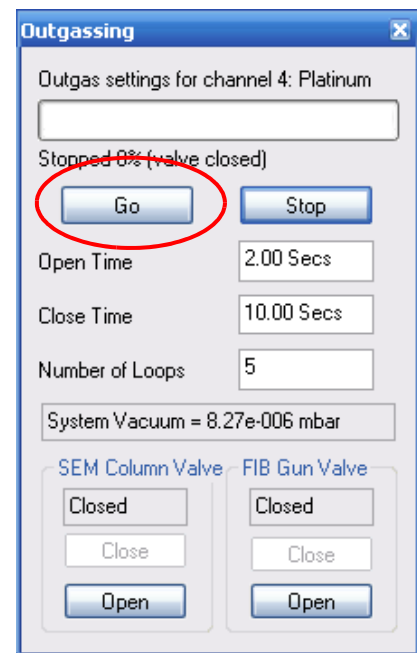
Click **Close**.

The column chamber valve in the SEM is closed.
The FIB gun valve is closed simultaneously.

- 8 Click the **Open Time** field and enter 2 seconds.
9 Click the **Close Time** field and enter a value of about 5 to 10 seconds.
10 Click the **Number of Loops** field and enter 5.



- 11 To start the outgassing procedure, click on **Go**.



- 12 Monitor the system vacuum by observing the **System Vacuum** value in the **Outgassing** panel.
- If, after the 5th loop, the vacuum has not reached 2×10^{-5} mbar or better, which is the pressure necessary for deposition, repeat the procedure.
- In this case, you should increase the number of loops in future outgassing procedures.

The outgassing procedure ends automatically.

If you wish to stop the procedure prematurely, click **Stop**.

**How to
continue**

Continue with selecting deposition conditions.

3. First steps

Operating the workstation

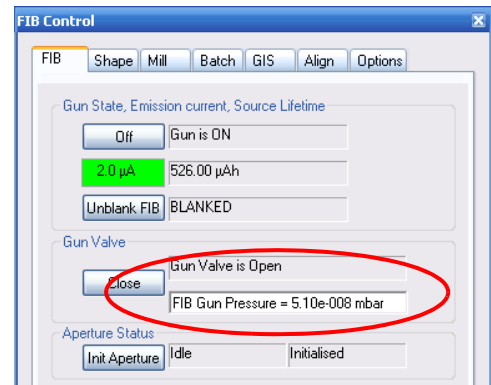
3.2.3.3. Selecting deposition conditions

Preconditions:

- Specimen has been moved to the coincidence point
- The platinum precursor has been heated and outgassed

Procedure:

- 1 Switch on the electron beam:
 - a Switch on the gun.
 - b Switch on the EHT.
- 2 Go to the **FIB** tab of the **FIB Control** panel.
- 3 Ensure the **FIB Gun Pressure** is better than 5×10^{-7} mbar (Canion) or 1×10^{-7} mbar (Cobra).



CAUTION

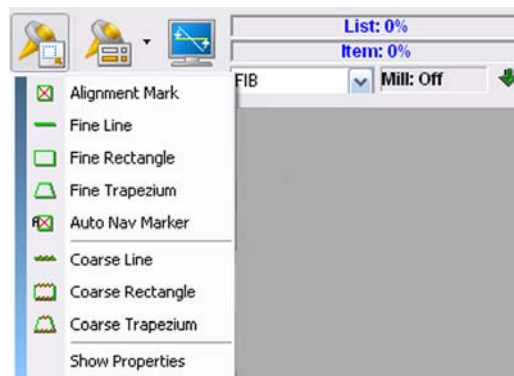
Danger of arcing. Danger of damaging the ion source.

Before switching on the ion beam, ensure the FIB gun pressure is better than 5×10^{-7} mbar (Canion) or 1×10^{-7} mbar (Cobra).

- 4 Switch on the ion beam:
 - a Go to the **FIB** tab of the **FIB Control** panel.
 - b Click **On**.
- 5 Select **FIB** mode from the drop-down menu.

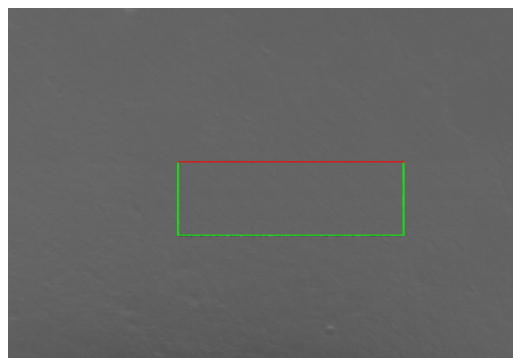


- 6 Select *Fine Rectangle* from the drop-down menu.



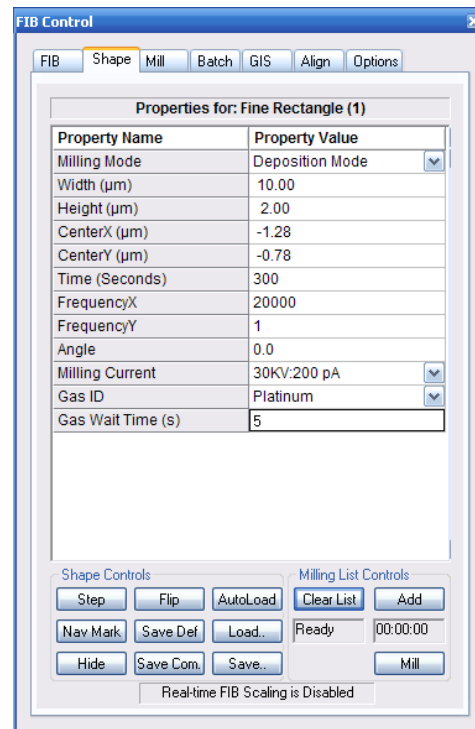
- 7 Click into the image area, where you wish to place the milling object.
 Hold the left mouse button and drag.

The milling object is displayed on the screen.



The **Shape** tab opens.

- 8 Enter the required parameters:
- a Milling Mode: *Deposition Mode*
 - b Width: *10 μm*
 - c Height: *2 μm*
 - d Time: *300 sec*
 - e FrequencyX: *20,000*
 - f FrequencyY: *1*
 - g Milling Current: *30 kV:200 pA*
 - h Gas ID: *Platinum*
 - i Gas Wait Time (s): *5 sec*



3. First steps

Operating the workstation

3.2.3.4. Starting the deposition procedure

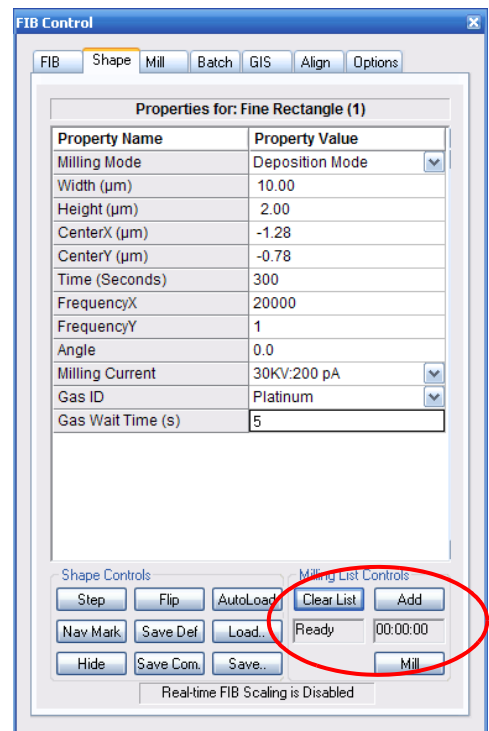
- 1 Click **Clear List**.

All previous milling objects are deleted from the milling list.

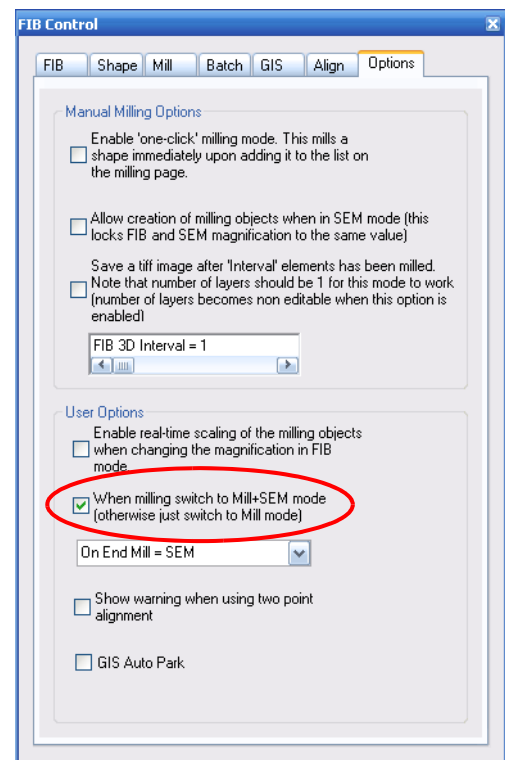
- 2 Click **Add**.

The current milling object is - together with the selected milling conditions - added to the milling list.

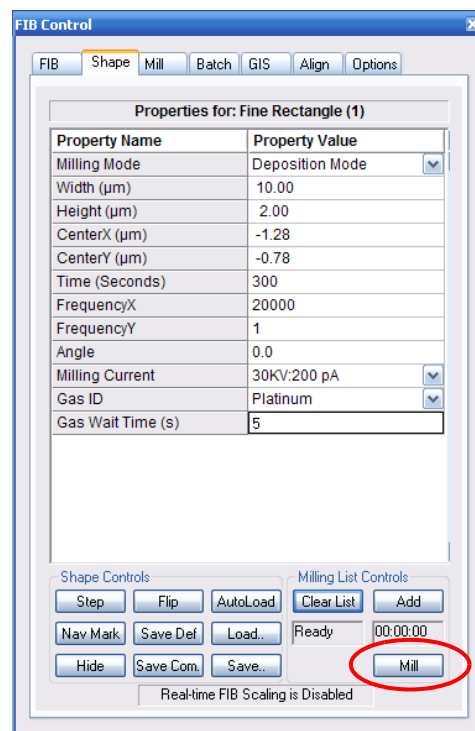
The time needed to process the object is shown under the **Add** button.



- 3 Go to the **Options** tab.
- 4 Tick the **When milling switch to Mill+SEM mode...** checkbox.



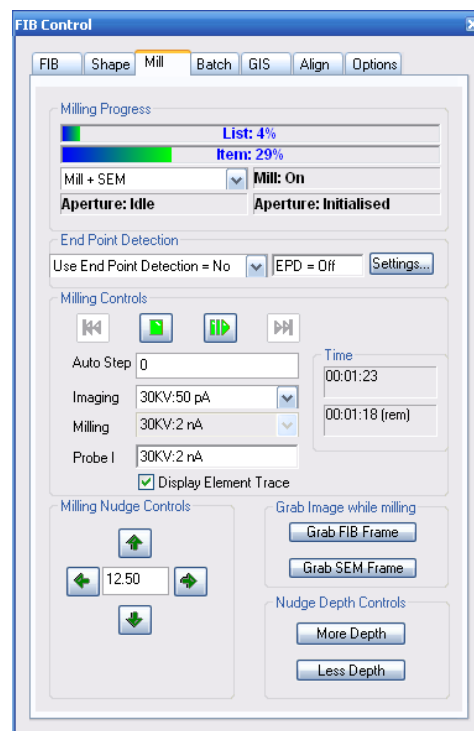
- 5 To start the deposition, go to the **Shape** tab and click **Mill**.



The GIS micro stage is moved automatically to the pre-defined position, which has been assigned to *Platinum*.

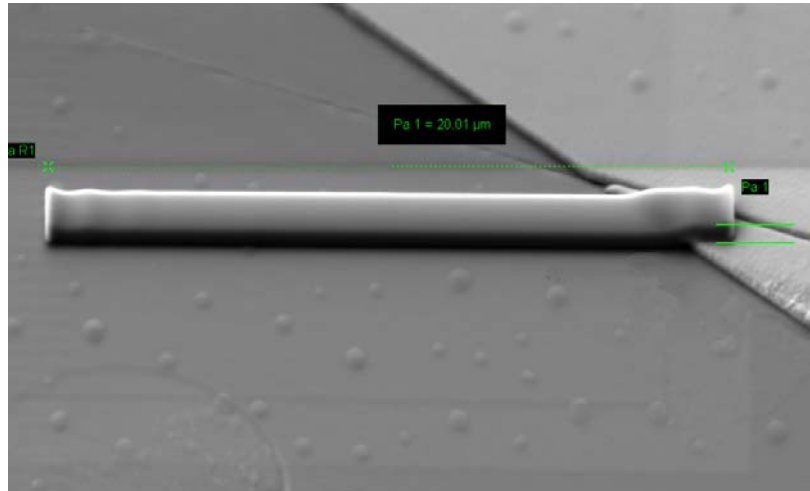
The deposition process starts.

The **Mill** tab opens, which allows you to directly control the deposition process.



3. First steps

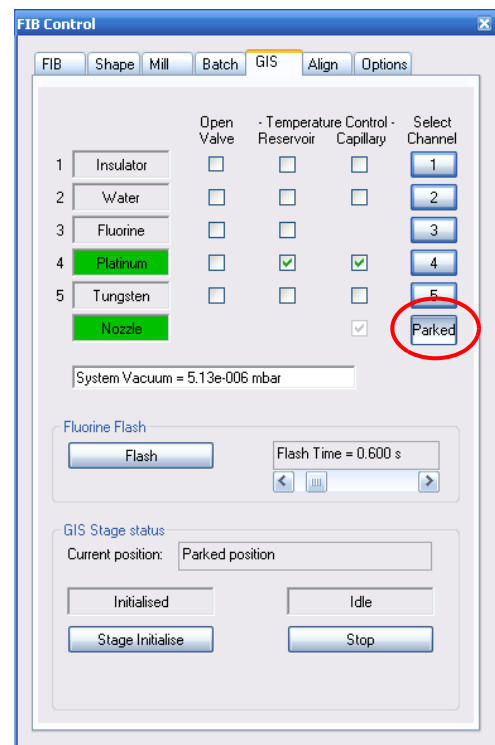
Operating the workstation



The deposition process ends automatically.

- 6 Move the GIS micro stage to the park position:
 - a Go to the **GIS** tab.
 - b Click **Parked**.

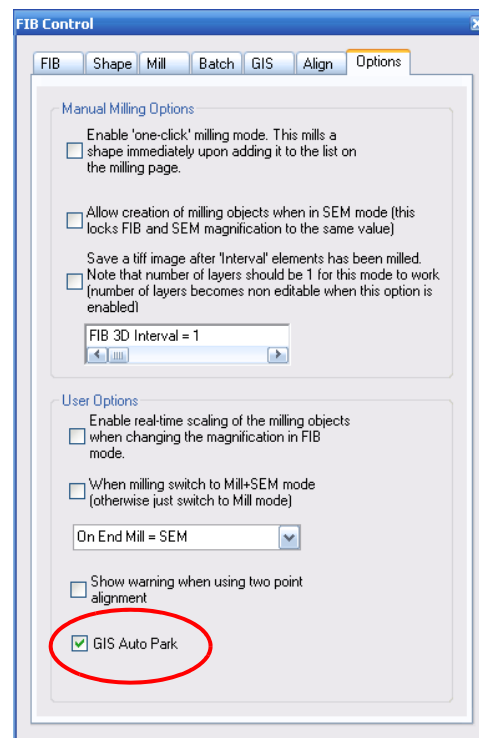
The GIS micro stage is driven to the safe park position.





IMPORTANT

If you tick the GIS Auto Park checkbox in the Options tab before starting the deposition (step 5), the GIS micro stage is automatically driven to the safe park position.



4. Operation

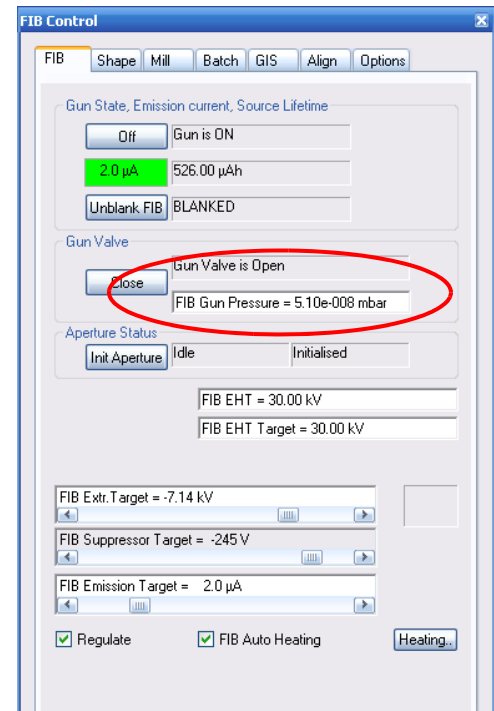
4.1. Controlling the vacuum

4.1.1. Checking the FIB gun pressure

- 1 Go to the **FIB** tab of the **FIB Control** panel.
- 2 Check the **FIB Gun Pressure**.

The *FIB Gun Pressure* is the ultra high vacuum in the FIB gun head area.

To indicate another pressure unit (*mbar, Pa, Torr*), click in the **FIB Gun Pressure** field.



CAUTION

Danger of arcing. Danger of damaging the ion source.

Before switching on the ion beam, ensure the FIB gun pressure is better than 5×10^{-7} mbar (Canion) or 1×10^{-7} mbar (Cobra).

4. Operation

Controlling the vacuum

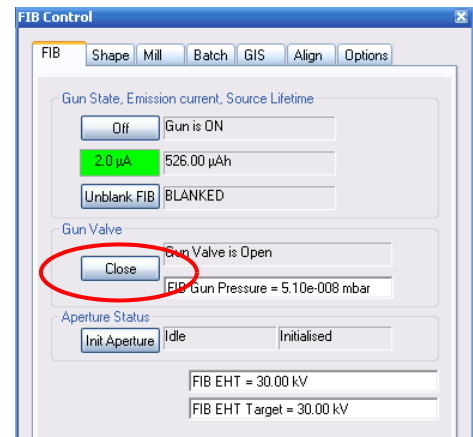
4.1.2. Controlling the gun valve

The gun valve separates FIB column (specimen chamber) and FIB gun area.

- 1 Go to the **FIB** tab of the **FIB Control Panel**.

In the **Gun Valve** field, the status of the gun valve is shown.

- 2 To change the status, click **Close/Open**.



IMPORTANT

To prevent any risk of damaging the ion source by a sudden vacuum decrease, the gun valve is secured by a vacuum interlock. To be able to open the gun valve the system vacuum must be better than 5×10^{-5} mbar.

4.2. Preparing the specimen position

4.2.1. Manually adjusting the tilt eucentricity

Before you can start imaging or milling, it might be necessary to adjust tilt eucentricity. By adjusting the eucentricity, the specimen surface is moved into the tilting plane of the super-eucentric stage. That's why the image does not shift out of the screen when the stage is tilted.

- 1 Generate a SEM image:
 - a Switch on SEM Gun and EHT.
 - b Select a detector.
 - c Set the following parameters:
 120 μm aperture, high current mode, WD= 15 mm, Mag = 500X, EHT= 5 kV
 fast scan speed e.g. 1, Noise Reduction = *Pixel Avg.*

CAUTION

Danger of damaging objective lens or specimen, if the specimen is too close to the objective lens.

Since the eucentricity is adjusted by using the M-axis, the working distance will be changed during the eucentricity setup.

Ensure the working distance is 10 mm or more.

- 2 Show the crosshairs by selecting **View/**
Crosshairs from the menu.

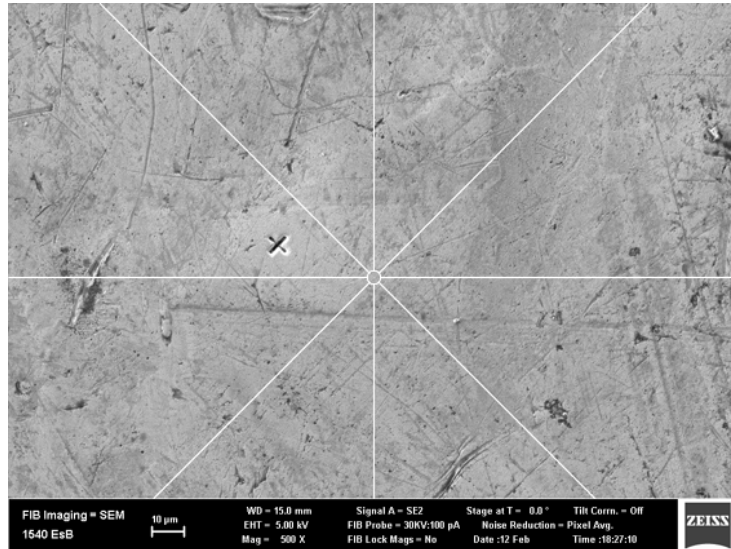
- 3 Go to the **Stage** tab.
 In the **Go To T(ilt)** field enter 0°.



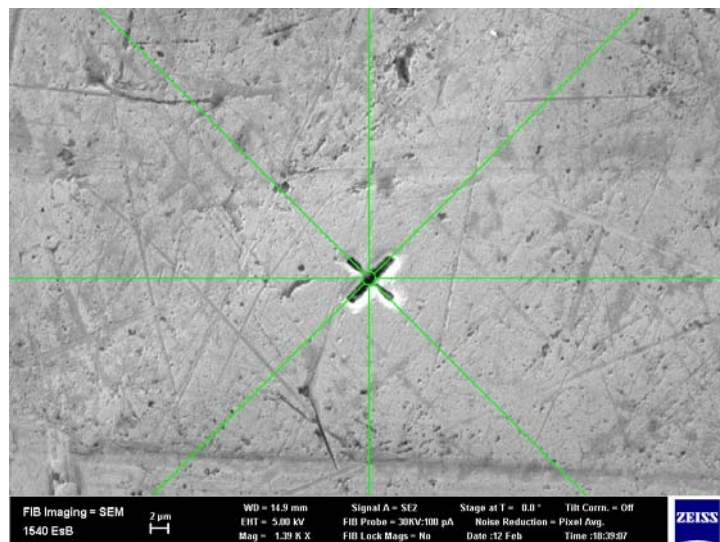
4. Operation

Preparing the specimen position

- 4 In the **SEM Control/Aperture tab** set the SEM Beam Shift to 0.
- 5 Select a feature on the specimen surface.



- 6 Shift the feature to the centre of the screen (centre of crosshairs).



- 7 In the **Go To T(ilt)** field enter 10°.

- 8 By changing the M-axis shift the feature back to the centre of the image:
 - a Open the **Panel Configuration Bar**.
Double-click **Soft Joystick**.
 - b Change M to shift the feature back to the centre.

Alternatively, use the M push buttons on the dual joystick controller to move the feature back to the centre.

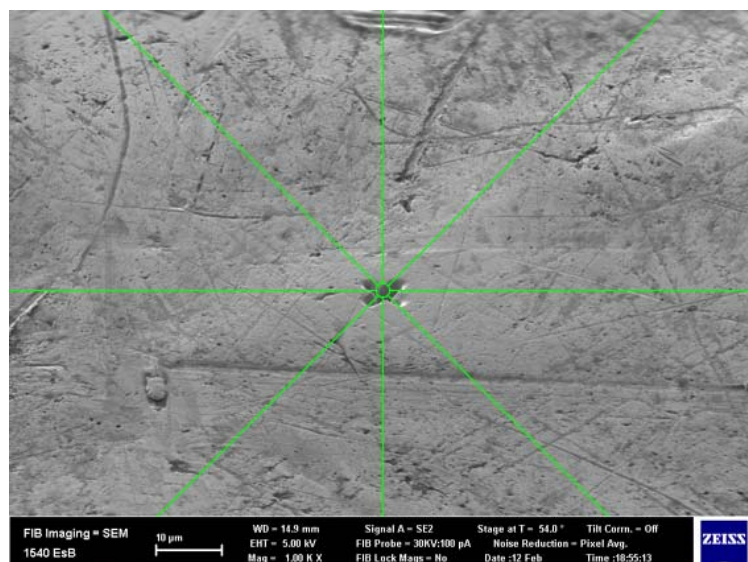
If the feature is moving upward on the screen, increase M.
If the feature is moving downward on the screen, decrease M.



IMPORTANT

Because M changes the working distance (WD), the image will run out of focus.

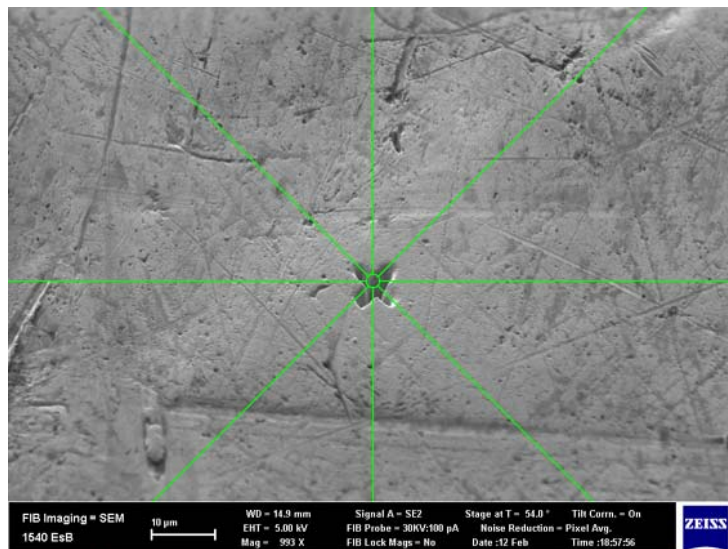
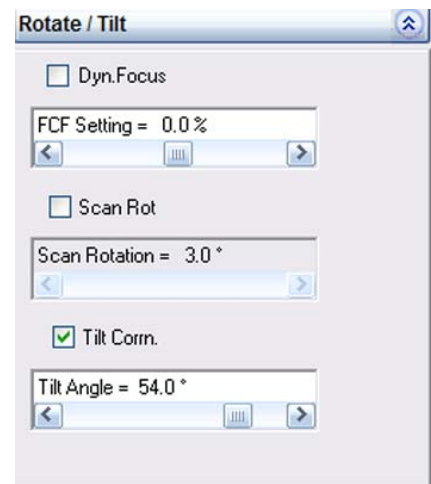
- 9 Focus the image.
- 10 Check the adjustment:
 - a Set Mag = 500X.
 - b In the **Go To T(ilt)** field enter 0°.
 - c Check.
- 11 In the **Go To T(ilt)** field enter 54°.



4. Operation

Preparing the specimen position

- 12 Activate the **Tilt Correction**:
 - a Select **Scanning /Rotate/Tilt** from the menu.
 - b Tick the **Tilt Corr.** checkbox.
 - c Set the tilt angle to 54° .
- 13 Shift the feature back by using the M-axis of the soft joystick.
- 14 Focus the image.



Alternatively, you can use the **FIB Daily Adjust** function.
Refer to section 3.1.2.

4.2.2. Shifting the specimen to the coincidence point

The coincidence point is the crossing point of electron beam (FESEM) and focused ion beam (FIB). The coincidence point is close to 5 mm.

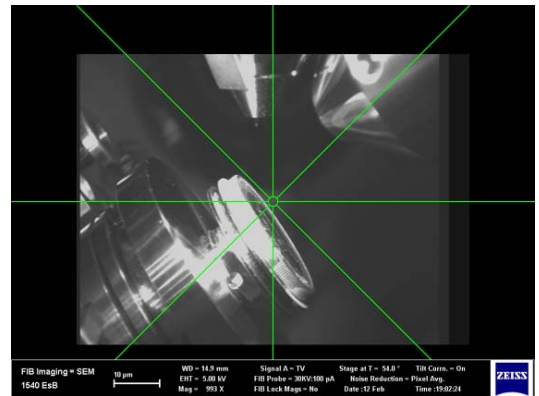
In order to be able to simultaneously image a feature as well in SEM mode as in FIB mode, the feature has to be located in the coincidence point.

CAUTION

Danger of damaging objective cap and/or specimen.

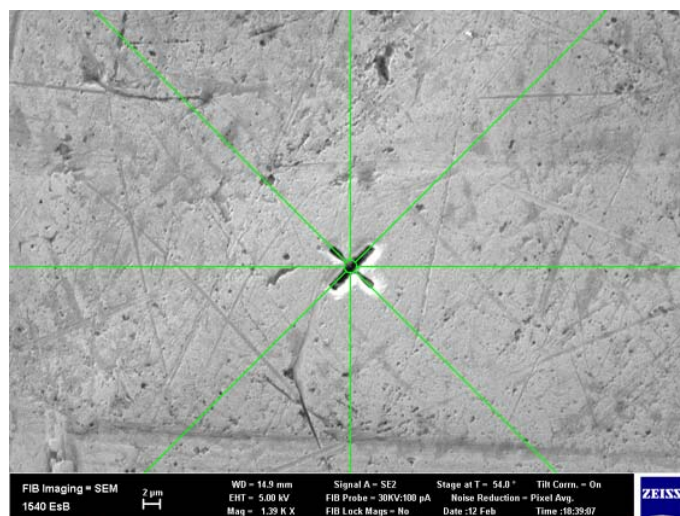
When using a carousel x stub sample holder, ensure all specimens have the same height. Prefer to use a single stub.

- 1 Select a fast scan speed.
- 2 Select **TV mode** to be able to ensure the distance between specimen and objective lenses is safe.
- 3 Go to SEM image.
- 4 Check the WD.



- 5 Show the crosshairs.

- 6 Shift a feature to the centre of the image.



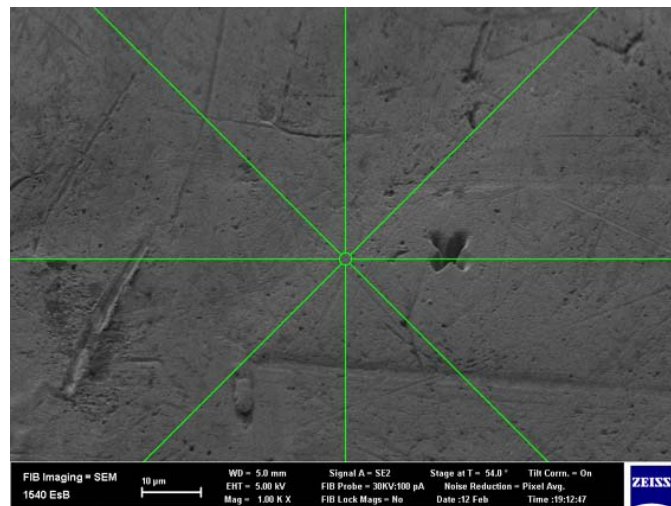
4. Operation

Preparing the specimen position

- 7 In the **Stage tab** of the **SEM Control** panel, ensure the **Track Z** checkbox is unticked.
- 8 Enter WD= 5 mm.

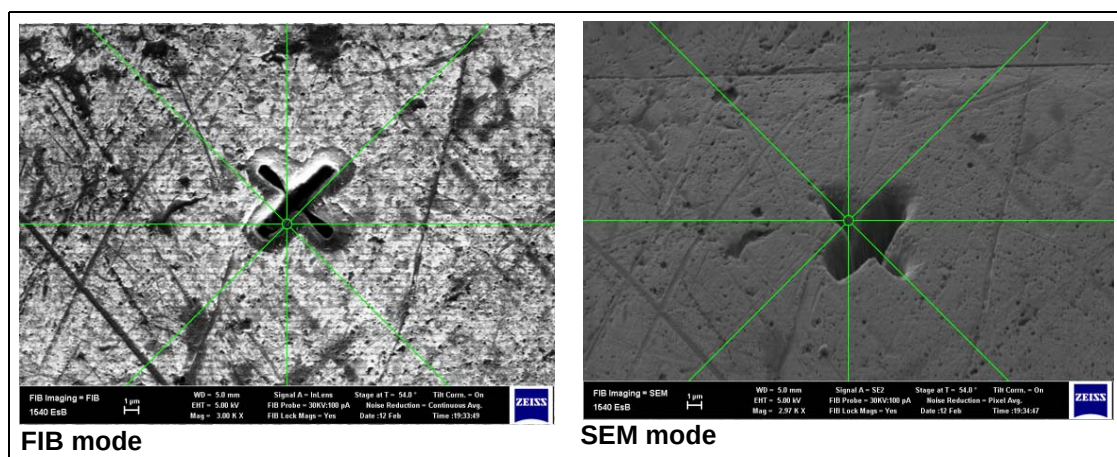
The image will be out of focus.

- 9 Use the dual joystick to shift the specimen in Z-direction until the image is in focus.
- 10 Use the **Focus** button to re-focus.
- 11 To check the WD double-click **WD** in the data zone.



- 12 Switch on the FIB.
- 13 Set the lowest possible magnification.
- 14 Couple the magnifications of SEM and FIB:
 - a Select **View/SEM Status** from the menu.
 - b In the **Select** tab, select **FIB Lock Mags**.
 - c Set **FIB Lock Mags=Yes** by clicking this entry.
- 15 Shift Z until the feature is in the centre of the screen.

The current WD is indicated, which corresponds to the coincidence point.



4.2.3. Aligning the specimen horizontally

If you wish to align a specimen detail horizontally, you can use the pre-defined point-to-point-state rotation function.

This function rotates the stage until the specimen detail is adjusted along a user-defined line.

Prerequisite: Tilt eucentricity has been adjusted.

CAUTION

Danger of damaging objective cap and/or specimen.

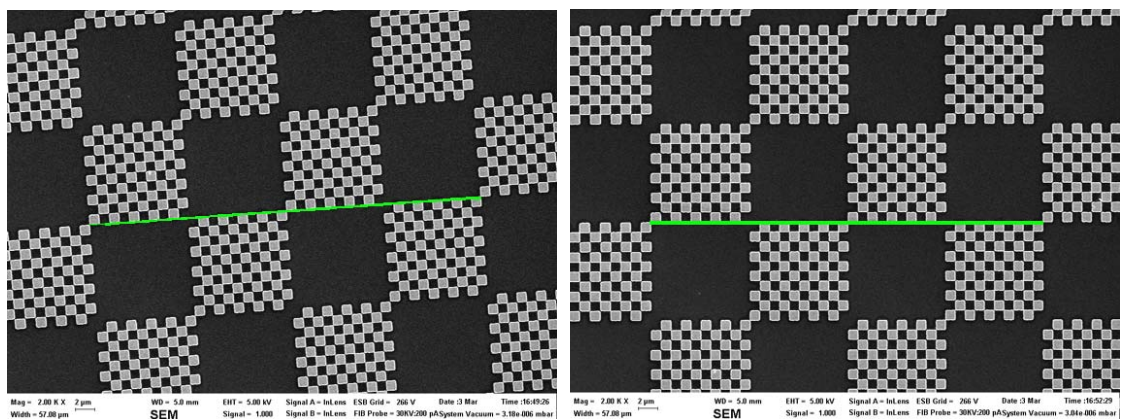
When using a carousel x stub sample holder, ensure all specimens have the same height. Prefer to use a single stub.

- 1 Click **Point-to-point Stage** icon.



- 2 Click to select the starting point of the horizontal line.
- 3 Click to select the end point of the horizontal line.

A line is shown. The stage rotates until it is lined up along the line.



4.3. Setting FIB conditions



IMPORTANT

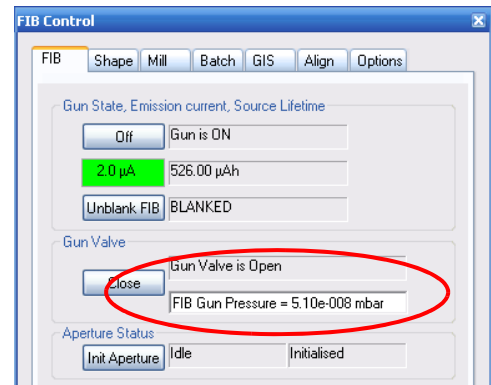
Be aware that the ion beam is always milling your specimen. Minimize the exposure as much as possible.

4.3.1. Controlling the ion beam

4.3.1.1. Switching on the ion beam

- 1 In the **FIB** tab of the **FIB Control** panel, check the **FIB Gun Pressure**.

The **FIB Gun Pressure** must be better than 5×10^{-7} mbar (Canion) or 1×10^{-7} mbar (Cobra).



CAUTION

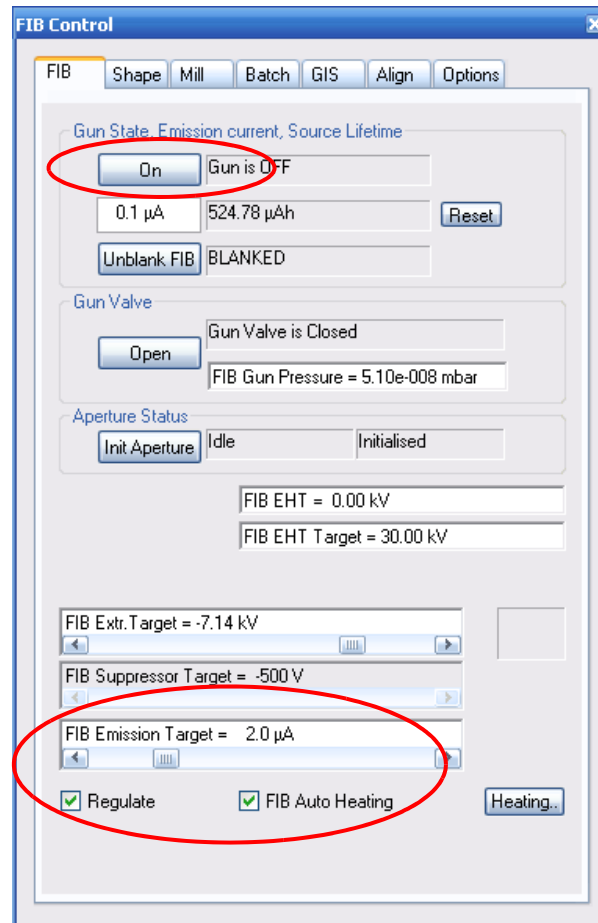
Danger of arcing. Danger of damaging the ion source.

Before switching on the ion beam, ensure the FIB gun pressure is better than 5×10^{-7} mbar (Canion) or 1×10^{-7} mbar (Cobra).

- 2 Check the current status of the system vacuum.
To be able to switch on the ion beam, the *System Vacuum* has to be 5×10^{-5} mbar or better.



- 3 Go to the **FIB** tab of the **FIB Control Panel**.
- 4 Ensure the **Regulate** checkbox and the **FIB Auto Heating** checkbox are ticked.
The **FIB Emission Target** should be 2.0 μA .



- 5 Click **On**.

4. Operation

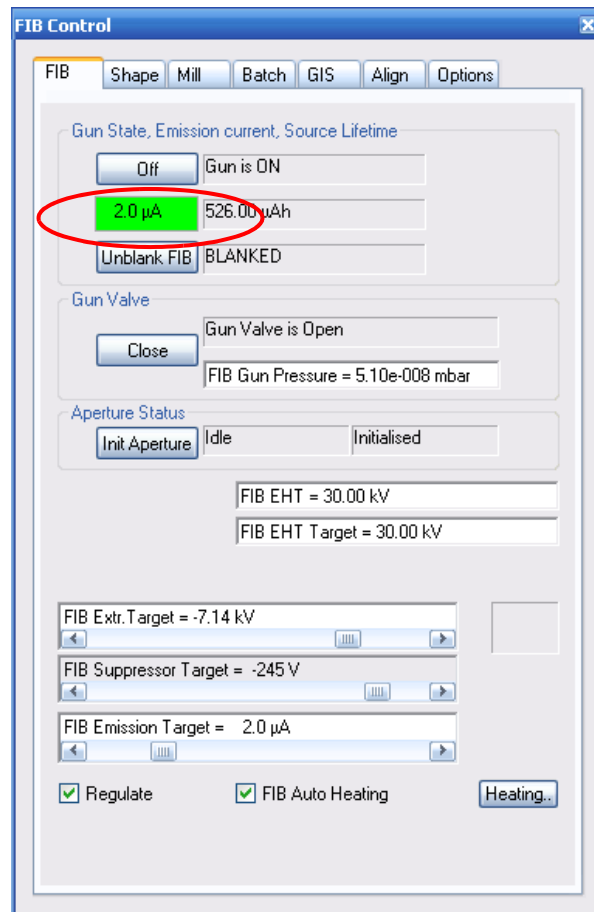
Setting FIB conditions

The FIB Gun is ramping up.

The gun valve is opened automatically.

Below the **Off** button, the emission current is shown.

The emission current should be about 2 μA like set by the **FIB Emission Target**.



The background of the display can have the following colours:

Green background:

The emission current equals the target ($\pm 0.1 \mu\text{A}$).

Yellow background:

The emission current differs from the target by more than $0.1 \mu\text{A}$.

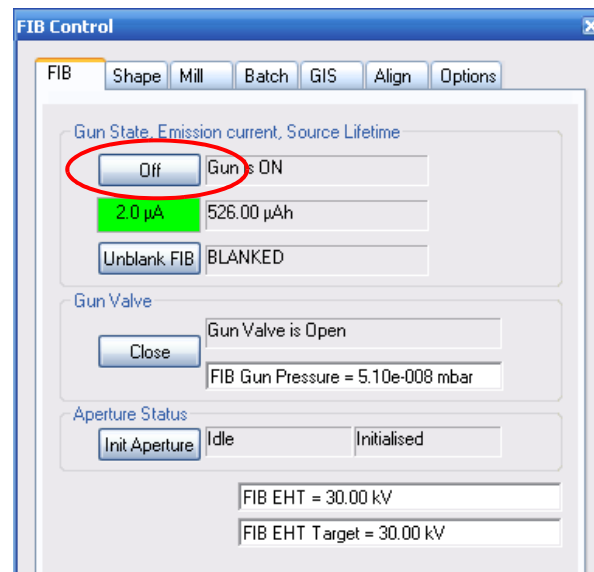
Red background:

The suppressor voltage has reached its limit and the emission current differs from the target significantly.

4.3.1.2. Switching off the ion beam

It is recommended switching off the ion beam when you do not work with the FIB for several hours like overnight or during weekends. This should help optimise the lifetime of the ion source, which is a consumable.

- 1 Go to the **FIB** tab of the **FIB Control Panel**.
- 2 Click **Off**.

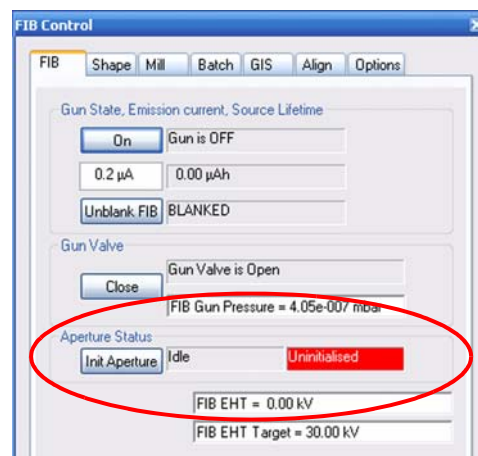


4.3.2. Initialising the FIB aperture

Initialising the FIB aperture is recommended after the PC has been re-started or when the red-highlighted **Uninitialised** message appears.

- 1 In the **FIB** tab of the **FIB Control Panel**, click **Init Aperture**.

The apertures are being initialised, i.e. the aperture strip is driven to the reference position and the back to the aperture position before initialisation.

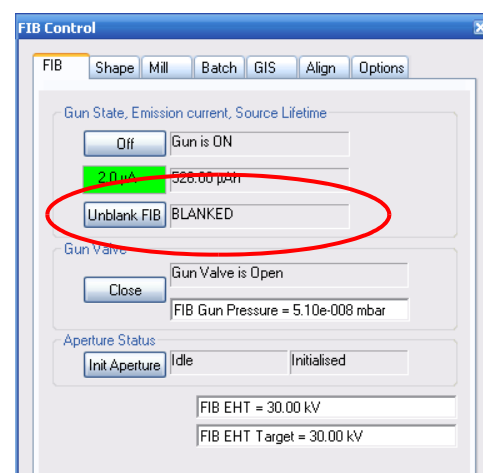


4.3.3. Blanking the ion beam

In the **FIB** tab of the **FIB Control Panel**, the status of the FIB beam (*unblanked/blanked*) is shown.

When the scan is frozen, the beam is automatically blanked.

- 1 To change the status of the FIB beam, click on **Unblank/Blank FIB**.



4.3.4. Regulating the emission current

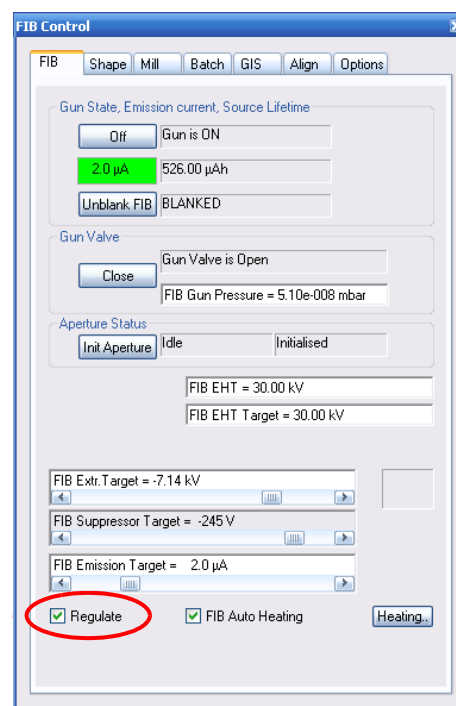
The emission current should be constant at the emission current target which is normally 2 μ A. This is achieved by adjusting the suppressor voltage. The suppressor voltage can have values between 0 V and -2000 V.

It is recommended that you activate the automatic regulation.

4.3.4.1. Automatic regulation

- 1 In the **FIB** tab of the **FIB Control** panel, tick the **Regulate** checkbox.

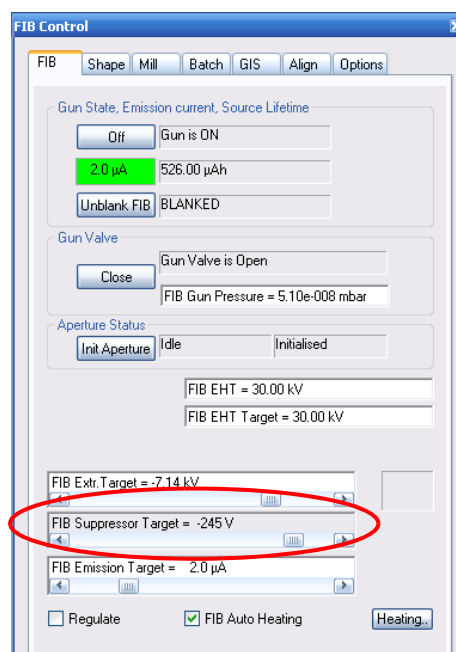
The emission current is regulated automatically by adjusting the suppressor voltage.



4.3.4.2. Manual regulation

The manual regulation is only recommended after you have talked with your local ZEISS service representative.

- 1 In the **FIB** tab of the **FIB Control** panel, untick the **Regulate** checkbox.
- 2 Use the **FIB Suppressor Target** slider to set the suppressor until an emission current of about 2 μ A or the desired emission current is achieved.



4.3.5. Defining user-specific FIB probe currents

The probe current to be selected from the drop-down list as *Milling Current* or *Imaging Current* can be edited via the **FIB Probe Table** functions.

The probe current can be continuously adjusted in the range between 1 pA and 50 nA. Among other things, the probe current depends on aperture size and condenser setting. As a standard, fifteen probe currents are pre-defined in the **FIB Probe Table**.

You can add up to fifteen additional user-specific probe currents.

Working with FIB EHT values of less than 5 kV requires the licence FIB-LOW-ENERGY.

Requires the user access level *Expert* or *Service*.

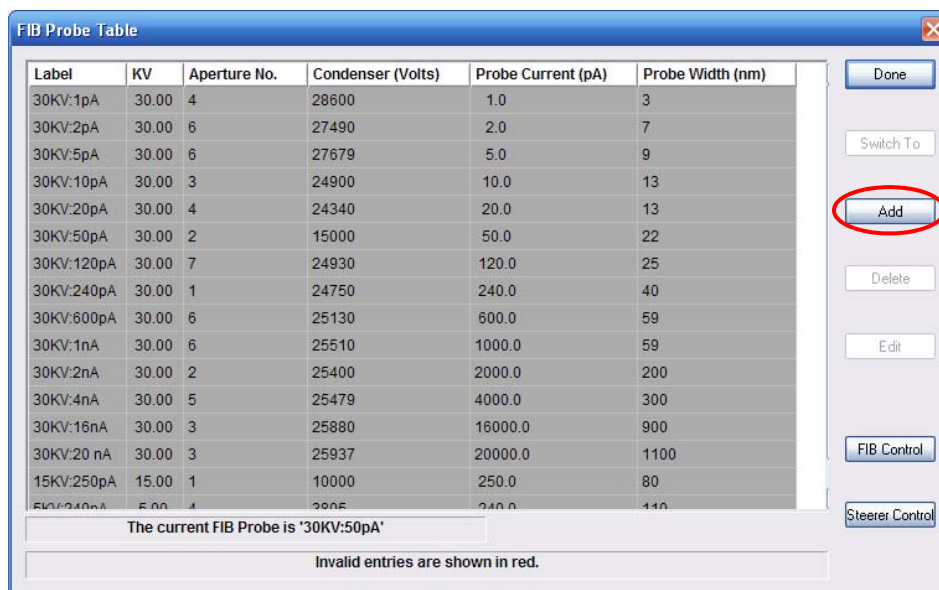
Prerequisites:

- SEM and FIB are switched on
- FIB apertures have been initialised
- Faraday cup is loaded in the specimen chamber

4.3.5.1. Entering a new FIB probe current

- 1 Open the **Panel Configuration Bar**.
- 2 Double-click **FIB Probe Table**.

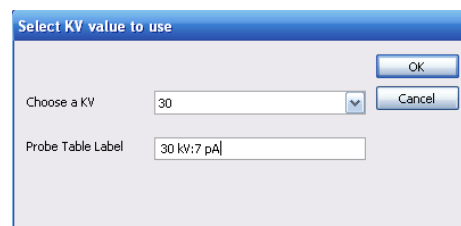
The **FIB Probe Table** panel opens.



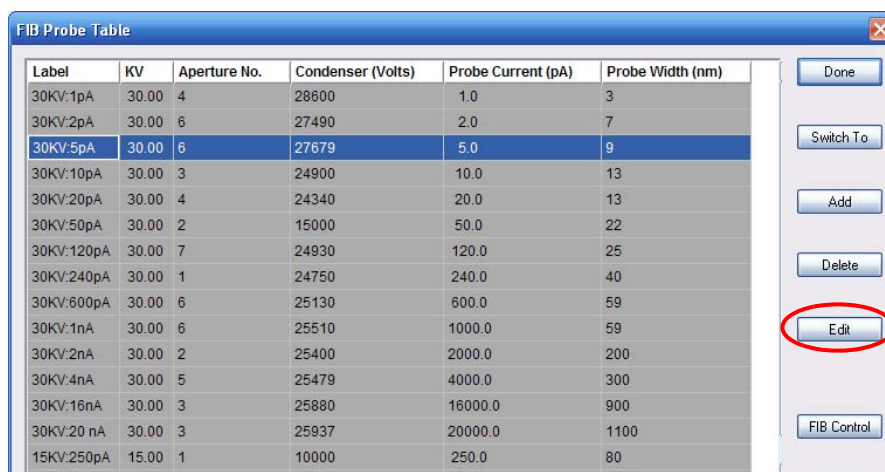
- 3 Click **Add**.

The **Select KV value to use** window opens.

- 4 Enter the required parameters.
- 5 Confirm by clicking **OK**.



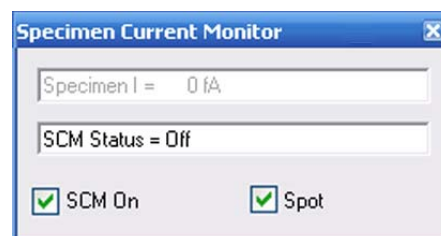
- 6 Edit the probe current:
 - a Select the new entry.
 - b Click **Edit**.



Label	KV	Aperture No.	Condenser (Volts)	Probe Current (pA)	Probe Width (nm)
30KV:1pA	30.00	4	28600	1.0	3
30KV:2pA	30.00	6	27490	2.0	7
30KV:5pA	30.00	6	27679	5.0	9
30KV:10pA	30.00	3	24900	10.0	13
30KV:20pA	30.00	4	24340	20.0	13
30KV:50pA	30.00	2	15000	50.0	22
30KV:120pA	30.00	7	24930	120.0	25
30KV:240pA	30.00	1	24750	240.0	40
30KV:600pA	30.00	6	25130	600.0	59
30KV:1nA	30.00	6	25510	1000.0	59
30KV:2nA	30.00	2	25400	2000.0	200
30KV:4nA	30.00	5	25479	4000.0	300
30KV:16nA	30.00	3	25880	16000.0	900
30KV:20 nA	30.00	3	25937	20000.0	1100
15KV:250pA	15.00	1	10000	250.0	80

- c Select a suitable aperture number from the drop-down list. Refer to table 4.1 or table 4.2.
- 7 Position the Faraday cup under the FIB column.

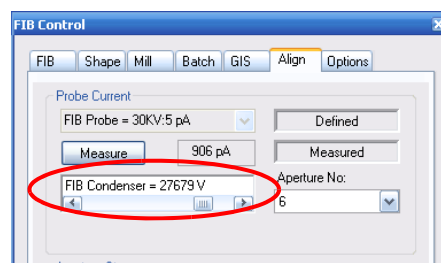
- 8 Start measuring the specimen current by using the **Specimen Current Monitor (Panel Configuration Bar/Specimen Current Monitor)**.



- 9 Tick the **SCM On** and the **Spot** checkbox.

- 10 In the **FIB Probe Table**, click **FIB Control**.

The **Align** tab of the **FIB Control** panel opens.



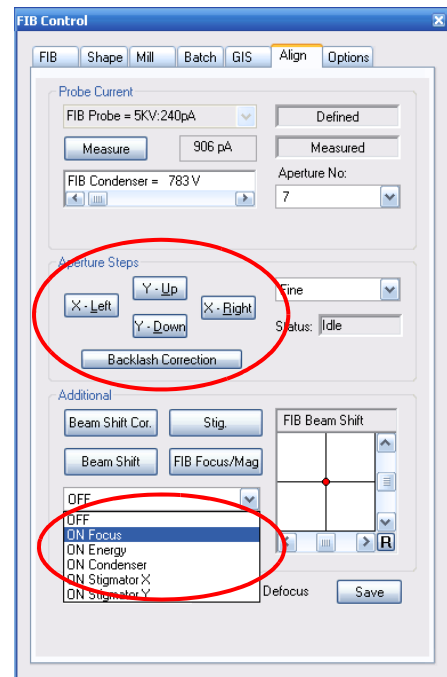
4. Operation

Setting FIB conditions

11 Wobble the aperture:

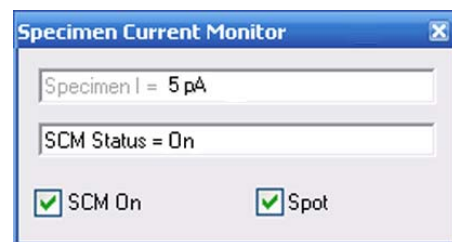
- a Select *ON Focus* from the drop-down menu.
- b Move the aperture: Use the buttons in the **Aperture Steps** field. Use only *Medium* or *Fine*.

The aperture has been aligned correctly when the image does not shift any more during the focus/un-focus cycle.



Adjust the **FIB Condenser** until the desired probe current is measured by the Specimen Current Monitor.

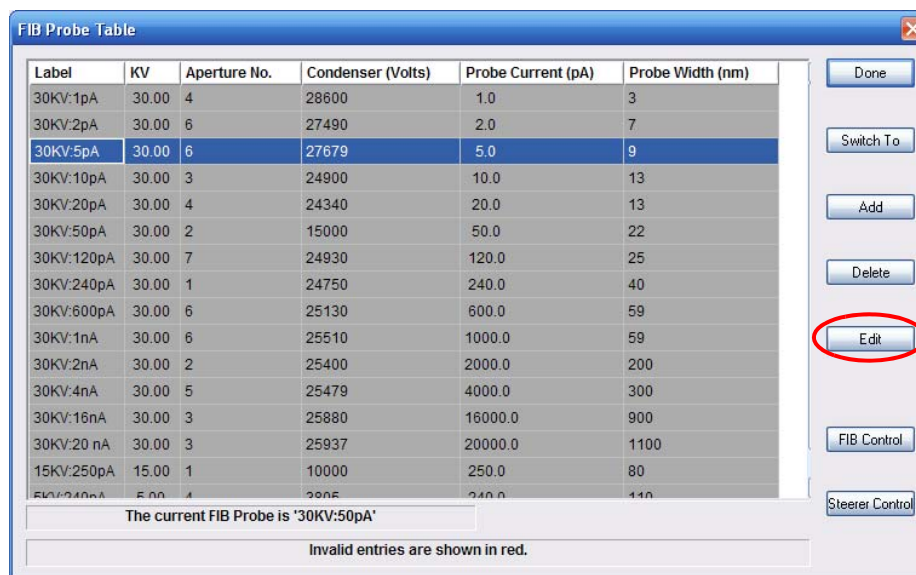
The condenser value is automatically adopted to the **FIB Probe Table**.



12 In the **FIB Probe Table**, click **End Edit**.

4.3.5.2. Editing a FIB probe current

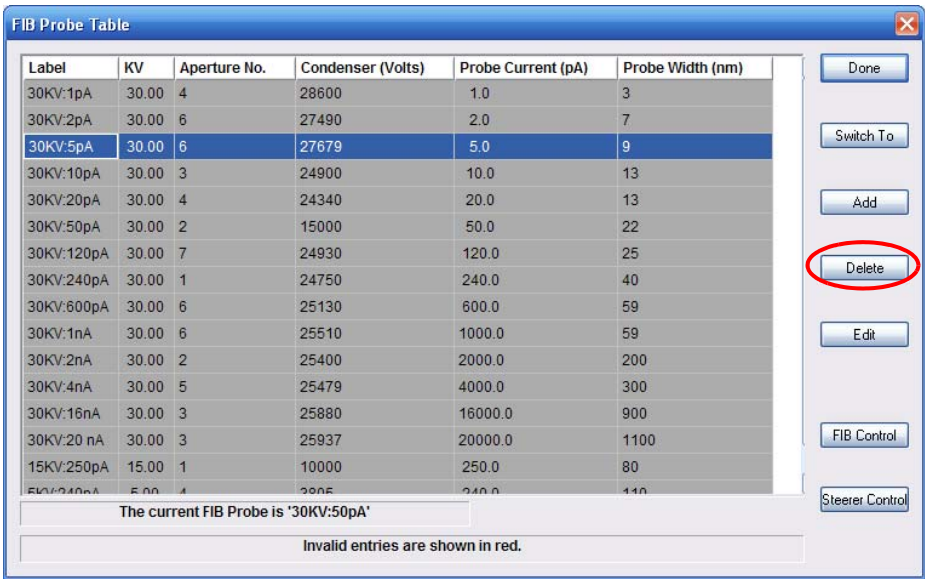
- 1 In the **FIB Probe Table**, select an entry.



- 2 Click **Edit**.
- 3 Make the required changes.
- 4 Click **End Edit**.

4.3.5.3. Deleting a FIB probe current

- 1 In the **FIB Probe Table**, select an entry.

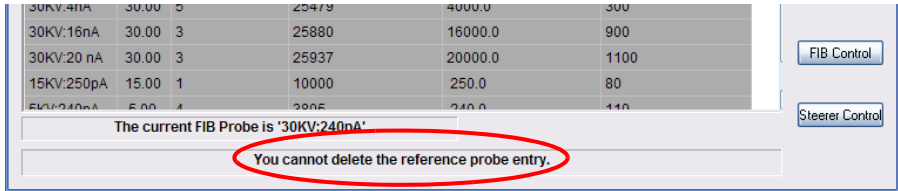


- 2 Click **Delete**.
- 3 Confirm.



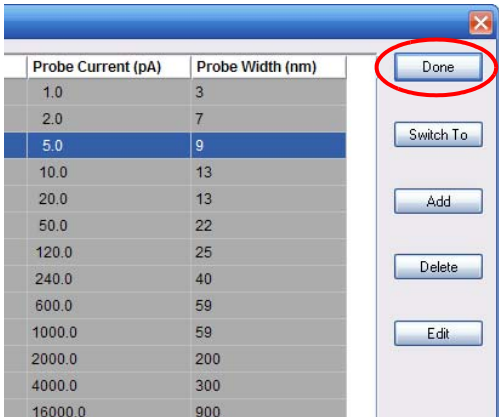
IMPORTANT

The reference probe current cannot be deleted. In the FIB Probe Table the message „You cannot delete the reference probe entry.“ is displayed.



4.3.5.4. Closing the FIB probe table

- 1 Click **Done**.



The **FIB Probe Table** closes.

4.3.6. Adjusting a FIB probe current at high kV (30 kV)

4.3.6.1. Overview

The FIB probe current is defined by emission current, condenser voltage and aperture diameter.

Canion FIB

Range	FIB probe currents	Aperture diameter	Aperture No.
Low probe currents	1, 2, 5 pA	10 µm	1
	5, 10, 20 pA	20 µm	2
	20, 50 , 100, 200 pA	50 µm	3, 4
	200, 500 pA 1 nA	100 µm	5
High probe currents	1, 2, 5 nA	200 µm	6
	5, 10, 20, 50 nA	400 µm	7

Table 4.1: Canion FIB: FIB probe currents and aperture numbering



IMPORTANT

The probe current of 50 pA is used as reference for the Canion FIB column. The other probe currents are dependent on this reference. If you change the reference values, all other probe currents will be changed as well.



IMPORTANT

Depending on special customer requirements, size and numbering of the apertures may be slightly different.

4. Operation

Setting FIB conditions

Cobra FIB

Range	FIB probe currents	Aperture diameter	Aperture No.
Low probe currents	1, 2 pA	10 µm	13
	5 pA	20 µm	12
	10 pA	30 µm	11
	20 pA	50 µm	10
	50 pA	80 µm	9
	120 pA	100 µm	8
	240 pA	150 µm	1
	600	200 µm	7
High probe currents	1 nA	200 µm	7
	2 nA	300 µm	2
	4 nA	400 µm	6
	16 nA	500 µm	3
	20 nA	600 µm	5
	-	700 µm	4

Table 4.2: Cobra FIB: FIB probe currents and aperture numbering

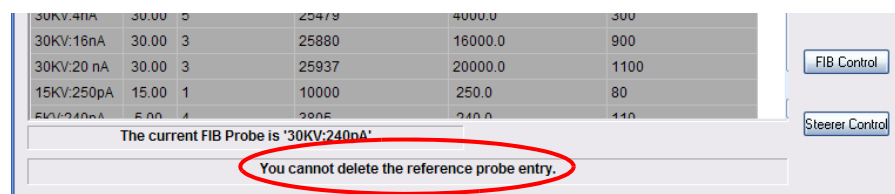


IMPORTANT

The probe current of 50 pA is used as reference for the Cobra FIB column. The other probe currents are dependent on this reference.

If you change the reference values, all other probe currents will be changed as well.

You can see that you have selected the reference probe current when the message „You cannot delete the reference probe entry.“ is displayed in the **FIB Probe Table**.



Preparing the adjustment

The extraction current should be kept constant while the other parameters can be changed in the **FIB Alignment** panel.

Possible reasons:

- After having changed the FIB Extractor Target

Depending on the operator's experience it may take up to a few hours to run through this procedure thoroughly.

Parts/special tools required	ZEISS part no.
Faraday cup	348342-8055-000
Piece of silicon wafer (bulk)	-

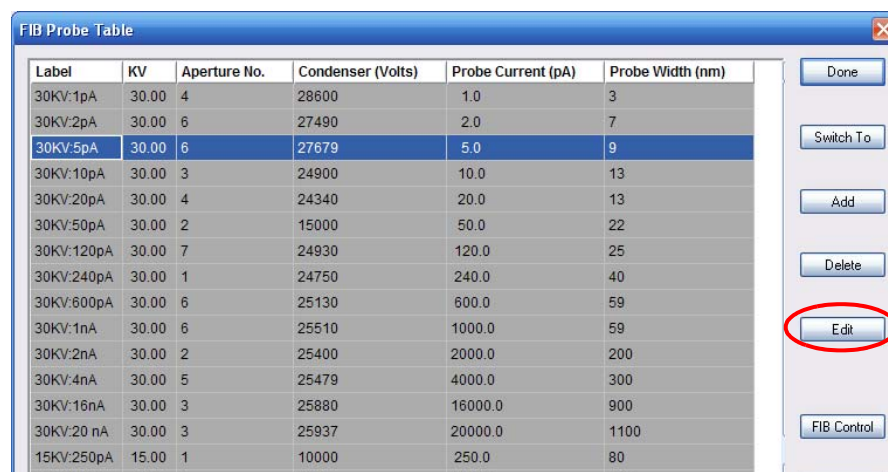
4. Operation

Setting FIB conditions

4.3.6.2. Adjusting a low probe current (pA)

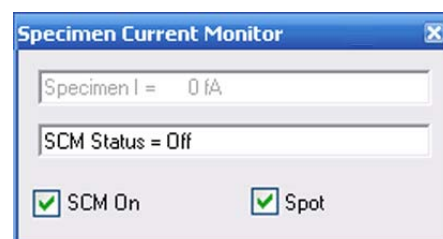
Procedure:

- 1 Load the Faraday cup.
- 2 Go to the coincidence point at 54°.
- 3 Ensure that the emission of the ion beam is stable.
- 4 Select **Panel Configuration Bar/FIB Probe Table**.
- 5 Edit a probe current:
 - a Select an entry.
 - b Click **Edit**.

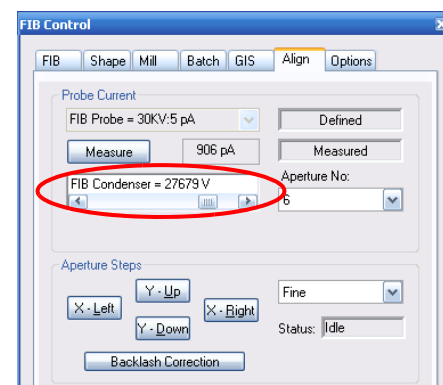


Label	KV	Aperture No.	Condenser (Volts)	Probe Current (pA)	Probe Width (nm)
30KV:1pA	30.00	4	28600	1.0	3
30KV:2pA	30.00	6	27490	2.0	7
30KV:5pA	30.00	6	27679	5.0	9
30KV:10pA	30.00	3	24900	10.0	13
30KV:20pA	30.00	4	24340	20.0	13
30KV:50pA	30.00	2	15000	50.0	22
30KV:120pA	30.00	7	24930	120.0	25
30KV:240pA	30.00	1	24750	240.0	40
30KV:600pA	30.00	6	25130	600.0	59
30KV:1nA	30.00	6	25510	1000.0	59
30KV:2nA	30.00	2	25400	2000.0	200
30KV:4nA	30.00	5	25479	4000.0	300
30KV:16nA	30.00	3	25880	16000.0	900
30KV:20 nA	30.00	3	25937	20000.0	1100
15KV:250pA	15.00	1	10000	250.0	80

- 6 Start measuring the specimen current by using the Specimen Current Monitor (**Panel Configuration Bar/Specimen Current Monitor**).
- 7 Tick the **SCM On** and the **Spot** checkbox.

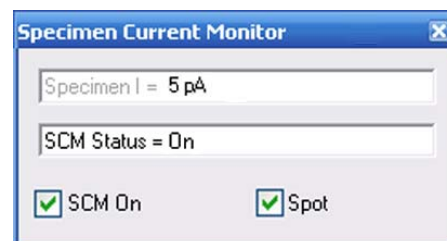


- 8 Go to **FIB Control/Align**.



- 9 Adjust the **FIB Condenser** until the desired probe current is measured by the Specimen Current Monitor.

The condenser value is automatically adopted to the **FIB Probe Table**.

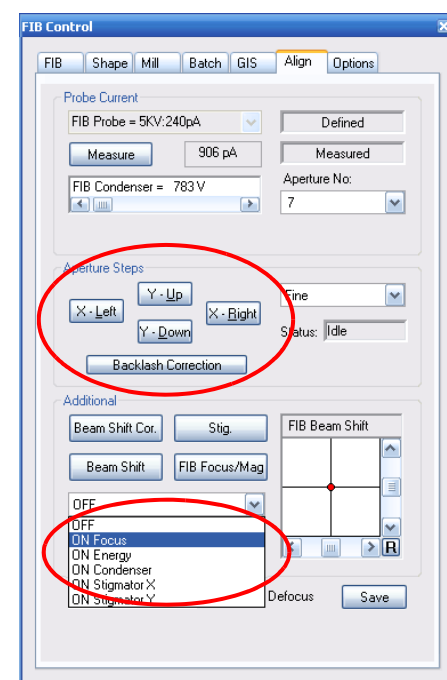


- 10 Focus the specimen surface: Use **Focus** and **Stigmation**.

- 11 Wobble the aperture:

- a Select *ON Focus* from the drop-down menu.
- b Move the aperture: Use the buttons in the **Aperture Steps** field. Use only *Medium* or *Fine*.

The aperture has been aligned correctly when the image does not shift any more during the focus/un-focus cycle.



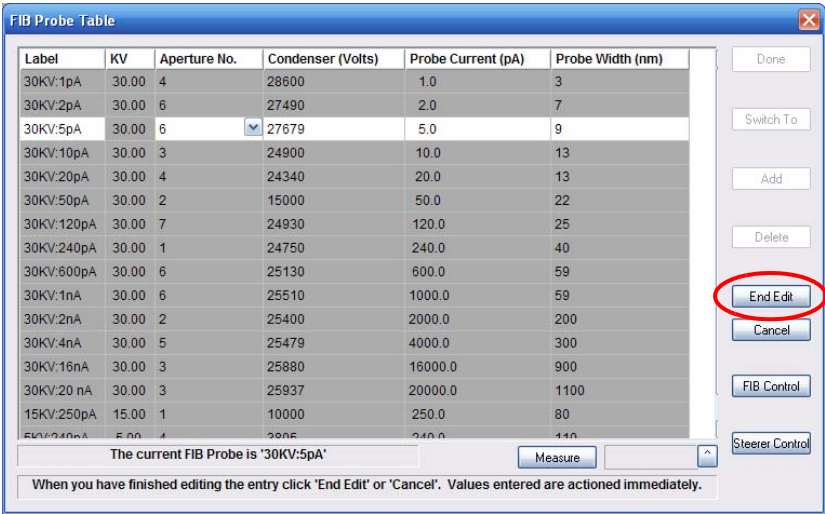
- 12 Re-focus the image: Use **Focus** and **Stigmation**.

- 13 If the results are not satisfying, repeat step 9 with a higher magnification.

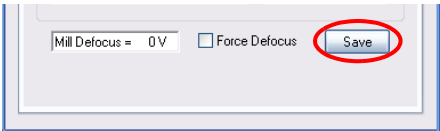
4. Operation

Setting FIB conditions

14 In the **FIB Probe Table**, click **End Edit**.



15 Click **Save**.



16 Repeat the procedure for all other probe currents.

How to continue

Adjust the Beam shift correction (refer to section 4.3.6.5.).

4.3.6.3. Adjusting a high probe current (nA)

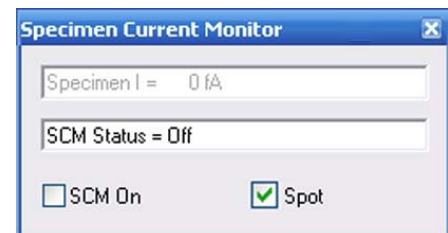
For the higher currents (nA range) usually the larger apertures need to be selected. It is very difficult to achieve a circular beam profile without halo by using the Focus wobble procedure.

Precondition:

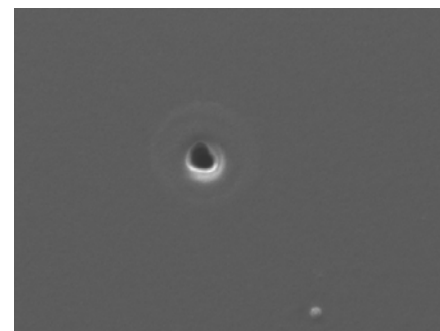
- Piece of silicon is loaded
- Probe currents have been adjusted roughly as described for pA probe currents (see previous section).

Procedure:

- 1 Burn a spot into the specimen for about 5 s:
Use the **Spot** mode.



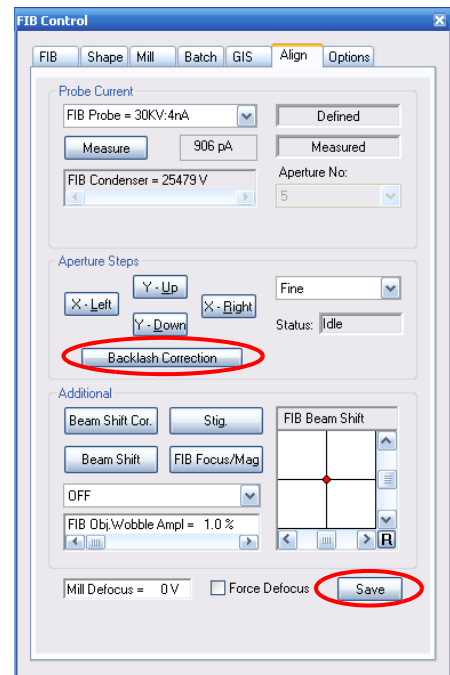
- 2 Check the halo.
- 3 If the spot is not round, move the aperture one step in one direction.
- 4 Burn a new spot.
- 5 If the halo is reduced, continue moving the aperture in this direction.
If the halo is increased, move the aperture in the opposite direction.
- 6 Repeat steps 4 to 5 until the burned spot is round.



4. Operation

Setting FIB conditions

- 7 In the **Align** tab of the **FIB Control** panel:
Click **Backlash Correction**.
- 8 Check the spot shape.
- 9 Click **Save**.



- 10 Repeat the procedure for all other nA probe currents.
- 11 If necessary optimise the probe current with the Defocus option (refer to section 4.3.6.4.).

How to
continue

Adjust Beam shift correction (refer to section 4.3.6.5.).

4.3.6.4. Optimising a high probe current (nA)

A probe current can have a halo round the center which significantly decreases the performance in terms of sputter rate and steepness of the side walls of a cross section.

If you cannot remove the halo by standard aperture alignment, use the defocus option.

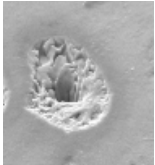
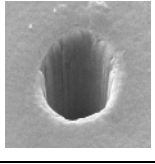
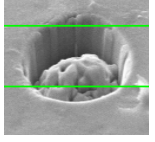
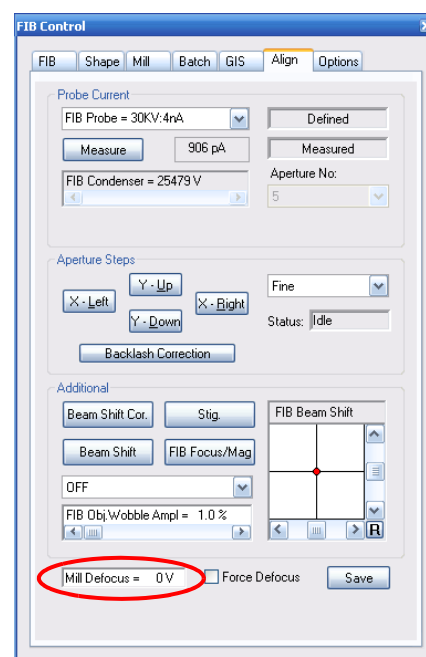
Image	Comment
	The ion beam is focussed, resulting in - an optimum imaging resolution but - the sputter rate is low due to the large halo.
	The focus voltage is reduced by -60 V resulting in - poor image quality, but - the sputter rate is increased due to the elimination of the halo and - high current density.
	The focus voltage is reduced by -120 V, both imaging and milling are of poor quality.

Table 4.3: Beam spots at different Focus voltages for 15 nA.

Procedure:

- 1 Adjust the probe current as described in section 4.3.6.3.
- 2 Go to **FIB Control/Align**
- 3 Set the defocus value:
 - a Double-click in the **Mill Defocus =** field.

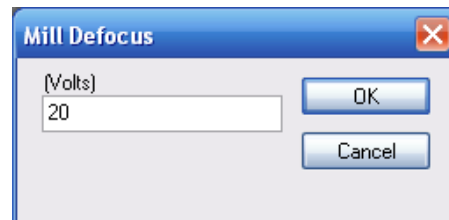




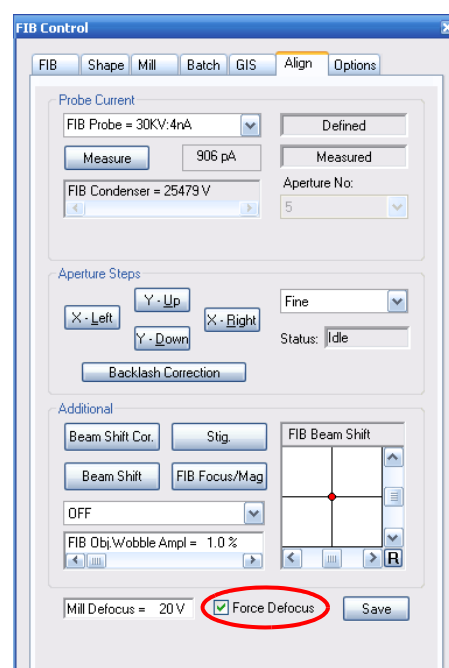
IMPORTANT

The defocus value is different for each current.

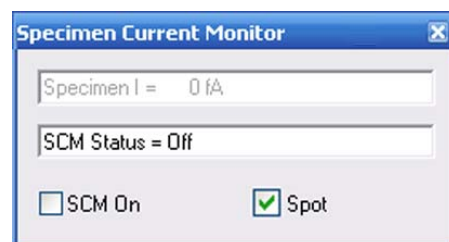
- b Enter a defocus value, e.g. 20V in the **Mill Defocus** window



- 4 Tick the **Force Defocus** checkbox.
The Defocus value is now applied when using spot mode.

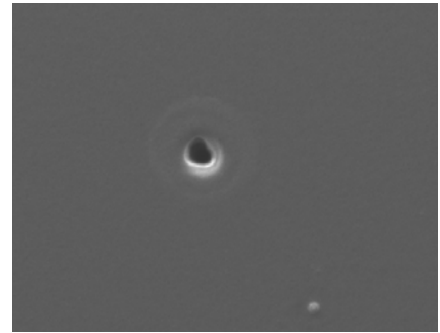


- 5 Burn a spot into the specimen for about 5 s to evaluate the spot quality:
Use the **Spot** mode.



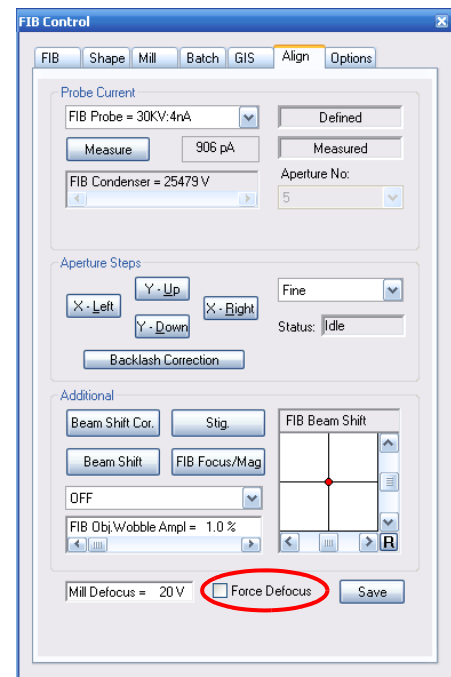
- 6 Check the halo.
7 Slowly increase the defocus value in 10 V steps.

- 8 Repeat steps 5 to 7 until the burned spot is round.



- 9 If the correct defocus voltage is reached, click **Save**.
- 10 Untick the **Force Defocus** checkbox.

Now, the adjustment is complete.



IMPORTANT

The defocus is automatically applied during milling.

4.3.6.5. Adjusting beam shift correction

The beam shift correction is used to correct the different beam positions of the different probe current settings. Because of the different condenser settings the beam path through the column can be slightly different. Therefore, the beam hits the sample at different locations. This can be corrected by using a part of the beam shift (called beamshift correction). The 30kV:50 pA probe current is the reference current where no correction is applied.

CAUTION

Danger of damaging the specimen

Especially while working with high currents the specimen can be damaged. Therefore make the settings with a Si wafer piece or move in an area of the specimen which can be damaged.



IMPORTANT

The 50 pA probe current is the reference probe current. All focus values and the beam shift correction are stored in reference to the 50 pA probe current. Therefore, this probe current must be adjusted first.

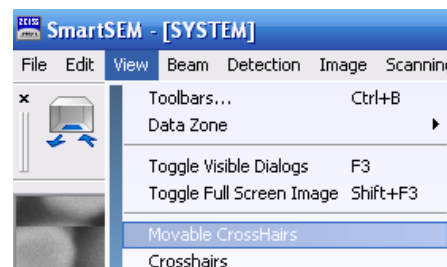
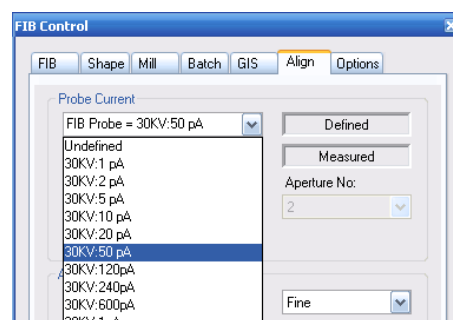


IMPORTANT

The Beamshift correction has only a limited range. The Beamshift correction values are zero for the 50 pA reference current.

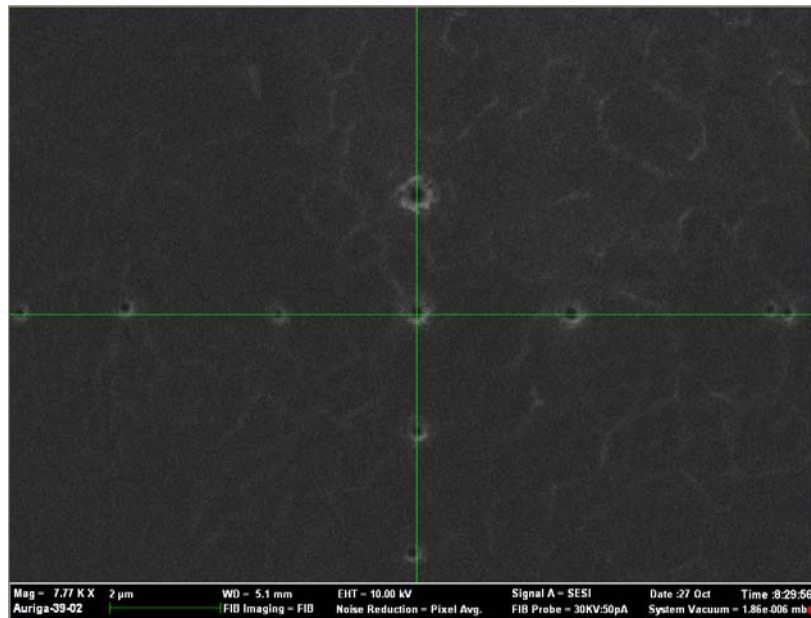
Procedure:

- 1 Select MAG 2000 (referred to Polaroid).
- 2 Go to **FIB Control/Align** and select the 30kV:50 pA reference current from the drop-down menu.
- 3 Select **View/Movable Crosshairs** from the menu bar.

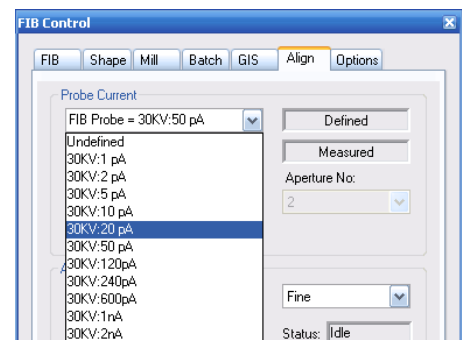


Crosshairs are displayed in the image area.

- 4 Move the crosshairs to a recognizable feature. To move the crosshairs, click the square in the centre and drag.



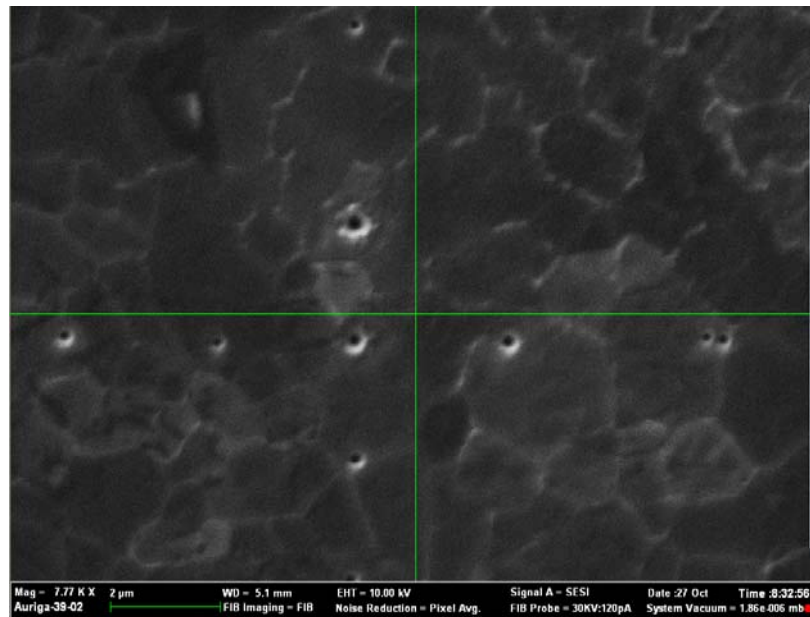
- 5 In the **FIB Control/Align** tab, select the next smaller probe current from the drop-down menu.



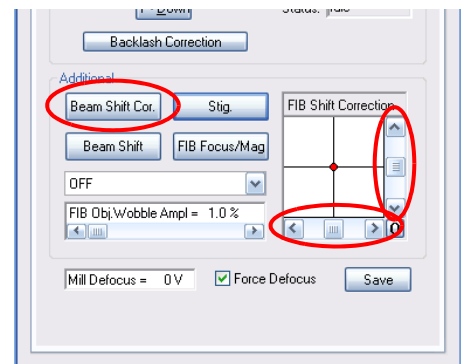
4. Operation

Setting FIB conditions

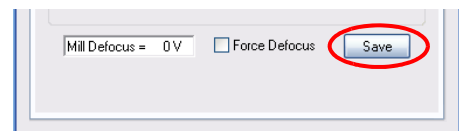
The feature is shifted to another position



- 6 Move the feature to the original position by using the beamshift correction.
 - a Click **Beam Shift Cor.**
 - b Move the crosshairs with the sliders or the red dot.

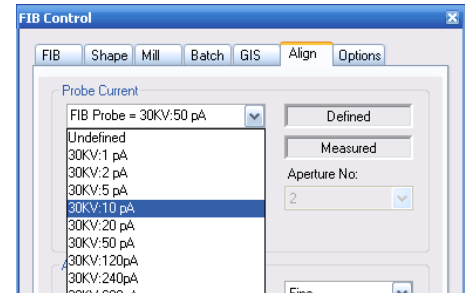


- 7 Click **Save** to save the adjustments.

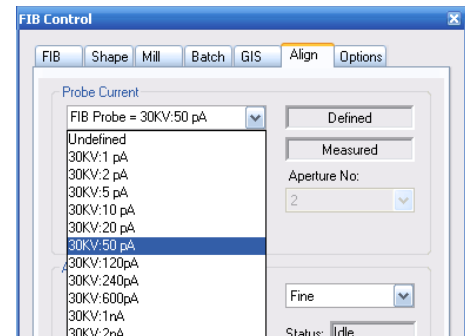


8 Repeat steps 5 to 7 with the next smaller probe current.

9 Adjust all smaller probe currents with this procedure.

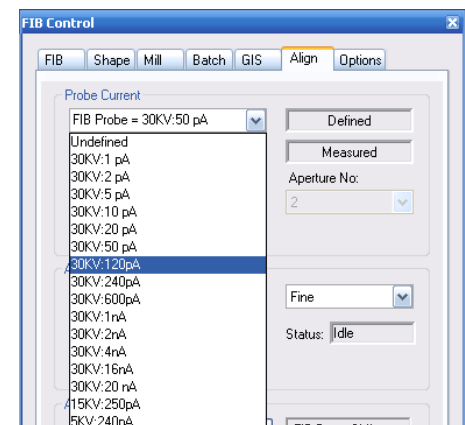


10 Select the 30KV:50 pA reference current to check the original position of the crosshairs. If necessary move the crosshairs to the original position.



11 Repeat steps 6 to 7 with the next higher probe current.

12 Adjust all higher probe currents with this procedure.



Now, the adjustment is complete.

4.3.7. Adjusting a FIB probe current at low kV (2 - 5 kV) (licence: FIB-LOW-ENERGY)

4.3.7.1. Overview

Requires the licence FIB-LOW-ENERGY.

The FIB probe current is defined by emission current, condenser voltage and aperture diameter.

Cobra FIB

Range	FIB probe currents	Aperture diameter	Aperture No.
1 kV	20 pA	50 µm	10
2 kV	20 pA	80 µm	9
5 kV	20 pA	80 µm	9
	240 pA	200 µm	7
15 kV	250 pA	150 µm	1

Table 4.4: Cobra FIB: FIB probe currents and aperture numbering

Preparing the adjustment

The extraction current should be kept constant while the other parameters can be changed in the **FIB Alignment** panel.

Possible reasons:

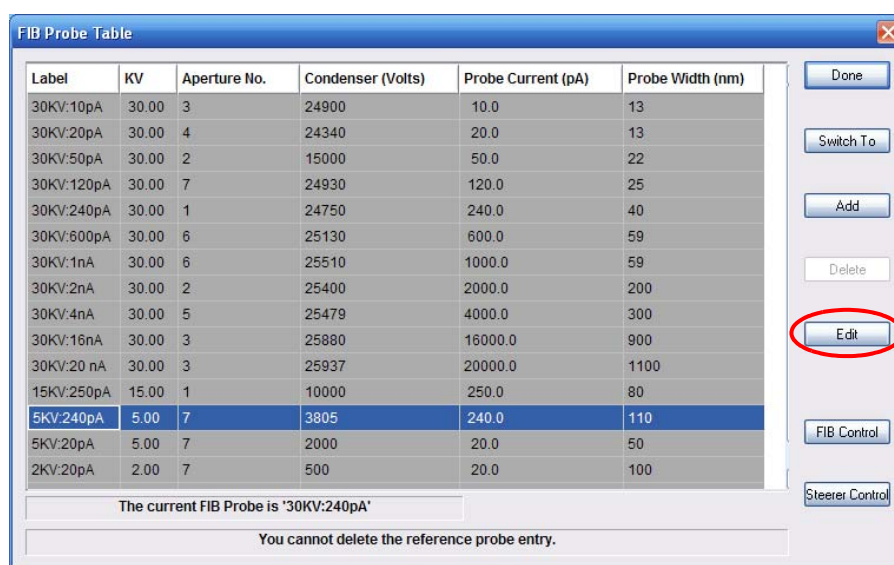
- After having changed the FIB Extractor Target

Parts/special tools required	ZEISS part no.
Faraday cup	348342-8055-000
Piece of silicon wafer (bulk)	-

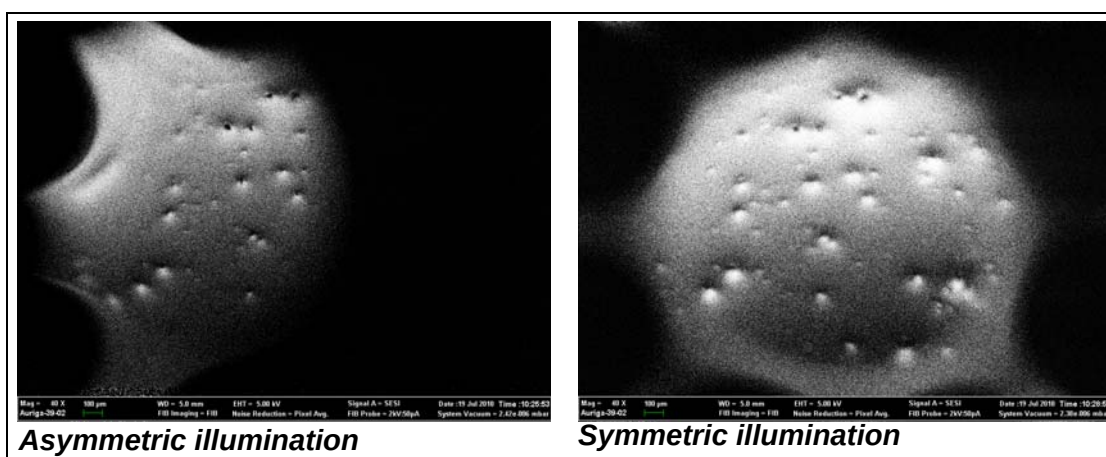
4.3.7.2. Adjusting a probe current (Canion column only)

Procedure:

- 1 Load the Faraday cup.
- 2 Go to the coincidence point at 54°.
- 3 Ensure that the emission of the ion beam is stable.
- 4 Select **Panel Configuration Bar/FIB Probe Table**.
- 5 Edit a probe current:
 - a Select an entry.
 - b Click **Edit**.



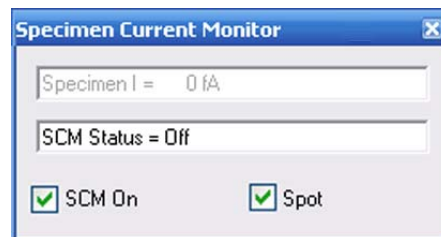
- 6 Go to the lowest magnification.
- 7 Use aperture steps to create a symmetric illumination.



4. Operation

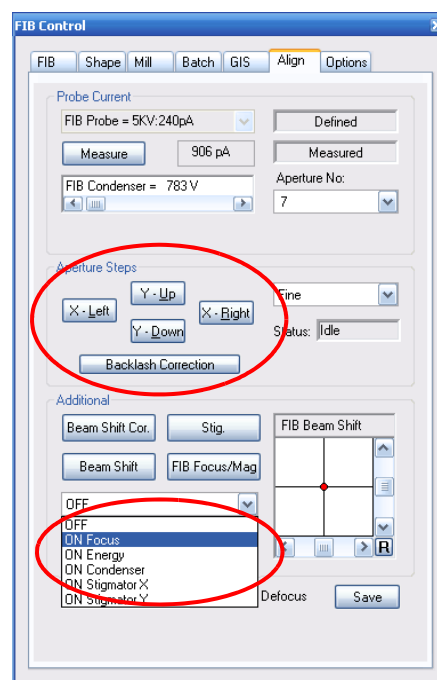
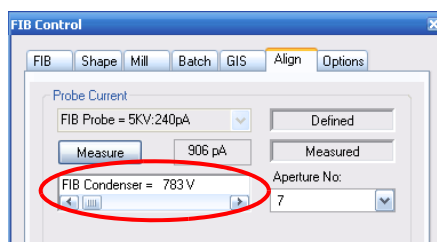
Setting FIB conditions

- 8 Start measuring the specimen current by using the Specimen Current Monitor (**Panel Configuration Bar/Specimen Current Monitor**) and the Faraday cup.
- 9 Tick the **SCM On** and the **Spot** checkbox.
- 10 Take the target value from the probe table as a starting value.
- 11 Go to **FIB Control/Align**.
- 12 Adjust the desired value (+10 %) with the **FIB condenser** slider.

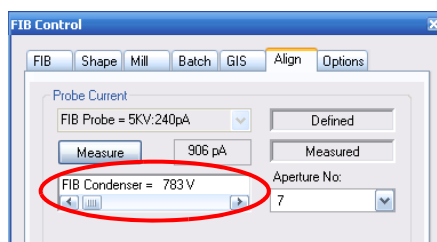


- 13 Raise the magnification to 1 kX-10 kX.
- 14 Wobble the aperture:
 - a Select *ON Focus* from the drop-down menu.
 - b Move the aperture: Use the buttons in the **Aperture Steps** field. Use only *Medium* or *Fine*.

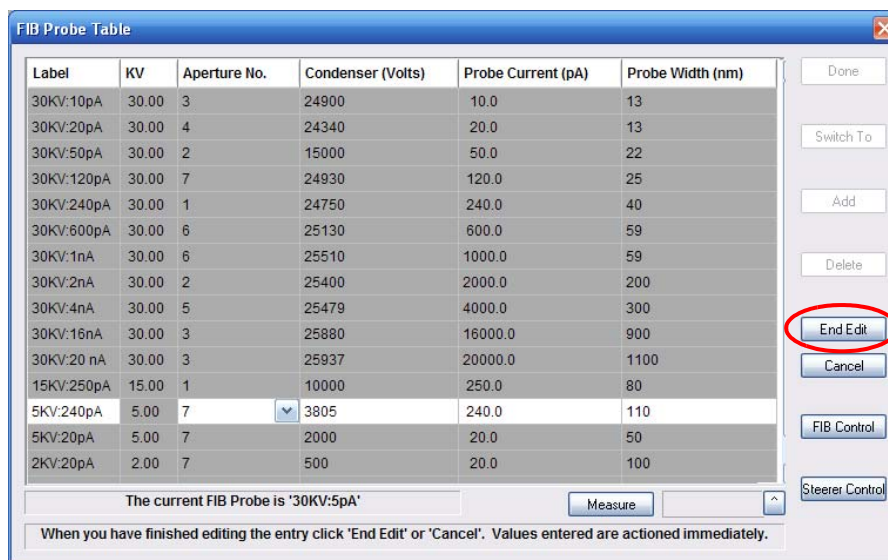
The aperture has been aligned correctly when the image does not shift any more during the focus/un-focus cycle.



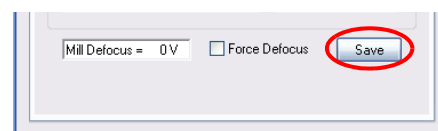
- 15 Check the current again and compensate with the **FIB condenser** slider if needed.



16 In the **FIB Probe Table**, click **End Edit**.



17 Click **Save** to save the adjustments.



**How to
continue**

Check the beam profile and optimize if necessary
(refer to section 4.3.6.3.).

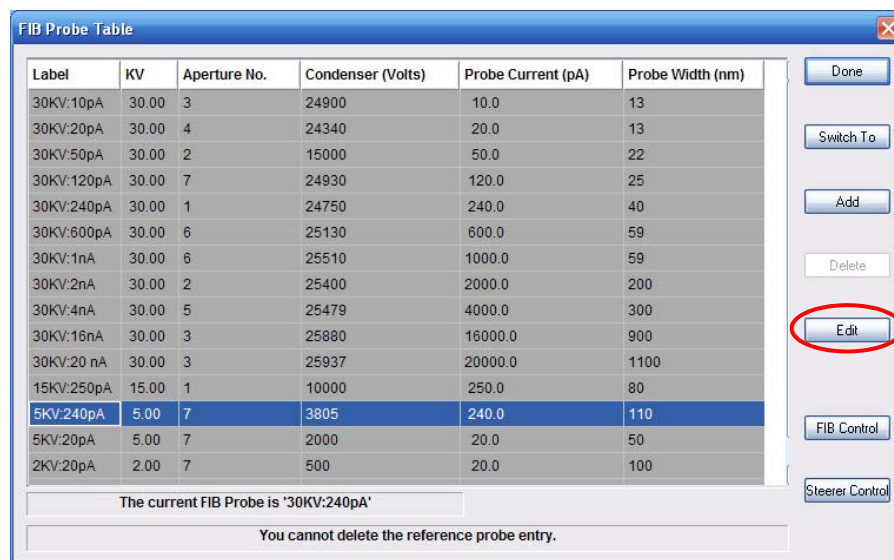
4. Operation

Setting FIB conditions

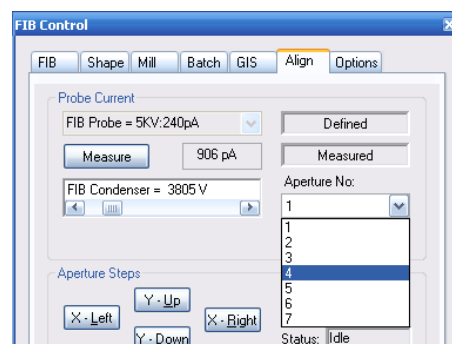
4.3.7.3. Adjusting a probe current (Cobra column only)

Procedure:

- 1 Load the Faraday cup.
- 2 Go to the coincidence point at 54°.
- 3 Ensure that the emission of the ion beam is stable.
- 4 Select **Panel Configuration Bar/FIB Probe Table**.
- 5 Edit a probe current:
 - a Select an entry.
 - b Click **Edit**.

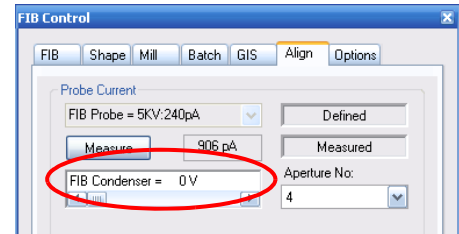


- 6 Go to **FIB Control/Align**.
- 7 Select the largest aperture from the dropdown menu (no 4, $\varnothing = 700 \mu\text{m}$).



- 8 Go to the lowest magnification.

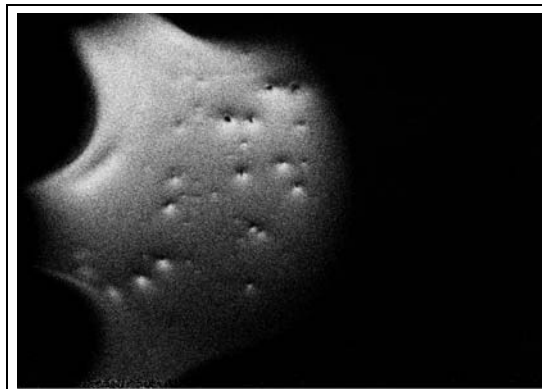
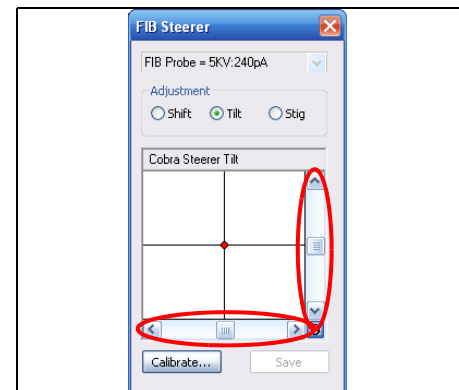
- 9 Set the **FIB Condenser** to minimum value.



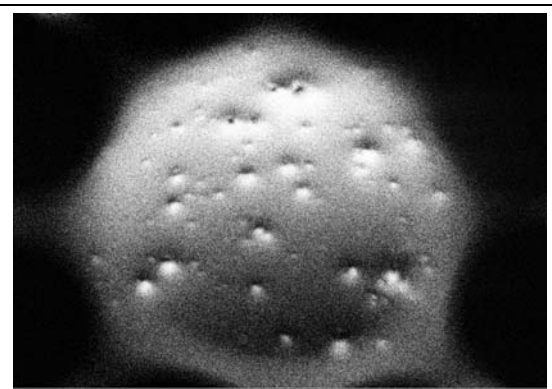
- 10 Select **Panel Configuration Bar/FIB Steerer**.

- 11 In the **FIB Steerer** panel, tick the **Tilt** checkbox.

- 12 To adjust symmetric illumination of the image, use the sliders or the red dot.

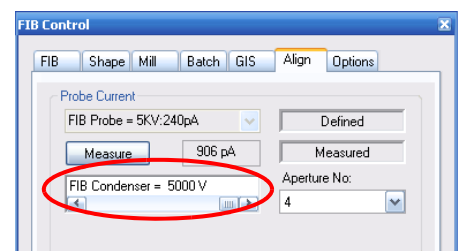


Asymmetric illumination



Symmetric illumination

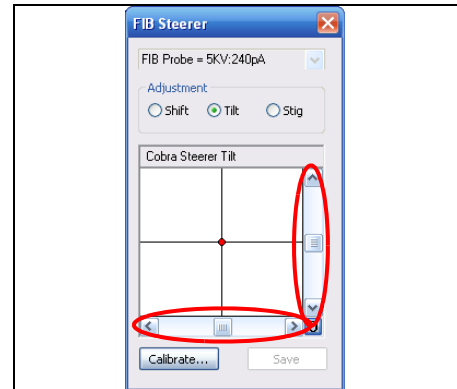
- 13 Increase **FIB Condenser** to maximum.



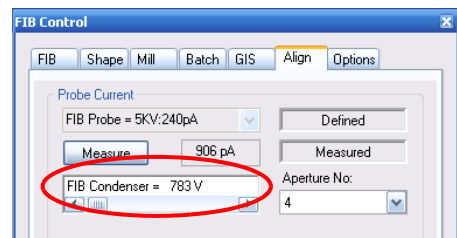
4. Operation

Setting FIB conditions

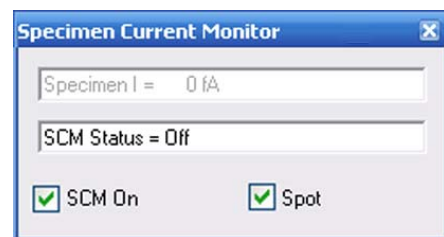
- 14 In the **FIB Steerer** panel, adjust symmetric illumination of the image with the sliders or the red dot.



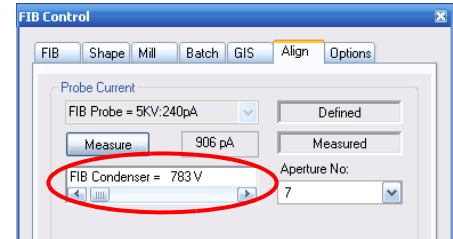
- 15 Check that no image shift or illumination change occurs when moving the **FIB Condenser** slider from min to max.



- 16 If image shift occurs, repeat the procedure.
- 17 Select the aperture corresponding to the selected probe current (refer to table 4.2 and table 4.4).
- 18 Start measuring the specimen current by using the Specimen Current Monitor (**Panel Configuration Bar/Specimen Current Monitor**) and the Faraday cup.
- 19 Tick the **SCM On** and the **Spot** checkbox.
- 20 Take the target value from the probe table as a starting value.



- 21 Adjust the desired value (+10 %) with the **FIB condenser** slider.

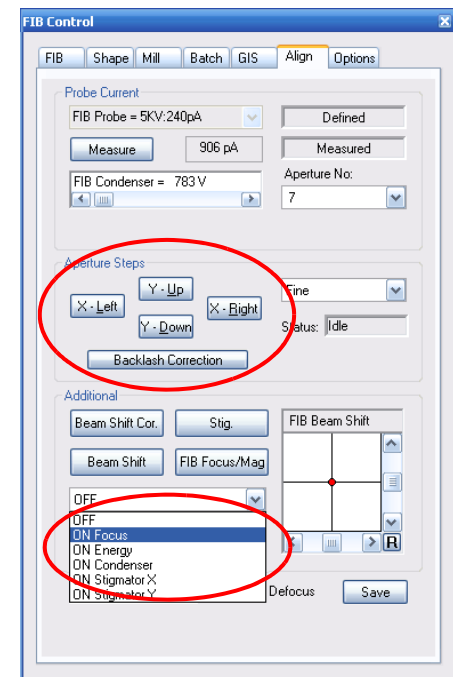


- 22 Raise the magnification to 1 kX-10 kX.

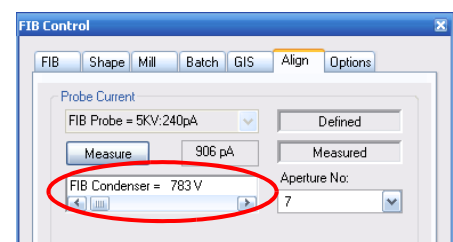
- 23 Wobble the aperture:

- Select *ON Focus* from the drop-down menu.
- Move the aperture: Use the buttons in the **Aperture Steps** field. Use only *Medium* or *Fine*.

The aperture has been aligned correctly when the image does not shift any more during the focus/un-focus cycle.



- 24 Check the current again and compensate with the **FIB condenser** slider if needed.

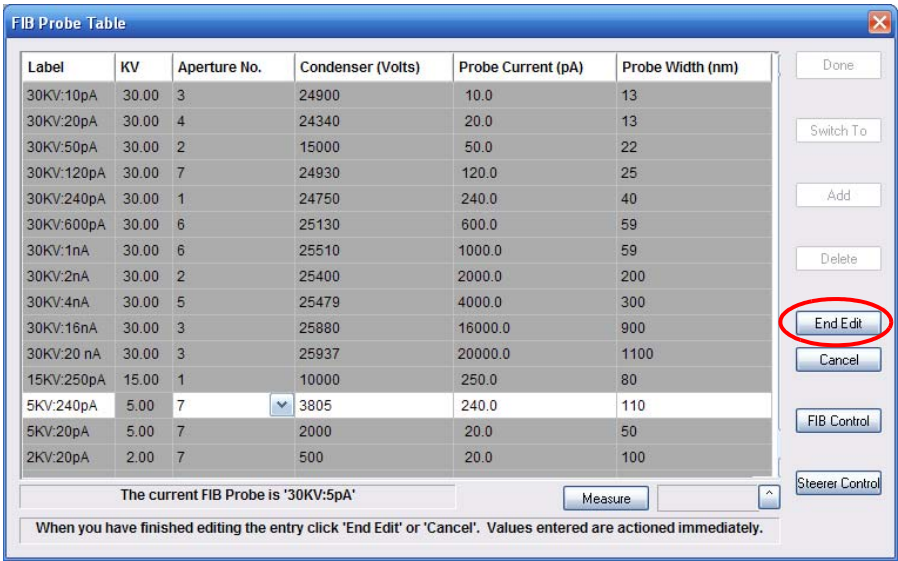


- 25 Check the shifting again and compensate with the **FIB Steerer**.

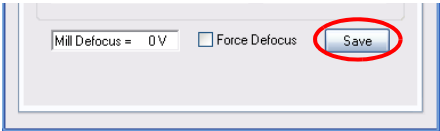
4. Operation

Setting FIB conditions

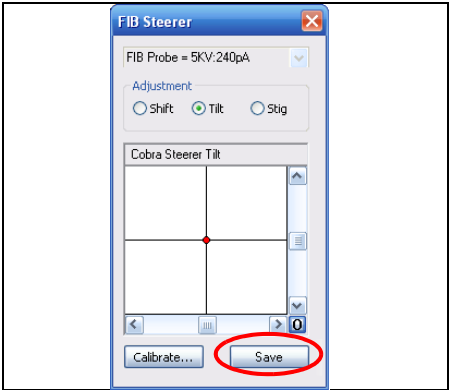
26 In the **FIB Probe Table**, click **End Edit**.



27 Click **Save** to save the adjustments.



28 Click **Save** in the **FIB Steerer** window to save the steerer values.



How to
continue

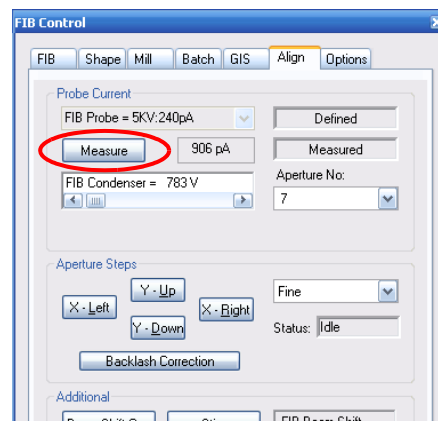
Check the Beamprofile and optimize if necessary
(refer to section 4.3.6.3.).

4.3.8. Quickly checking the FIB probe current

There is a possibility to quickly measure the probe current within the FIB column.

- 1 Go to the **Align** tab of the **FIB Control** panel.
- 2 Click **Measure**.

Depending on the condenser voltage, the Faraday cup may not be hit accurately enough to measure the probe current correctly. That's the reason why there may be a difference between the value measured via SCM and the value measured with the Faraday cup on the specimen stage.



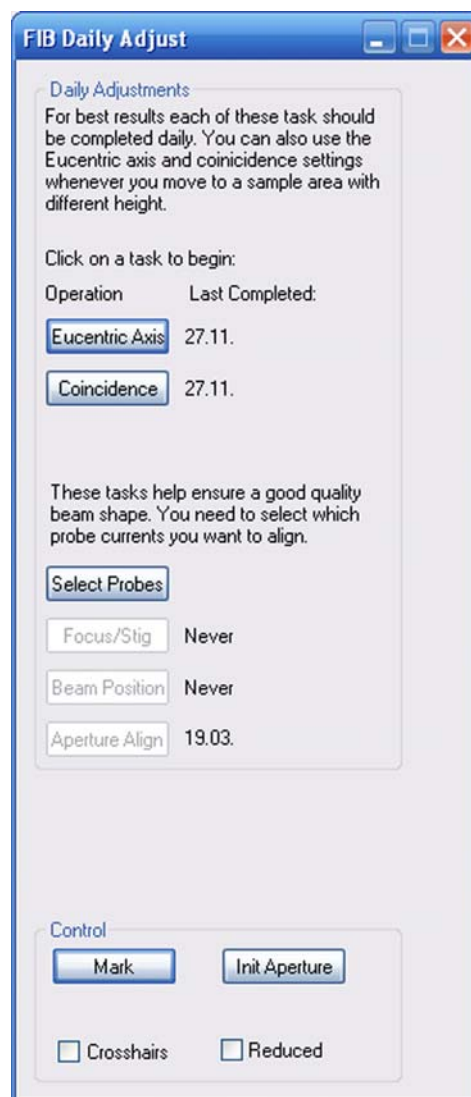
4.3.9. Using the FIB Daily Adjust wizard

FIB Daily Adjust is a wizard that guides through the most important FIB parameters that you should use during your daily work.

4.3.9.1. Opening the wizard

- 1 Open the **Panel Configuration Bar**.
- 2 Double-click **FIB Daily Adjust**.

The **FIB Daily Adjust** panel opens.



4.3.9.2. Adjusting tilt eucentricity

For details refer to section 3.1.2.

4.3.9.3. Setting the coincidence point

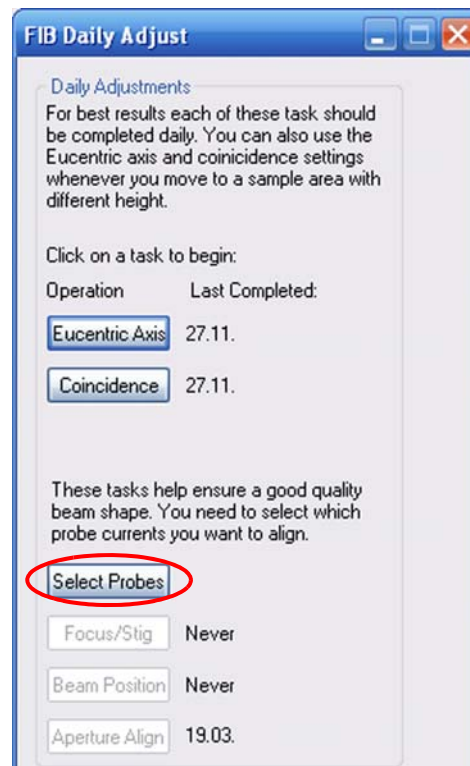
For details refer to section 3.1.4.

4.3.9.4. Adjusting the probe currents

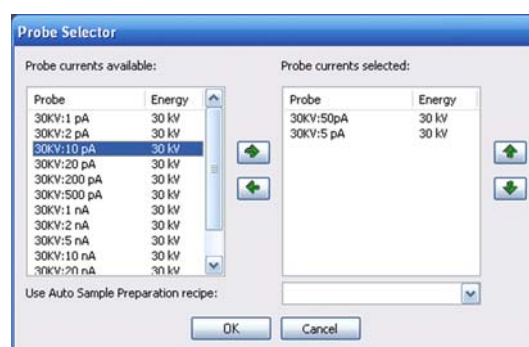
These tasks help to ensure a good beam shape.

Requires the *FIB Probe Alignment* privilege.

- 1 Select the probe current(s) you wish to work with.
 - a Click **Select Probes**.



- b Select the probe current(s).
 - c Confirm.



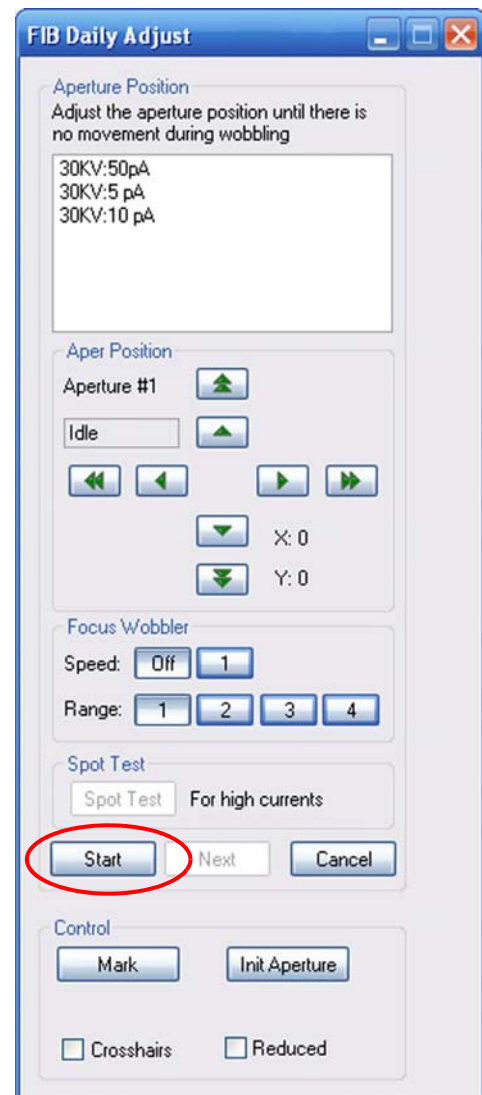
IMPORTANT

30kV:50pA is always selected because it is used as reference for certain adjustment procedures.

4. Operation

Setting FIB conditions

- 2 Adjust the apertures:
 - a Click **Aperture Align**.
 - b Click **Start** and follow the instructions in the wizard.



- 3 Adjust focus and stigmator:
 - a Click **Focus/Stig**.
 - b Click **Start** and follow the instructions in the wizard.



4. Operation

Setting FIB conditions

- 4 Adjust the beam position:
 - a Click **Beam Position**.
 - b Click **Start** and follow the instructions in the wizard.

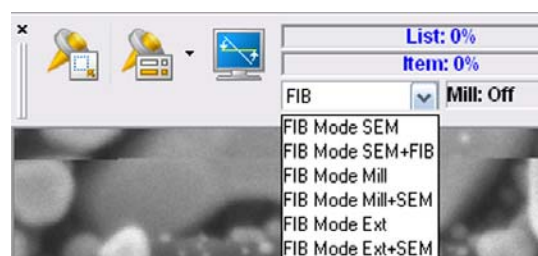


4.4. Imaging

4.4.1. Selecting an imaging mode

Depending on your application, you can select the imaging mode.

- 1 Switch on Gun and EHT.
- 2 Select the imaging mode from the drop-down menu.



Three different imaging modes are available:

Imaging mode	FIB Mode..	Characteristics	Typical application
SEM imaging	SEM	Electron beam is active, ion beam is blanked. The SE signal is synchronised to the SEM scan.	High resolution FESEM
FIB imaging	FIB	Electron beam is blanked, ion beam is active. The SE sig- nal is synchronised to the FIB scan.	Channelling contrast imaging, voltage contrast imaging. Defining milling patterns on the specimen surface Grain analysis
CrossBeam[®] operation	SEM + FIB	Image is composed of SEM and FIB components. With the optional dual scan both beams are scanned com- pletely independently from each other.	Setting the coincidence point.
	Mill	No image Mills with the milling parame- ters set (milling current).	Only deposition by ion beam. No deposition by electron beam.
	Mill + SEM	Mills and generates a SEM image.	SEM real-time imaging of the ion milling or deposition.

Moreover, two external controls are available:

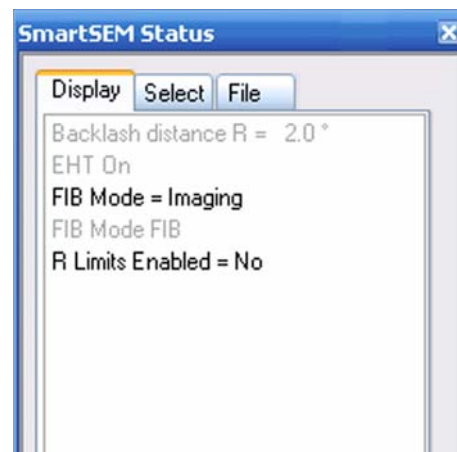
External Control			
	Ext	External control, no image.	EDX, external lithography systems
	Ext + SEM	External control, electron beam is active.	EDX, external lithography systems under control of the SEM image

4.4.2. Coupling the magnifications of SEM and FIB together

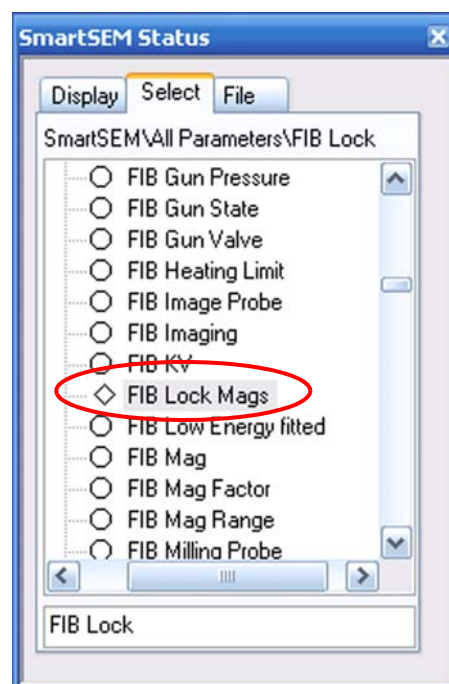
This function allows you to work with the same magnification in SEM mode and in FIB mode at the same time. When changing from one mode to the other, the magnification does not change, because it is locked.

If the magnifications are coupled together, the minimum magnification of the SEM is limited to the minimum magnification of the FIB.

- 1 Select **View/SEM Status** from the menu.



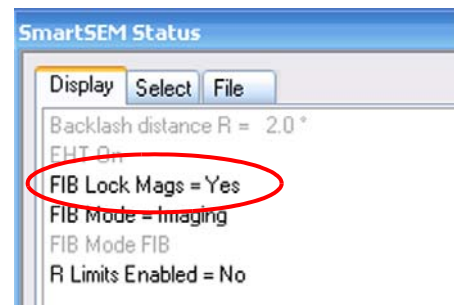
- 2 In the **Select** tab, select *FIB Lock Mags*.



4. Operation

Imaging

- 3 In the **Display** tab, set *FIB Lock Mags*=Yes by clicking this entry.



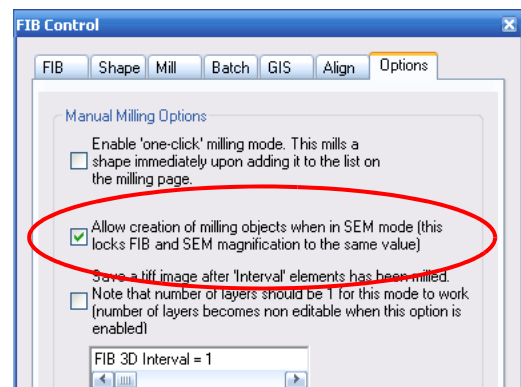
To uncouple the magnification, click *FIB Lock Mags*= until *FIB Lock Mags*=No is shown.



IMPORTANT

To easily couple or uncouple the magnifications, you can assign a menu to an icon in the toolbar.

The *FIB Lock Mags* function can also be activated by ticking the **Allow creation of a milling object** checkbox in the **Options** tab of the **FIB Control** panel.



4.4.3. Using the Nano Tomography Wizard



IMPORTANT

If a Capella FIB column is installed, refer to the SmartFIB® Online Help for details.

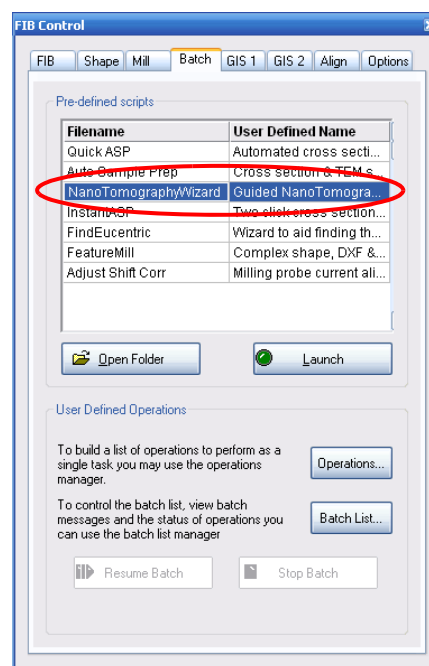
The **Nano Tomography Wizard** provides a simple method to create a series of images through a section of material.

Preconditions:

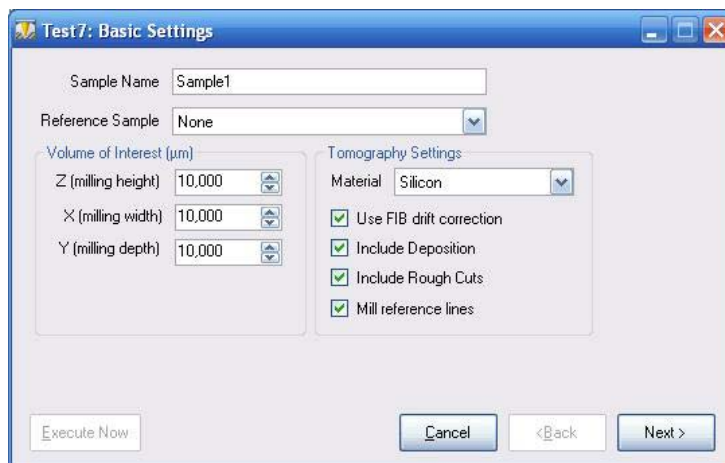
- Specimen has been moved to the coincidence point, tilted to 54°. Refer to section 4.2.2.
- Electron beam has been switched on.
- Ion beam has been switched on. Refer to section 4.3.1.1.

Prodedure:

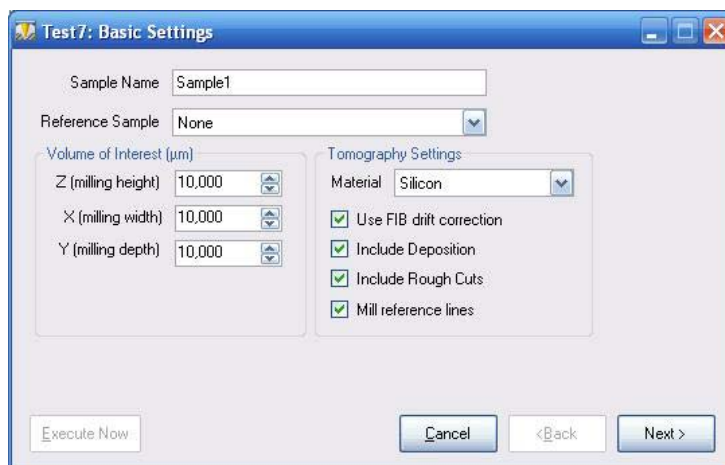
- 1 Go to the **Batch** tab in the **FIB Control** panel.
- 2 Double-click **NanoTomographyWizard**.



- The **Basic Settings** window opens.



4.4.3.1. Basic Settings

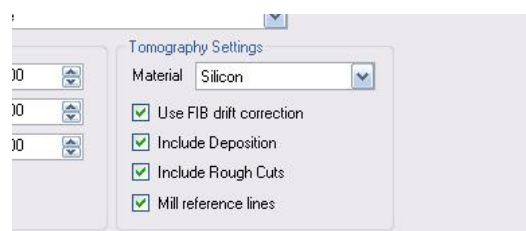


- If you want to use settings from a previously processed specimen, select them from the **Reference Sample** drop-down list.
- Enter the **Sample Name**.
A new folder with the same name will be created in the current imaging folder.
- Enter the desired **Volume of Interest** in μm :
 - Enter the milling height under **Z**.
 - Enter the milling width under **X**.
 - Enter the milling depth under **Y**.



X and Y define the front face of the volume of interest, which will be imaged with the SEM.

- 4 Choose the **Tomography Settings**:
 - a To define a rate of FIB material removal, choose the sample material.



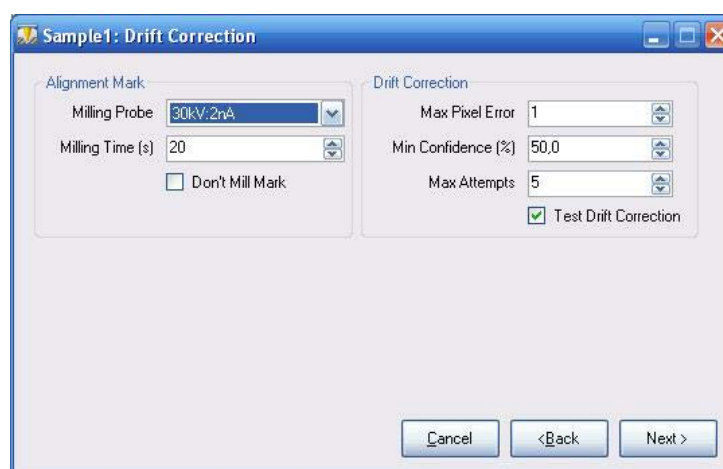
IMPORTANT

By default, only Silicon is available. To be able to select from a variety of materials, create new materials using the FIB Materials Editor (see section 4.5.5.).

- b Ticking of boxes will include the operations:
 - **Use FIB drift correction**: DC will be applied during the tomography milling and rough cut milling if latter option is chosen. This step is optional, if a unique feature is present.
 - **Include Deposition**: A sacrificial material layer will be deposited to protect the top face of the volume of interest.
 - **Include Rough Cuts**: Needed to allow SEM observation of the volume of interest front face.
 - **Mill reference lines**: Reference lines can be helpful to align the tomography image stack and measure slice thicknesses. This is an optional step.

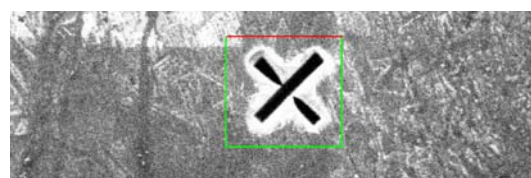
- 5 Click **Next**.

4.4.3.2. Drift Correction



This step is only displayed, if the **Use FIB drift correction** checkbox was ticked in the **Basic Settings** window.

In this step, an alignment mark is milled on the specimen surface. Afterwards, an image will be taken as a reference and compared to the current image. Based on the differences, the drift correction will be applied.

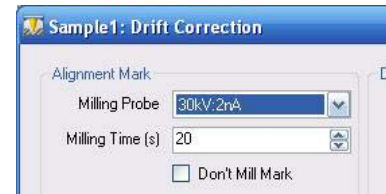


- 1 Set the imaging conditions to assure a good signal to noise ratio in the FIB image, e.g. Pix.Avg., Scan Speed = 5.

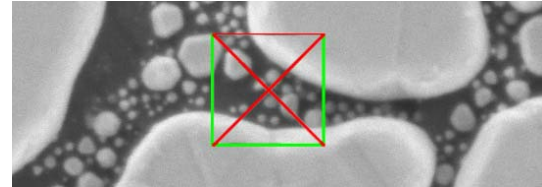
4. Operation

Imaging

- 2 If preferred, set **Milling Probe** according to the material.
- 3 Set the milling time.

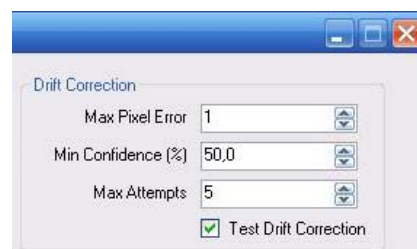


- 4 Drag and drop to resize and place the alignment mark.
- 5 To not mill the cross, tick the **Don't Mill Mark** checkbox.



6 Choose the **Drift Correction** settings:

- **Maximum Pixel Error:** Defines required matching precision in pixels between current and reference image.
- **Minimum Confidence (%):** Confidence is a measure of the similarity between current and reference image. Confidence of 100% means both images are identical. A reasonable value is 50%.
- **Maximum Number Attempts:** Defines the maximum number of attempts to achieve an image match within the required accuracy.
- **Test Drift Correction:** Activates/deactivates the optional drift correction test. This is just to test the drift correction. If this checkbox is unticked, the drift correction will be carried out nevertheless.

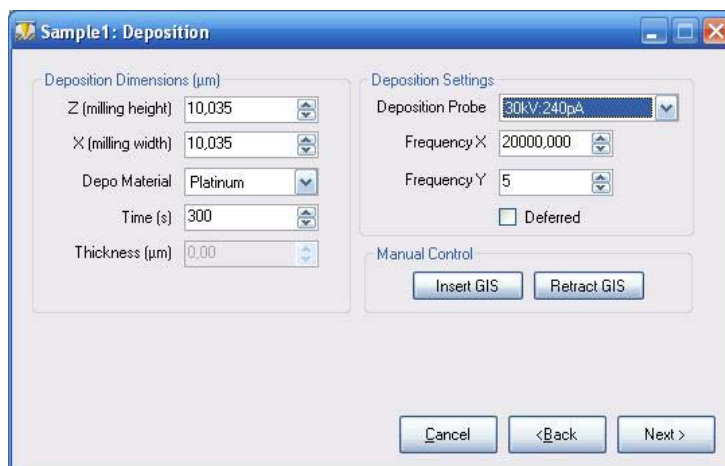


7 Click **Next**.

A reference cross is milled unless the **Don't Mill Mark** checkbox is ticked.

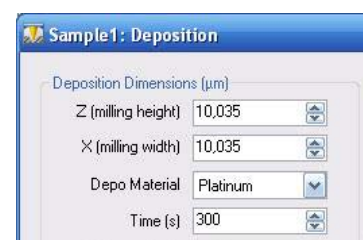
The FIB reference image is acquired and saved in the image directory in the **Sample Name** folder. Additionally, a drift correction test will be performed, if the **Test Drift Correction** checkbox is ticked.

4.4.3.3. Deposition



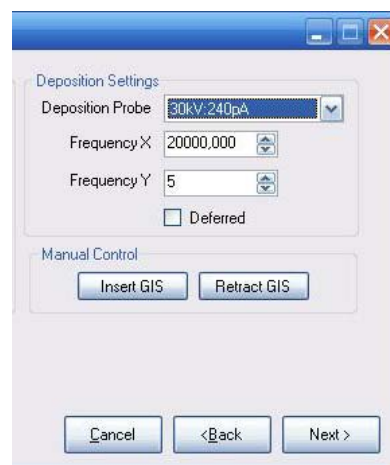
This step is only displayed, if the **Deposition** checkbox was ticked in the **Basic Settings** window. To protect the specimen surface, a layer of material will be applied.

- 1 Enter the desired **Deposition Dimensions** based on experience.



- 2 Enter the **Deposition Settings** based on the **Deposition Dimensions**:

- a **Deposition Probe:**
Set this parameter depending on the **Deposition Dimensions**.
- b Enter the desired settings for the analog Scan Generator in **Frequency X / Y**.
A reasonable setting is **Frequency X**: 20000 and **Frequency Y**: 5.
- c If you want to have the deposition carried out later on in the process, tick the **Deferred** checkbox.



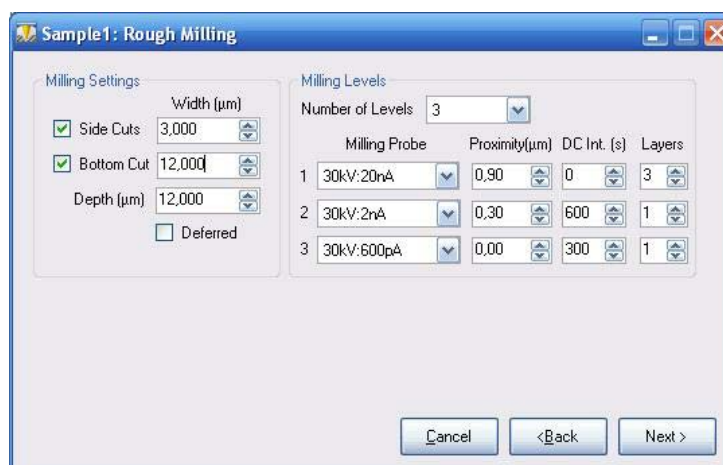
- 3 To insert the GIS, click **Insert GIS**.



- 4 Click **Next**.

The deposition will be carried out unless the **Deferred** checkbox is ticked.

4.4.3.4. Rough Milling



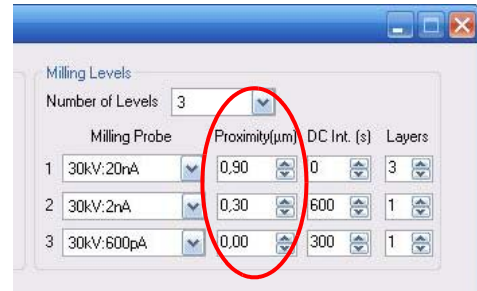
This step is only displayed, if the **Include Rough Cuts** checkbox was ticked in the **Basic Settings** window.

Material removal in front of the volume of interest (bottom cut) is necessary to allow SEM observation of the volume of interest front face. Optional side cuts left and right of the volume of interest aim at avoiding possible closing of SEM view due to redeposition artifacts during the tomography run.

- 1 Set the desired **Milling Settings**:
 - d To perform side cuts and / or bottom cuts, tick the **Side Cuts** checkbox.
 - e Type in the respective cut widths or drag and drop the objects on the FIB image to resize the cuts around the volume of interest area.
 - f Tick the **Deferred** checkbox, if the rough cuts should be run automatically in a batch job.
- 2 Set the desired **Milling Levels**:
 - a The rough cuts will be milled in up to three different steps (Number of Levels).
At least two levels are recommended.



- b Set the **Milling Probe** for each level.
The first should have a higher milling probe current to be able to remove more material. The following levels should have less milling probe current to mill more precisely. The last level should be set to the same current as in the **Tomography Milling** window (see section 4.4.3.6.).



Set the **Proximity** for each level.

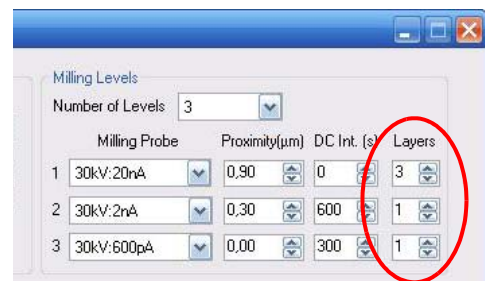
This parameter defines the distance in μm from the volume of interest boundaries at which the milling will stop .

At higher currents it is recommended to choose higher proximity, because the beam might exceed the boundaries of the volume of interest and can therefore damage the boundaries. Following levels with less milling probe current should be set to lower proximity. The last level, which should be set to the same milling probe current as in Tomography Milling should be set to 0.00 proximity.

- c Set the Drift Correction Interval (**DC Int.**).

This parameter defines time intervals in seconds at which a drift correction will be carried out. It is recommended to use higher values for more precision with levels which are set to small or no proximity.

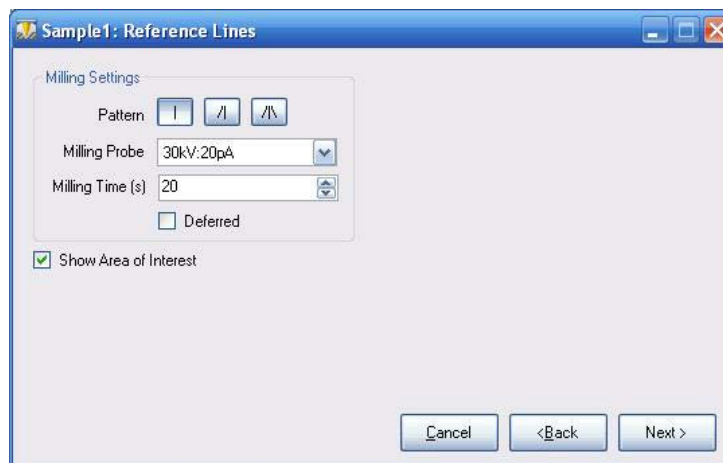
- d In **Layers** define the number of milling paths for the respective milling step.
If **Layers** is set to 1 milling of bottom and side cuts will be done in parallel.



- 3 To mill the rough cuts, click **Next**.

The rough cuts will be milled unless the **Deferred** checkbox is ticked.

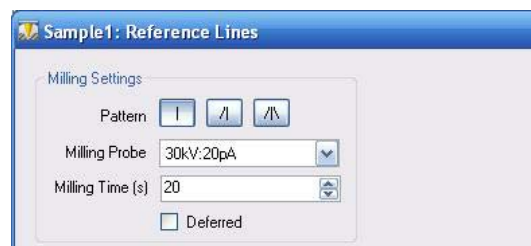
4.4.3.5. Reference Lines



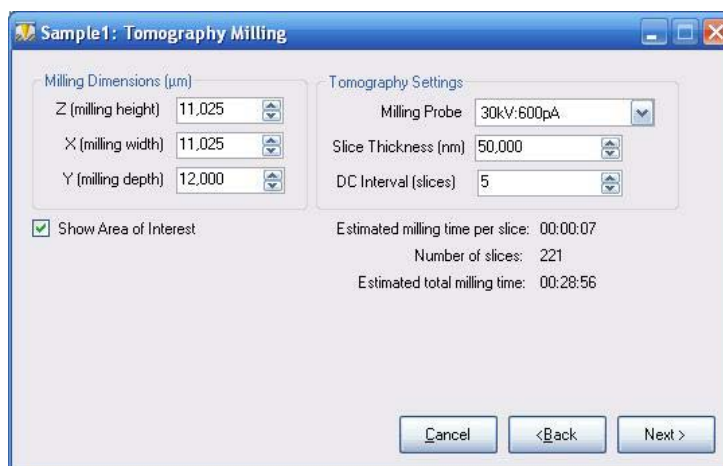
This step is only displayed, if the **Mill reference lines** checkbox was ticked in the **Basic Settings** window.

Reference lines can be used to align the tomography image stack and measure slice thicknesses during postprocessing. Pressing Next will mill the reference lines unless Deferred is ticked.

- 1 Set the desired **Milling Settings**:
 - a Choose between three different reference line patterns. The single line pattern allows postalignment of the tomography stack. Additionally, the two and three line patterns allow determination of the slice thicknesses.
 - b If desired, enter the desired **Milling Probe**.
A small current should be chosen (approximately 50pA).
 - c Set the **Milling Time**.
 - d Tick the **Deferred** checkbox, if the reference lines should be run automatically in a batch job.
- 2 Tick the **Show Area of Interest**:
This function displays the top face of the volume of interest in the FIB image to allow easy positioning of the reference lines.
- 3 Click **Next**.



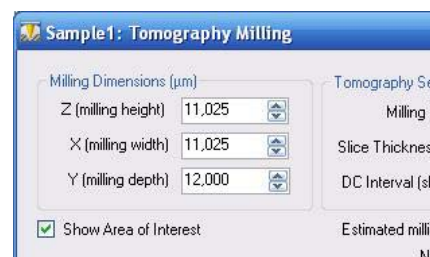
4.4.3.6. Tomography Milling



Tomography Milling page.

- 1 Set the desired **Milling Dimensions**:

Type in the dimensions in μm of the tomography milling object or drag and drop the milling object on the FIB image. As a default the milling area is set equal to the top face of the volume of interest. It is recommended to choose a slightly bigger value for X.

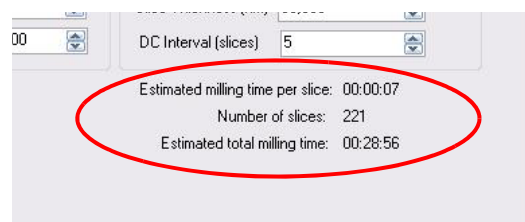


- 2 Set the desired **Tomography Settings**:

- a Set the **Milling Probe**. It is recommended to choose the same value as selected for the last level in **Rough Milling** (section 4.4.3.4.)
- b Set the **Slice Thickness**:
To achieve highest accuracy, before milling the FIB mag will be set automatically to a value at which the FIB image pixel size is a factor of the slice thickness (AutoMag).
- c Set the **DC Interval**:
This value determines, after how many slices a drift correction will be applied.

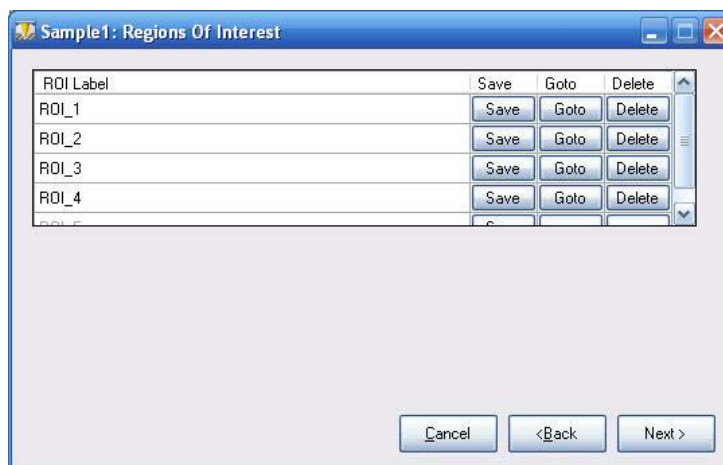


At the bottom of the window the resulting parameters are displayed. These parameters, such as the number of slices depend on the entered values.



- 3 Click **Next**.

4.4.3.7. Regions of Interest



IMPORTANT

Do not try to find your region of interest by moving the stage. A tomography will be impossible if the stage is moved. Only use SEM beam shift to center your region of interest.

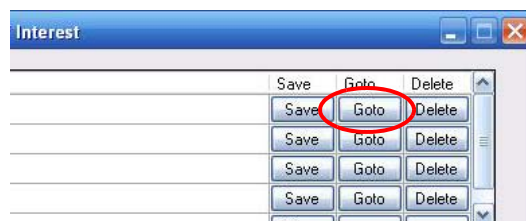
- 1 Using SEM beam shift, center your region of interest (ROI).
- 2 Set the desired SEM imaging conditions.
- 3 To save the imaging conditions, click **Save**.



- 4 Repeat steps 1 - 4 for the next ROIs.
Up to 20 ROIs are possible.

If you want to recall previously saved imaging conditions,

- a click **Goto**.

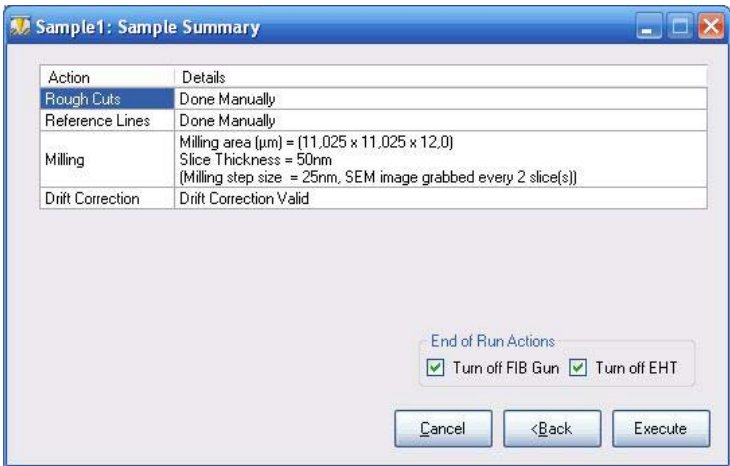


ROIs can be renamed any time by typing over the name.

Each ROI can be imaged with the SEM at different imaging conditions (detector, image resolution, scanning conditions, etc.).

- 5 Click **Next**.

4.4.3.8. Sample Summary



IMPORTANT
*As the milling takes a certain amount of time, it is recommended to tick the **End of Run Actions** checkboxes. This allows you to start the milling at the end of the work day or before the weekend.*

6 A summary of the parameters is displayed.

If any parameters need to be changed,

- a click **Back** until the respective step is reached.

7 If wished, tick the **End of Run Actions** checkboxes:

Turn off FIB Gun: Switches off the FIB gun after completion of the process.

Turn off EHT: Switches off the EHT after completion of the process.

8 Click **Execute**.



The milling will now start. If the **End of Run Actions** checkboxes have been ticked, the FIB gun and / or EHT will be switched off after completion.

4.5. Milling

Milling stands for the local removal of surface material by means of the focused ion beam. For instance, you can mill cross sections which allows you to get a 3D view into the specimen.

Milling is done by processing individual milling objects. The milling object defines the area to be scanned by the focused ion beam. Milling objects are geometrical patterns such as line, rectangle, and trapezium. Moreover, several milling parameters such as milling mode, milling current, width, and height characterise a milling object.

The number of milling objects that can be shown on the screen is limited to 16.

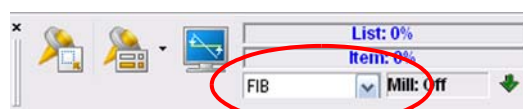
Preconditions:

- Electron beam has been switched on
- Ion beam has been switched on
- Tilt eucentricity should be adjusted
- Specimen has been moved to the coincidence point

4.5.1. Selecting milling conditions

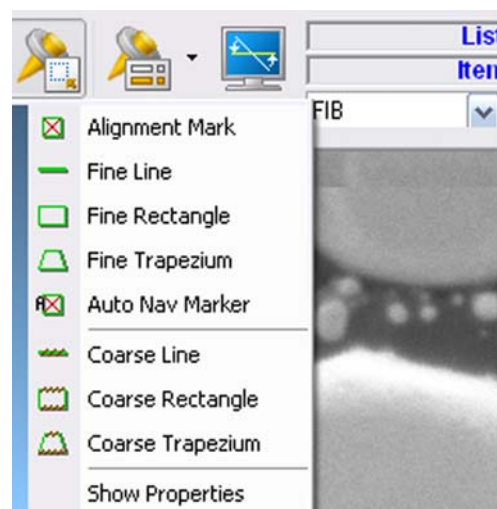
4.5.1.1. Selecting a pattern

- 1 Select **FIB** mode from the drop-down menu.



- 2 Select a milling object from the drop-down menu.

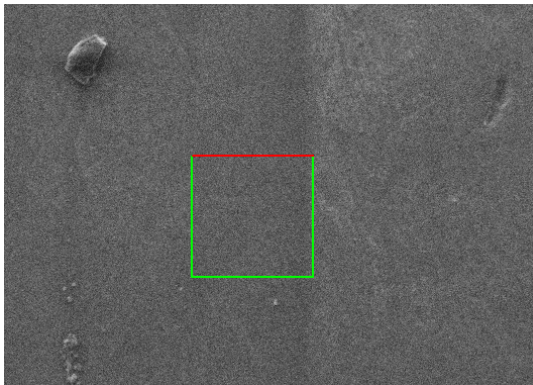
The **Fine** and **Coarse** submenus can be used as a template to save milling parameters for coarse milling and fine milling.



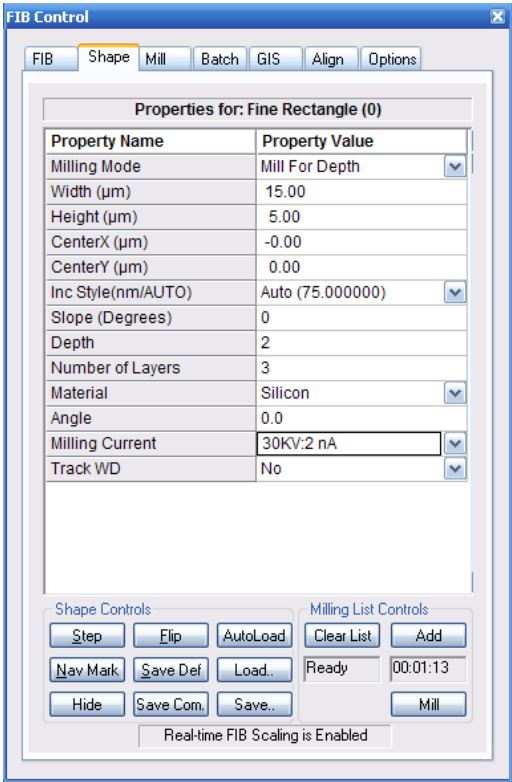
4. Operation

Milling

- 3 Left-click and drag on the screen.
- The milling object is shown on the screen.



The **Shape** tab opens.



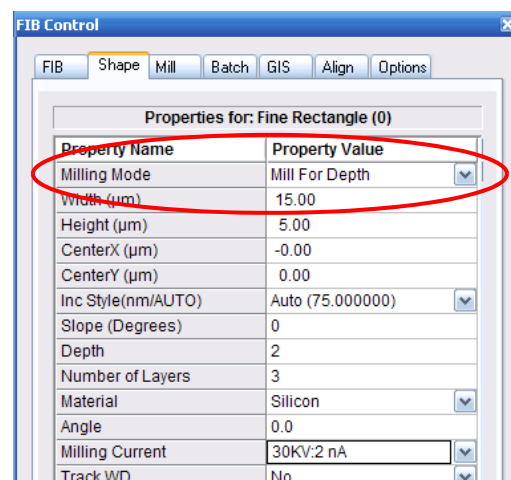
How to continue

Select the milling mode.

4.5.1.2. Selecting the milling mode

The milling mode defines the type of milling application.

- 1 In the **Shape** tab of the **FIB Control** panel, select a **Milling Mode** from the drop-down list.



The following milling modes are available.

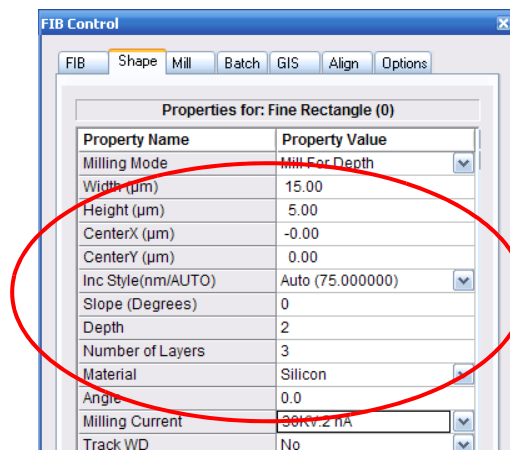
Milling mode	Application	Characteristics
Mill for time	Milling for a given period of time, cross sections	Ion beam scans in a line from the green side (start, X) to the red side (end, Y) of the milling object
Mill for depth	Milling a given depth, cross sections	
<i>Among the milling modes you can also select "Deposition". Since the deposition or etching of substances requires the optional gas injection system (GIS), deposition and etching are treated in an extra subchapter. Refer to section 4.6.</i>		
Deposition	Deposition, Etching Depositing or etching for a given period of time.	Object area is evenly exposed to the ion beam. Requires the precise injection of process gases.
Deposition w. Thickness	Deposition, Etching Depositing or etching for a given thickness.	

How to continue

Select the object properties.

4.5.1.3. Selecting object properties

- 1 In the **Shape** tab of the **FIB Control** panel, select the required object properties.

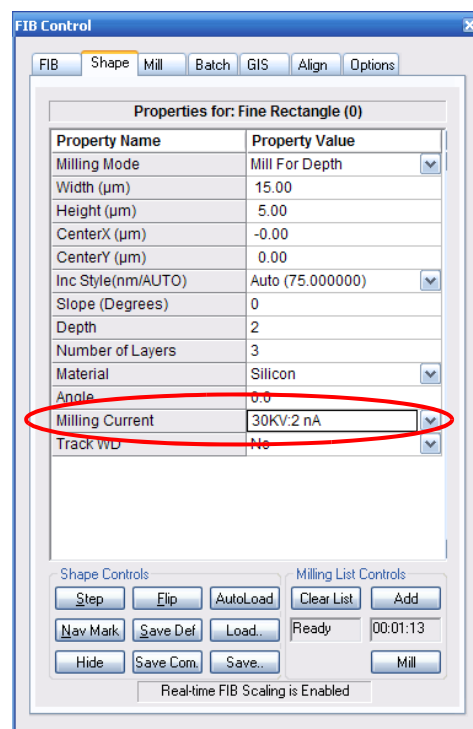


Continue with selecting the milling current.

4.5.1.4. Selecting the milling current

The milling current defines the probe current that is used for the milling process.

- 1 In the **Shape** tab of the **FIB Control** panel, select the **Milling Current** from the drop-down list.
- 2 Depending on your application, select the **Milling Current** from the drop-down list.



IMPORTANT

*The milling current is the probe current used for milling.
The available milling currents can be modified in the FIB Probe Table.
Refer to section 4.3.5.*

How to continue

You can save the milling object (section 4.5.2.1.) or continue with starting the milling process (section 4.5.3.1.).

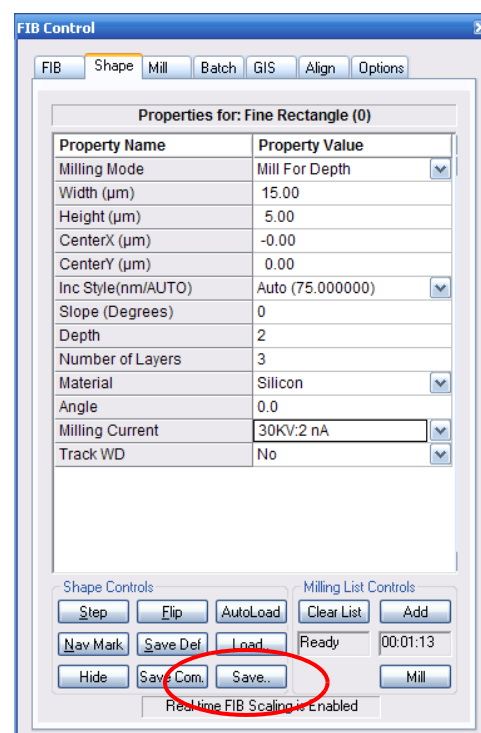
4.5.2. Working with pre-defined milling objects

When you have defined a milling object you can save it. This allows you to recall parameters you have already specified.

4.5.2.1. Saving milling objects

The milling objects shown in the image area can be saved together in a file.

- 1 Create one or more milling objects.
- 2 Define all required parameters.
- 3 In the **Shape** tab, click **Save**.



- 4 Enter a file name.
- 5 Click **Save**.

The milling object(s) are saved as a .mob file.

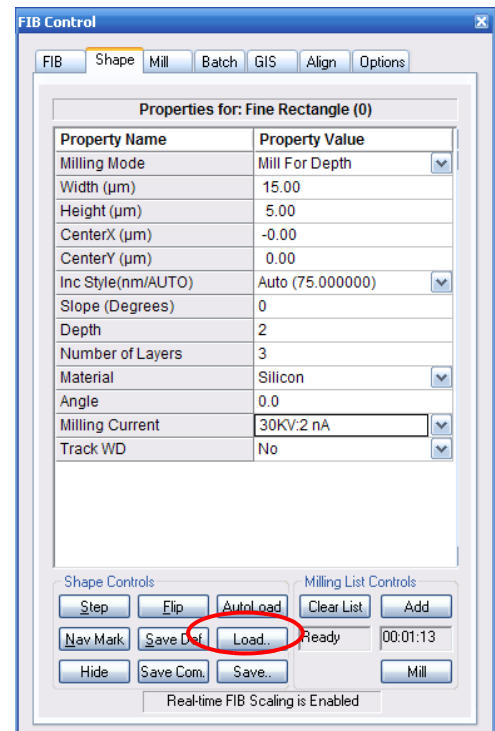
4.5.2.2. Loading milling objects onto the screen

- 1 In the **Shape** tab, click **Load**.
- 2 Select a file.
- 3 Click **Open**.

The milling objects saved in the file are shown on the screen.

- 4 Select the milling objects you wish to work with.
- 5 Click **Add**.

The milling object is added to the current milling list.

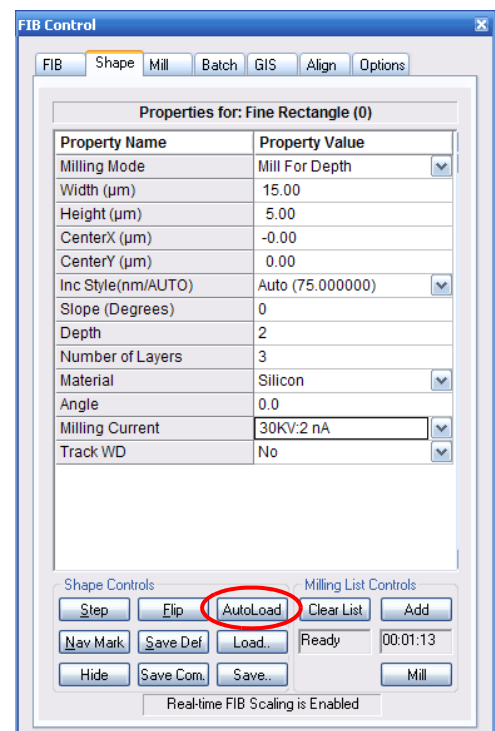


4.5.2.3. Loading milling objects onto the current milling list

- 1 In the **Shape** tab, click **AutoLoad**.
- 2 Select a file.
- 3 Click **Open**.

The milling objects are added to the current milling list.

The total time required to process the milling objects is shown under the **Add** button.



4.5.3. Controlling the milling process

4.5.3.1. Starting the milling process

After having defined all milling parameters you can start the milling process.

- 1 In the **Shape** tab in the **FIB Control** panel, click **Clear List**.

All previous milling objects are deleted from the list.

- 2 Click **Add**.

The current milling object is added to the milling list.

The total time needed to process all objects on the milling list is shown under the **Add** button.

- 3 Click **Mill**.

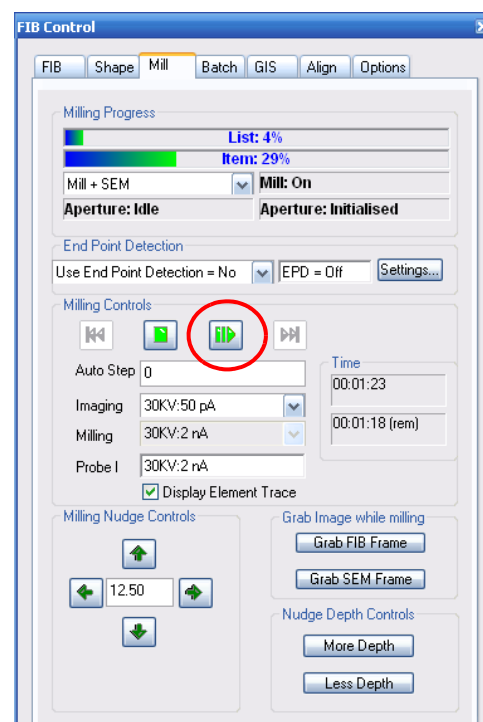
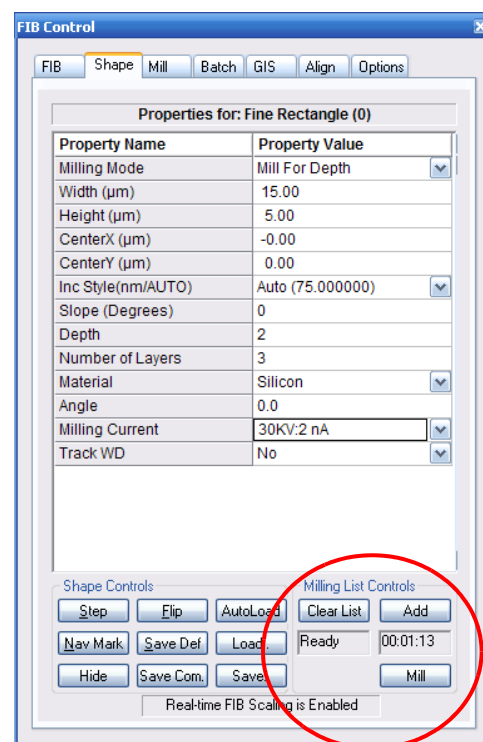
The milling process starts.

The progress marker is shown.

Alternatively:

- a Go to the **Mill** tab in the **FIB Control** panel.
- b Click the **Start/Pause** button.

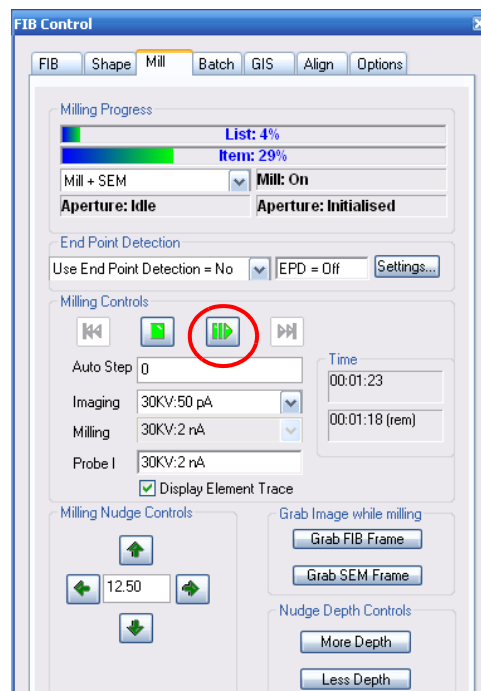
The milling process ends automatically, when all milling objects on the milling list have been processed.



4.5.3.2. Pausing the milling process

You can pause the milling process manually.

- 1 Go to the **Mill** tab in the **FIB Control** panel.
- 2 Click the **Start/Pause** button.

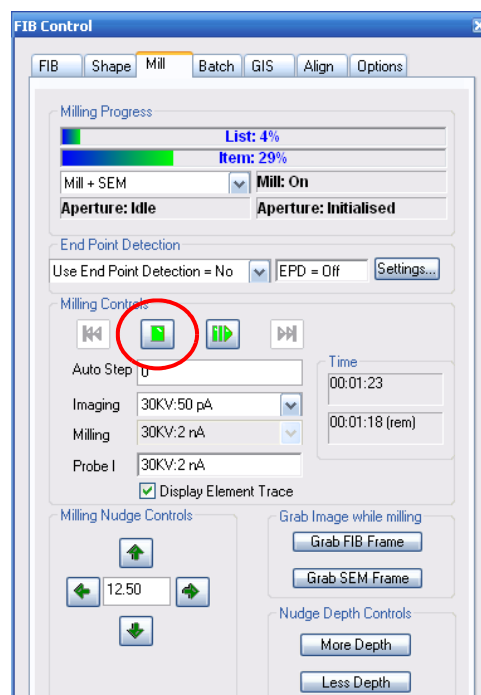


4.5.3.3. Stopping the milling process

The milling process ends automatically when all milling objects on the milling list have been processed.

However, you can stop the milling process manually.

- 1 Go to the **Mill** tab in the **FIB Control** panel.
- 2 Click the **Stop** button.

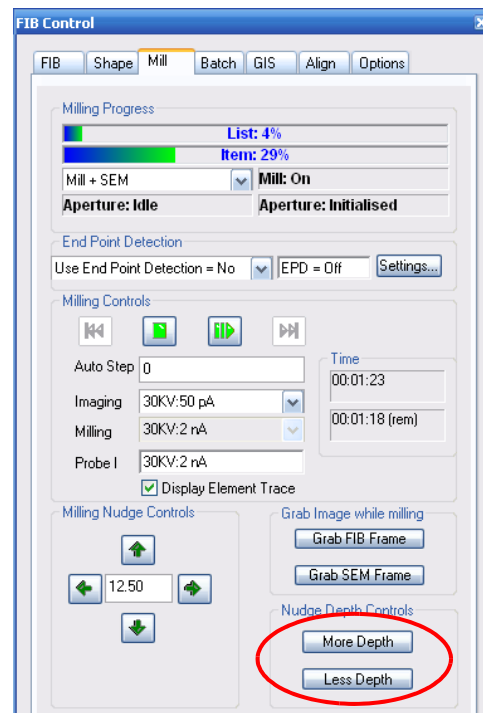


4.5.4. Changing parameters while milling

Although milling is in progress, you can modify depth and position of the milling object.

4.5.4.1. Modifying the depth

- 1 Go to the **Mill** tab in the **FIB Control** panel.
- 2 To increase depth, click **More Depth**.
One click increases the depth by 5 % of the entered value.
- 3 To decrease depth, click **Less Depth**.
One click decreases the depth by 5 % of the entered value.



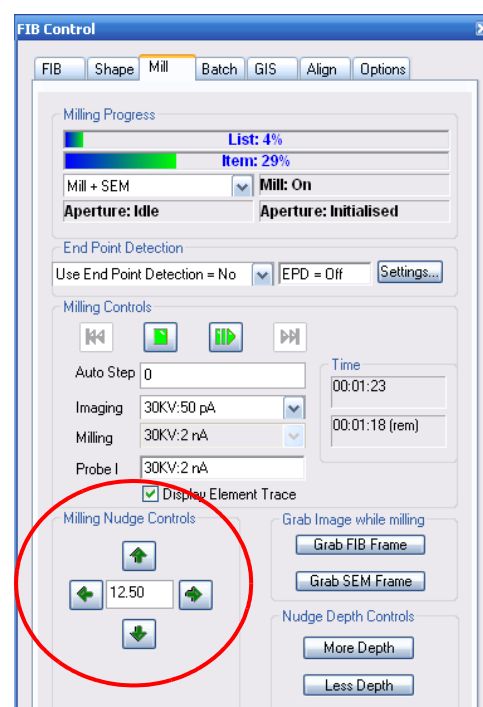
4.5.4.2. Displacing the milling object

- 1 Go to the **Mill** tab in the **FIB Control** panel.
- 2 To displace the milling object, click the respective **arrow** in the **Milling Nudge Controls** field.



IMPORTANT

The value in the box is indicated in nm.



4.5.5. Entering material properties (FIB Materials Editor)

The **FIB Materials Editor** is designed for the creation of material definitions. These are used by various components in the FIB software to allow you to specify a target depth and slope angle for a milling operation.

The information provided allows the software to calculate the milling times required to achieve the depth specified. This information is used by the FIB user interface, the feature milling program and the Auto Sample Preparation software. It is also available to Visual Basic applications using the FIB software API.

4.5.5.1. Adding a new material

- 1 Select **Programs/SmartSEM/FIB Materials Editor**.

The **Depth Milling Data** window opens.

- 2 Click **Add**.



The **Add New Material** window opens.

There are two ways to define the sputter rate of a new material:

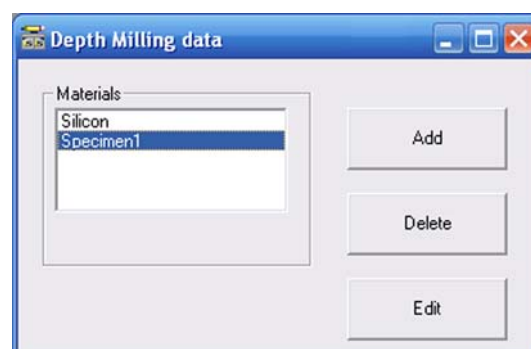
- A cross section was milled with **Mill for Depth** using a known material, e.g. silicon. The depth has been measured. Then, the milling rate ratio can be defined and used for the new milling rate.
Example: A cross section is milled into a new material with a target depth of 5 μm using silicon as material, the measured depth is 10 μm , so the sputter rate ratio is 2. Enter 2 in the **Material Editor**.
- The sputter rate of the new material is already known or is calculated by measuring a milled cross section using **Mill for Time**. Then it can be typed into the second option.

- 3 Enter the required settings.
- 4 Click **OK**.

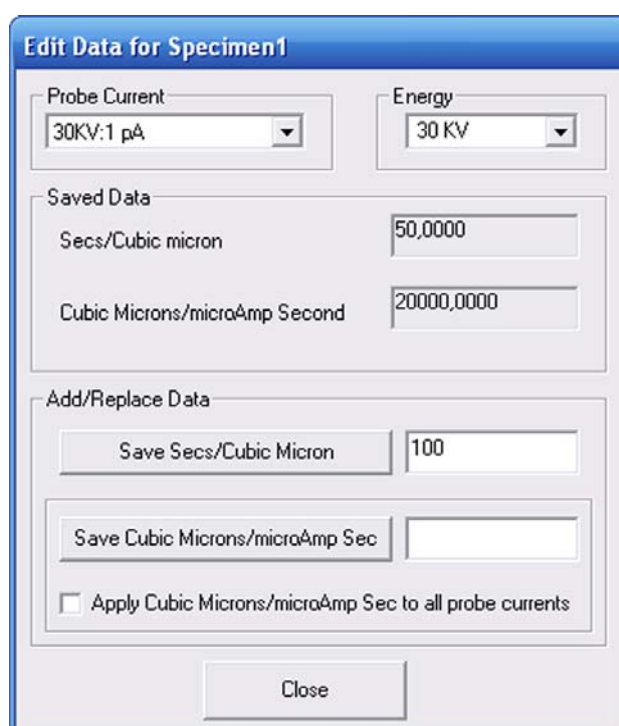


4.5.5.2. Editing an existing material

- 1 Select an entry.
- 2 Click **Edit**.



The **Edit Data** window opens.



- 3 Enter the required values.
- 4 Click the respective **Save** button.

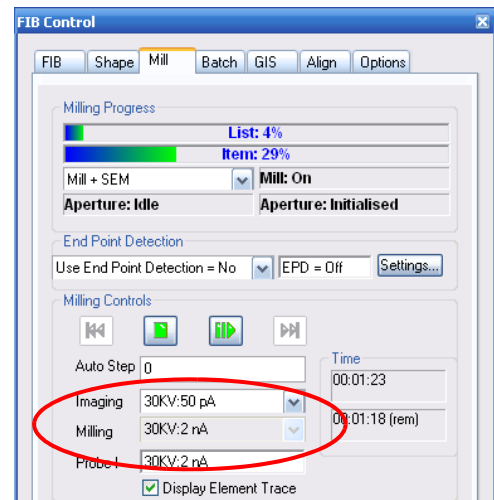
If you wish to apply the values to all probe currents, tick the **Apply Cubic Microns... to all probe currents** checkbox.

- 5 Click **Close**.

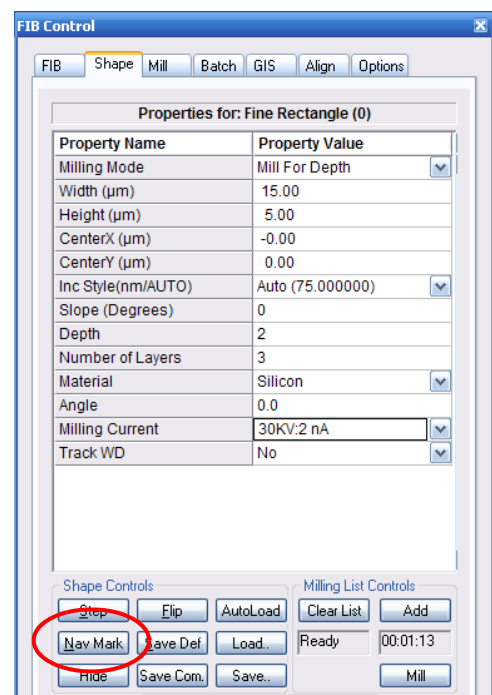
4.5.6. Milling a navigation mark

In order to ease navigation on the specimen surface, you can mill a navigation mark.

- 1 Go to the **Mill** tab in the **FIB Control** panel.
- 2 Select a suitable **Milling current**.



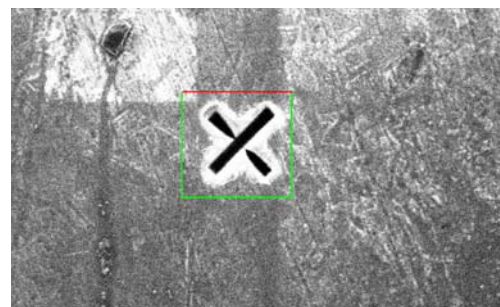
- 3 Go to the **Shape** tab.
- 4 Click **Nav. Mark**.



A cursor is shown on the image.

- 5 Move the cursor to the position where you wish to mill the navigation mark.
- 6 Click.

A cross-shaped navigation mark is milled by the ion beam.



4.5.7. Milling any shapes (feature milling)

The feature milling function allows you to mill any geometrical object, letters (texts) or image files (bmp or dxf).

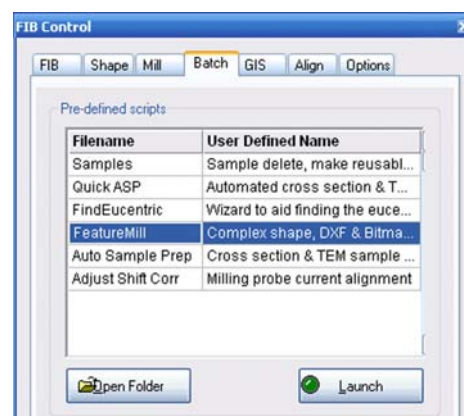
The ion beam scans the specimen surface following horizontal lines which are called “chords”. A chord list is created from all created objects which are indicated as red areas in the **FeatureMill** window.

Additionally you could mill circles with annular milling (refer to section 4.5.7.2.). In this special function the ion beam scans the specimen surface following circle lines.

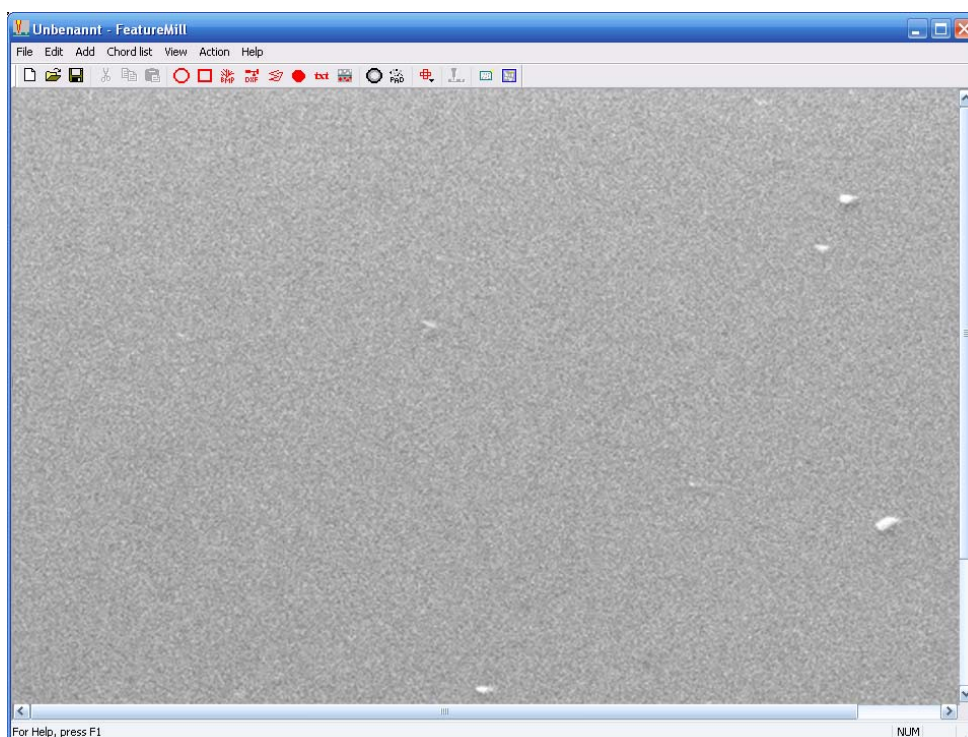
4.5.7.1. Creating an object

- 1 In the **Batch** tab of the **FIB Control** panel, double-click **FeatureMill**.

Alternatively, select **Start/Programs/FIB Feature Milling**.



The **Feature Mill** window opens. The image that is currently scanned in SmartSEM®, is automatically grabbed and shown in the **Feature Mill** window.



4. Operation

Milling

- 2 Create an object. You can use the following toolbar icons:

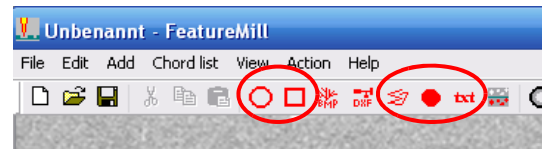
Ellipse

Rectangle

Poly line

Polygon

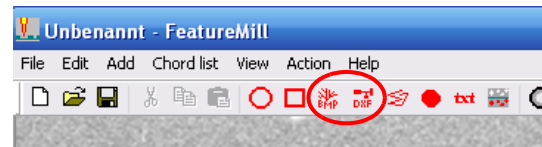
Add text



- 3 You can load a file by using the toolbar icons:

Bitmap

DXF file



The created objects are shown on the screen.

The size of an object depends on the magnification at which the image was grabbed from Smart-SEM®.



**How to
continue**

Continue with starting the milling procedure. To do so, you can use the **FeatureMill** function or you can use the milling list.

4.5.7.2. Annular milling

With the annular milling function you can mill circles more exactly because the ion beam scans the specimen surface following circle lines.

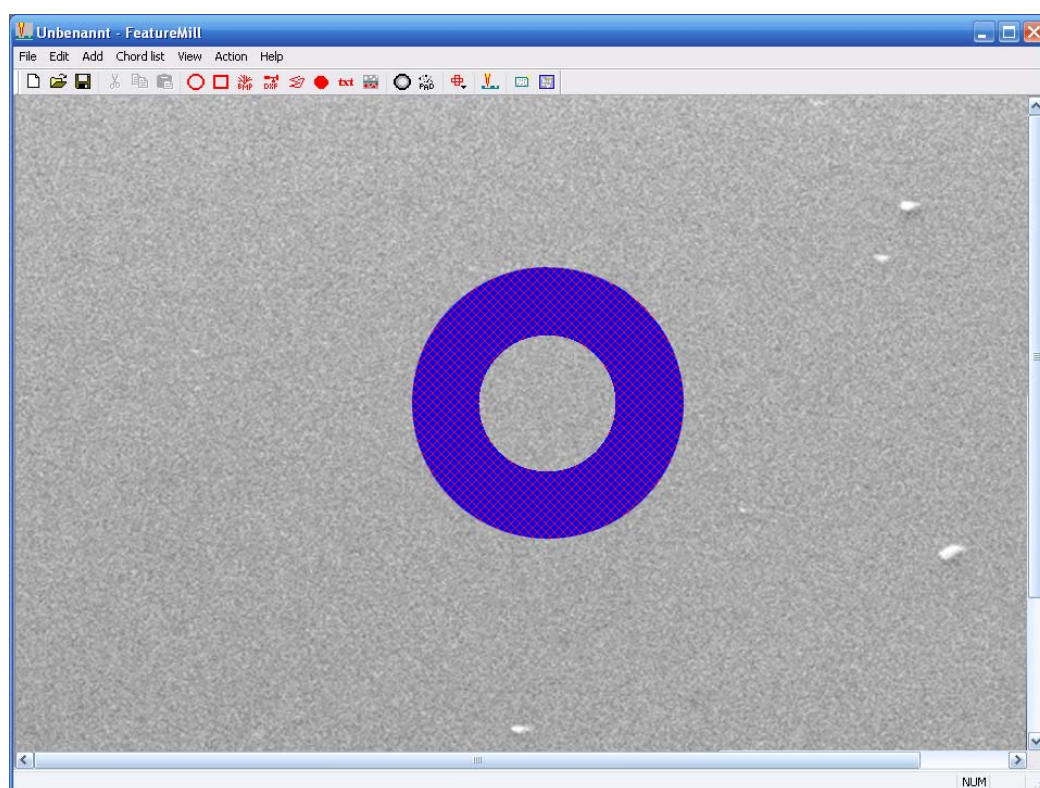
- 1 Click the **Annular Milling** icon in the toolbar.



- 2 Create a circle.

The created circle is shown on the screen.

The size of the circle depends on the magnification at which the image was grabbed from Smart-SEM®.



How to continue

Continue with starting the milling procedure. To do so, you can use the **FeatureMill** function or you can use the milling list.

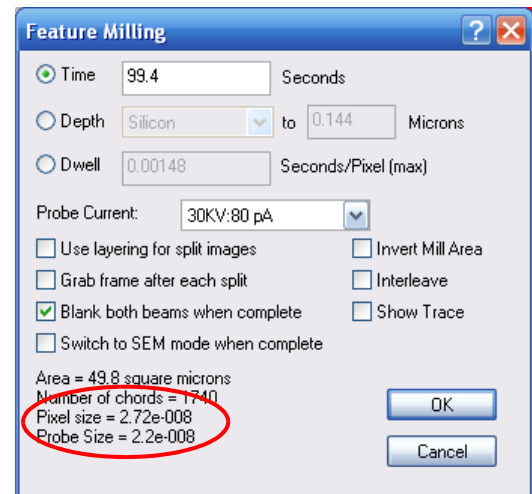
4.5.7.3. Using the FeatureMill function

- 1 Click the **Feature Mill** icon.



The **Feature Milling** dialog opens.

- 2 Enter the required parameters.



- 3 Ensure that *Pixel size* and *Probe size* are about the same.
Change the magnification until both values are roughly the same.
- 4 To start milling, click **OK**.



IMPORTANT

If your workstation has the optional dual scan generator, you can watch the milling process. The workstation changes to SEM + FIB while milling.



4.5.7.4. Using the milling list

If your workstation does not have the optional dual scan gen, but you wish to watch the milling process, you can convert the chord list to milling elements and add them to the milling list.

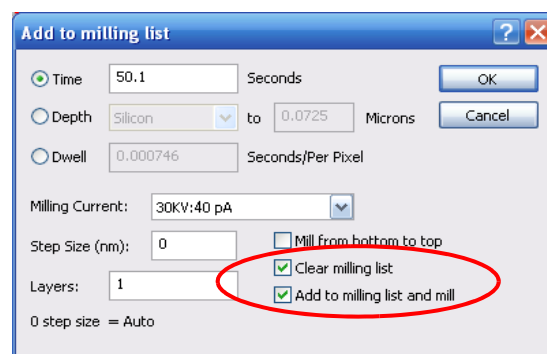
You can set time and/or depth, milling current, milling direction, the number of milling layers. Moreover, you can decide if the milling list should be cleared first and if milling should start immediately.

This method may not be ideal for all kind of objects depending on their shape.

- 1 Select **Chord list/Add to milling list**.

The **Add to milling list** window opens.

- 2 Tick the **Add to Milling list..** checkbox.
- 3 Enter the required parameters.
- 4 Click **OK**.



The milling procedure starts.



4.5.7.5. Position and Dwell

Use this command to add a Position and Dwell object to the screen.

The selected file defines the beam path and the dwell times, and is a simple Comma Separated Variable (.CSV) format (internally - .txt files can be used) defining the beam position and dwell time. There is one point on each line of the file containing first the x-coord of the beam, then the y-coord, and finally the dwell time in ms

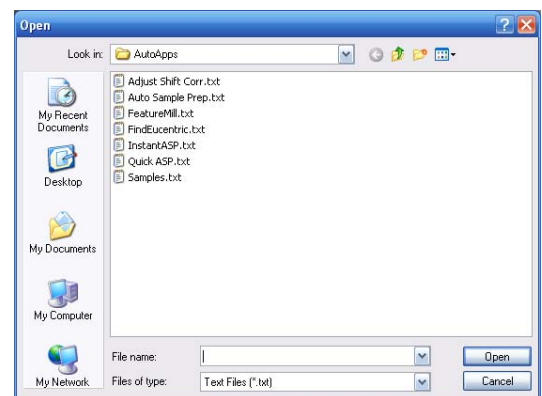
There is no header or footer information required, e.g. the following will mill a very small rectangle:

```
512, 384, 50  
to  
532, 384, 50  
512, 385, 50  
to  
532, 385, 50  
512, 386, 50  
to  
532, 386, 50
```

- 1 Click the **Position and Dwell** icon in the tool-bar to open the **Open** dialog.



- 2 Select a File name.
- 3 Click **Open**.



If the file can be loaded successfully then the mouse cursor will change to a cross over the view.

- 4 Click and drag out the area of the Position and Dwell that you want.
- 5 If you press **<ctrl>** whilst dragging out this area then the bounding rectangle will be forced to have the same aspect ratio as the source file.
- 6 If you press **<shift>** the bitmap will scale to the current aspect ratio.

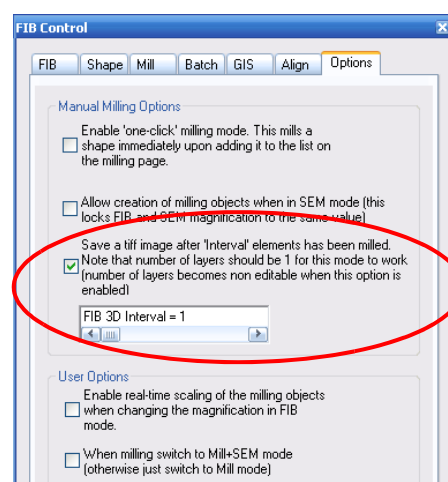
4.5.8. Recording a series of tiff images

This function allows you to record a series of high quality tiff images, which can be compiled to a video sequence or used with the Smart3D software for 3D reconstruction. When selecting this function, the workstation permanently changes between **Mill** mode and **SEM** mode.

In **SEM** mode, the images are taken. Since the images are NOT taken during the milling procedure, image interferences will be minimised. All tiff files are stored in one container file in the user image directory specified in the user preferences.

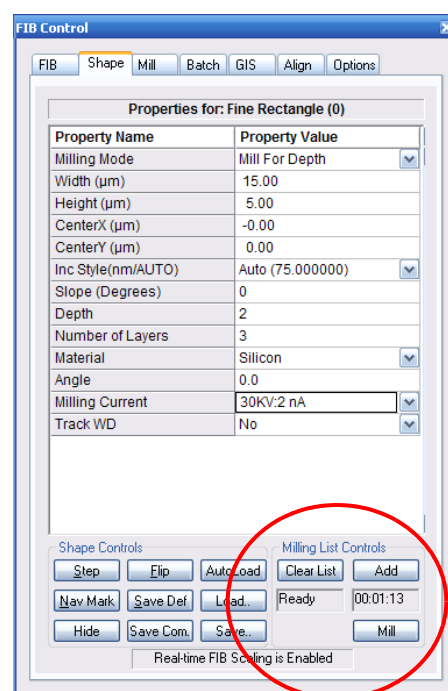
With the **FIB 3D Interval =** slider you can set the interval of recorded images. If you set *FIB 3D Interval = 1*, with every scanned line an image will be recorded. If you set e.g. *FIB 3D Interval = 4*, with every fourth scanned line an image will be recorded. Thus the milling process is faster but delivers less information.

- 1 Go to the **Options** tab of the **FIB Control** panel.
- 2 Tick the **Save a tiff image file....** checkbox.
- 3 Set the **FIB 3D Interval =** slider.



- 4 Select a milling object.

- 5 Go to the **Shape** tab.



- 6 Click **Clear List**.
- 7 Click **Add**.
- 8 Click **Mill**.

The image files are automatically stored.

4.5.9. Using the drift correction (licence: DRIFT CORR)

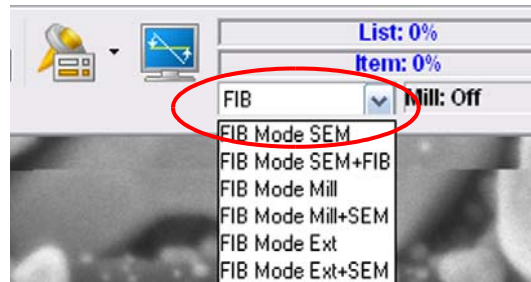
Drift correction is most useful, especially over long milling periods so that the effects of stage drift or thermal effects do not cause any damage of the areas to be milled.

The drift correction settings determine how and how often drift correction is used.

Requires a special dongle (MIL dongle) and the licence DRIFT CORR.

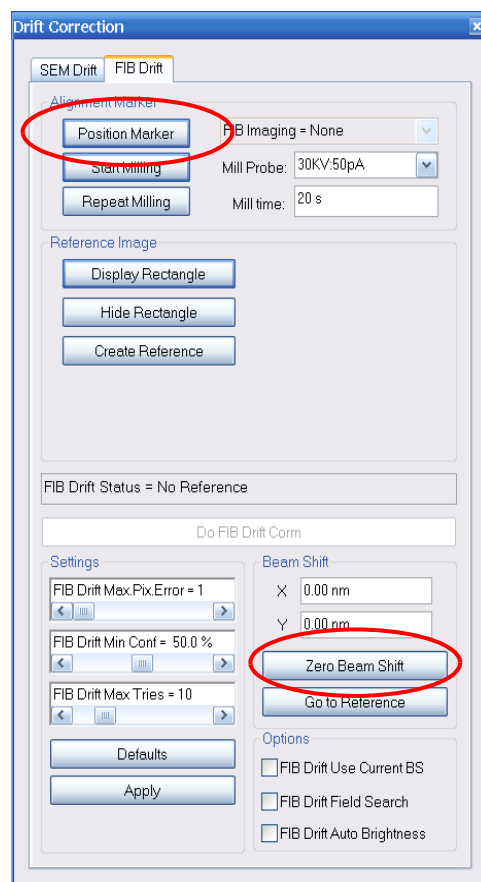
4.5.9.1. Setting the FIB drift

- 1 Select **FIB Mode**.



- 2 Set the following parameters:
Pixel averg., Scan speed 5-6
- 3 Select the detector with the best contrast.

- 4 Open the **Panel Configuration Bar**.
- 5 Double-click **Drift Correction**.
- 6 Go to the **FIB Drift** tab.
- 7 Click **Zero Beam Shift**.
- 8 Click **Position Marker**.

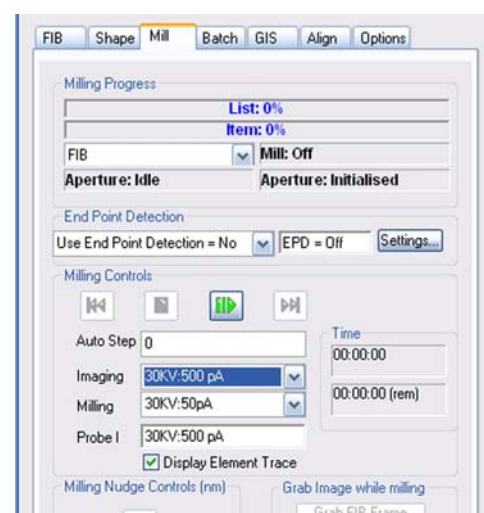


The milling object is shown.



9 Go to the **Mill** tab.

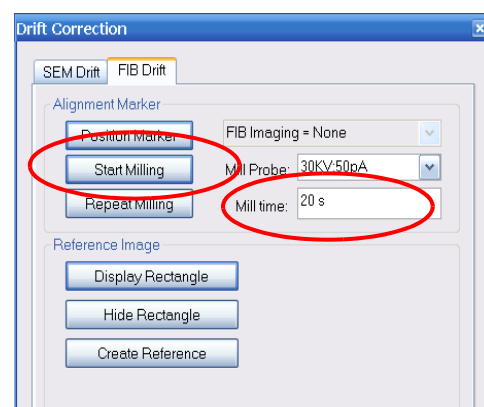
Select a probe current e.g. 30 kV, 500 pA.



10 Go to the **FIB Drift** tab.

11 Enter a **Mill time** of e.g. 20 sec.

12 Click **Start Milling**.



4. Operation

Milling

A cross-shaped alignment mark is being milled.

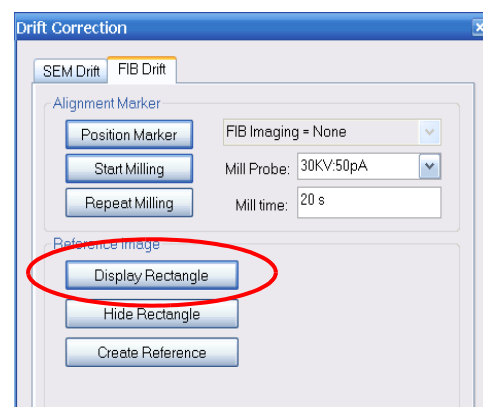


- 13 Go to SEM image.
Check the quality of the alignment mark.



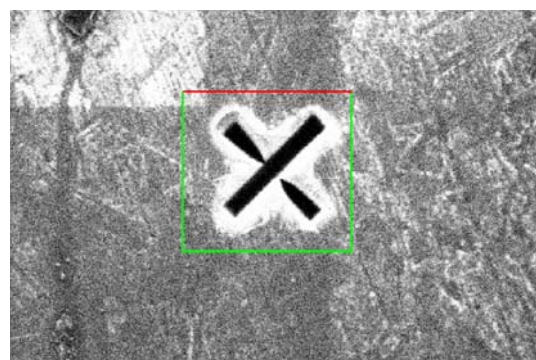
- 14 Check the quality of the alignment mark.
- 15 If required, mill again by clicking **Repeat Milling**.
- 16 Go to FIB image.
- 17 Refocus the image.
- 18 Adjust a good contrast.

- 19 In the **FIB Drift** tab, click **Display Rectangle**.



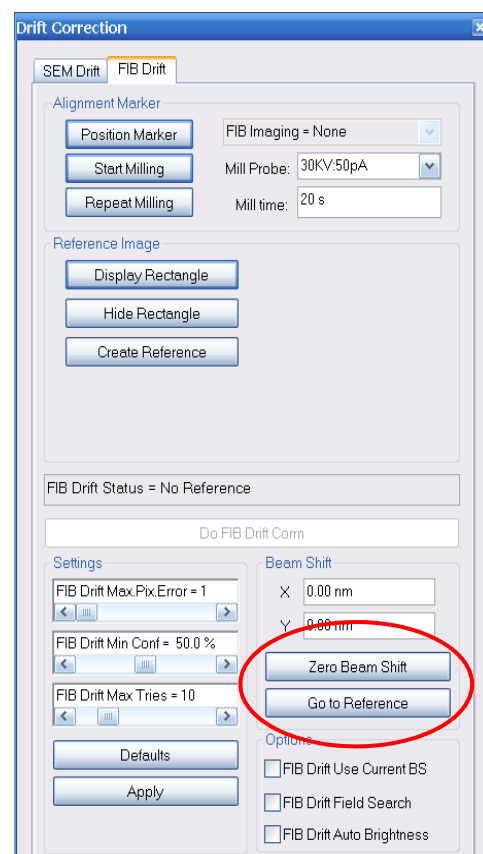
A rectangle is shown on the screen.

- 20 Shift the rectangle so that the alignment mark is in the centre of the rectangle.



- 21 Click **Zero Beam Shift**.
22 Click **Create Reference**.

When creating a reference, the system remembers all settings that were used e.g. scan speed, FIB probe current, detector selection etc.



4. Operation

Milling

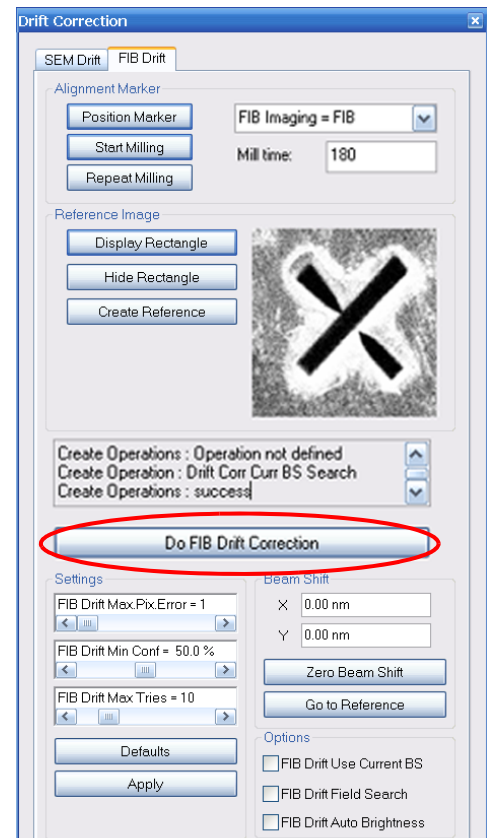
23 Wait until the image of the cross is shown in the panel.

A message appears:

"Create operations: success"

24 Click **Do FIB Drift Correction**.

The system changes to previous scan speed settings.



To delete the rectangles: Click **Hide Rectangle**.



IMPORTANT

Any feature can be used as reference feature.

4.5.9.2. Setting the SEM drift

- 1 Change to **SEM Mode**.
- 2 Display a rectangle.
- 3 Shift the rectangle so that the cross is in the centre of the rectangle.
- 4 Depending on your application, switch off the tilt compensation.
- 5 Click **Zero Beam Shift**.
- 6 Click **Create Reference**.

Wait until the SEM image of the cross is shown in the panel.

- 7 Click **Do SEM Drift Corr.**



4.6. Working with the Gas Injection System (GIS, optional)

For deposition of metals and insulators as well as for etching, the optional gas injection system (GIS) is used. The GIS consists of precursor reservoirs for up to five different process gases, a capillary and a nozzle for each gas and a GIS micro stage for accurate positioning of the nozzles.

Up to two gas injection systems can be installed:

- Multi GIS + Single GIS
- Single GIS + Single GIS

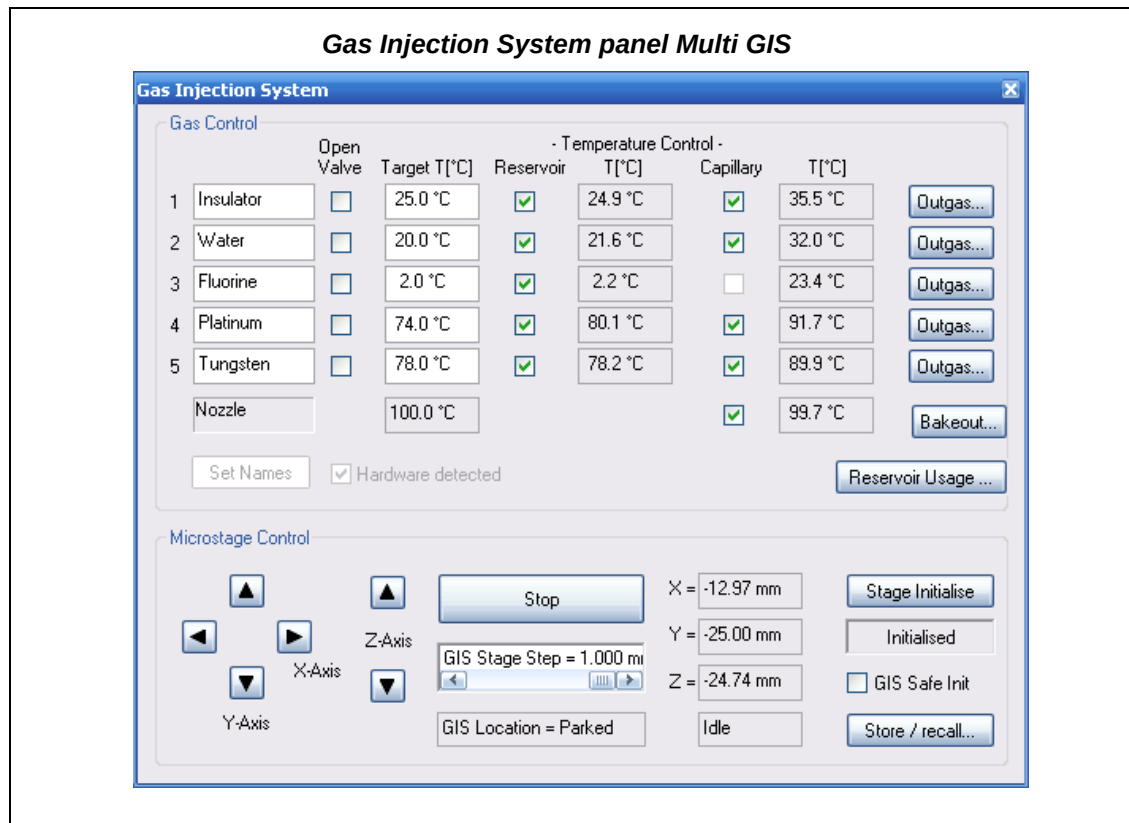
For more detailed information, refer to the Instruction Manual Multi GIS and the Instruction Manual Single GIS.



IMPORTANT

Depending on the configuration, the Gas Injection System panel looks different. If two GIS are installed, the microstage and the insert/retract control are located in the Stage Control tab.

Apart from the missing microstage, the operation of the Single GIS is the same. In the following sections, the Multi GIS is described as a reference.



Gas Injection System panel Single GIS

Gas Control		Open Valve	Target T [°C]	Reservoir	- Temperature Control -		
					T [°C]	Capillary	T [°C]
1	Platinum	☐	75.0 °C	☒	75.0 °C	☒	90.0 °C

Set Name

☐ Hardware detected

Insert Nozzle GIS Location = Moving Reservoir Usage ...

Retract Nozzle Busy

Gas Injection System panel Multi GIS + Single GIS

Multi-GIS		Open Valve	Target T [°C]	Reservoir	- Temperature Control -		
					T [°C]	Capillary	T [°C]
1	enter name	☐					
2		☐	17.0 °C	☐	20.4 °C	☐	20.4 °C
3		☐	17.0 °C	☐	20.4 °C	☐	20.4 °C
4		☐	17.0 °C	☐	20.4 °C	☐	20.4 °C
5		☐	17.0 °C	☐	20.4 °C	☐	20.4 °C
	Nozzle	☐	17.0 °C	☐		☐	17.0 °C

Hardware detected

Outgas... Outgas... Outgas... Outgas... Outgas... Bakeout...

Single GIS		Open Valve	Target T [°C]	Reservoir	- Temperature Control -		
					T [°C]	Capillary	T [°C]
1	Tungsten	☐	20.0 °C	☐	16.5 °C	☐	18.5 °C

Hardware detected

Reservoir Usage ...

4. Operation

Working with the Gas Injection System (GIS, optional)

4.6.1. Preparing the precursors

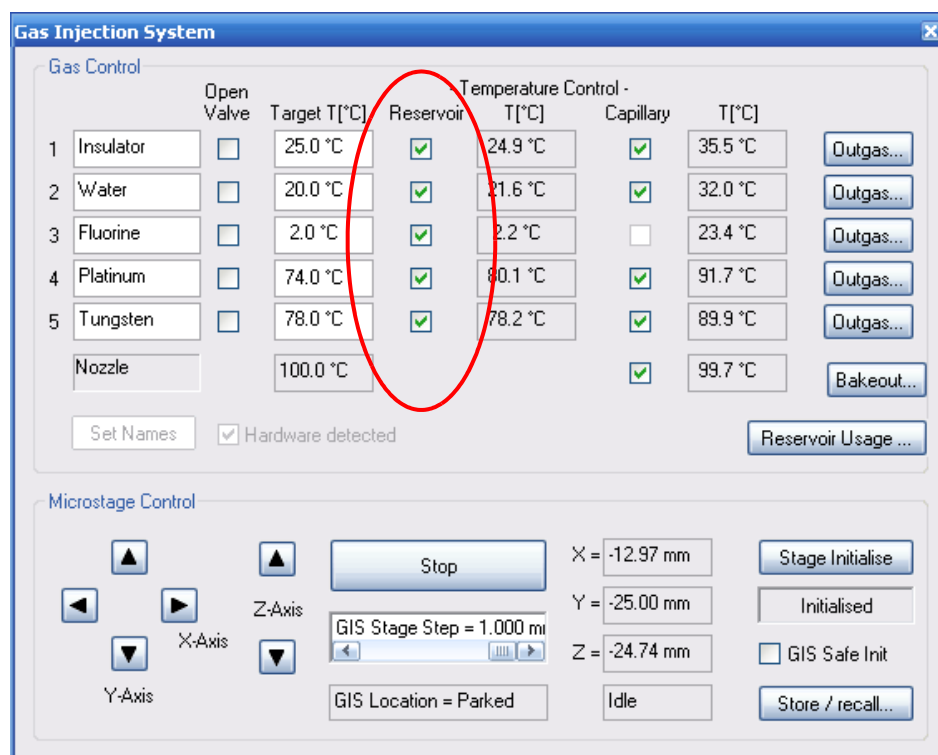
4.6.1.1. Heating the reservoirs

The reservoirs - except for the fluorine precursor (XeF_2) - are heated in order to liberate the process gases from the precursor substances and to improve their reactivity.

The fluorine precursor (XeF_2) is never heated, because this substance is volatile at room temperature. With GIS version 4, the fluorine precursor is cooled by means of a Peltier cooling element.

- 1 Open the **Panel Configuration Bar**.
- 2 Double-click **Gas Injection System**.

The **Gas Injection System** panel opens.



- 3 Click the **Reservoir** checkbox of the precursor you wish to work with.

The **Capillary** checkbox is ticked automatically.

It is recommended that the heating remains switched on at all times to ensure stable conditions, because it can take some time until the optimum working temperature is achieved.

The temperature should be adjusted in a way, that - when opening the respective reservoir valve - the system vacuum is about $1 - 2 \times 10^{-5}$ mbar.

4.6.1.2. Outgassing a reservoir

Outgassing is required to remove excess gas from the reservoirs. If the channels are not used daily, the gas pressure in the reservoir is built up. Outgassing basically consists of a series of open and close cycles of the reservoir valve to let small amounts of gas get out of the reservoir. This will help to avoid an unintended breakdown of the system vacuum when the precursor is used next time.

Possible reasons:

- The reservoir has not been used for several hours
- With GIS without Peltier-cooling:
Before every use of the fluorine precursor (XeF_2)

CAUTION

For gas injection systems without Peltier-cooling only:

Risk of strong increase of the pressure in the fluorine precursor (XeF_2) reservoir.

The system vacuum may decrease abruptly when the fluorine precursor reservoir valve is opened.

Outgas the channel for the fluorine precursor before every working session.

With GIS with Peltier-cooling, the fluorine precursor reservoir does not need to be outgassed before every use.

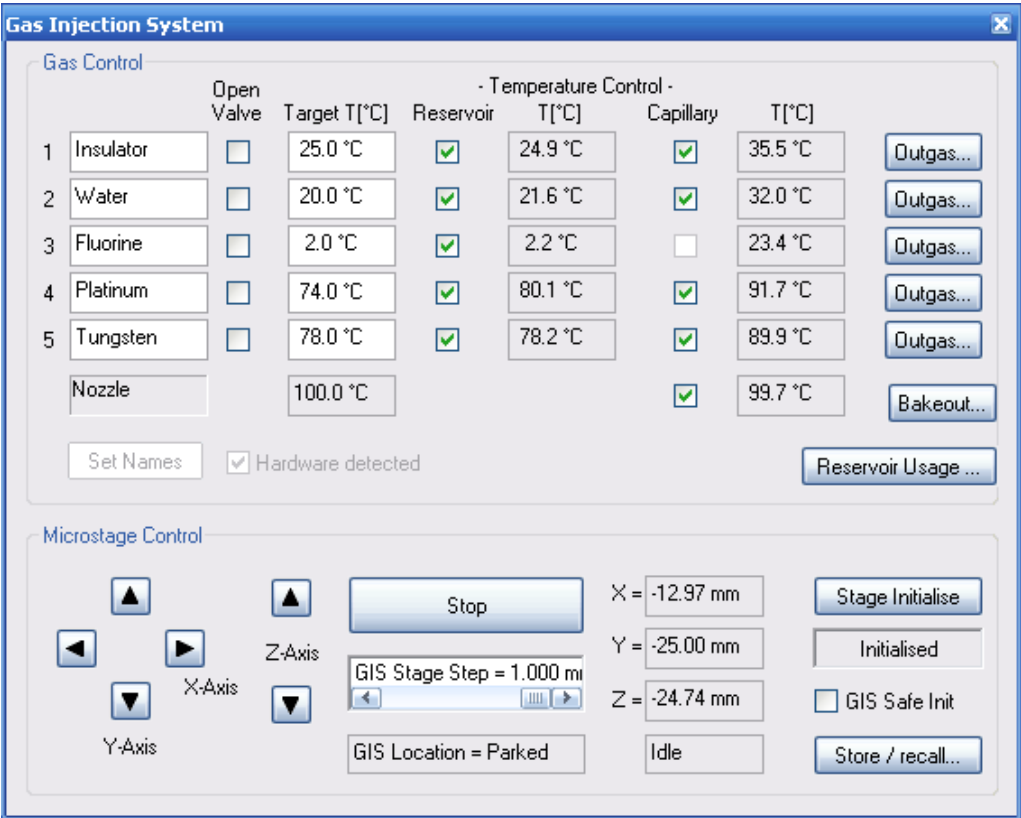
Procedure:

- 1 Switch on the heating of the capillary and the reservoir you wish to use.
- 2 Switch off the SEM EHT.
- 3 Switch off the FIB EHT.
- 4 Open the **Panel Configuration Bar**.
- 5 Double-click **Gas Injection System**.

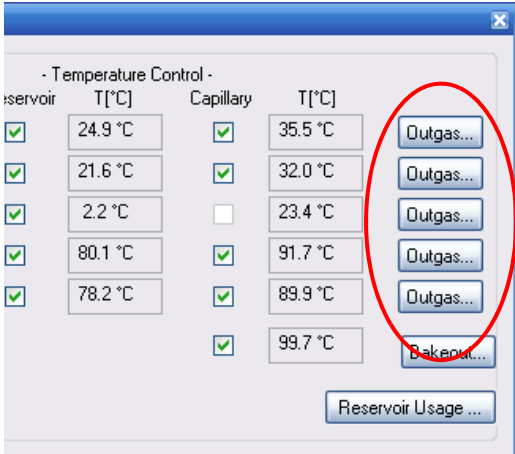
4. Operation

Working with the Gas Injection System (GIS, optional)

The **Gas Injection System** panel opens.



- 6 Outgas depending on the precursor, you wish to work with.

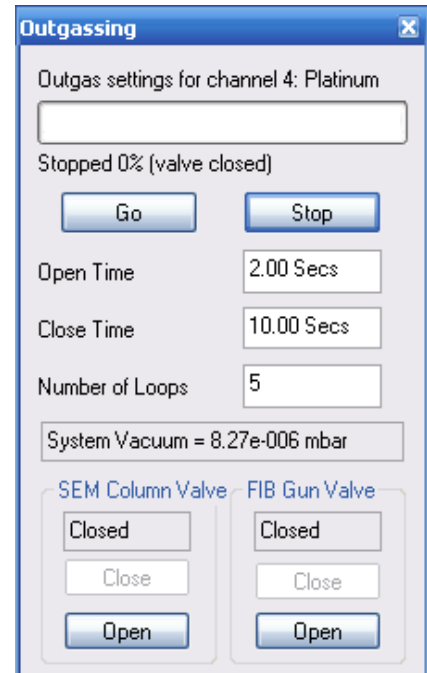


The **Outgassing** panel opens.

- 7 In the **SEM Column Valve** field:
Click **Close**.

The column chamber valve in the SEM is closed.
The FIB gun valve is closed simultaneously.

- 8 Click the **Open Time** field and enter 2 sec.
- 9 Click the **Close Time** field and enter a value of about 5 to 10 sec.
- 10 Click the **Number of Loops** field and enter 5.

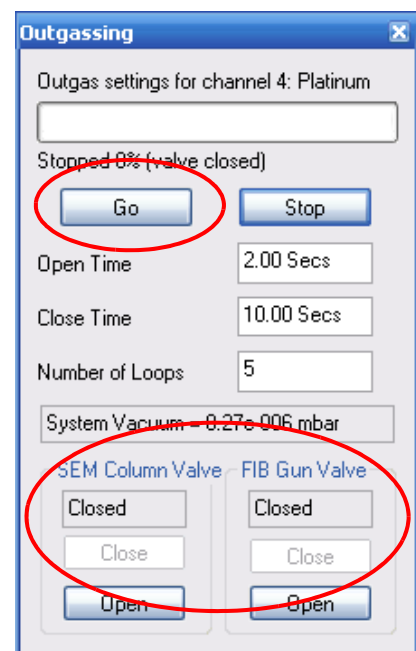


CAUTION

Danger of damaging electron source and ion source

*Before starting the outgassing procedure:
Ensure that EHT and FIB EHT are switched off.
Ensure that SEM column valve and FIB column valve are closed.*

- 11 To start the outgassing procedure, click on **Go**.



4. Operation

Working with the Gas Injection System (GIS, optional)

- 12 Monitor the system vacuum by observing the System Vacuum value in the **Outgassing** panel. If, after the 5th loop, the vacuum has not reached 2×10^{-5} mbar or better, which is the pressure necessary for deposition, repeat the procedure.

In this case, you should increase the number of loops in future outgassing procedures.



IMPORTANT

Duration of the outgassing depends of several factors such as GIS version, material, precursor etc. While outgassing find out which parameters are relevant for your system.

4.6.2. Positioning the GIS micro stage (Multi GIS only)

The GIS micro stage is used to position the GIS nozzles. There are five nozzles, one for each of the reservoirs. The Single GIS has no microstage it can only be inserted and retracted.

4.6.2.1. Approaching a certain working position

For each of the five nozzles a working position is pre-defined by the factory or ZEISS service representative, respectively.

The positions can be recalled by means of the buttons in the **Select Channel** row.

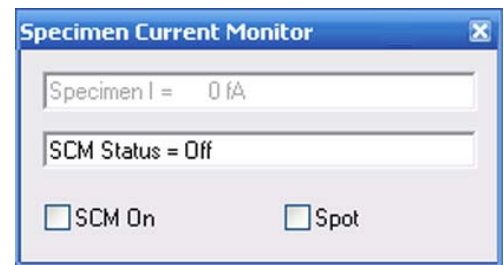
Procedure:

CAUTION

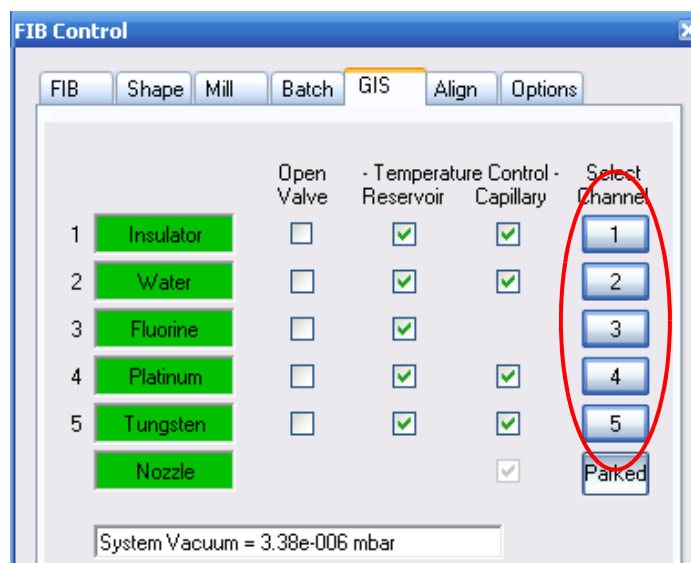
In order to avoid any risk of damaging parts while moving a GIS micro stage, the touch alarm function should be active.

Therefore, ensure the Specimen Current Monitor is switched OFF.

- 1 Switch off the **Specimen Current Monitor**.
 - a Select **Tools/Go To Panel** from the menu.
 - b Double-click **Specimen Current Monitor**.
 - c Untick the **SCM On** checkbox.
- 2 In the **GIS** tab of the **FIB Control** panel, click the channel number.



The GIS micro stage is driven to the stored position.



4. Operation

Working with the Gas Injection System (GIS, optional)

4.6.2.2. Approaching the park position

The park position is a pre-defined safe position of the GIS micro stage. In the park position, the GIS is retracted as far as possible in Y-direction and is situated directly underneath the FIB objective lens. This prevents interferences during milling or imaging and keeps the nozzles out of the stage operation area.

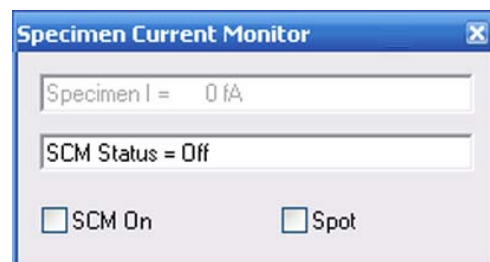
Procedure:

CAUTION

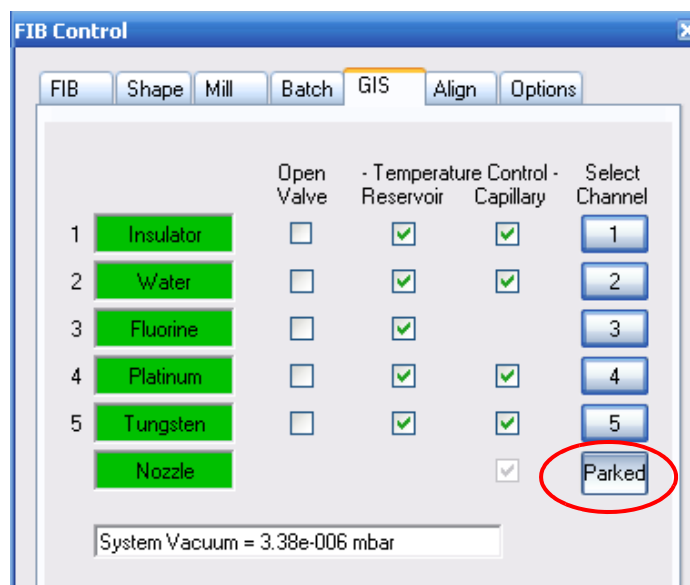
In order to avoid any risk of damaging parts while moving a GIS micro stage, the touch alarm function should be active.

Therefore, ensure the Specimen Current Monitor is switched OFF.

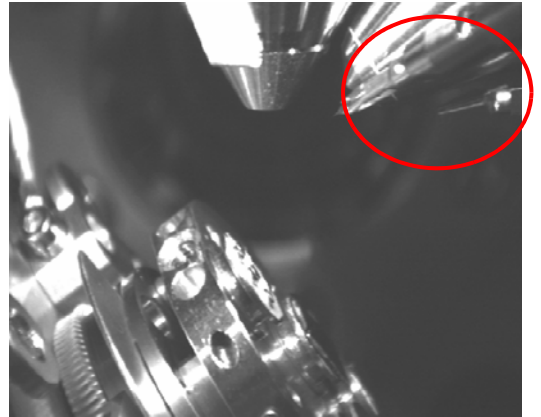
- 1 Switch off the **Specimen Current Monitor**.
 - a Select **Tools/Go To Panel** from the menu.
 - b Double-click **Specimen Current Monitor**.
 - c Untick the **SCM On** checkbox.



- 2 In the **GIS** tab of the **FIB Control** panel, click **Parked**.



The GIS micro stage is driven to the park position.



4. Operation

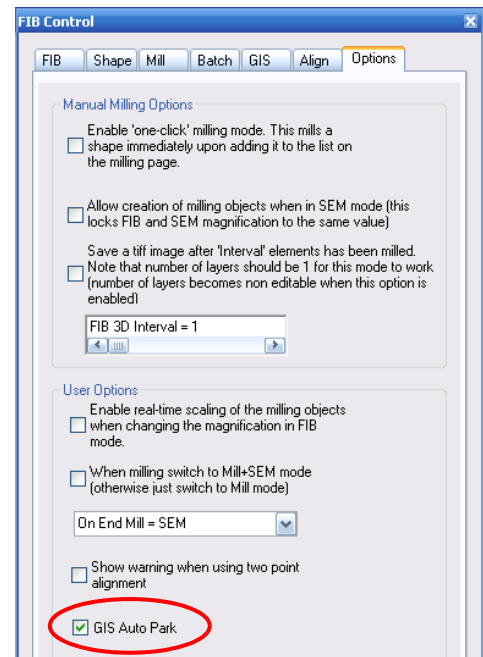
Working with the Gas Injection System (GIS, optional)

4.6.2.3. Activating the GIS Auto Park function

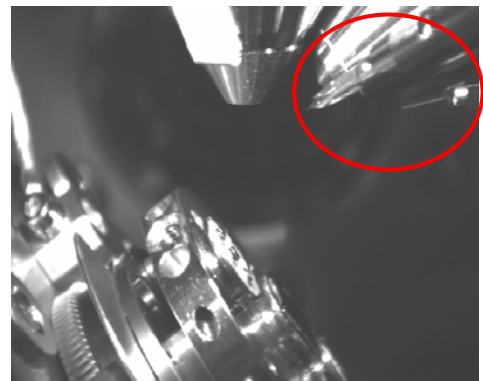
The park position is a pre-defined safe position of the GIS micro stage. In the park position, the GIS is retracted as far as possible in Y-direction and is situated directly underneath the FIB objective lens. This prevents interferences during milling or imaging and keeps the nozzles out of the stage operation area.

For most applications it is recommended that you activate the GIS auto park function. This will ensure that the GIS micro stage is driven to the park position as soon as the GIS micro stage is no longer needed at the working position. This will avoid any risk of damaging nozzles.

- 1 In the **Options** tab of the **FIB Control** panel:
Tick the **GIS Auto Park** checkbox.



As soon as the milling/deposition process is over, the GIS micro stage is driven to the park position.



IMPORTANT

For some applications, the GIS Auto Park function should be DISABLED. This applies to shock-sensitive applications. Ensure the GIS Auto Park checkbox is UNTICKED.

4.6.3. Gas assisted desposition



IMPORTANT

If a Capella FIB column is installed, refer to the SmartFIB® Online Help for details.

There are different applications or processes, that require a deposition of a metal or an insulator:

- Surface protection layer for cross sections or TEM lamella preparation
- Circuit modification

The ion beam is required to start and maintain the chemical deposition process. On the other hand, deposition only occurs when more material is deposited than sputtered by the ion beam.

Deposited material	Precursor
Tungsten, W	W(CO) ₆ Tungsten hexacarbonyl
Platinum, Pt	C ₉ H ₁₆ Pt Methyl cyclopentadienyl(trimethyl)platinum
Insulator, SiO ₂	PMCPS, C ₅ H ₂₀ O ₆ Si ₅ 2,4,6,8,10-Pentamethylcyclopentasiloxane

Milling objects Deposition is done by processing a milling object, usually with the specimen stage at 54°.

4. Operation

Working with the Gas Injection System (GIS, optional)

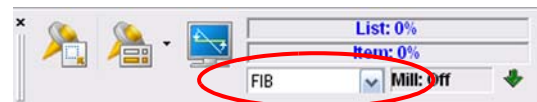
4.6.3.1. Selecting deposition conditions

Preconditions:

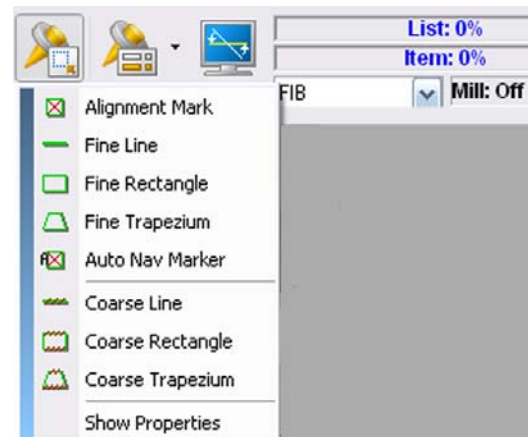
- Reservoirs have been heated. Refer to section 4.6.1.1.
- Reservoirs have been outgassed. Refer to section 4.6.1.2.
- Specimen has been moved to the coincidence point, tilted to 54°. Refer to section 4.2.2.
- Electron beam has been switched on.
- Ion beam has been switched on. Refer to section 4.3.1.1.

Procedure:

- 1 Select **FIB** mode from the drop-down menu.



- 2 Select a milling pattern from the drop-down menu.
- 3 Position the milling object.

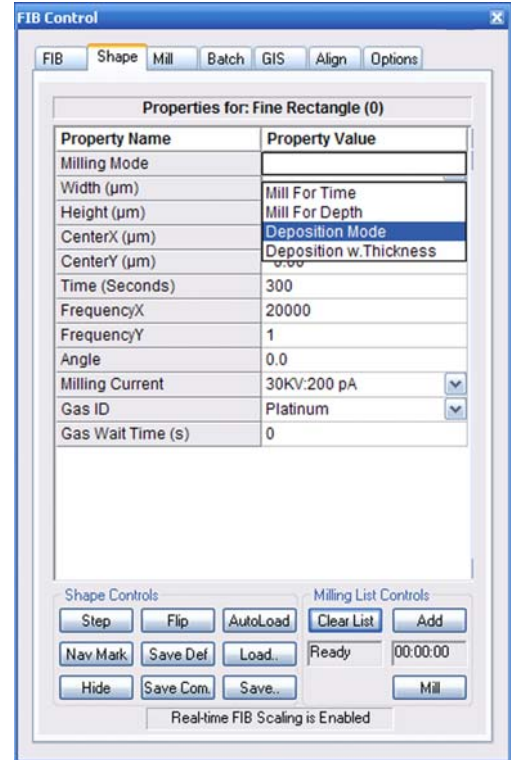


- 4 In the **Shape** tab of the **FIB Control** panel, select the object properties according to the selected **Milling** mode.

Deposition Mode:

Deposits material for a given period of time

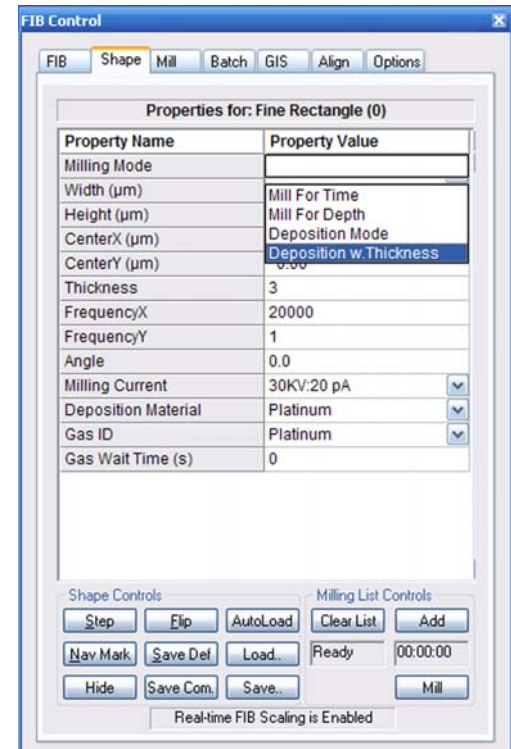
- a Set the parameters as required by your application.
- b Select the **Gas ID** from the drop-down list:
 - Tungsten
 - Platinum
 - Insulator
 - Carbon



Deposition w. Thickness:

Deposits material to a given thickness

- a Set the parameters as required by your application.
- b Select the **Deposition Material** from the drop-down list.
 The items shown in the drop-down list can be edited by using the **FIB Deposition Materials Editor**. Refer to section 4.6.5.
- c Select the **Gas ID** from the drop-down list:
 - Tungsten
 - Platinum
 - Insulator
 - Carbon



4. Operation

Working with the Gas Injection System (GIS, optional)

4.6.3.2. Starting the deposition procedure

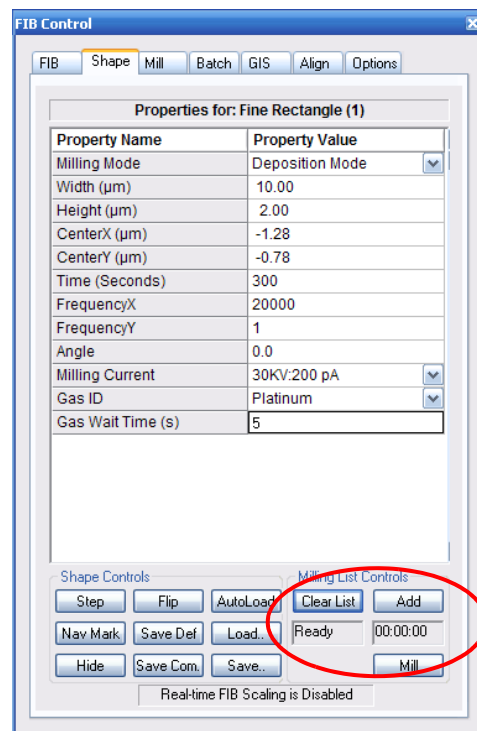
- 1 Click **Clear List**.

All previous milling objects are deleted from the milling list.

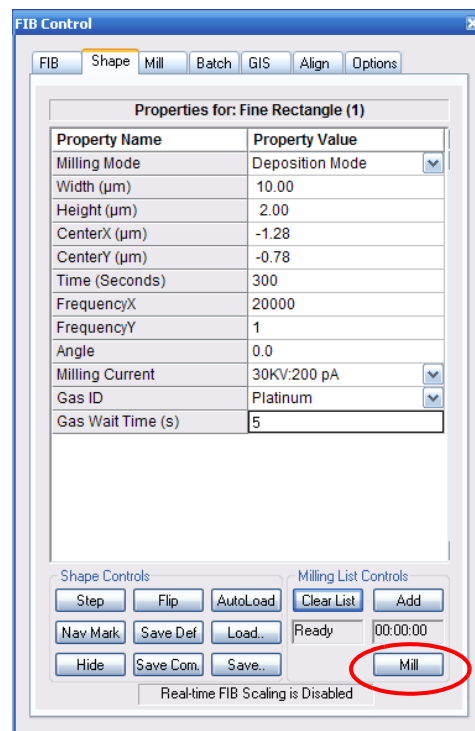
- 2 Click **Add**.

The current milling object is - together with the selected milling conditions - added to the milling list.

The time needed to process the object is shown under the **Add** button.



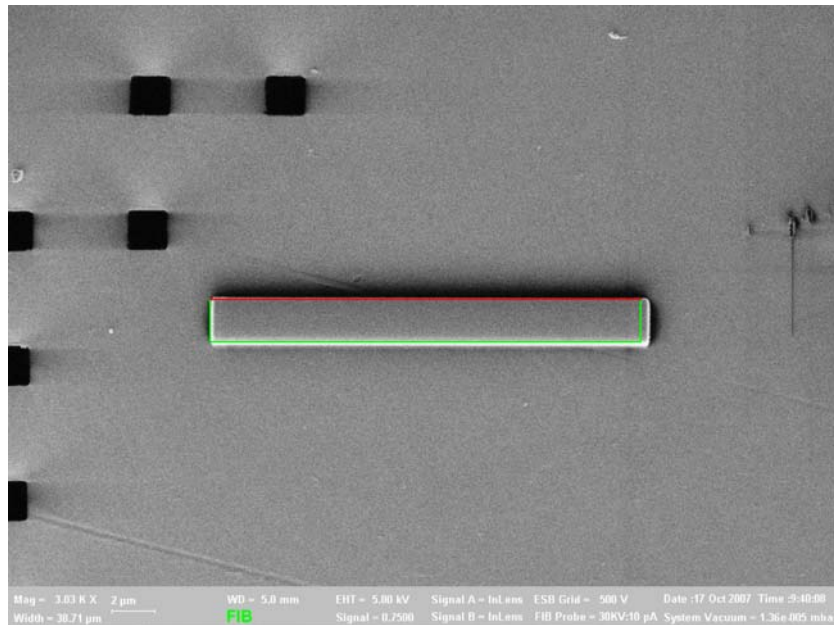
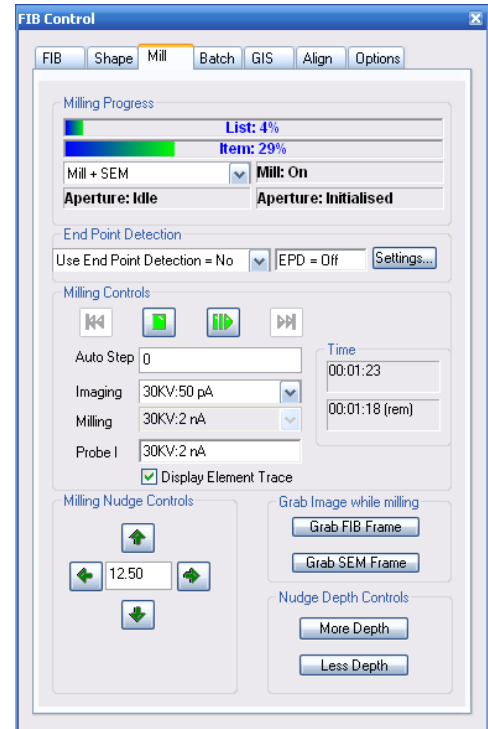
- 3 To start the deposition, click **Mill**.



The GIS micro stage is moved automatically to the pre-defined position, which has been assigned to the selected precursor.

The deposition process starts.

The **Mill** tab opens, which allows you to directly control the deposition progress.



The deposition process ends automatically.

4.6.4. Gas assisted etching (GAE)



IMPORTANT
If a Capella FIB column is installed, refer to the SmartFIB® Online Help for details.

Gas assisted etching (GAE) allows you to selectively increase etching rates compared to etching with ion beam or electron beam alone.

Etching reagent	Selectively etches
Xenondifluoride, XeF ₂	Si, SiO ₂
Water (reactive products)	Carbon, organic materials

Milling objects Etching is done by processing a milling object, usually with the specimen stage at 54°. There are different etching types:

- Physical etching: only the ion beam is used to remove material
- Chemical etching: the ion beam and precursor gases are used to remove material

Types of etching		
Physical etching		
Ion milling	Physical etching means that only the ion beam is used to remove material within a selected area (1). The removed material is re-deposited (2) at the side walls faster than it can be pumped away. Therefore, the side walls are uneven and the ability to mill deep holes is limited .	
Chemical Etching		
Gas assisted etching (GAE)	GAE means that the ion beam hits a selected area (3) on the specimen surface and interacts with a precursor. The precursor is split up into a volatile, inactive substance and a volatile active substance. The inactive substance is pumped away. The volatile active substance reacts with the substrate and becomes a volatile compound which removes the substrate. Using GAE improves the aspect ratio of the milled holes and enhances the removal rate. Thus, the sidewall angles come closer to 90° (4).	

Table 4.5: Types of etching

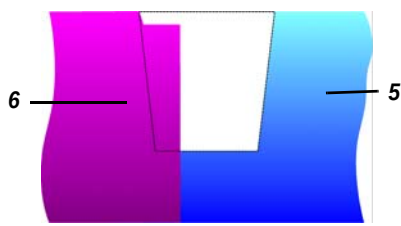
Types of etching		
Selective etching	GAE is also material-selective, because etching reagents etch different materials (5 , 6) at different rates.	

Table 4.5: Types of etching

4. Operation

Working with the Gas Injection System (GIS, optional)

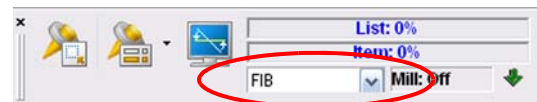
4.6.4.1. Selecting etching conditions

Preconditions:

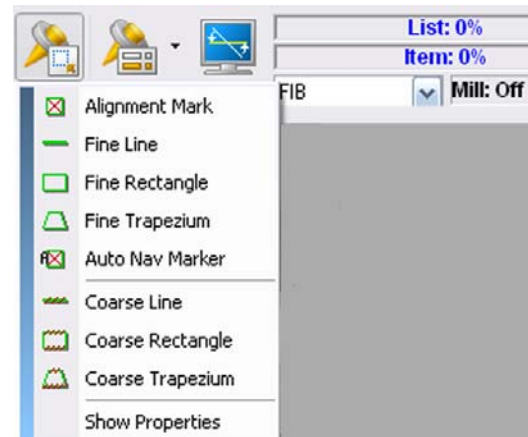
- Reservoirs have been heated. Refer to section 4.6.1.1.
- Reservoirs have been outgassed. Refer to section 4.6.1.2.
- Specimen has been moved to the coincidence point, tilted to 54°. Refer to section 4.2.2.
- Electron beam has been switched on.
- Ion beam has been switched on. Refer to section 4.3.1.1.

Procedure:

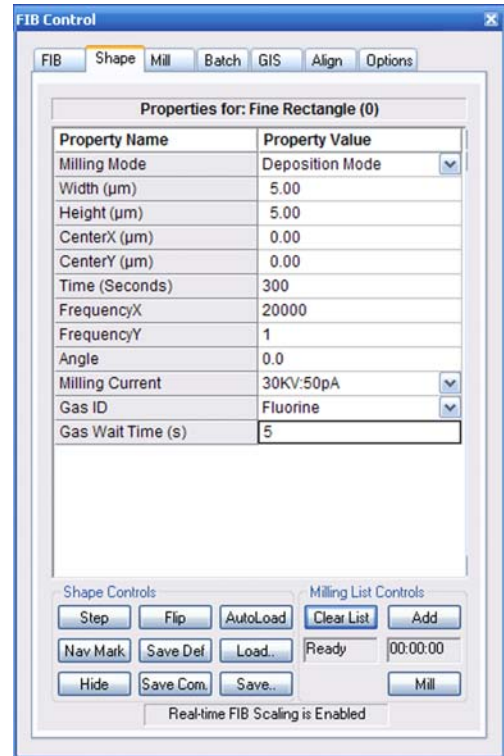
- 1 Select **FIB** mode from the drop-down menu.



- 2 Select a milling pattern from the drop-down menu.



- 3 In the **Shape** tab of the **FIB Control** panel, select the object properties:
 - a Select **Deposition** mode.
 - b Set the parameters as required by your application.
 - c Select the **Gas ID** from the drop-down list:
 - *Fluorine*
 - *Water*



4. Operation

Working with the Gas Injection System (GIS, optional)

4.6.4.2. Starting the etching procedure

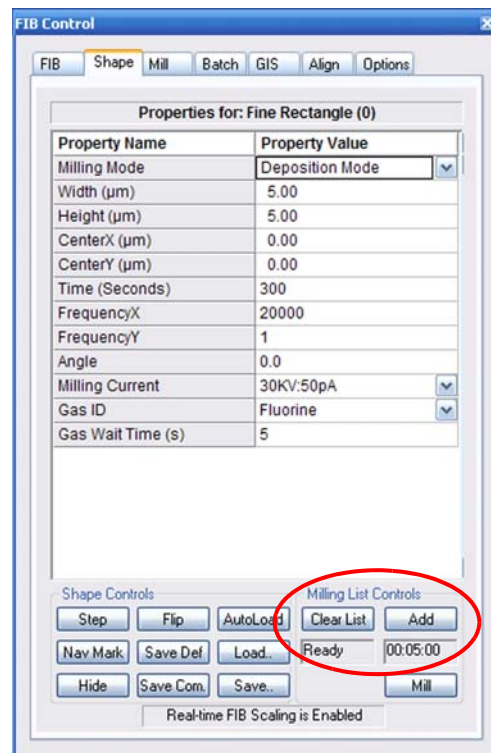
- 1 Click **Clear List**.

All previous milling objects are deleted from the milling list.

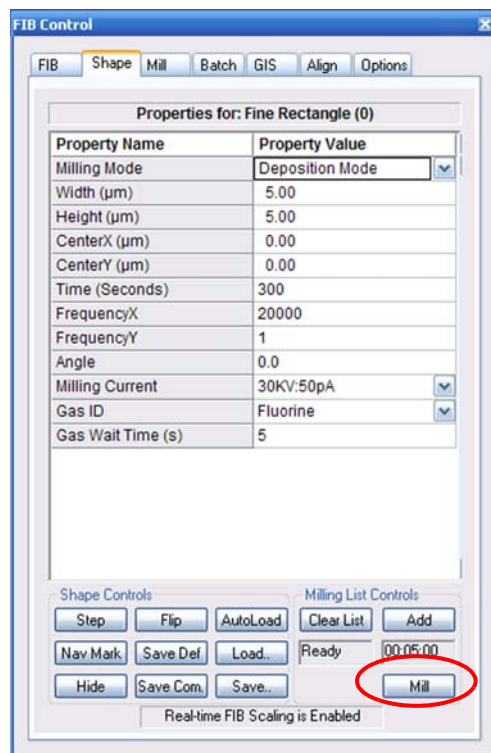
- 2 Click **Add**.

The current milling object is - together with the selected milling conditions - added to the milling list.

The time needed to process the object is shown under the **Add** button.



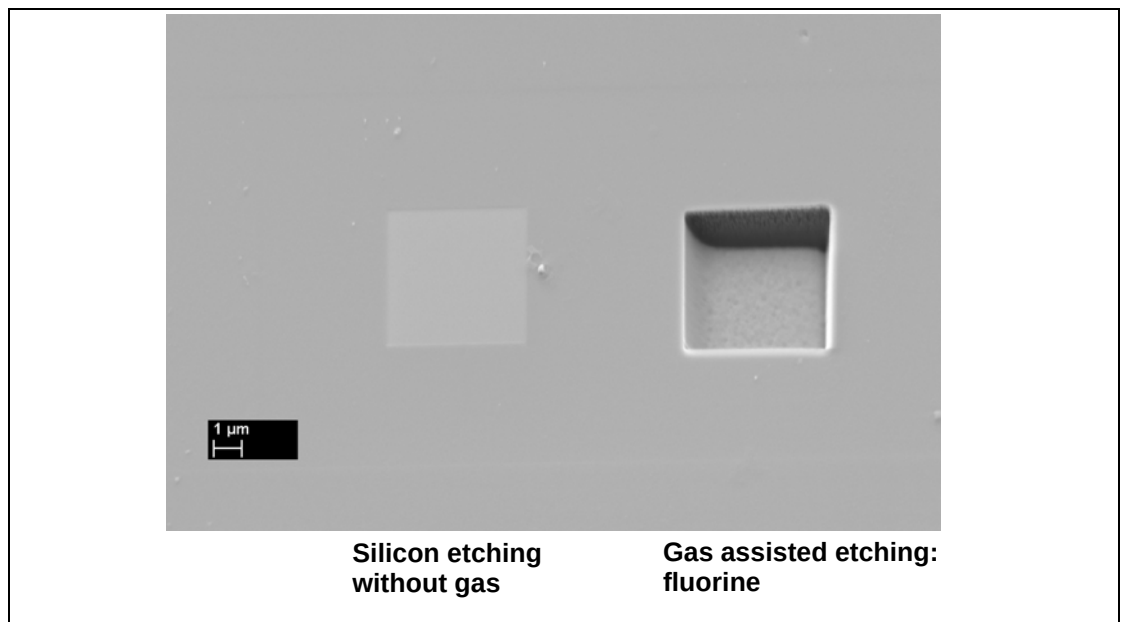
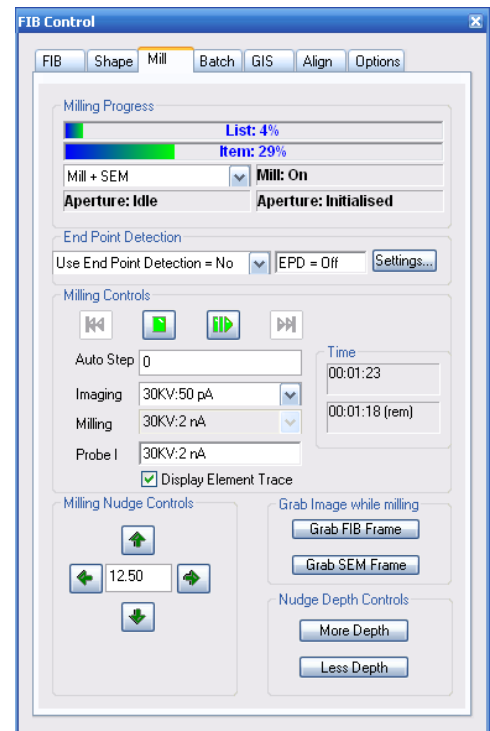
To start the etching, click **Mill**.



The GIS micro stage is moved automatically to the pre-defined position, which has been assigned to the selected precursor.

The etching process starts.

The **Mill** tab opens, which allows you to directly control the etching progress.



The etching process ends automatically.

4. Operation

Working with the Gas Injection System (GIS, optional)

4.6.4.3. Decorating semiconductor cross sections (fluorine flash)

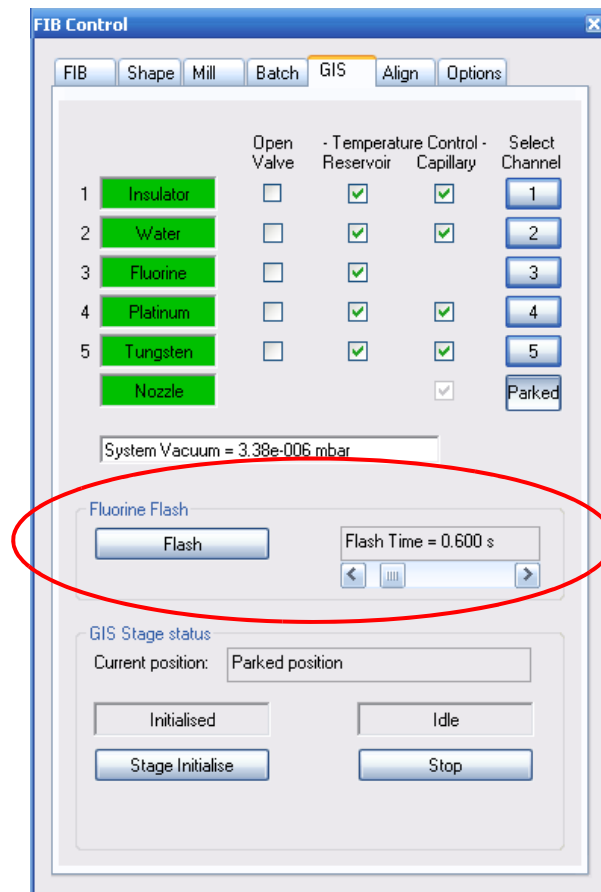
To be able to distinguish Si and SiO₂, which tend to show almost the same contrast values, the fluorine flash is used to decorate the cross section: A quick burst of xenondifluoride is flushed over the substrate while the specimen is being milled by means of the ion beam.

Since Si and SiO₂ have different etching rates, both materials can be distinguished easily.

Moreover, the fluorine flash function is suitable to increase etching rates during the milling process.

Procedure:

- 1 Go to the **GIS** tab of the **FIB Control** panel.
- 2 Set the **Flash Time** by moving the slider.
- 3 Click **Flash**.



4.6.5. Entering material properties (FIB Deposition Materials Editor)



IMPORTANT

If a Capella FIB column is installed, refer to the SmartFIB® Online Help for details.

The FIB Deposition Materials Editor is designed for the creation of material definitions. These are used by various components in the FIB software which allow you to specify a particular deposition thickness or etching depth.

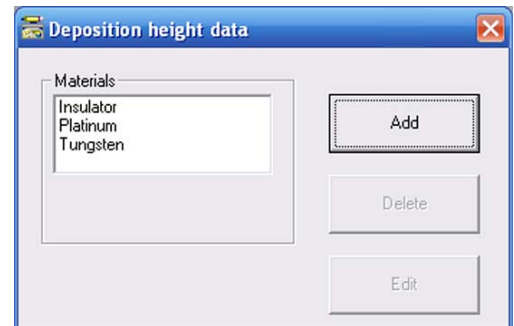
The information provided allows the software to calculate the time required to achieve the height or depth specified.

4.6.5.1. Adding a new material

- 1 Select **Programs/SmartSEM/
FIB Deposition Materials Editor.**

The **Deposition Height Data** window opens.

- 2 Click **Add**.



The **Add New Material** panel opens.

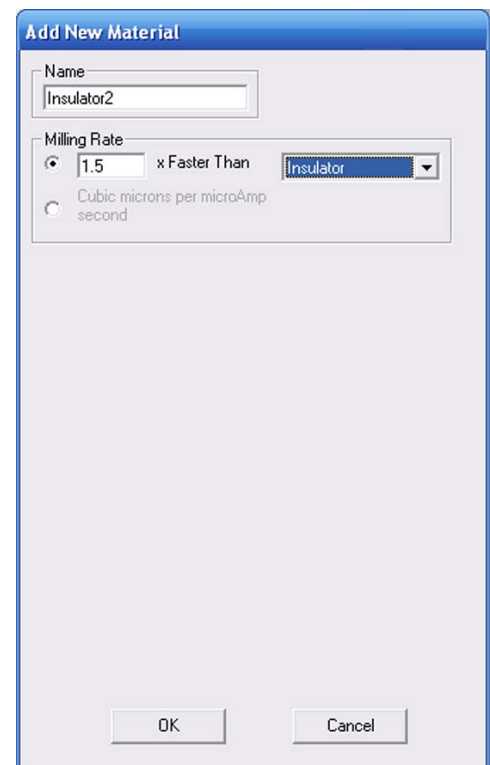
- 3 Enter the required settings.
- 4 Click **OK**.

The new entry appears in the list.

There are two ways to define the deposition rate of a new material:

- An object was deposited with **Deposition w. Thickness** using a known material, e.g. insulator. The thickness has been measured. Then, the deposition rate ratio can be defined and used for the new deposition rate.
- The deposition rate of the new material is already known or is calculated by measuring a deposited object using **Deposition Mode**. Then it can be typed into the second option.

- 5 Enter the required settings.
- 6 Click **OK**.

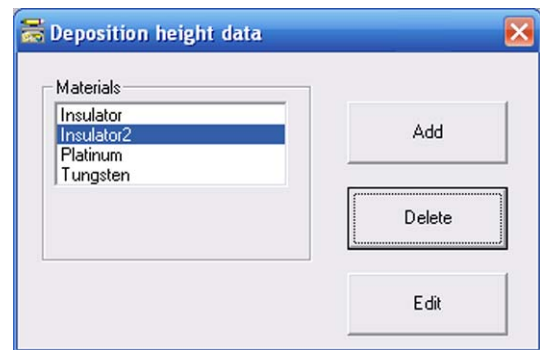


4. Operation

Working with the Gas Injection System (GIS, optional)

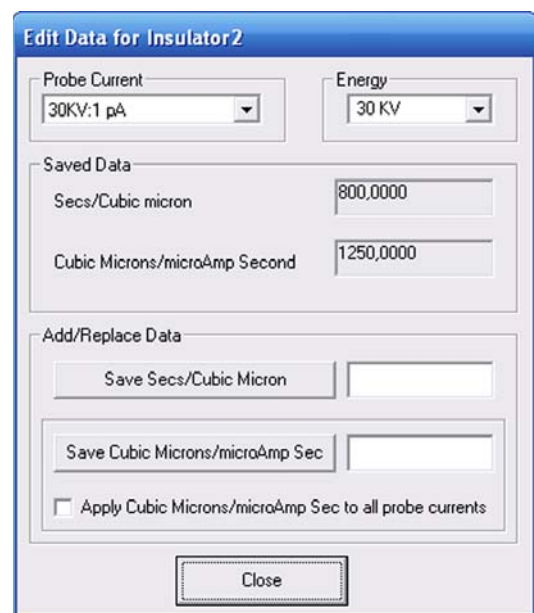
4.6.5.2. Editing an existing material

- 1 Click **Edit**.



The **Edit Data** window opens.

- 2 Enter the required data.
- 3 Click **Close**.



4.6.6. Electron beam deposition or etching



IMPORTANT

If a Capella FIB column is installed, refer to the SmartFIB® Online Help for details.

Depositing and etching with the electron beam is a suitable method for materials that cannot be processed with the focused ion beam.
 Another advantage is, that there is no impairment of surfaces (i.e. no generation of amorphous layers).

CAUTION

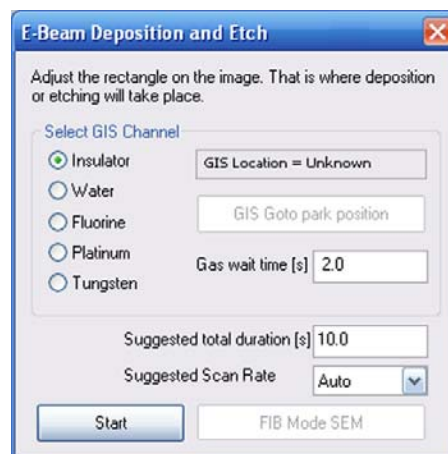
***Danger of damaging GIS micro stage or specimen.**
 Move the specimen surface to the coincidence point before starting the electron beam deposition or etching process.*

- 1 Open the **Panel Configuration Bar**.
- 2 Double-click **E-Beam Deposition and Etch**.

The **E-Beam Deposition and Etch** panel opens.

A desposition object is shown in the image area.

- 3 Resize the deposition object to the appropriate size.
- 4 Select the required precursor.



Precursor/gas	Application
Insulator, SiO ₂	Deposition
Platinum, Pt	Deposition
Water (reactive products)	Etching of materials that contain carbon e.g. diamond like carbon layers (DLC)
Fluorine, XeF ₂	Etching of Si-containing materials
Tungsten, W	Deposition

- 5 Set a **Gas Wait Time**.
- 6 Set a **Total Duration Time**.

4. Operation

Working with the Flood Gun (optional)

- 7 Set a **Scan Rate**.
- 8 Click **Start**.

4.7. Working with the Flood Gun (optional)

The optional Flood Gun can be controlled by hardware or by software. For detailed information on how to operate the Flood Gun using the hardware controls, refer to the Instruction Manual Flood Gun.

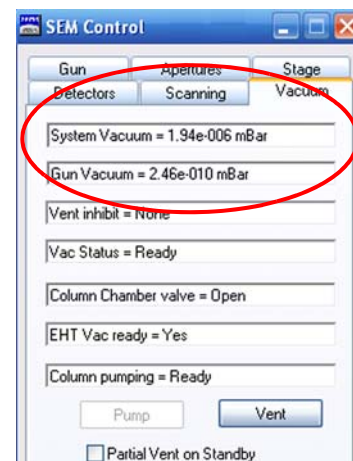
4.7.1. Switching on the Flood Gun

CAUTION

Risk of damaging the filament when the Flood Gun is operated at bad vacuum or atmospheric pressure.

Before switching on the Flood Gun, ensure the system vacuum is better than 5×10^{-6} mbar.

- 1 Check the system vacuum:
 - a In the SmartSEM user interface, open the **SEM Control** panel.
 - b Go to the **Vacuum** tab.
 - c Ensure the system vacuum is better than 5×10^{-6} mbar.



- 2 Check that the Flood Gun power supply is switched on and the **Remote** LED is on.



- 3 Open the **Panel Configuration Bar**.
- 4 Double-click **Flood Gun**.

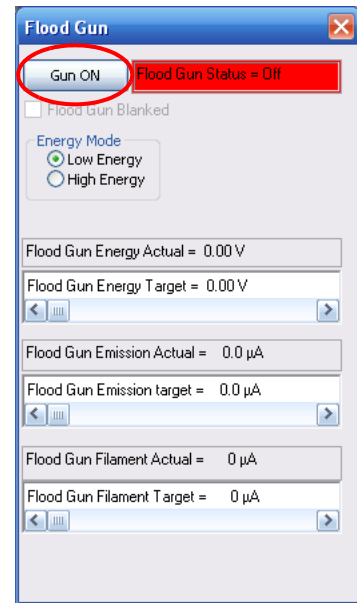
The **Flood Gun** window opens.

5 Click **Gun On**.

The Flood Gun switches on using the previously set parameters.

6 Set the energy (acceleration voltage) with the **Flood Gun Energy Target** slider.

7 Slowly increase the filament current with the **Flood Gun Filament Target** slider until the desired emission is shown on the display.



A typical setting is:

- Acceleration voltage: 8 eV
- Filament heating current: 2 µA
- Detector settings: SE2, collector voltage -50 V

Now, a spray of low energy electrons neutralize the specimen surface.

**How to
continue**

Once the charge neutralization is no longer required, switch off the Flood Gun as described in the next chapter.

CAUTION

Risk of damaging the filament when the Flood Gun is operated at bad vacuum or atmospheric pressure.

Before ventilating the specimen chamber or transferring the specimen via airlock or

injecting gases via Gas Injection System (GIS) or Charge Compensator, switch OFF the Flood Gun.

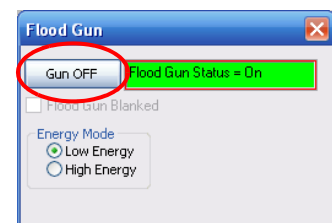
Ensure the Flood Gun is only operated at a system vacuum better than 5×10^{-6} mbar.

4.7.2. Switching off the Flood Gun

The Flood Gun should be switched off as soon as the charge neutralisation is no longer required.

It is not necessary to switch off the Flood Gun power supply.

1 Click **Gun Off**.



4. Operation

Working with the Flood Gun (optional)

5. Applications



IMPORTANT

If a Capella FIB column is installed, refer to the SmartFIB® Online Help for details.



IMPORTANT

As this section deals with advanced operation sequences required for special applications, it is assumed that the operator is already familiar with the operation of the Cross-Beam® workstation.

5.1. Manual Sample Preparation

The Manual Sample Preparation is suitable for the preparation of TEM lamellas and SEM cross sections.

Requires FIB and GIS.

Preconditions:

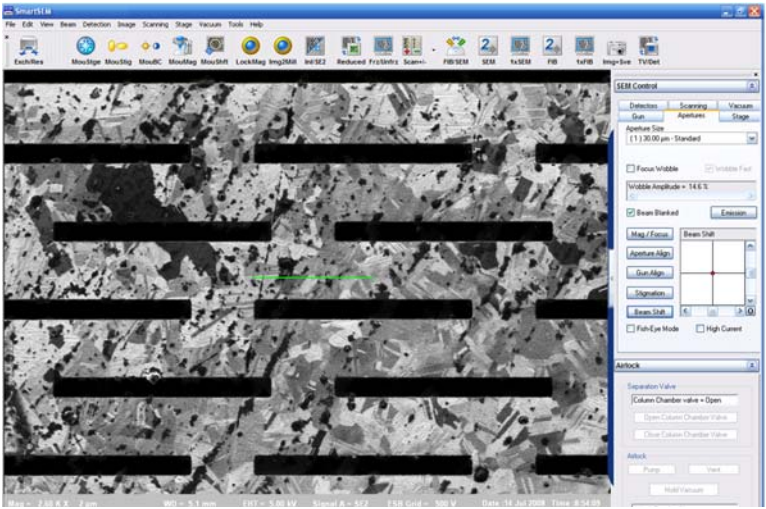
- Electron beam has been switched on.
- Ion beam has been switched on.
- Specimen has been moved to the coincidence point, tilted to 54°. Tilt eucentricity has been adjusted.
- Platinum precursor has been outgassed.
- FIB probe currents have been adjusted.

The following procedure makes a TEM lamella for in-situ lift-out.

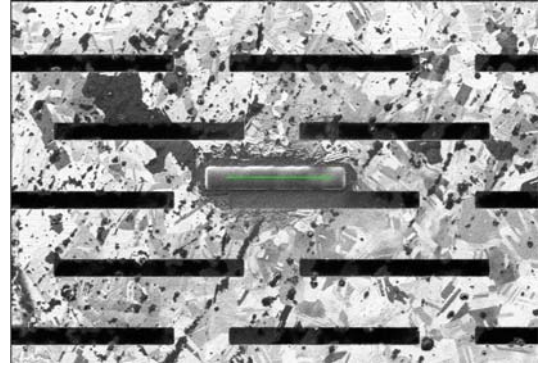
- 1 Change to **FIB** mode.
- 2 For example, set the following parameters:
30 kV FIB, 5 kV SEM, WD at the coincidence point.
- 3 Select the area of interest on your specimen.
- 4 Show an annotation line.
- 5 Move the annotation line to the intended location of the TEM lamella to be prepared.

5. Applications

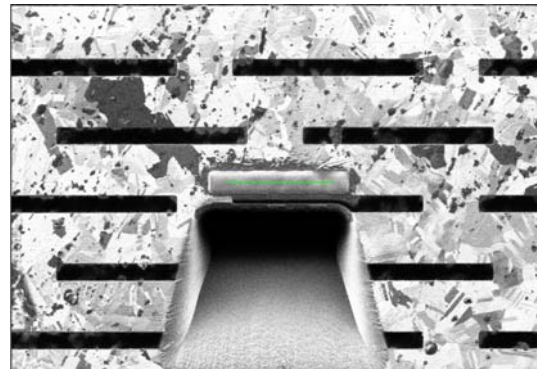
Manual Sample Preparation



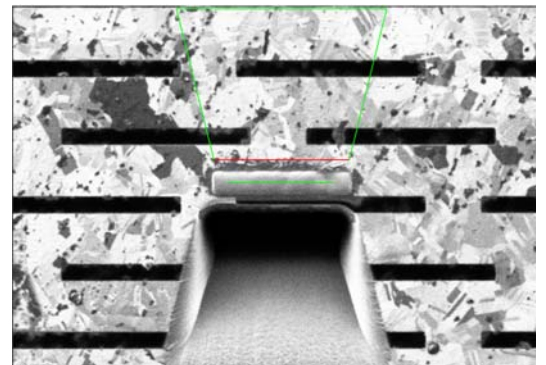
- 6 Deposit a protection layer e.g. platinum.
The protection layer should be $0.5\text{-}1.0\text{ }\mu\text{m}$ thick.



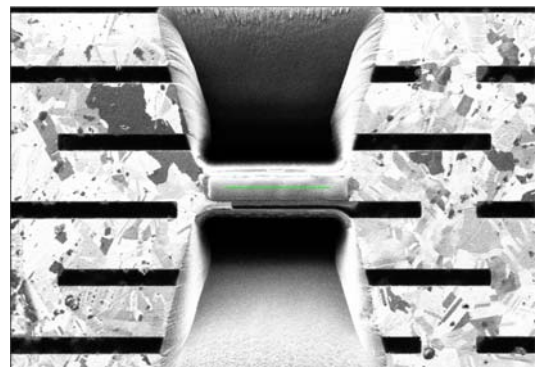
- 7 Do the coarse milling:
- a Select a trapezium and position it $1\text{-}2\text{ }\mu\text{m}$ from the annotation line.
 - b Mill the trapezium with a high probe current e.g. 16 nA .



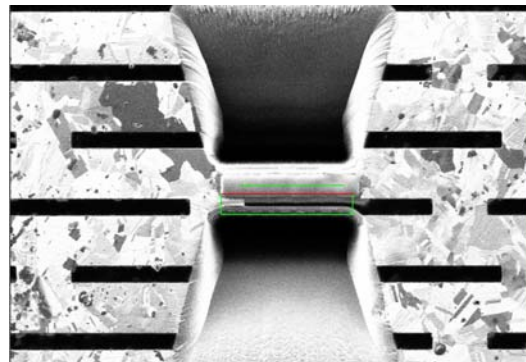
- c Flip the trapezium and move it to the opposite side of the TEM lamella.



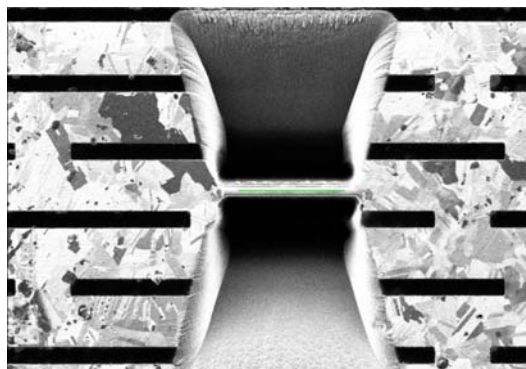
- d Mill the trapezium with a high probe current e.g. 16 nA .



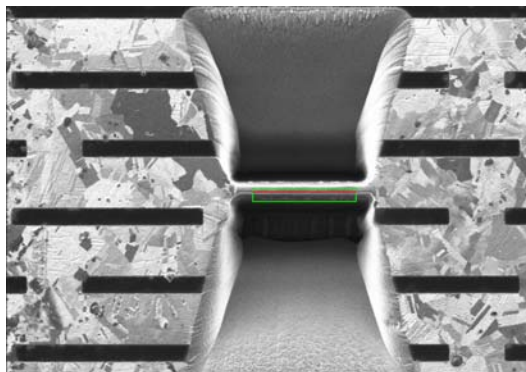
- 8 Do the medium milling:
- a Select a rectangle and position it $0.5 - 1.0 \mu\text{m}$ from the annotation line.
 - b Mill the rectangle with a medium probe current e.g. 2 nA .



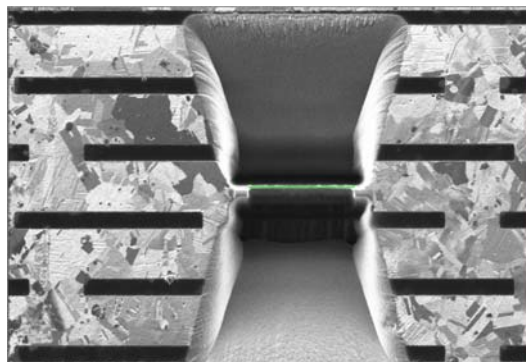
- c Repeat steps a and b with a rectangle at the opposite side of the TEM lamella.



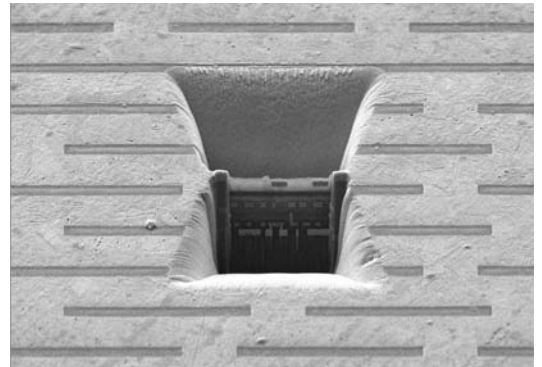
- 9 Do the fine milling:
- a Tilt the sample to 55.5° .
 - b Select a rectangle.
Position the rectangle next to the annotation line at a distance corresponding to:
[half the desired TEM lamella thickness + about 50 nm].



- c Mill the rectangle with a low probe current e.g. 120 pA .
- d Tilt the sample to 52.5° .
- e Repeat steps b and c with a rectangle at the opposite side of the TEM lamella.



- 10 Tilt the sample to 0° .
- 11 Cut the TEM lamella laterally and at its base.
To check the cutting, change between **FIB** mode and **SEM** mode at specimen tilt 0° .



How to
continue



IMPORTANT

*The following procedure depends on the type of micromanipulator you use.
For details refer to the instructions given by the micromanipulator manufacturer.*

- 12 Lift out the TEM lamella.
- 13 Attach the TEM lamella to the TEM sample grid.
- 14 Do the final polishing until the desired lamella thickness is obtained:
The procedure is similar to the fine milling, but with an even smaller probe current e.g. 50 pA .

5. Applications

Auto sample preparation (licence: TEM sample prep)

5.2. Auto sample preparation (licence: TEM sample prep)

The Auto Sample Preparation (ASP) routines of SmartSEM® allow the automated FIB preparation of cross sections and TEM lamellas.

All milling parameters for a particular sample preparation type are stored in a database entry and can repeatedly be applied to other specimen regions as often as required.

Requires FIB and GIS.

Requires the licence TEM Sample Preparation which includes the licence DRIFT correction and the dongle belonging to it.

There are two software interfaces:

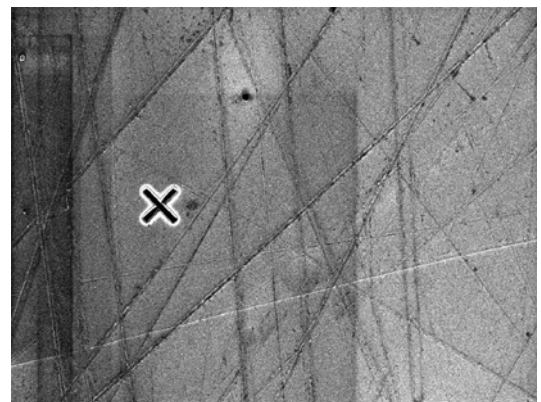
- Quick auto sample preparation (Quick ASP)
Allows you to create and execute a new sample definition with a few mouse clicks.
- Auto sample preparation wizard (ASP wizard)
Allows you to design new recipes or to modify existing samples.

5.2.1. Overview

ASP includes the following steps:

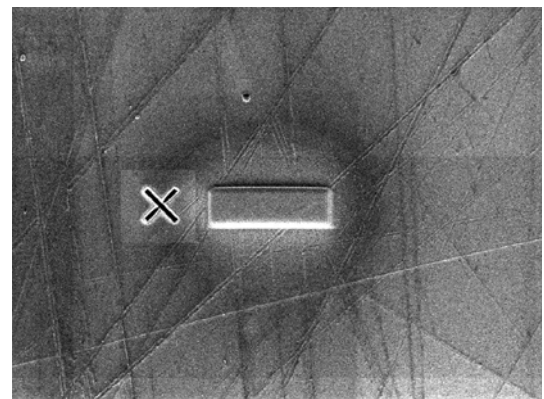
- Milling of an alignment mark

The alignment mark is used as a reference to correct the milling patterns for stage drift.



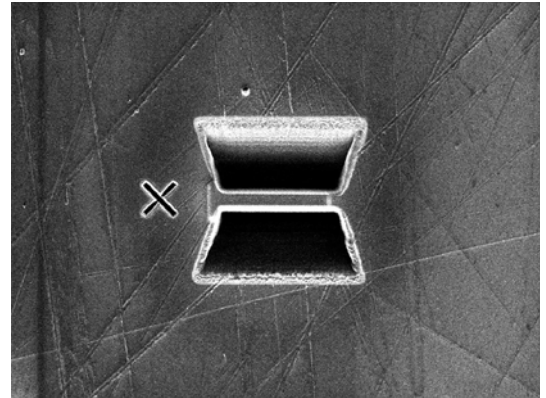
- Protection layer (optional)

Platinum or another metal can be deposited in order to protect the sample from the milling ion beam.



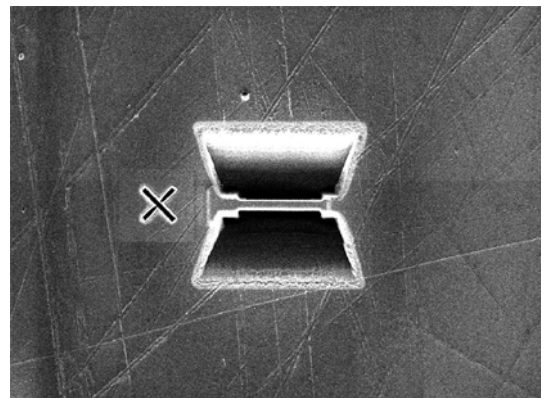
- Coarse milling

Milling with a high ion current removes the bulk of the material around the desired location of the cross section or TEM lamella.



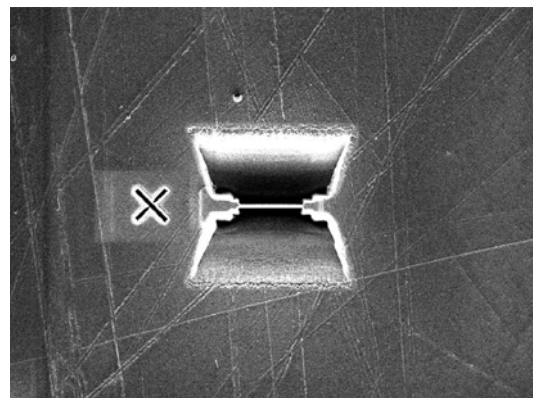
- Medium milling

Milling with a medium ion current makes the TEM lamella thinner.



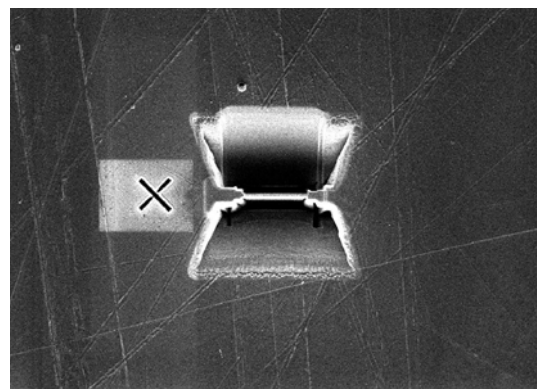
- Fine milling

Milling with a low ion current prepares the final TEM lamella thickness.



- Cut-out

For TEM lamellas that are to be lifted out by using a micromanipulator, the TEM lamella can be cut out automatically. After that step, the TEM lamella is ready for lift-out.



5.2.2. Sample settings

Samples are defined by sets of milling and deposition parameters. Two different types of such sets are used:

- **Milling samples:**
Applying a reference sample to a particular location on a specimen defines a milling sample. It additionally contains stage coordinates.
- **Reference samples:**
They contain all necessary settings that completely define a sample design.

A set of reference samples is delivered together with the SmartSEM[®] software, suitable for typical standard applications. These reference samples can be used to immediately produce TEM or SEM samples from your specimens by using Quick ASP.



IMPORTANT

Feel free to use the reference samples as a work base for your own sample development. You can tweak them bit by bit according to your needs using the ASP wizard, or by exporting them to text files and editing them directly, until you achieve the desired results.

Try playing with the settings for

- lamella width
- lamella depth
- lamella thickness
- number of coarse and medium milling layers
- fine milling proximity
- different ion currents to assess the effect on the milling result and duration of the ASP process.

The following table summarises important reference samples.
The samples are designed for semiconductor specimens (substrate: silicon).

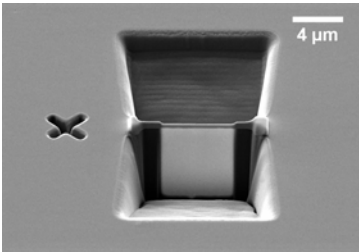
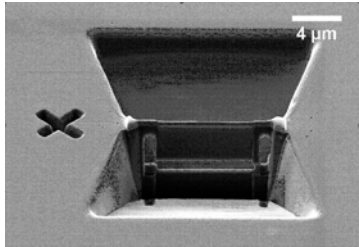
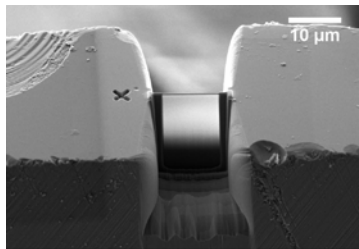
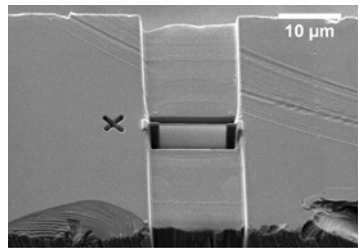
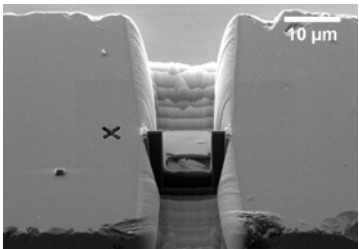
File name	Description	Pattern
200nm_Liftout.ref	10 x 6 x 0.2 μm^3 TEM lamella for lift-out with subsequent manual cut-out before the lift-out. Width of electron transparent area: 6 μm The finished TEM lamella can be cut out with the ion beam, e.g. at 0° stage tilt	
300nm_Liftout_Cutout.ref	12 x 6 x 0.3 μm^3 TEM lamella for lift-out with automated cut-out. Width of electron transparent area: 9 μm Both, the left and the right vertical cut do not cut completely through the TEM lamella. You may change the length of either cut in the settings of this reference sample, so that the side at which the manipulator needle comes in will be completely cut free.	
200nm_H-bar.ref	15 x 6 x 0.2 μm^3 H-bar type TEM lamella. Width of electron transparent area: 11 μm When setting up the sample at the target region of your specimen, adjust the size of the coarse trapeziums to match the thickness of the specimen.	
200nm_H-bar_DepStyle.ref	15 x 4 x 0.2 μm^3 H-bar type TEM lamella using deposition style milling for the coarse boxes. Width of electron transparent area: 9 μm This sample yields smoother coarse box walls and bottom than the sample above, but is slower.	
70nm_H-bar_FC	15 x 6 x 0.07 μm^3 H-bar type TEM lamella using fine correction. Width of electron transparent area: 9 μm With this reference, set up your samples with the alignment mark in the center of the screen as described in section 5.2.4.9.	

Table 5.1: Reference samples

5. Applications

Auto sample preparation (licence: TEM sample prep)

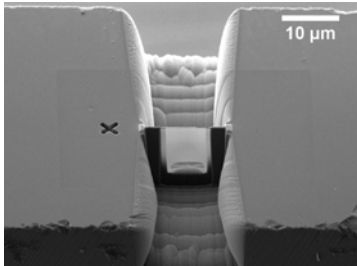
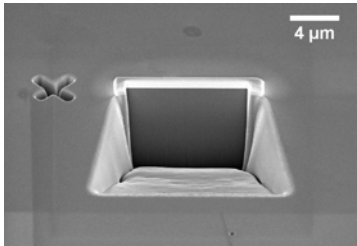
File name	Description	Pattern
120nm_H-bar_FC_Polish.ref	15 x 6 x 0.12 μm^3 H-bar type TEM lamella using fine correction and final polishing at low ion current. Width of electron transparent area: 7 μm. With this reference, set up your samples with the marker cross in the center of the screen as described in section 5.2.4.9.	
BottomXSection.ref	11 x 6 μm^3 cross section cut from below the cross section target line. This reference sample provides a quick cross section that can be immediately imaged with the SEM.	

Table 5.1: Reference samples

5.2.3. Using Quick ASP

For most purposes, **Quick ASP** will be the primary interface for auto sample preparation. Instead of having to go through several pages of a wizard, you can create and execute a new sample definition with a few mouse clicks only.

Quick ASP allows you to select a pre-defined reference sample. Then you only have to specify location, length and depth of a TEM lamella or cross section and to define an alignment mark for automated drift correction.

Requires to have at least one pre-defined reference sample.

Preparing the system

- 1 Initialise the FIB aperture: In the **FIB** tab of the **FIB Control** panel, click **Init Aperture**.
- 2 Minimise the beam shift between the different current relative to each other:
 - a Select a specimen with good conductivity.
 - b Open the **FIB Daily Adjust** panel from the **Panel Configuration Bar**.
 - c Select the probe currents you work with.
 - d Click **Beam Position** and follow the instructions in the wizard.

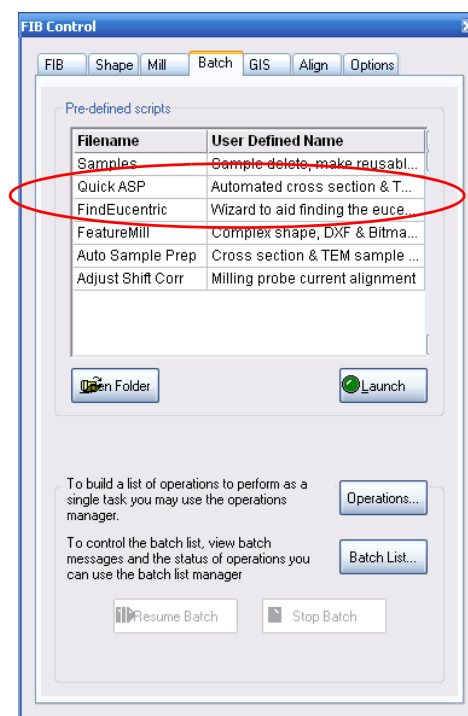
Alternatively, you can use the **Adjust Shift Correction** function in the **Batch** tab of the **FIB Control** panel.

- 3 Switch to **SEM** mode.
- 4 Adjust eucentricity as precisely as possible.
- 5 Move your specimen location to the coincidence point.
- 6 Switch to **FIB** mode.
- 7 Set the following parameters:
50 pA
mag 2500x, scan speed 6, pixel avg.
- 8 Set **FIB Beam Shift** back to zero.
- 9 Select the SE2 detector.
- 10 Adjust focus, brightness, and contrast until you get a crisp image with good contrast.

5. Applications

Auto sample preparation (licence: TEM sample prep)

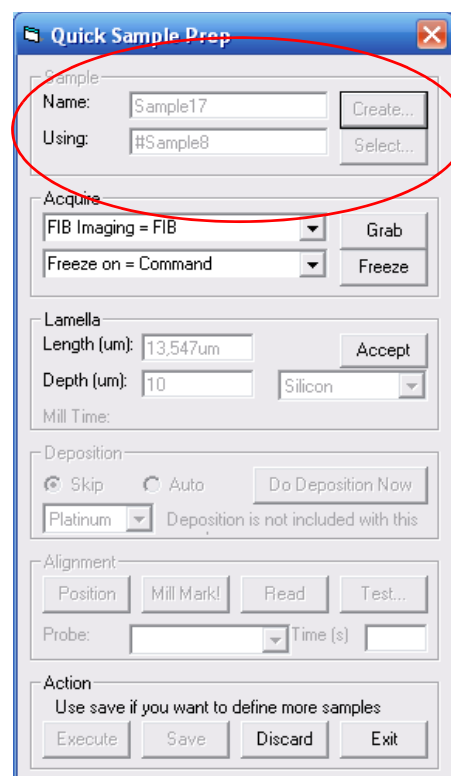
- 11 Go to the **Batch** tab of the **FIB Control** panel.



- 12 Double-click **Quick ASP**.

Selecting a sample name

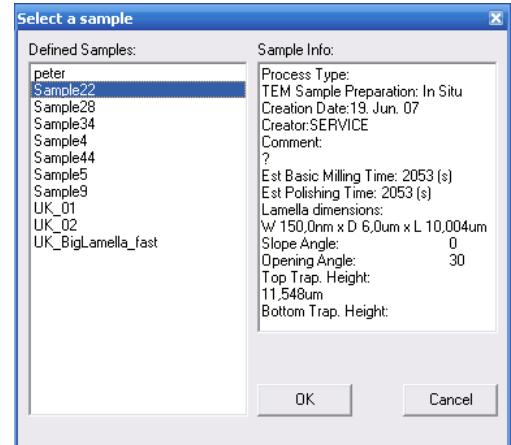
- The **Quick Sample Prep** window opens.
13 In the **Name** field, enter a sample name.



- 14 Click **Create**.

The **Select a sample** window opens.

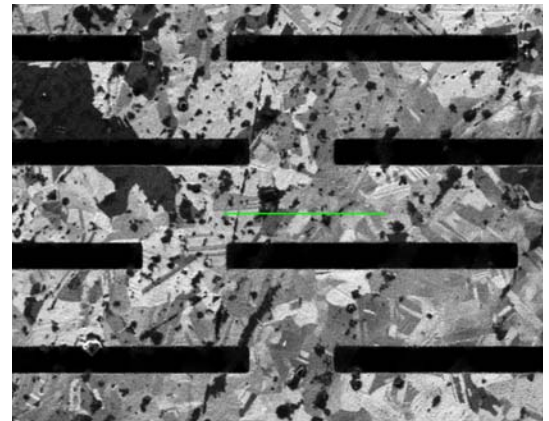
- 15 In the **Defined Samples** section, select a pre-defined reference sample.
- 16 Confirm by clicking **OK**.



Defining the TEM lamella location

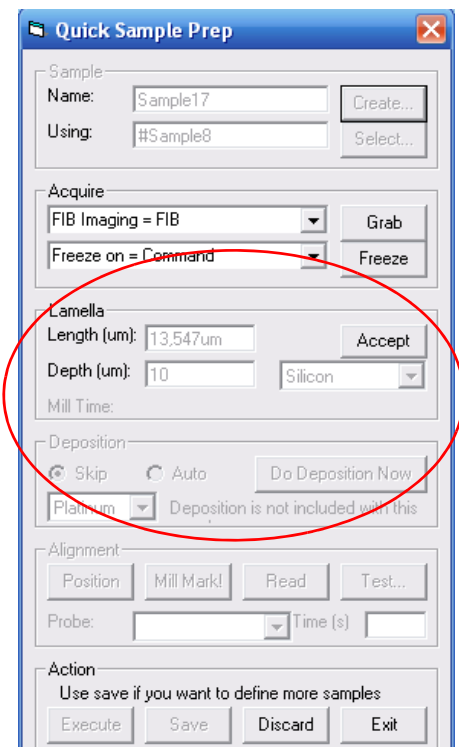
The TEM lamella is shown as an annotation line in the image area.

- 17 Move the annotation line to the desired location.



Defining the TEM lamella settings

- 18 Select the type of specimen material from the drop-down list.
- 19 Enter the required settings, e.g. TEM lamella parameters.



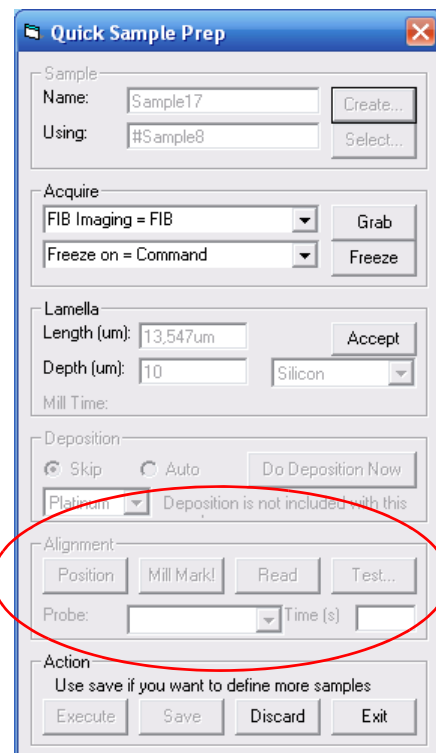
5. Applications

Auto sample preparation (licence: TEM sample prep)

Preparing the automated drift correction

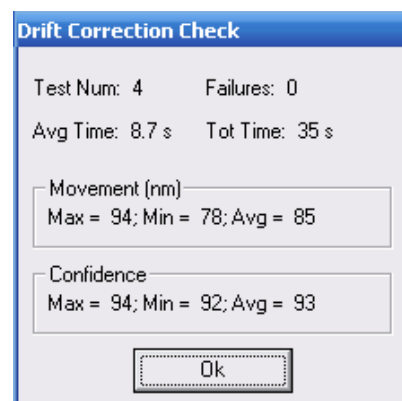
20 To prepare the automated drift correction, mill a cross-shaped alignment mark:

- a Click **Position**.
An alignment mark is shown on the image area.
- b Move the alignment mark to the preferred location.
Ensure the alignment mark does not contact any milling area.
- c Click **Mill Mark!**.
The alignment mark is being milled.
- d Click **Read**.
The reference image is taken.



21 To check the quality of the reference image:

- a Click **Test**.
A drift correction check is performed.

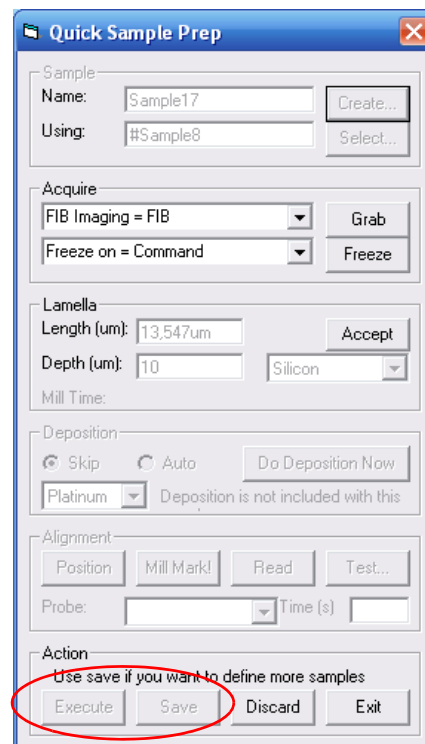


IMPORTANT

The Confidence level must not be smaller than the Certainty Level % set in the Drift Correction Settings. If the test yields a smaller confidence level, try to improve the reference image quality by adjusting contrast and brightness, using a slower scan speed, or deeper milling of the alignment mark.

- b Click **OK**.

22 If you want to define more samples, click **Save**.



To start the milling process, click **Execute**.

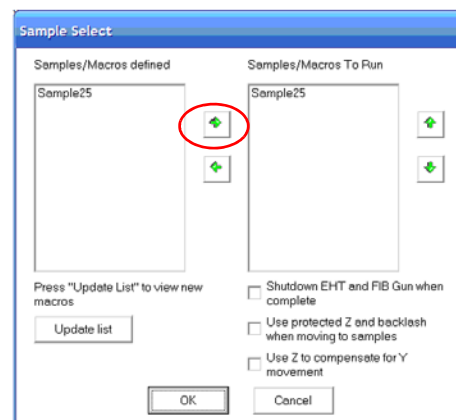
The **Sample Select** window opens.

23 Select the desired samples/macros on the left column.

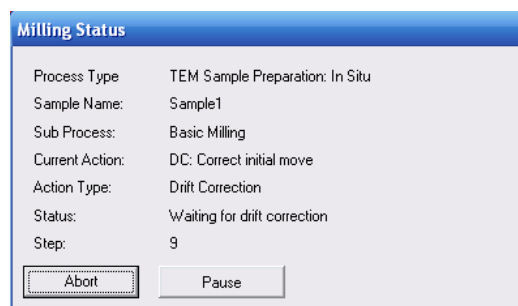
24 Click the arrow button to transfer the selected items to the right column.

The selected items are added to the queue of batch operations.

25 Click **OK**.



The sample is automatically processed.
The milling status window is shown.



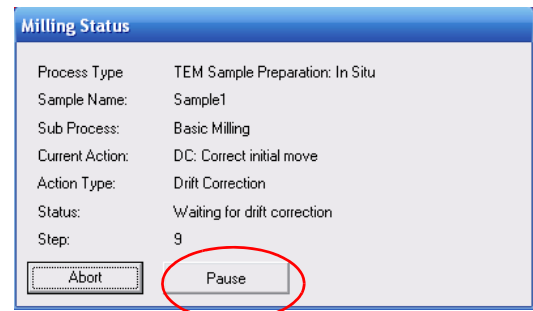
5. Applications

Auto sample preparation (licence: TEM sample prep)

Interrupting the procedure

- 1 To interrupt the procedure, click **Pause**.

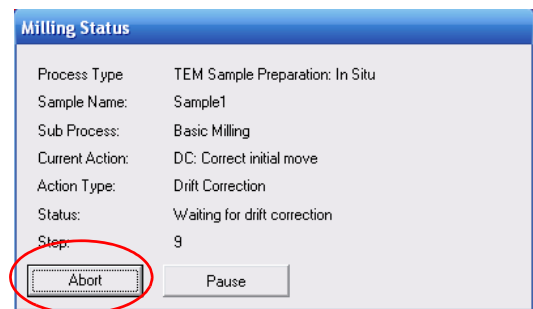
To continue after pausing, click **Paused**.



Stopping the procedure

- 1 To stop the procedure, click **Abort**.

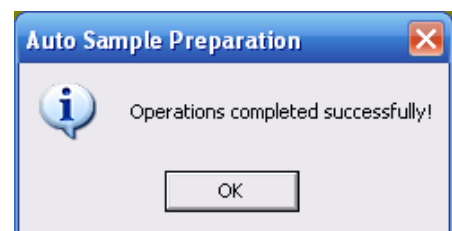
2 Confirm.



Automatic end of procedure

As soon as the procedure is finished, a message is shown.

- 1 To continue operation of the workstation, click **OK**.

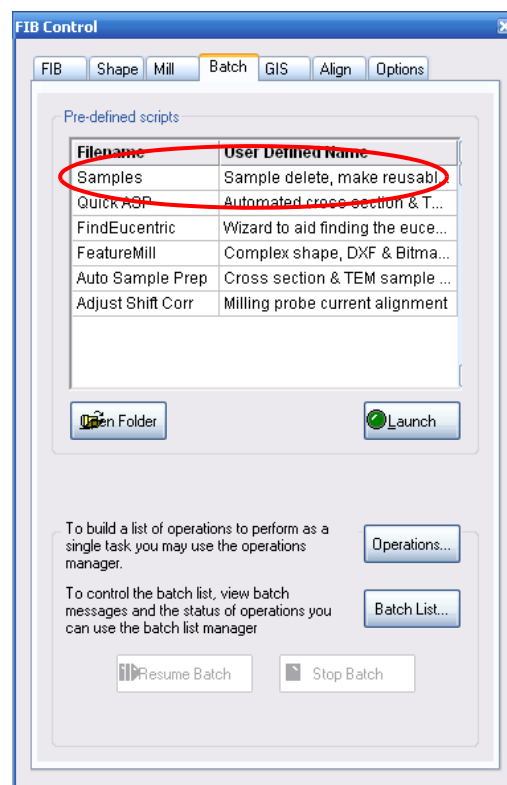


5.2.4. Editing pre-defined reference samples with the Sample Manager

You can edit pre-defined reference samples by means of the functions which are combined in the **Sample Manager**.

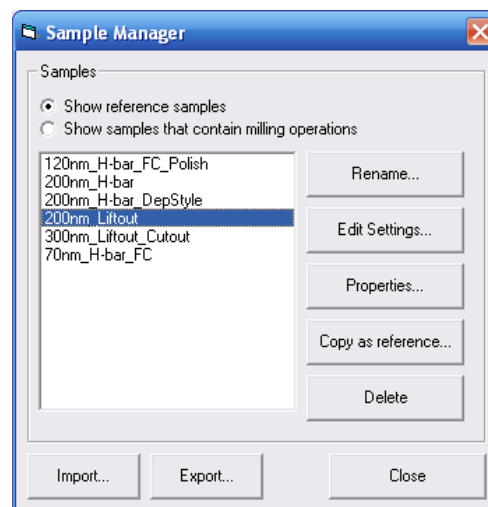
5.2.4.1. Opening the Sample Manager

- 1 Go to the **Batch** tab of the **FIB Control** panel.



- 2 Double-click **Samples**.

The **Sample Manager** window opens.

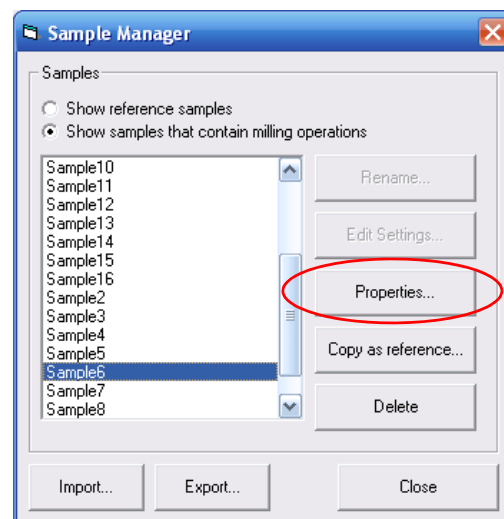


5. Applications

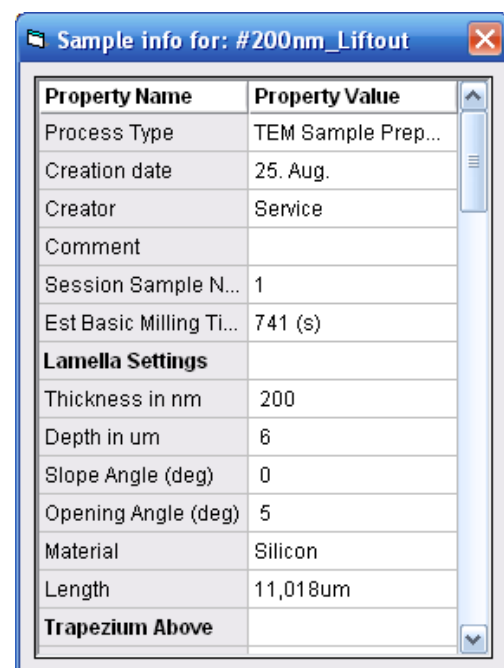
Auto sample preparation (licence: TEM sample prep)

5.2.4.2. Showing the sample properties

- 1 In the **Sample Manager**, select a sample.
- 2 Click **Properties**.



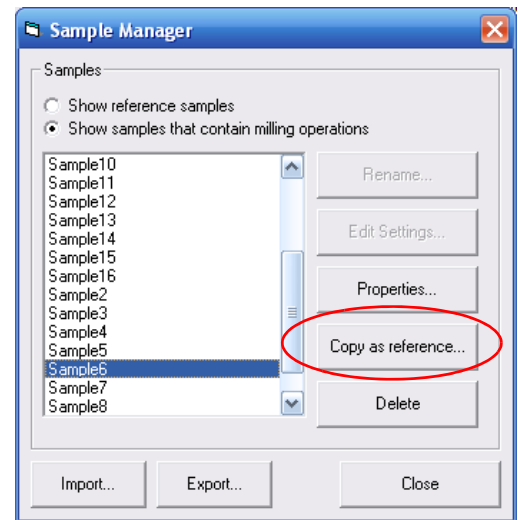
- 3 The **Sample Info** window opens.



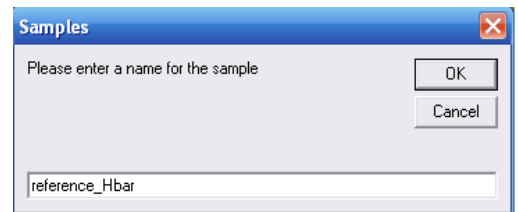
5.2.4.3. Copying a sample as a reference

1 In the **Sample Manager**, select a sample.

2 Click **Copy as reference**.



3 Enter a name for the sample and confirm.



The new reference is added to the list in the **Sample Manager**.

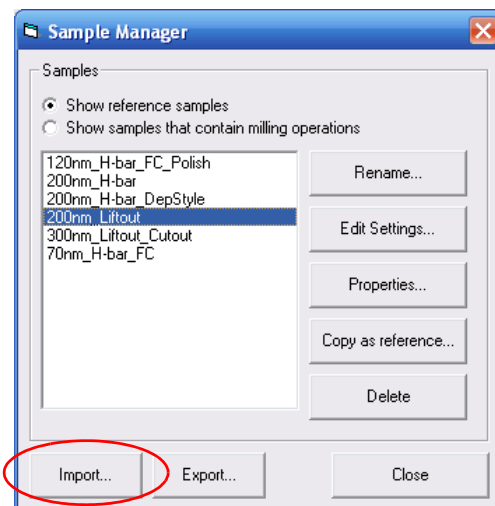
5. Applications

Auto sample preparation (licence: TEM sample prep)

5.2.4.4. Importing a sample

This function allows you to import sample files from other sources.

- 1 In the **Sample Manager**, select a sample.



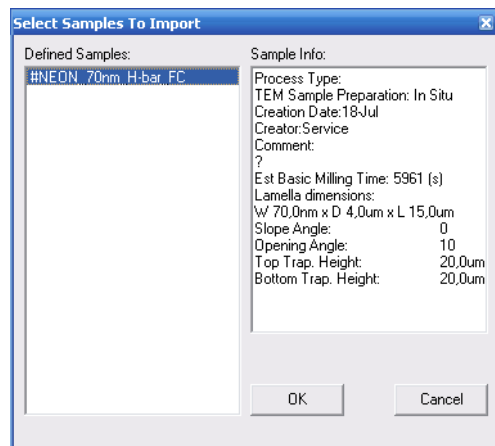
- 2 Click **Import**.

- 3 Select the file to be imported.

- 4 Click **Open**.

The **Select Samples To Import** window opens.

- 5 Select a sample to show its properties.
- 6 Confirm.

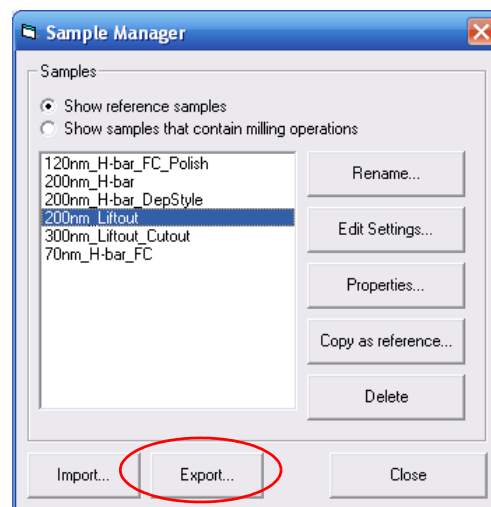


The sample is added to the list in the **Sample Manager**.

5.2.4.5. Exporting a sample

You can save sample files at any location.

- 1 In the **Sample Manager**, select a sample.
- 2 Click **Export**.

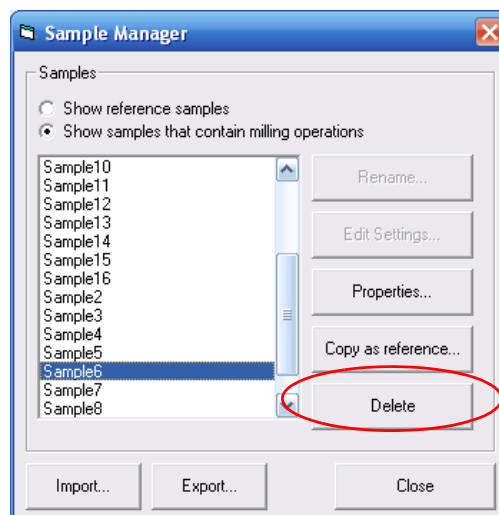


- 3 Select the location.
- 4 Click **Save**.

5.2.4.6. Deleting a sample

- 1 In the **Sample Manager**, select a sample.

- 2 Click **Delete**.
- 3 Confirm.



The sample is deleted from the list.

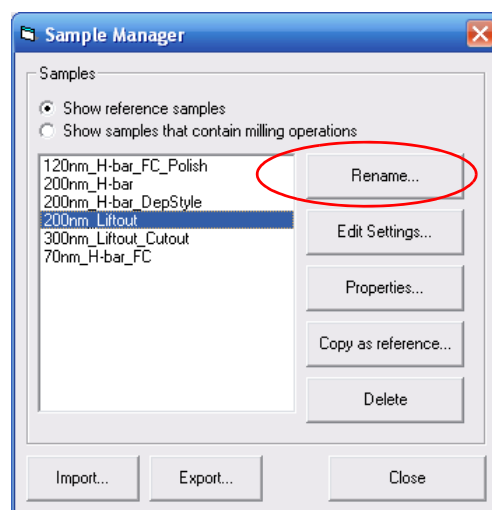
5. Applications

Auto sample preparation (licence: TEM sample prep)

5.2.4.7. Renaming a reference sample

This function is only applicable to reference sample files.

- 1 In the **Sample Manager**, select a reference sample.
- 2 Click **Rename**.

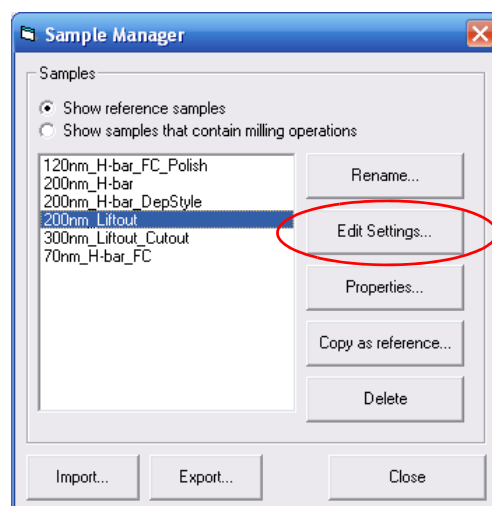


- 3 Enter a new name and confirm.

5.2.4.8. Changing the settings of a reference sample

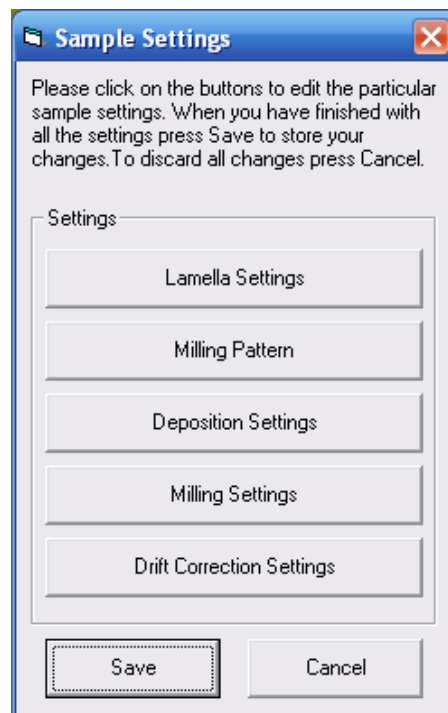
This function is only applicable to reference sample files.

- 1 In the **Sample Manager**, select a reference sample.
- 2 Click **Edit Settings**.



The **Sample Settings** window opens.

- 3 Select the settings you wish to change:
 - **Lamella settings**
Sets length, depth, and target thickness of the lamella, sample material, and coarse cut slope.
 - **Milling Pattern**
Displays the milling areas, allows changing the height and the opening angle of the coarse cut trapeziums.
 - **Deposition Settings**
Allows changing the deposition parameters.
 - **Milling Settings**
Allows changing whether polishing is enabled as well as changing probe currents, step sizes, proximity, frequencies or dwell times and pixel fill factors, step back and number of layers for each milling step.
 - **Drift Correction Settings**
Allows changing the number of drift correction attempts, accuracy, certainty, and drift correction interval.



IMPORTANT

A detailed description of the meaning of the various parameters is available in the Smart-SEM[®] help.

5. Applications

Auto sample preparation (licence: TEM sample prep)

5.2.4.9. Activating the fine correction function

This function is suitable to improve the precision of the ASP.

Fine correction takes two reference images, one (full frame) at the definition magnification and one (reduced raster) at a higher, user-defined magnification. The system uses the low magnification image for drift correction after stage movement. Then, the system does additional high precision drift correction while using the high magnification reference.

- 1 In the **Sample Settings** window, click **Drift Correction Settings**.
- 2 Set **Use Fine Correction** Yes.

Property Name	Property Value
Fine Correction	
Use Fine Correction	Yes
FC Mag	2504,5
Drift Correction	
Max Attempts	10
Pixel Accuracy	2
Certainty Level %	25
Restore SEM Image	No
Update SEM Beam ...	No
Coarse DC interval (s)	240
Medium DC interval (...)	120
Fine DC interval (s)	60

☐ Show Necessary Settings Only ☐ Keep On Top

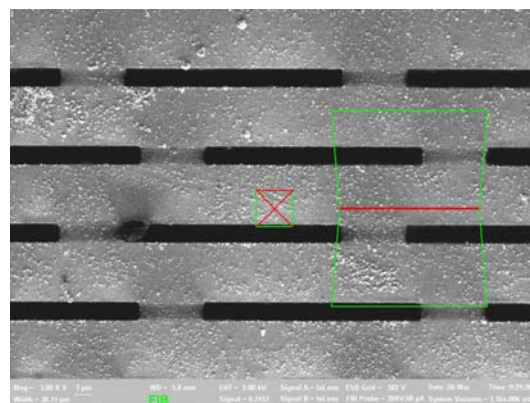
Setting up an ASP sample that uses high magnification fine correction

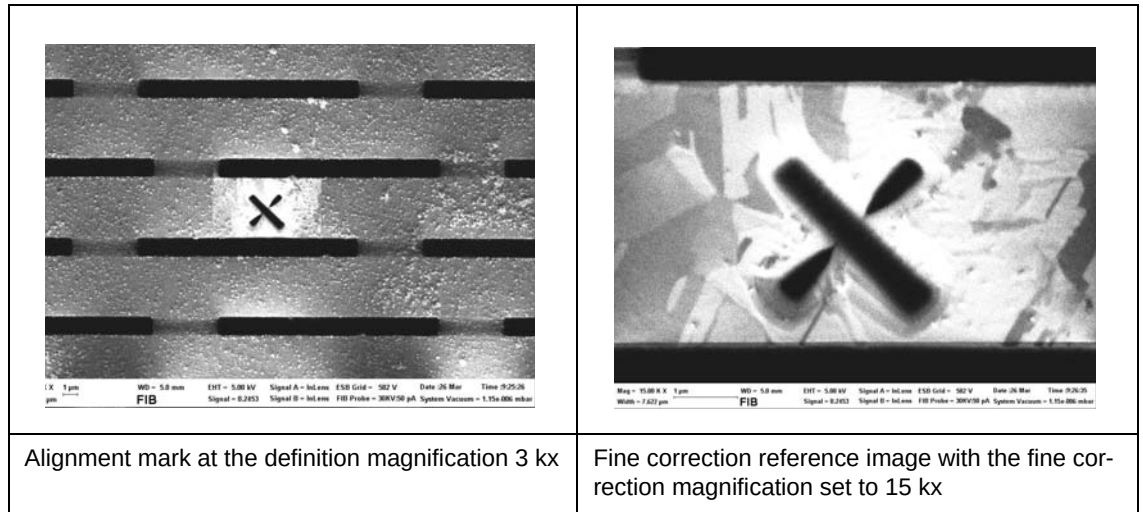
When defining the sample the usual way, i.e. with the TEM lamella in the center of the screen and the alignment mark off-center next to the TEM lamella, the maximum applicable magnification for fine correction is limited to the magnification at which both the alignment mark and the TEM lamella are still visible in the same image (about 3,800 x). Therefore, to use higher fine correction magnifications the mark must be placed in the center of the screen.

The usual size of the alignment mark (3 μm x 3 μm) is too large for fine correction magnifications above 12 kx.

Reduce its size and the milling time by about 50 % for magnifications up to 20 kx.

- 1 Place the alignment mark as exactly as possible in the center of the screen (use crosshairs for centering).
- 2 Place the TEM lamella off-centre.





For magnifications higher than 20 kx, burn a mark in the center of the screen by activating **Spot** mode instead of milling a cross.
Alternatively, produce a rectangular hole by zooming in to, e.g. 200 kx and scanning for a while.

5.2.5. Using the ASP wizard

This wizard allows designing new sample recipes for your particular requirements, or tweaking existing samples.

All parameters involved in milling a sample can be changed by the operator.

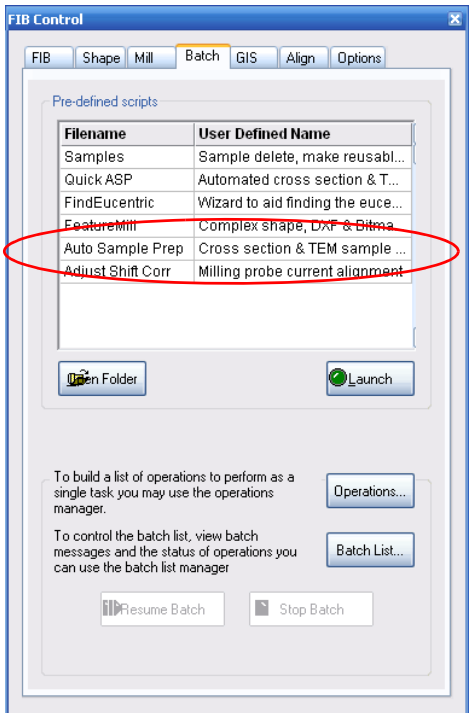
Requires the Auto Sample Preparation licence.



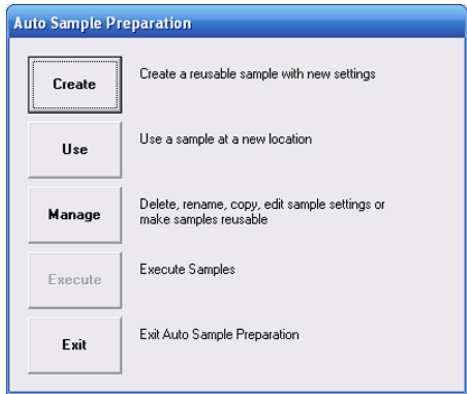
IMPORTANT
A detailed description of the meaning of the various parameters is available in the help.

5.2.5.1. Opening the ASP wizard

- 1 Go to the **Batch** tab of the **FIB Control** panel.
- 2 Double-click **Auto Sample Prep**.



The **Auto Sample Preparation** window opens.

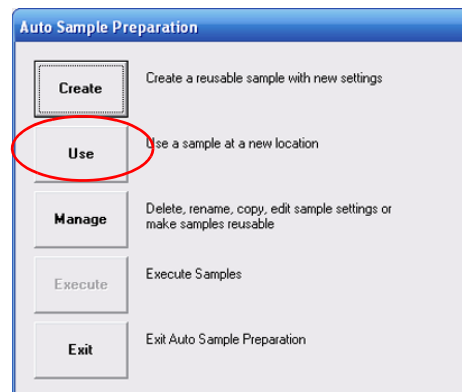


5.2.5.2. Applying an existing sample to a new location

- 1 In the **Auto Sample Preparation** window, click **Use**.

The **Select a sample** window opens.

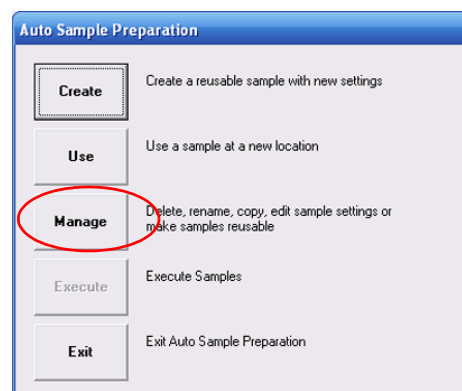
- 2 Select a sample from the list.
- 3 Click **OK**.



5.2.5.3. Editing a reference sample

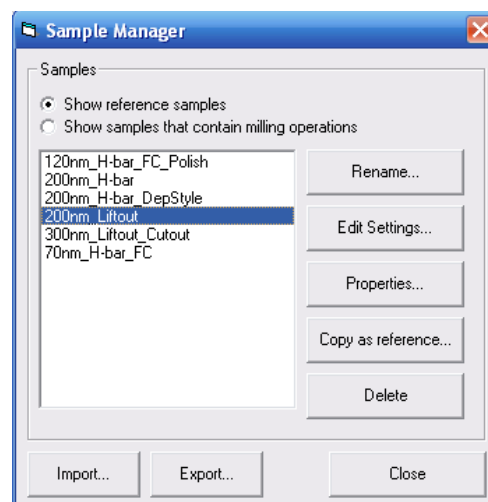
This function can only be applied to reference samples.

- 1 In the **Auto Sample Preparation** window, click **Manage**.



The **Sample Manager** window opens.

- 2 Select a reference sample.
- 3 Click the settings you wish to change.



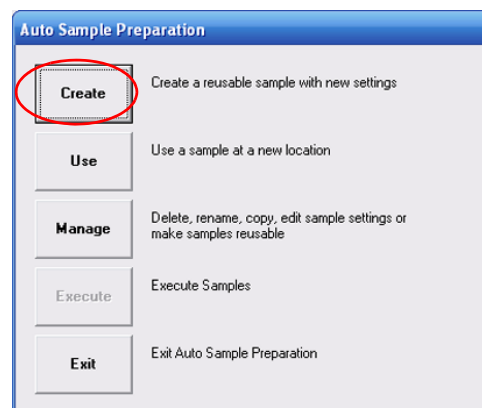
5. Applications

Auto sample preparation (licence: TEM sample prep)

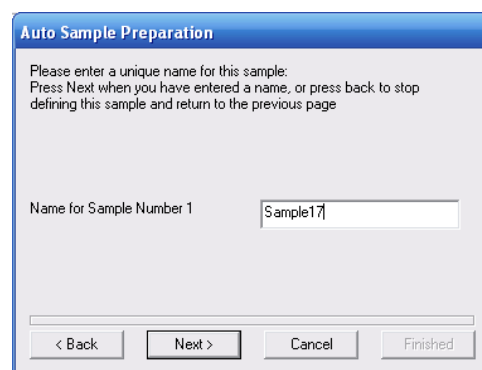
5.2.5.4. Creating a completely new sample

This function generates a reference sample or a sample to be milled.

- 1 In the **Auto Sample Preparation** window, click **Create**.



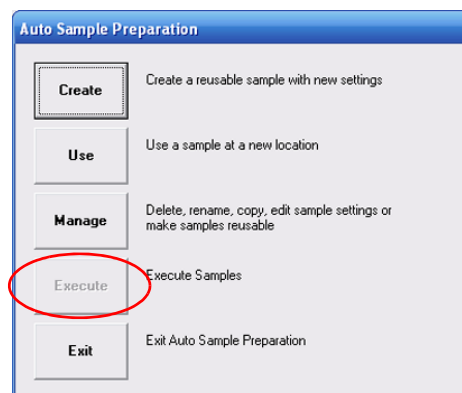
- 2 Follow the instructions in the wizard.



5.2.5.5. Executing a milling sample

This function runs a milling sample.

- 1 In the **Auto Sample Preparation** window, click **Execute**.

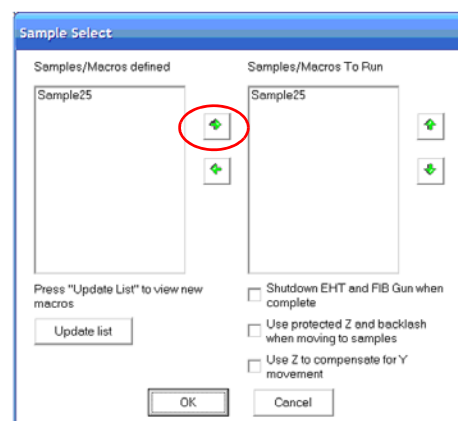


The **Sample Select** window opens.

- 2 Select the desired samples/macros on the left column.
- 3 Click the arrow to transfer the selected items to the right column.

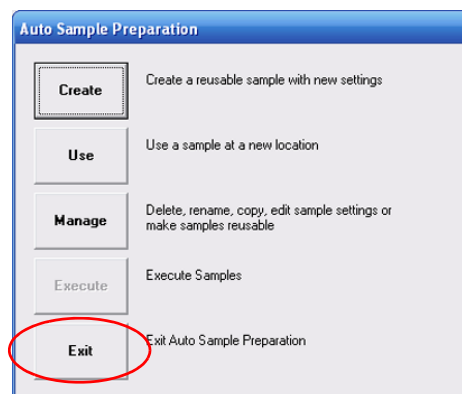
The selected items are added to the queue of batch operations.

- 4 Click **OK**.



5.2.5.6. Closing the ASP wizard

- 1 In the **Auto Sample Preparation** window, click **Exit**.

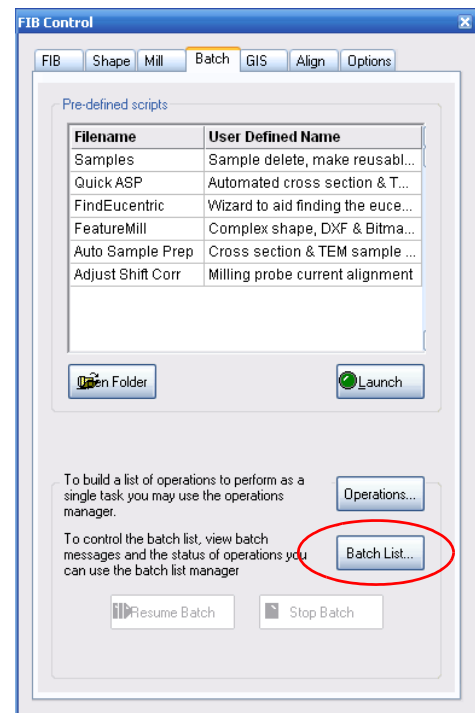


5. Applications

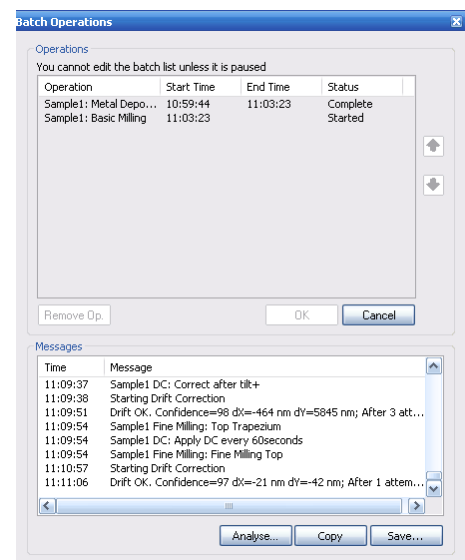
Auto sample preparation (licence: TEM sample prep)

5.2.6. Showing the batch list of an ongoing process

- 1 In the **Batch** tab of the **FIB Control** panel, click **Batch List**.



The **Batch Operations** window opens. It shows the current process steps.



5.2.7. Optimising your results

The following tables summarises important hints which may help to improve your results.

Key word	Recommendation
Probe currents	During the definition of ASP samples, different ion currents have to be defined for coarse, medium, and fine milling, as well as for cut-out and auto polishing. All these ion currents, as well as the imaging ion current used during definition of the ASP samples, must be aligned as precisely as possible so that there is no beam shift between the different currents relative to each other. Any misalignments can lead to a wrong position of the milled cross section or TEM lamella, wrong lamella thickness, or the formation of 'secondary' lamellas. This alignment can be done using the Beam Position utility in the FIB Daily Adjust wizard or the Adjust Shift Correction routine to be found in the Batch tab of the FIB Control window. If possible, initialise the FIB aperture and do the beam shift alignment immediately before working with ASP, in particular, prior to any extended run of ASP. This routine is critical to achieve proper results. The alignment takes only a few minutes. Always run the beam shift alignment on a sample with good conductivity, with conductivity equivalent to bare silicon or better. It is a good idea to permanently mount a bare silicon wafer piece for this purpose on the same sample holder that you use for ASP as a matter of routine. For maximum precision, define the same current for fine milling and polishing (e.g. 50 pA) as used for imaging during sample definition.
Eucentricity	Adjust eucentricity as precisely as possible. Use a FIB magnification of 2000 x to 3000 x. If stage tilting takes place during the ASP (e.g., for automated cut-out or final polishing), and you are not sure if the eucentricity is good enough, use 2000 x and chose 'Fine Correction' with a higher magnification in the milling settings.
Defining a sample	Use Pixel Avg and scan speed 5 to 7 when defining a sample. The same settings will automatically be used for drift correction.
Imaging	Use the SE detector. Adjust focus, brightness, and contrast to get a crisp image with good contrast.
Milling conditions	Ensure that the materials file you are using is correct. The actual depth of a milling pattern should not deviate from the nominal depth by more than 20 percent. Use multiple layers for milling (typically 3) to achieve smoothly milled coarse and medium milling boxes. Stepbacks between the coarse/medium/fine milling areas should be chosen that correspond to the expected beam shift between the respective ion currents used. For lift-out of TEM lamellas, you will usually want to leave the sample rather thick (300 to 1000 nm), since it will be thinned and polished to the final thickness only after the lift-out has taken place when the TEM lamella is already attached to the TEM grid.

5. Applications

Auto sample preparation (licence: TEM sample prep)

Key word	Recommendation
Drift/ Drift correction	In some cases, specimens showing periodic surface structures may cause erroneous drift correction. If this is the case, deposit a metal or insulator square of about twice the size of the alignment mark at the location where you want to mill the mark.
	Ground the specimen well in order to avoid drift correction errors due to charging effects. For non-conductive samples, ion beam deflection by sample surface charging will make precise drift correction impossible. Such samples will need to be coated with a conductive surface layer, e.g., sputtered Pd, Au, Cr, or C.
	Ensure that specimen drift has settled before you define the samples.
	Mill the alignment mark deep enough so that it appears black with a white rim. For Si 90 s at 600 pA, and for Cu 180 s at 600 pA work well.
Drift correction/ Fine correction	Activate the function Fine Correction in order to improve ASP precision. You should use the Test drift correction option when doing this, to ensure that the high magnification is suitable, and that the increased rate of erosion will not be a problem.
	While the ASP precision scales with the drift correction magnification provided the system is well aligned, keep in mind that electromagnetic stray fields, mechanical vibrations or noise interfering with your system can show up in the FIB image and limit the achievable precision.

Further reading

The following literature can be downloaded from the Nano Technology Systems Division Website: www.zeiss.com/microscopy

- Application Note:
Automated Sample Preparation
- Application Note:
In-situ Lift-out Preparation of TEM lamellas
- Application Note:
Automated FIB In-situ Lift-out Sample Preparation in the ZEISS CrossBeam®

6. Troubleshooting

6.1. Overview

Error messages

When an error message occurs, a message window will pop up. This indicates a serious condition which must immediately be drawn to the operator's attention. Most error messages are self-explaining.

The following table summarises important error symptoms and gives a clue how to remedy.

Keyword	Symptom	Possible reason	Recommended action
FIB	Emission is unstable.	Ion source needs to be regenerated.	Ensure the ion source is regenerated automatically. Refer to section 3.1.3.
		Ion source may be used up (>1500 $\mu\text{A/h}$).	Contact the ZEISS service representative to have the ion source replaced.
FIB	No emission.	Ion source needs to be regenerated.	Regenerate the ion source manually. Refer to section 6.2.2.
		Ion source may be used up.	Contact the ZEISS service representative to have the ion source replaced.
FIB	No image.	Aperture position is not correct.	Initialise the FIB aperture.
FIB	Emission current is too high e.g. 4 or 5 μA for more than 30 min.		Change the extractor target. Open the Gun Monitor and record the parameters FIB Suppressor Target and FIB Emission I and send it to your ZEISS service representative.
	Emission current is higher than 10 μA for more than 30 min.	Ion source is heated before.	
FIB	Suppressor voltage is approaching to -2000 V	Gallium oxide needs to be removed from the ion source.	Regenerate the ion source by heating. Refer to section 6.2.2.
With optional GIS			
GIS	Reservoir valve opens, but the system vacuum does not increase.	Temperature is too low.	Adjust the heating temperature of the precursor. Refer to section 6.3.3.
		Capillary or nozzle is blocked.	Bakeout the GIS. Refer to section 6.3.4.
		Precursor is used up, reservoir is empty.	Contact the ZEISS service representative to have the reservoir replaced.
Deposition (if valve is on)	Deposition rate is too low, system vacuum is about 10^{-6} mbar.	Precursor is heated at too low temperature.	Increase the target temperature of the precursor heating. Refer to section 4.6.1.1.

6. Troubleshooting

Overview

Keyword	Symptom	Possible reason	Recommended action
GIS/Vacuum (if valve is on)	System vacuum is bad (about $3\text{-}4 \times 10^5$ mbar).	Precursor is heated at too high a temperature.	Decrease the target temperature of the precursor heating. Refer to section 4.6.1.1.
User interface	Mill button in the Shape tab is not visible.	Software settings.	Disable 'one-click' milling mode in the Options tab.
With optional Flood Gun			
Flood Gun	No communication can be established with SmartSEM®	Loose cable connection. Flood Gun controller has an old firmware version. Flood Gun is not activated in FIB Configurator.	Check the cable connection. If this does not help, contact the ZEISS service representative.

6.2. Focused ion beam (FIB)

6.2.1. Checking the lifetime of the ion source

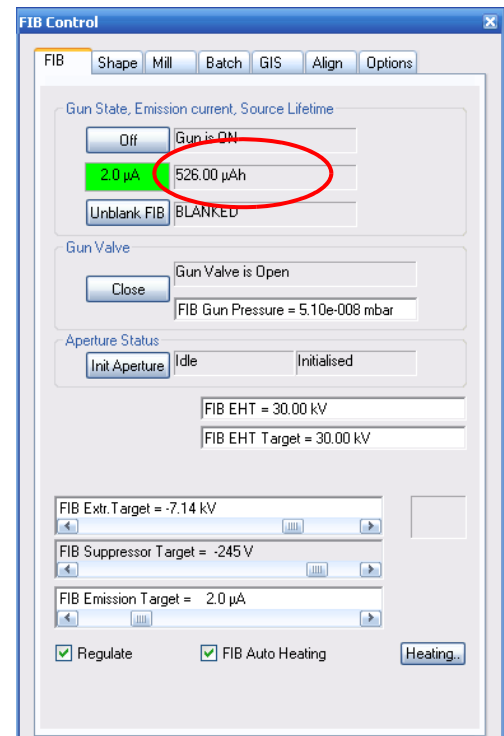
The ion source is a consumable that is used up during operation.

In order to have a clue of the ion supply you should check the ion source lifetime.

- 1 Select **FIB** from the **FIB** drop-down menu.

The **FIB** tab of the **FIB Control Panel** opens.

The lifetime of the ion source is indicated as μAh .



IMPORTANT

When the lifetime of the ion source approaches 1500 μAh you should contact the ZEISS service representative to have the ion source replaced.

6.2.2. Regenerating the ion source by heating manually

Requires the *Supervisor* privilege. To be performed only by specially trained advanced operators.
Requires user level *Service*.

The manual heating procedure is used

- after using auto heating five times or
- if the suppressor voltage has reached -2000 V while a probe current of 2 μA cannot be maintained any more or
- if the ion source does not start emitting.



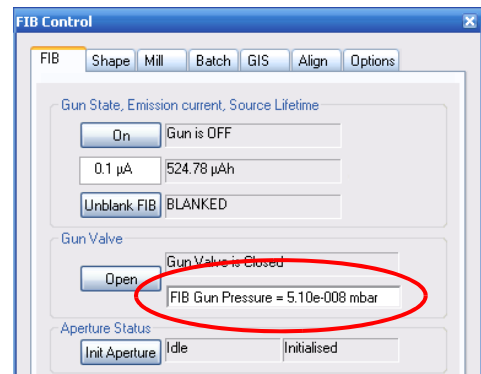
IMPORTANT

The manual heating will be required after having performed the Auto Heating for about 5 times, i.e. about every 2 - 3 weeks. However, this interval is dependent on the usage of the workstation. All Auto Heating cycles are listed in the log file of the EM Server.

Procedure:

- 1 In the **FIB** tab of the **FIB Control** panel, check the **FIB Gun Pressure**.

The **FIB Gun Pressure** must be better than 5×10^{-7} mbar (Canion) or 1×10^{-7} mbar (Cobra).

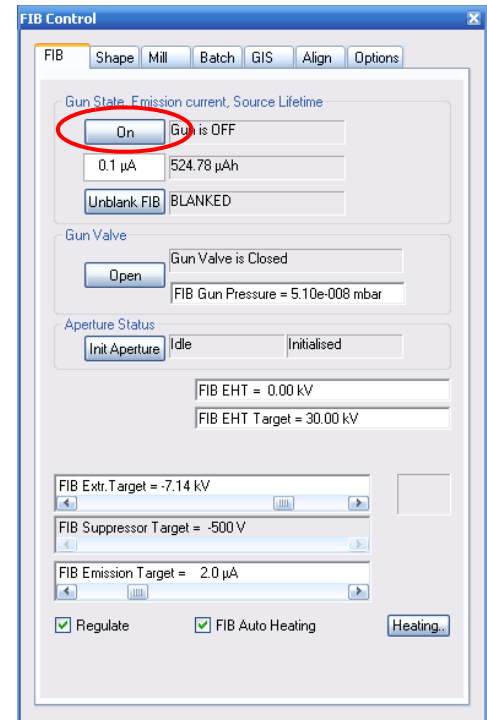


CAUTION

Danger of arcing. Danger of damaging the ion source.

Before switching on the ion beam, ensure the FIB gun pressure is better than 5×10^{-7} mbar (Canion) or 1×10^{-7} mbar (Cobra).

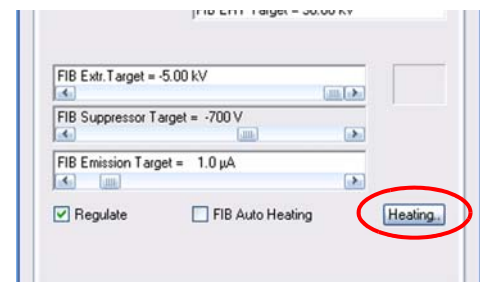
- Click **ON** to switch on the ion gun.



CAUTION

*Danger of damaging the ion source.
Ensure the FIB gun is switched ON before you start the manual heating procedure.*

- Click **Heating**.



Alternatively, select **FIB Filament Heating**
from the **Panel Configuration Bar**.

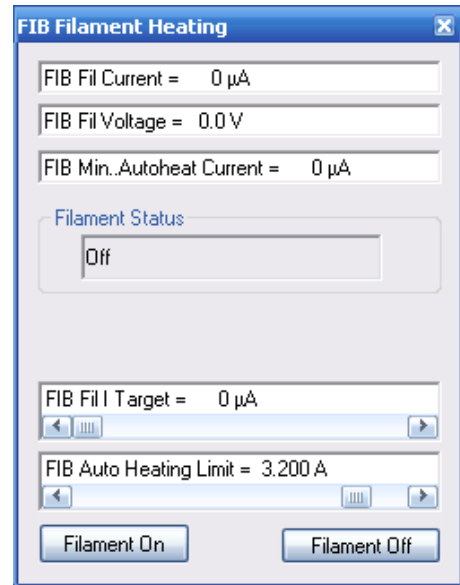
CAUTION

*Danger of damaging the ion source due to overheating.
Carefully change the settings.
Excessive filament heating may reduce source life.
Only heat as long as necessary.*

6. Troubleshooting

Focused ion beam (FIB)

- The **FIB Filament Heating** panel opens.
- 4 Enter **FIB Fil I Target** = 2.5 A or higher.
 - 5 To start the heating procedure, click **Filament On**.
 - 6 While watching the emission, wait about 10 seconds.
 - 7 If there is no emission, slowly increase the **FIB Fil I Target** by 100 mA steps until the emission begins and the suppressor target starts regulating towards 0.
 - 8 When the suppressor voltage is well between 0 and -1000 V, or when the emission is increasing rapidly, stop the procedure:
Click **Filament Off**.
 - 9 Notice the **FIB Fil Current** value at which the ion source starts emitting.
 - 10 Set the **FIB Auto Heating Limit**:
 - a Remember the value at which the ion source has started emitting.
 - b Add 500 mA to the value of first emitting and enter this value.
 - 11 Set the **FIB Min..Autoheat Current**:
 - a Subtract 300 mA to the value of first emitting and enter this value.



How to continue

If you heated manually after using auto heating five times or if the suppressor voltage has reached -2000 V while a probe current of 2 µA cannot be maintained any more:

- Continue with initialising the FIB apertures (see section 3.1.3. step 7).

If you heated manually because the ion source does not start emitting:

- Contact the local ZEISS service representative if the emission current does not increase again.

6.3. Gas Injection System (GIS, optional)

6.3.1. Re-adjusting the GIS nozzle positions with the microstage

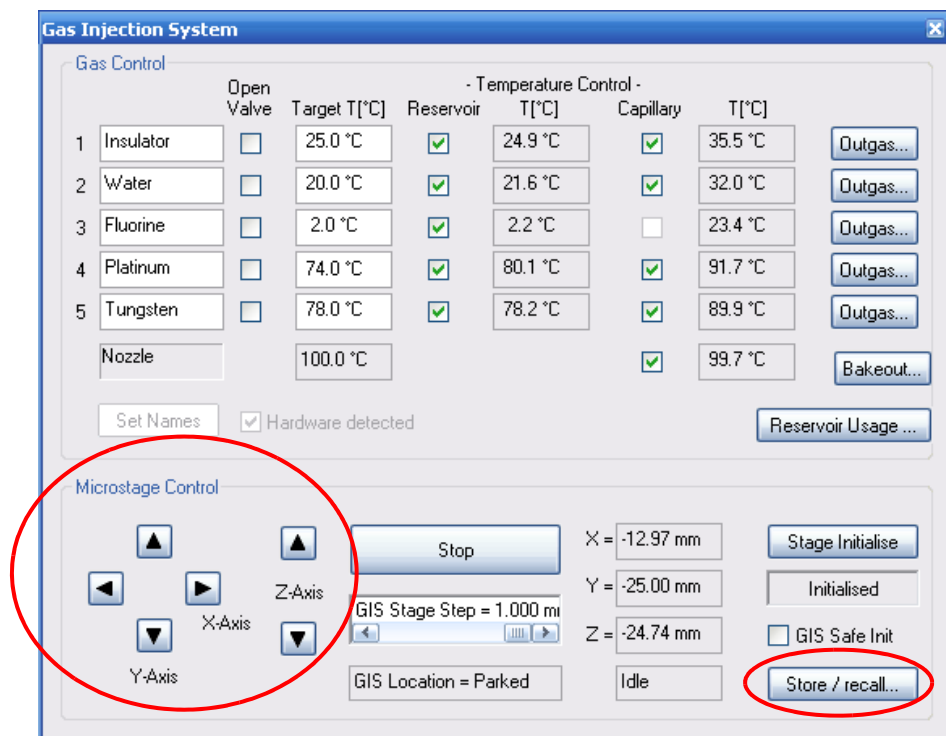
If the pre-defined nozzle positions have to be changed, you can re-adjust them.

Requires the *Supervisor* privilege.

- 1 Select **Tools/Goto Panel**.
- 2 Double-click **Gas Injection System**.

The **GIS** panel opens.

- 3 Click **Stage Initialise**.
- 4 Carefully move the GIS micro stage to the desired position:
Under Chamber Scope control, move the GIS micro stage by clicking the respective arrows in the **Microstage Control** field.

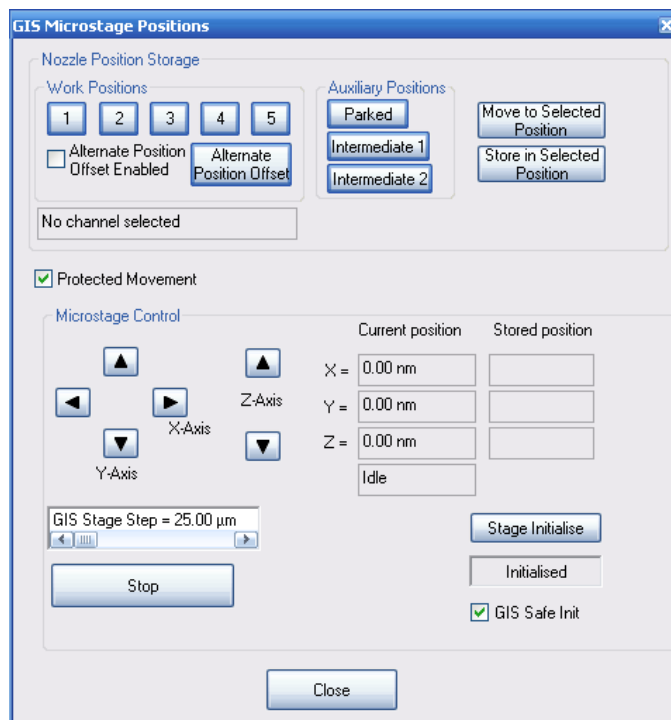


- 5 Click **Store/recall**.

6. Troubleshooting

Gas Injection System (GIS, optional)

The **GIS Microstage Positions** panel opens.



- 6 Select the channel.
Channel 0 is reserved for the park position.
- 7 Change to SEM view.
- 8 Show the crosshairs.

CAUTION

Risk of damage if intermediate positions are deactivated.

Ensure the 'Protected movement' checkbox is ticked. This will cause that the GIS micro stage is moved via the intermediate position thus minimizing any risk of damaging the nozzles.

6.3.1.1. Setting alternate nozzle positions

Different GIS working positions are needed depending on whether the sample is presented in the 54° angle to the FIB or at a lower angle e.g. 0-10°. These different working positions are defined by a simple offset to the five standard work positions.

The required alternate work positions are achieved by adding a single offset (ΔY , ΔZ) in the Y- and Z- axes of the GIS to the standard work positions. It is neither required to change the X- axis settings nor to store five individual alternate nozzle positions.

The offsets are defined as:

- $\Delta Y = (\text{current Y-position}) - (\text{average of the Y positions of the five standard positions})$
- $\Delta Z = (\text{current Z position}) - (\text{average of the Z positions of the five standard positions})$

Procedure:

- 1 Move the GIS Microstage to a working position.
- 2 Move the stage in Y and Z to the desired alternate position.

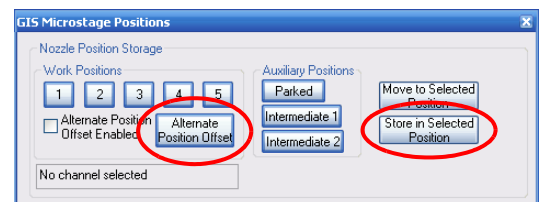


IMPORTANT

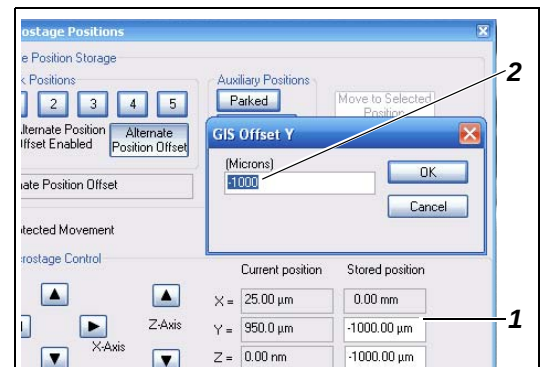
The alternate working position must be within the range of - 1000.0 μm to 1000.0 μm .

- 3 Click **Alternate Pos Offset**.
- 4 Click **Store in Selected Position**.

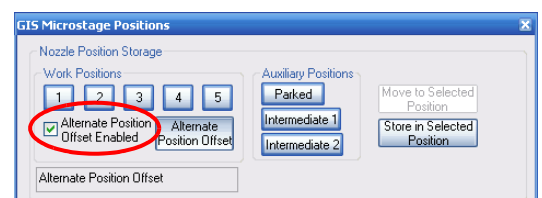
The position is now stored.



The offsets can also be edited by clicking in **Stored position (1)** and entering the desired value (2).



The alternate positions can now be used by ticking the **Alternate Position Offset Enabled** checkbox.



Different working positions will now be on display if ΔY and ΔZ are non-zero.

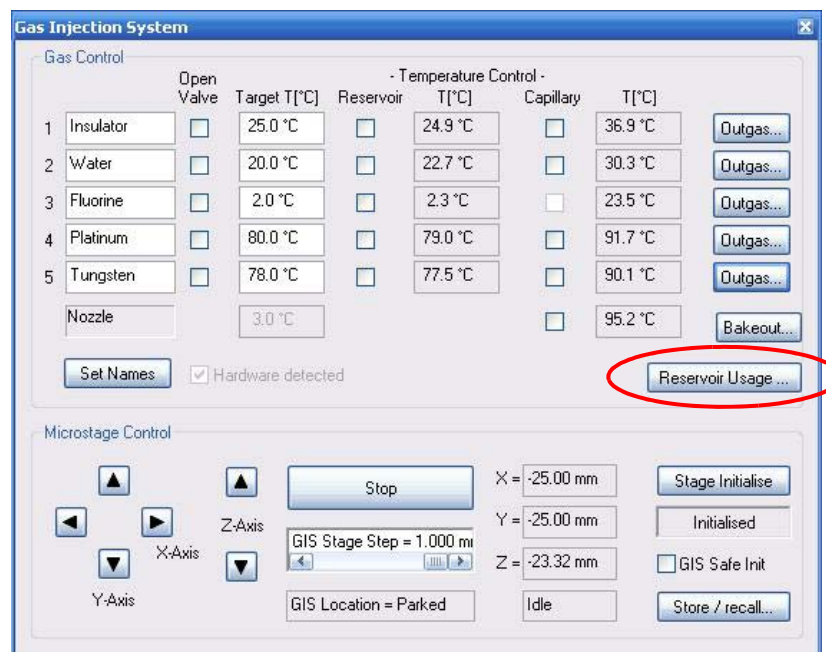
6.3.2. Checking the precursor supply

Precursors are consumables that are used up during operation.

In order to have a clue of the precursor supplies you should check the precursor life.

- 1 Open the **Panel Configuration Bar**.
- 2 Double-click **Gas Injection System**.

The **Gas Injection System** panel opens.

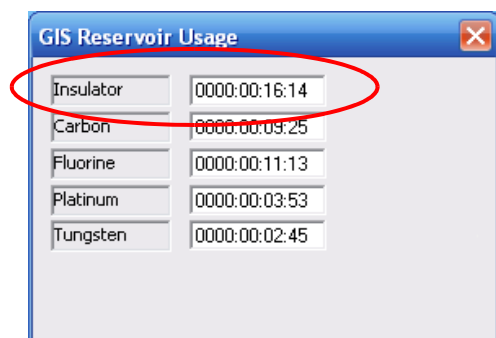


- 3 Click **Reservoir Usage**.

The **GIS Reservoir Usage** opens.

The time indicated corresponds to the duration of the open state of the respective reservoir valve.

In the example shown, the *Insulator* has a precursor life of 16 minutes and 14 seconds.



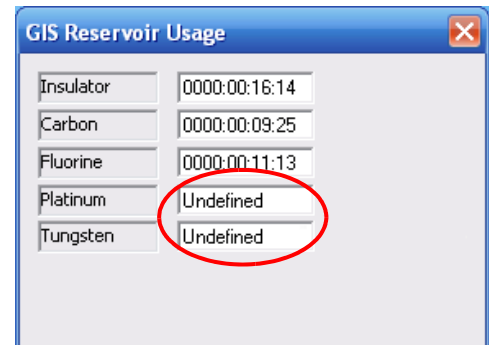
IMPORTANT

When the usage time approaches to 100 h the precursor is running out. Contact the ZEISS service representative to have the reservoir replaced. Note that usage data for carbon are not yet available.



IMPORTANT

If the message „Undefined“ is displayed in the GIS Reservoir Usage window, contact the local ZEISS service representative.



6.3.3. Adjusting the heating temperatures of the precursors

The heating temperatures of the precursors are pre-set by the ZEISS service representative. In the course of time it might be necessary to adjust these heating temperatures.

- 1 Monitor the system vacuum by using the **Gun Monitor**.
- 2 Select **Panel Configuration Bar/Gas Injection System**.

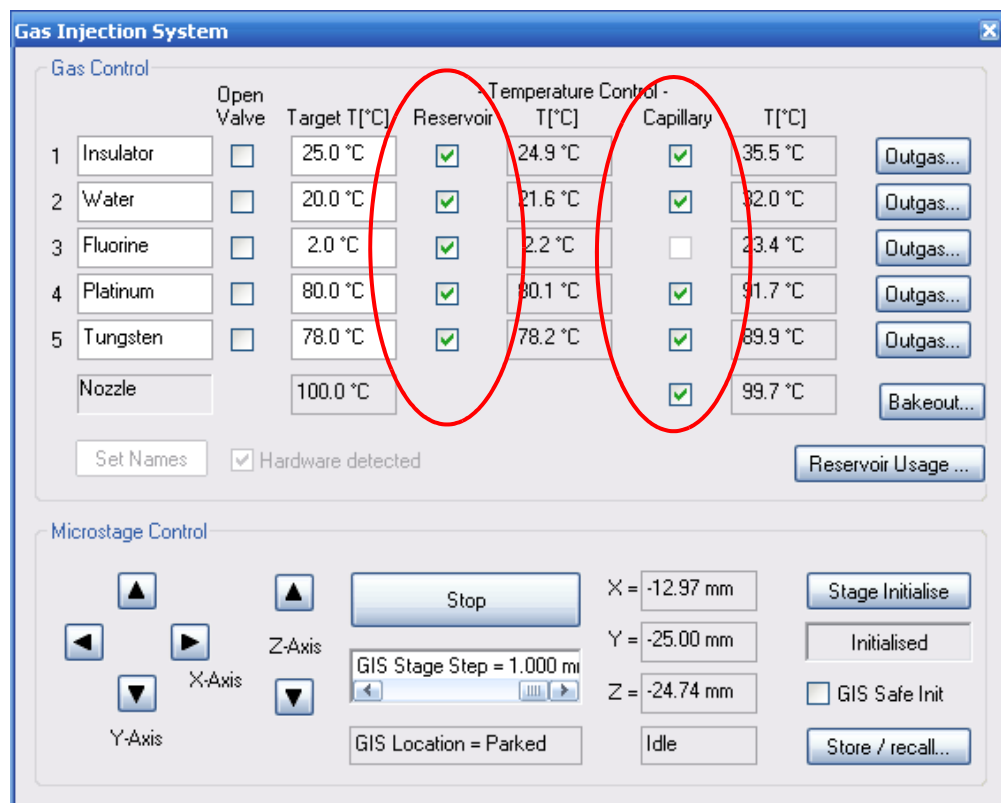
CAUTION

Risk of condensation in capillaries and nozzles

When material condensates, capillaries and nozzles might be blocked.

Heat the capillaries before changing the heating temperature. (Do this over night.)

- 3 Ensure reservoirs and capillaries are heated; the checkboxes **Reservoir** and **Capillary** must be ticked



- 4 Ensure the target temperatures have been reached for at least 30 minutes.

CAUTION

*Risk of vacuum drops. Electron source might get damaged.
Outgas the reservoirs before changing the heating temperature.*

- 5 Outgas the reservoirs. Refer to section 4.6.1.2.
- 6 Open the reservoir valve by ticking the respective **Open Valve** checkbox.
- 7 Change the temperature of the reservoir gradually by one-degree-steps until the system vacuum is between 1×10^{-5} mbar and 3×10^{-5} mbar.
Check the values in the **Gun Monitor**.

If the system vacuum is below 1×10^{-5} mbar:

- a Increase the temperature according to the state of the vacuum system.
- b Wait 30 minutes.
- c Check the vacuum again.

If the system vacuum is above 2×10^{-5} mbar:

- a Decrease the temperature according to the state of the vacuum system.
- b Wait 30 minutes.
- c Check the vacuum again.



IMPORTANT

The pressure of carbon is not detectable.

6. Troubleshooting

Gas Injection System (GIS, optional)

6.3.4. Baking out the GIS

During the bakeout, the nozzles and the capillaries are cleaned.

Requires the *Supervisor* privilege.

Possible reasons:

- GIS has not been used for a longer period

Precondition:

- System vacuum must be better than 5×10^{-6} mbar

CAUTION

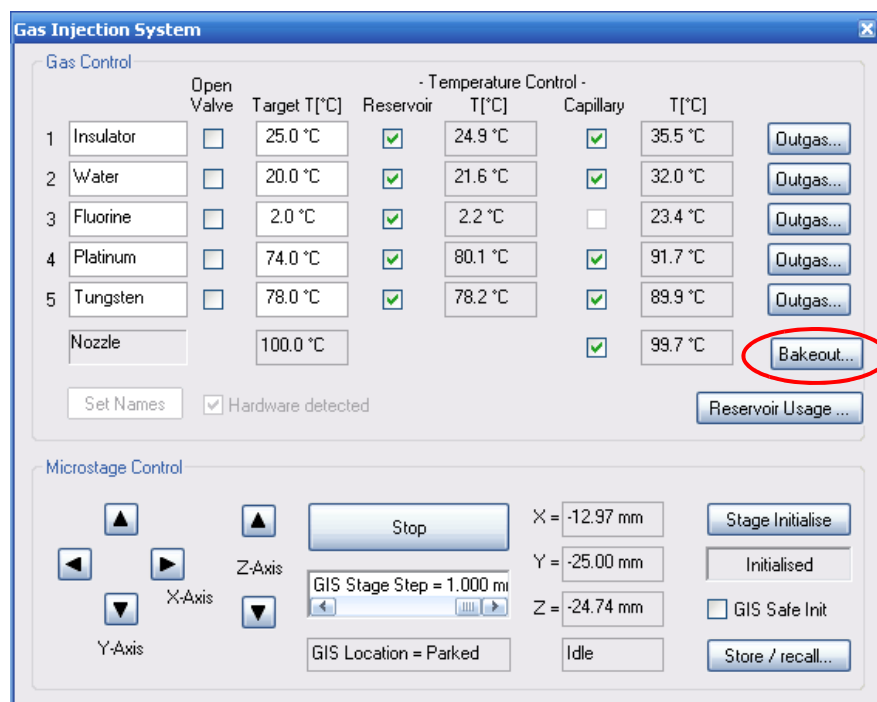
Hot temperature during bakeout.

The FIB column could be damaged.

Before starting the bakeout, make sure the GIS does not touch any column parts.

Procedure:

- 1 Open the panel **Gas Injection System**.
- 2 Click **Bakeout**.



The panel **GIS Bakeout** opens.

- 3 Set the **GIS capillary temperature** and the **GIS nozzle bakeout temperature**, each to 90°C.
- 4 Tick the **GIS Capillary bakeout** checkbox.
- 5 Tick the **GIS Nozzle bakeout** checkbox.
- 6 Click **OK**.



The bakeout starts. Both, the capillaries and the nozzle block are heated to 90°C.

- 7 Monitor the system vacuum: Open the **Gun Monitor Utility**.

During the bakeout, the nozzles and the capillaries are cleaned. This leads to a pressure increase inside the specimen chamber.

- 8 Perform the bakeout, until the system vacuum corresponds to the value monitored before the bakeout was started.
- 9 Finish the bakeout: Click the button **Cancel Bakeout**.

**How to
continue**

Continue with outgassing. Refer to section 4.6.1.2.

7. Summary of software functions

The different software functions can be called via:

- FIB toolbar
- FIB Control panel
- Panel Configuration Bar
- Shortcuts

7.1. FIB toolbar



IMPORTANT

If a Capella FIB column is installed, refer to the SmartFIB® Online Help for details.

The different panels and dialogs necessary to operate the CrossBeam® workstation can be called by using the FIB toolbar and its submenus.



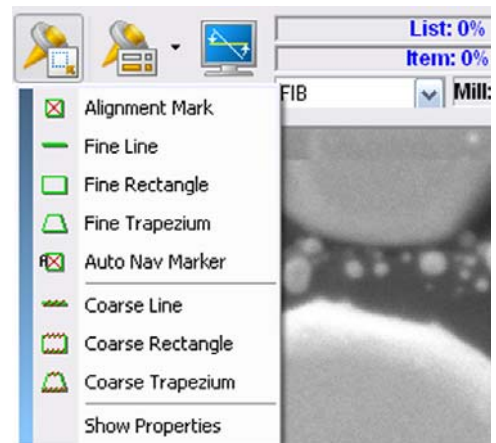
- **Manual Milling dialog**
The drop-down menu only available, if *FIB mode FIB* is selected or if **Allow creation of milling objects...** is ticked in the **Options** tab of the **FIB Control** panel.
- **FIB drop down-menu**
Opens the **FIB Control** panel.
- **Point-to-point stage rotation**
Aligns the specimen horizontally.
- **FIB Mode selection**
Drop-down menu for selection of the imaging mode.
- **Milling status**
Opens the milling status window.

7.1.1. Manual Milling dialog



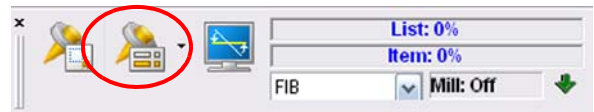
The drop-down menu only available, if *FIB mode FIB* is selected or if **Allow creation of milling objects...** is ticked in the **Options** tab of the **FIB Control** panel.

- **Alignment Mark**
Creates an alignment mark (cross) and opens the **Shape** tab.
- **Fine Line**
Creates a fine line and opens the **Shape** tab.
- **Fine Rectangle**
Creates a fine rectangle and opens the **Shape** tab.
- **Fine Trapezium**
Creates a fine trapezium and opens the **Shape** tab.
- **Auto Nav Marker**
Creates a cross.
- **Coarse Line**
Creates a coarse line and opens the **Shape** tab.
- **Coarse Rectangle**
Creates a coarse rectangle and opens the **Shape** tab.
- **Coarse Trapezium**
Creates a coarse trapezium and opens the **Shape** tab.
- **Show Properties**
Opens the **Shape** tab.



The fine and coarse submenus can be used as a template to save milling parameters for coarse milling and fine milling. To do so, enter the desired parameter settings and click **Safe Def** in the **Shape** tab.

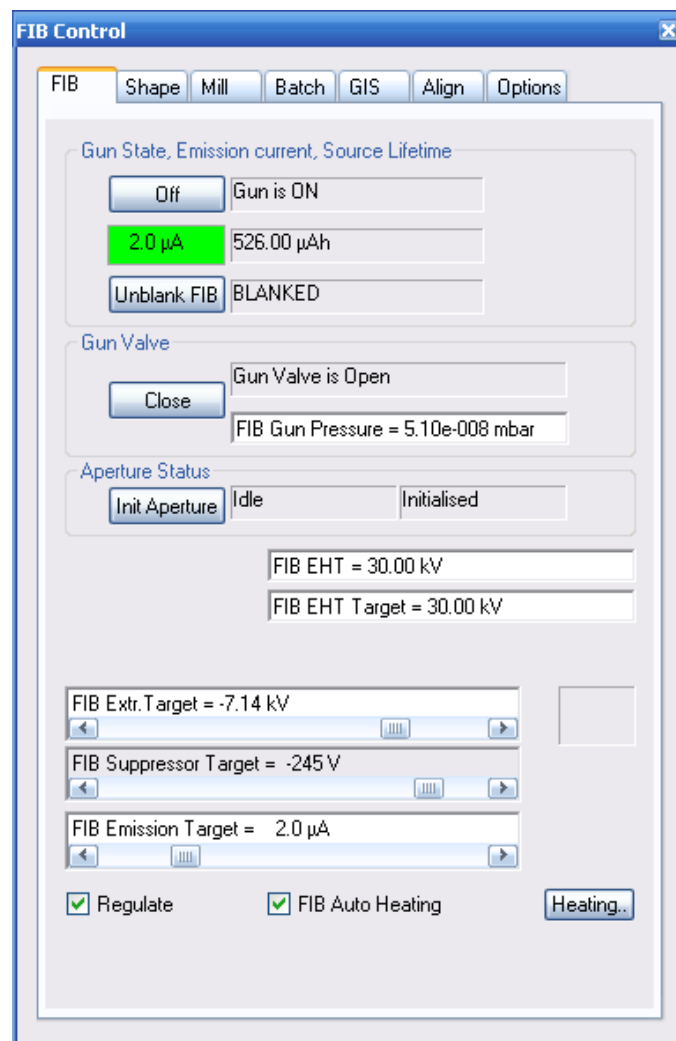
7.1.2. FIB drop-down menu



The **FIB drop down-menu** opens the **FIB Control** panel, which includes the most important FIB functions in seven different tabs.

Clicking the arrow button opens the submenu.

7.1.2.1. FIB tab



- **On/Off**
Switches the ion gun on/off.

7. Summary of software functions

FIB toolbar

- **µA**
Indicates the emission current
Red background: The suppressor voltage has almost reached its limit.
Yellow background: The emission current differs from the target by more than 0.1 µA.
Green background: The emission current equals the target (+/- 0.1 µA).
- **Blank/Unblank FIB**
If blanked, the ion beam does not hit the specimen.
- **Close/Open**
Closes/opens the gun valve, which separates gun head area and specimen chamber.
- **Init Aperture**
Initialises the FIB apertures.
The fields next to the button indicate the status of the apertures.
If the background is red, the aperture have not been initialised
- **FIB EHT =**
Indicates the acceleration voltage of the ion gun.
- **FIB EHT Target=**
Indicates the desired acceleration voltage of the ion gun.
- **FIB Extractor Target=**
Sets the FIB extractor voltage.



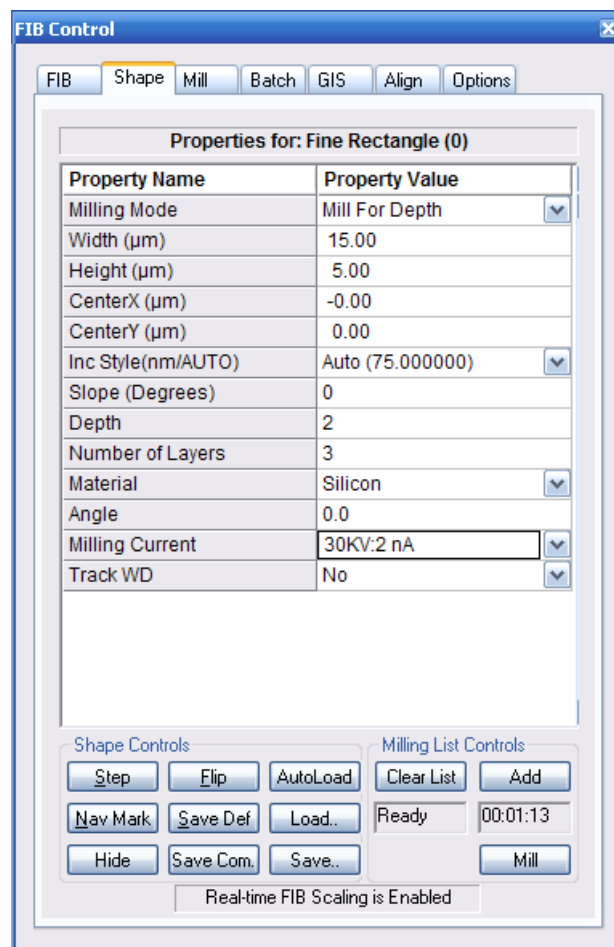
IMPORTANT

Changes of the FIB Extractor Target require a complete alignment of the FIB probe currents.

- **FIB Suppressor Target=**
Sets the desired suppressor voltage.
- **FIB Emission Target=**
Sets the desired emission target.
- **Regulate**
If ticked, the emission current is regulated automatically by adjusting the suppressor voltage.
- **FIB Auto Heating**
If ticked, the filament will be heated automatically when required.
When reaching -2000 V, the FIB source will be regenerated automatically.
- **Heating**
Opens the **FIB Filament Heating** panel.

7.1.2.2. Shape tab (standard)

Standard: Workstation with analogue FIB scan generator



- **Milling Mode**
Selects the milling mode
Mill for Time: Mills for a given period of time.
Mill for Depth: Mills a given depth.
Deposition Mode: Deposits or etches for a given period of time.
Deposition w Thickness: Deposits or etches a given thickness (height).
- **Width (μm)**
Sets the size of the milling object.
- **Height (μm)**
Sets the size of the milling object.
- **CenterX (μm)**
Sets the position of the milling object in relation to the center of the screen.
- **CenterY (μm)**
Sets the position of the milling object in relation to the center of the screen..
- **Inc Style (nm/AUTO)**
Sets the step size of the milling.

7. Summary of software functions

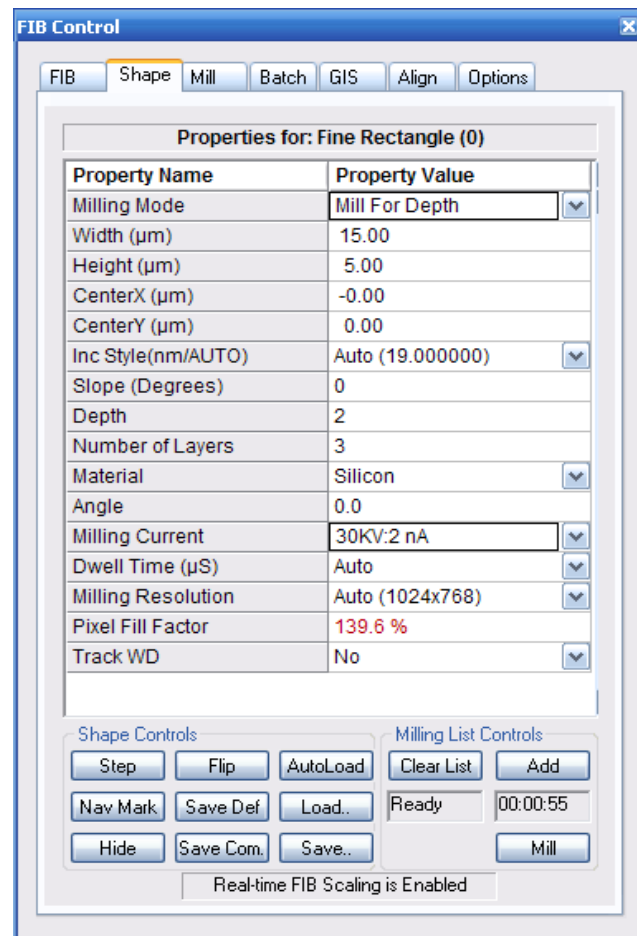
FIB toolbar

- **Slope (Degrees)**
With Mill for Depth only. Sets the geometrical slope to be milled.
- **Depth**
Sets the depth to be milled.
- **Number of Layers**
Defines how deep a milling element is milled in one go.
With a value greater than one, the milling element is milled only to a small depth and then the same area is milled again and again according to the number of layers.
- **Material**
Allows selection of pre-defined materials, which have been edited in the **FIB Materials Editor** before.
- **Angle**
Angle of the milling object.
- **Milling Current**
Selects the milling current.
- **Track WD**
Tracks the working distance while milling into the depth.

- **Step**
Adds a milling object of the same shape to the existing one.
- **Nav. Mark**
Sets a navigation mark (cross).
- **Hide/Show**
Hides/shows the milling object.
- **Flip**
Adds the reflected milling object to the existing one.
A window asks how large the distance (step) between both object should be.
- **Save Def.**
Stores the properties of the selected milling mode. The stored properties can be recalled only by the individual user.
- **Save Com.**
Stores the properties of the selected milling mode. The stored properties can be recalled by all users.
- **AutoLoad**
Loads and adds a pre-defined milling object (.mob file) to the current milling list.
- **Load**
Loads a pre-defined milling object (.mob file) onto the screen.
- **Save**
Saves the milling objects displayed on the screen.
- **Clear List**
Deletes the current list of milling objects.
- **Add**
Adds the selected milling object to the milling list.
- **Ready**
Shows the time required to perform the milling.
- **Mill**
Starts the milling process.

7.1.2.3. Shape tab (with optional dual scan generator)

Requires the option dual scan: Workstation with digital FIB scan generator



- **Milling Mode**
Selects the milling mode
Mill for Time: Mills for a given period of time.
Mill for Depth: Mills a given depth.
Deposition Mode: Deposits or etches for a given period of time.
Deposition w Thickness: Deposits or etches a given thickness (height).
- **Width (µm)**
Sets the size of the milling object.
- **Height (µm)**
Sets the size of the milling object.
- **CenterX (µm)**
Sets the position of the milling object.
- **CenterY (µm)**
Sets the position of the milling object.
- **Inc Style (nm/AUTO)**
Sets the step size of the milling.

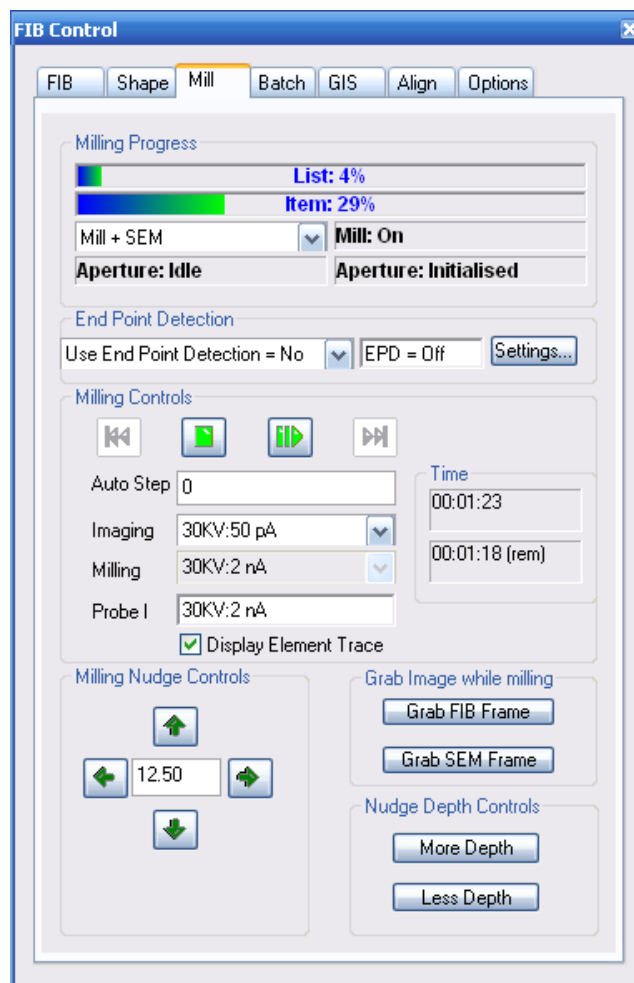
7. Summary of software functions

FIB toolbar

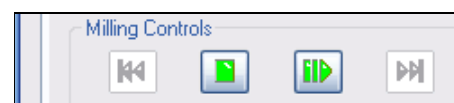
- **Slope (Degrees)**
With Mill for Depth only. Sets the geometrical slope to be milled.
- **Depth**
Sets the depth to be milled.
- **Number of Layers**
Defines how deep a milling element is milled in one go.
With a value greater than one, the milling element is milled only to a small depth and then the same area is milled again and again according to the number of layers.
- **Material**
Allows selection of pre-defined materials, which have been edited in the FIB Materials Editor before.
- **Angle**
Angle of the milling object.
- **Milling Current**
Selects the milling current.
- **Dwell time (µs)**
Dwell time per pixel in microseconds to use during milling.
- **Milling resolution**
Defines the milling resolution.
- **Pixel fill factor**
Compares the target pixel size given the resolution and magnification selected and the probe width.
- **Track WD**
Tracks the working distance while milling into the depth.
- **Step**
Adds a milling object of the same shape to the existing one.
- **Nav. Mark**
Sets a navigation mark (cross).
- **Hide/show**
Hides/shows the milling object.
- **Flip**
Adds the reflected milling object to the existing one.
A window asks how large the distance (step) between both object should be.
- **Save Def.**
Stores the properties of the selected milling mode. The stored properties can be recalled only by the individual user.
- **Save Com.**
Stores the properties of the selected milling mode. The stored properties can be recalled by all users.
- **AutoLoad**
Loads and adds a pre-defined milling object (.mob file) to the current milling list.
- **Load**
Loads a pre-defined milling object (.mob file) onto the screen.
- **Save**
Saves the selected milling object.

- **Clear List**
Deletes the current list of milling objects.
- **Add**
Adds the selected milling object to the milling list.
- **Ready**
Shows the time required to perform the milling.
- **Mill**
Starts the milling process.

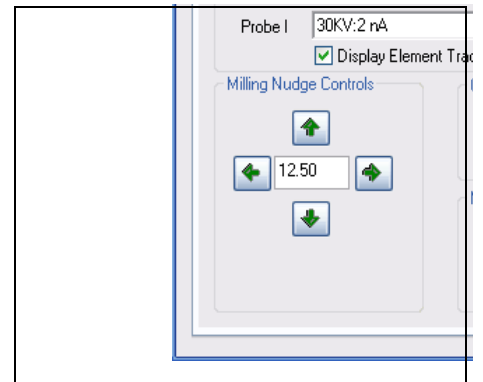
7.1.2.4. Mill tab



- **Milling progress**
Indicates the ongoing of the milling.
- **FIB drop-down menu**
Selects the imaging mode.
- **End Point Detection** (drop-down menu)
Activates/deactivates the function **End Point Detection** (used to detect the point at which milling should be paused by detecting the signal changes generated during milling).
- **EPD=**
Shows the selected status of the **End Point Detection**.
- **Settings**
Opens the **FIB End Point Detection** panel.
- **Milling Controls**
Backward: Jumps to the previous milling object.
Stop: Ends the milling process.
Start/Pause: Starts respectively interrupts the milling process.
Forward: Jumps to the next milling object



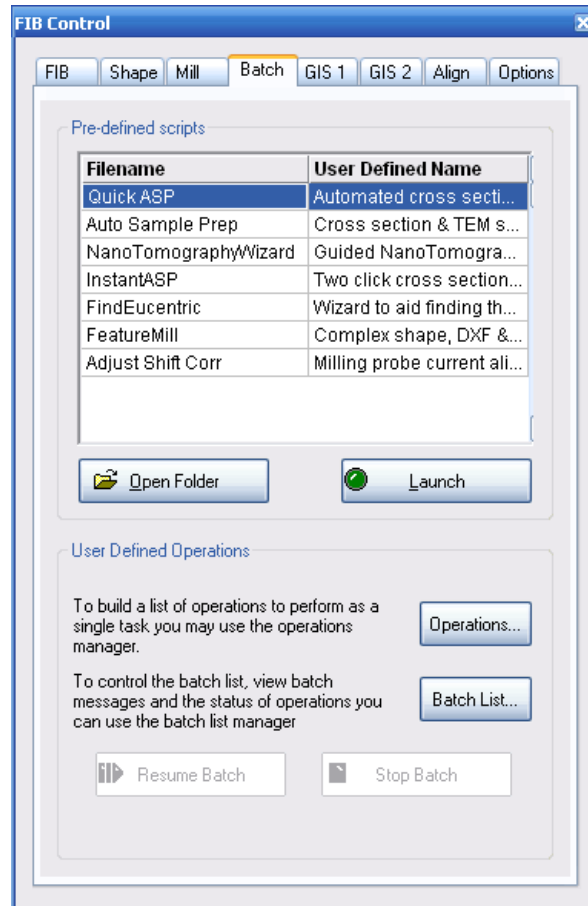
- **Auto Step**
Defines the new starting point after the milling pause.
- **Imaging**
Opens a drop-down list with the pre-defined probe currents.
Sets the probe current used for imaging.
- **Milling**
Opens a drop-down list with the pre-defined probe currents.
Sets the current used for milling.
- **Probe I**
Sets the probe current.
- **Display Element Trace**
If ticked, the progress marker is shown in the image.
- **Milling Nudge Control**
Arrow buttons allow displacing the milling object while milling.
The milling object is shifted by x nm in arrow direction.
- **Grab FIB frame**
Records a FIB image.
- **Grab SEM frame**
Records a SEM image.
- **More Depth**
Increases the depth to be milled. Change by 5% of the current value per mouse click.
- **Less Depth**
Decreases the depth to be milled. Change by 5% of the current value per mouse click.



7. Summary of software functions

FIB toolbar

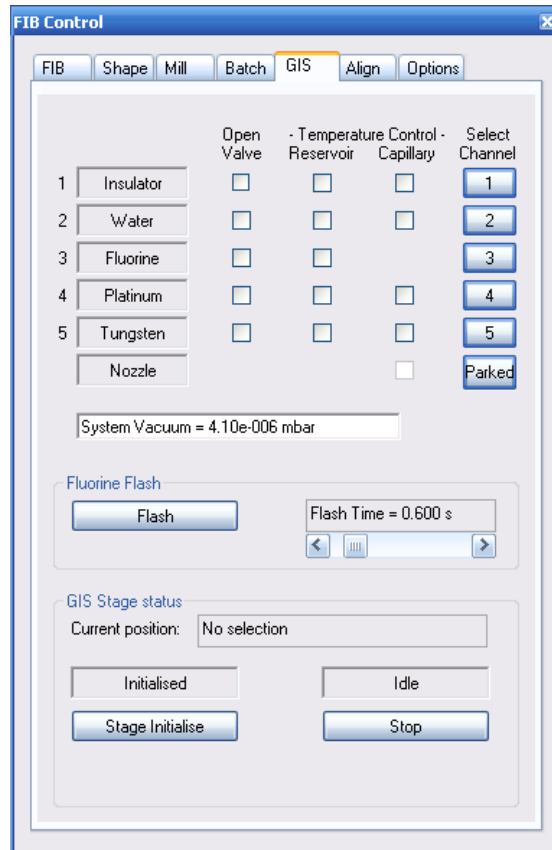
7.1.2.5. Batch tab



- **Quick ASP**
Quick user interface to use pre-defined recipes. Suitable for cutting cross sections and TEM lamellas.
- **Auto Sample Prep**
Requires licence. Opens a wizard that is designed to help automate the milling of multiple samples for TEM or cross section viewing.
- **Nano Tomography Wizard**
Opens the **Nano Tomography Wizard**.
- **Instant ASP**
Two click cross section...
- **Find Eucentric**
Opens a wizard to find the eucentric point.
- **FeatureMill**
Open the feature milling functions that allow you to mill any geometrical shapes.
- **Adjust Shift Corr**
Opens the **Milling Shift Wizard**.
- **Operations**
Opens the **Batch** manager.
- **Batch List**
Opens the **Batch Operations** dialog.

7.1.2.6. GIS tab (Multi GIS)

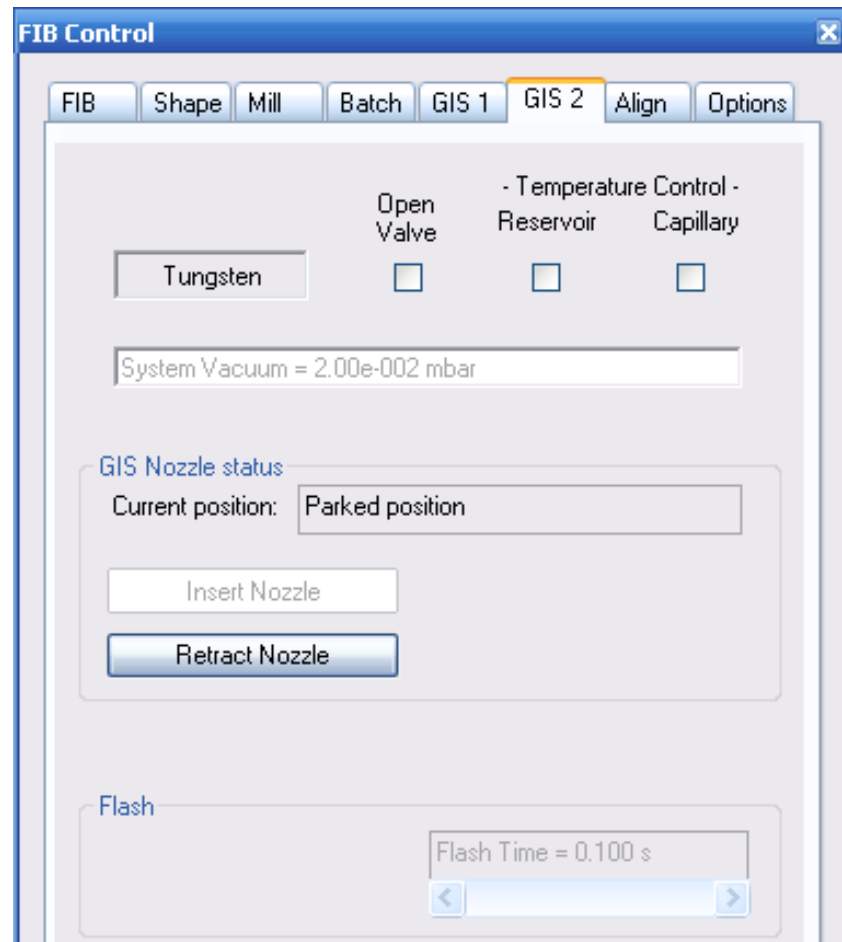
Depending on the configuration, there is either one or two **GIS** tabs.



- **Open Valve**
If ticked, the valve of the respective precursor is open.
- **Reservoir**
If ticked, reservoir and capillary of the respective precursor is heated.
- **Capillary**
If ticked, the capillary of the respective precursor is heated.
- **Select Channel** buttons
Selects the precursor to be injected,
When clicking this button the GIS micro stage drives to a position predefined for the respective precursor.
- **System vacuum**
Indicates the vacuum in the specimen chamber.
- **Flash**
Flashes fluorine into the specimen chamber. For cross section decoration.
- **Flash Time**
Sets the duration of the fluorine flash.
- **Stage Initialise**
Initialises the GIS micro stage.
- **Stop**
Cancels the GIS micro stage movement.

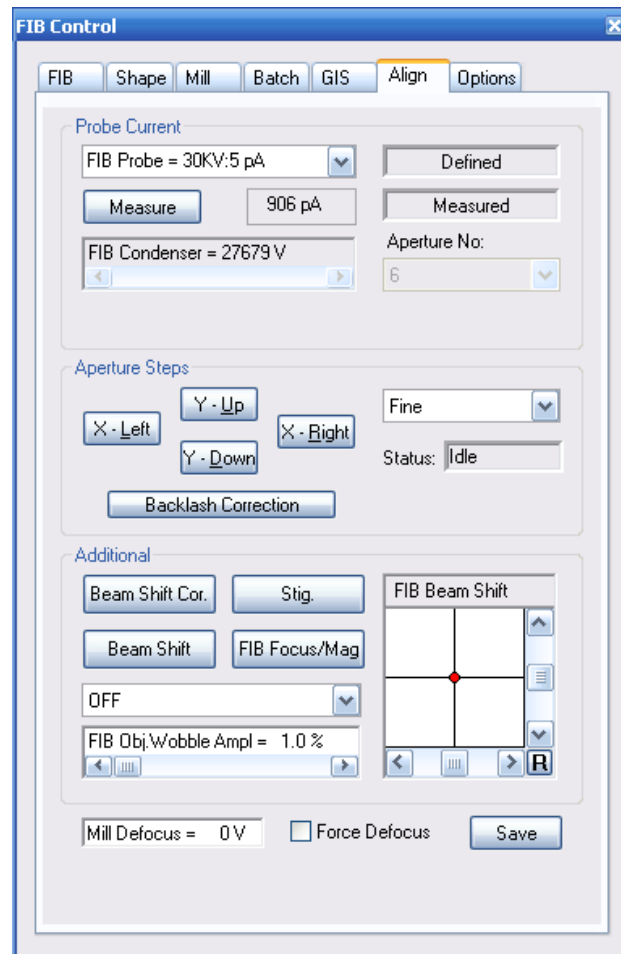
7.1.2.7. GIS 2 tab (Single GIS)

If two gas injection systems are installed, there is one tab for each GIS in the **FIB Control** window. GIS 2 can only be a Single GIS, while GIS 1 can either be a Multi GIS or a Single GIS.



- **Open Valve**
If ticked, the valve of the respective precursor is open.
- **Reservoir**
If ticked, reservoir and capillary of the respective precursor is heated.
- **Capillary**
If ticked, the capillary of the respective precursor is heated.
- **System vacuum**
Indicates the vacuum in the specimen chamber.
- **Current position**
Indicates the current position of the GIS nozzle.
- **Insert Nozzle**
Inserts the nozzle.
- **Retract Nozzle**
Retracts the nozzle.
- **Flash Time**
Sets the duration of the fluorine flash.

7.1.2.8. Align tab



- **FIB Probe =**
Selects the FIB probe settings.
- **Measure**
Measures the probe current by using the built-in Faraday cup.
- **FIB Condenser =**
Indicates the condenser voltage for the selected probe current.
- **Aperture No.**
Shows the number of the aperture for the selected probe current.
- **Aperture Steps**
Buttons to moves the aperture.
Y-Up
Y-Down
X-Left
X-Right
- **Backlash Correction**
Enables a better reproducibility of the aperture.

7. Summary of software functions

FIB toolbar

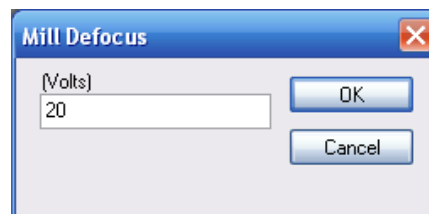
- **Drop-down menu**
Sets the parameters for aperture alignment.
Fine (2 μm)
Coarse (20 μm)
Medium (200 μm)
Next Aper. (2000 μm)
- **Beam Shift Cor.**
Activates the beam shift correction.
- **Stig**
Activates the stigmator function.
- **Beam Shift**
Activates the beam shift function.
- **FIB Focus/Mag**
Activates the FIB focus and magnification function.
- **Drop-down menu**
Selects one of the following settings:
OFF
ON Focus
ON Energy
ON Condenser
ON Stigmator X
ON Stigmator Y



IMPORTANT

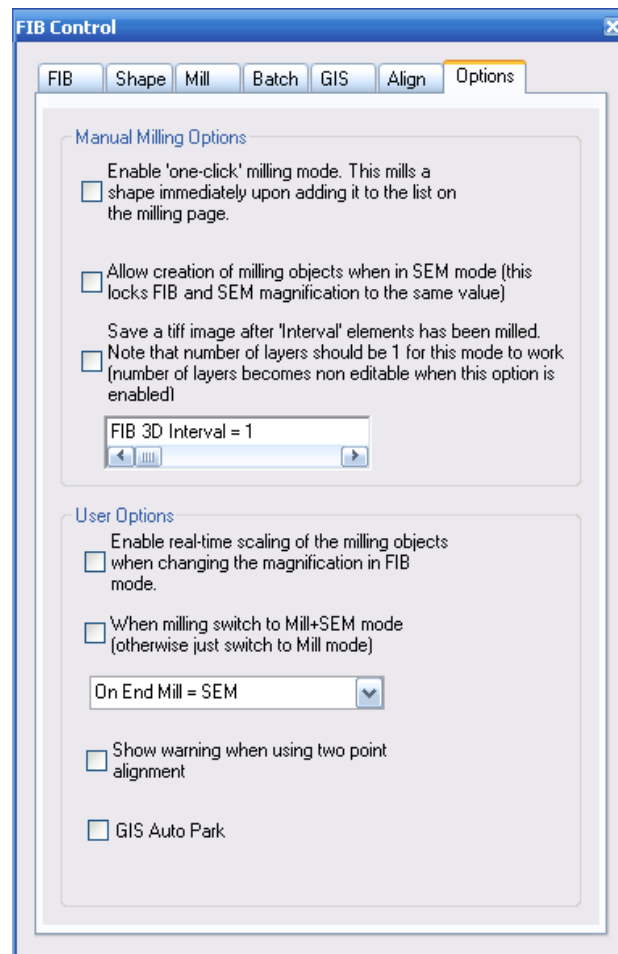
Regular operation only requires the ON Focus setting.

- **FIB Obj. Wobble Ampl.**
Sets the intensity of wobble.
- **Mill Defocus =**
Opens the **Mill Defocus** window to set the defocus value.



- **Force Defocus**
The Defocus value is now applied when using spot mode.
- **Save**
Saves the settings.

7.1.2.9. Options tab



- **Enable 'one-click' milling mode...**
If ticked, you can start the milling process by a single click **Add + Mill** in the **Shape** tab.
- **Allow creation of milling...**
If ticked, you can create milling objects in SEM mode.
This might be useful for surface-sensitive specimens.
- **Save a tiff image file after...**
If ticked, a series of tiff files is recorded.
- **FIB 3D Interval =**
Sets the FIB 3D Interval.
- **Enable real-time scaling...**
If ticked, the size of the milling object is constant no matter which magnification is selected.
- **When milling switch to Mill+SEM...**
If ticked, the workstation automatically switches to **Mill+SEM** mode so that you can watch the milling process.
If unticked, the workstation changes to **Mill** mode.

7. Summary of software functions

FIB toolbar

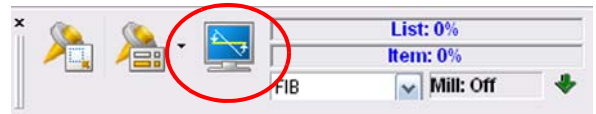
- **On End Mill=**
Selects the mode to which the workstation changes after having finished the milling procedure.
FIB (FIB imaging)
SEM (SEM imaging)
FIB (FIB imaging, but blanked)
SEM (blanked)
- **Show warning when using ...**
If ticked, a warning is shown, when the two point alignment is activated.
- **GIS Auto Park**
If ticked, the GIS micro stage automatically approaches to the park position after having finished the milling procedure/deposition procedure.



IMPORTANT

*For some applications, the GIS Auto Park function should be DISABLED.
This applies to shock-sensitive applications e.g. for using deposition in order to mount a needle onto a TEM sample for internal lift-out.
Ensure the GIS Auto Park checkbox is UNTICKED.*

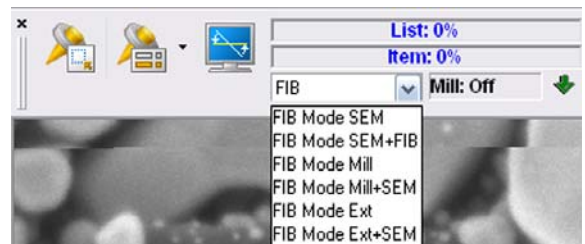
7.1.3. Point-to-point stage rotation



- **Point-to-point-stage**
Rotates the stage until the specimen detail is adjusted along a user-defined line.

7.1.4. FIB Mode selection

Allows you to select the imaging mode.

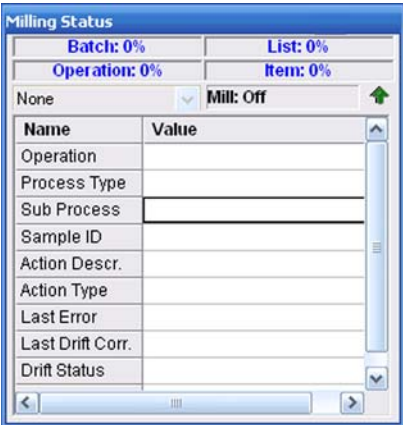


- **FIB Mode FIB**
Ion beam scans, electron beam is blanked.
- **FIB Mode SEM**
Electron beam scans, ion beam is blanked.
- **FIB Mode SEM + FIB**
Both beams scan.
- **FIB Mode Mill**
Electron beam is blanked, ion beam mills.
- **FIB Mode Mill + SEM**
Electron beam is scanning, ion beam mills.
- **FIB Mode Ext**
Electron beam is blanked, ion beam is unblanked and driven by an external scan generator.
- **FIB Mode Ext + SEM**
Electron beam is scanning, ion beam is unblanked and driven by an external scan generator.

7.1.5. Milling status



Opens the **Milling status** window.



To close the **Milling status** window click the green arrow.

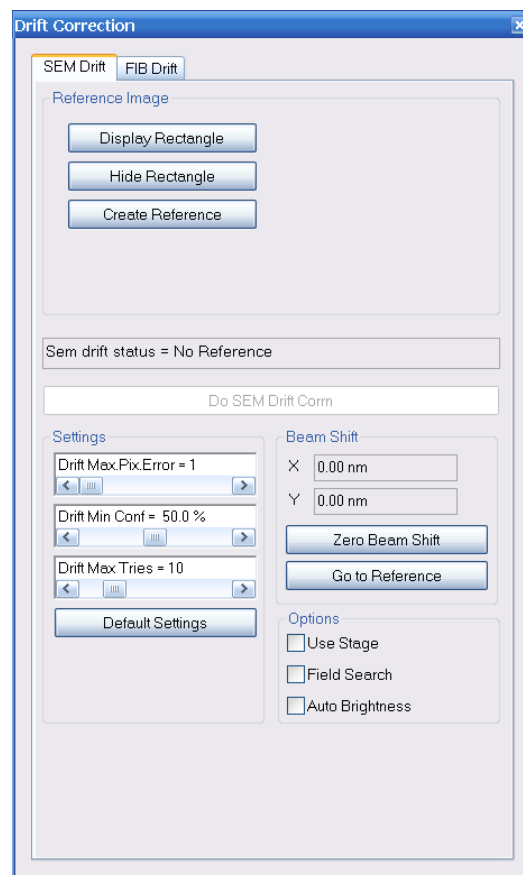
7.2. Panels on the Panel Configuration Bar

7.2.1. Drift Correction

Requires the licence DRIFT CORR and the MIL dongle.

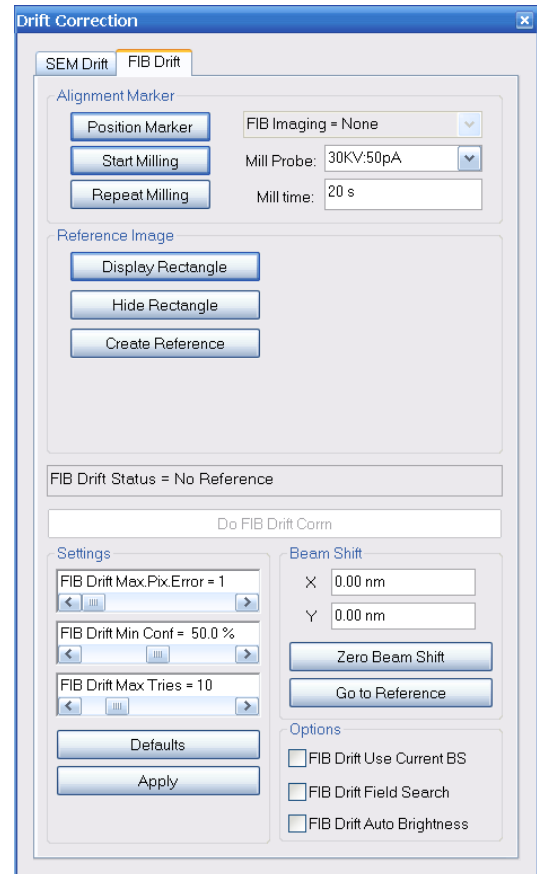
SEM Drift tab

- **Display Rectangle**
Shows the rectangle.
- **Hide Rectangle**
If activated, the rectangle no longer shown.
- **Create Reference**
Creates the reference selected by the displayed rectangle.
- **Do SEM Drift Corr**
Performs the SEM drift correction procedure.
- **Drift Max. Pix. Error**
Sets the maximum pixel error.
- **Drift Min Conf**
Shows the minimum confidence.
- **Default Settings**
Returns to the default settings.
- **Zero Beam Shift**
Sets the beam shift to zero.
- **Go to Reference**
Moves the specimen stage to the reference point.
- **Use Stage**
If ticked, the Use Stage function is active.
- **Field Search**
If ticked, the Field Search function is active.
- **Auto Brightness**
If ticked, the Auto Brightness function is active to optimise image recognition.



FIB Drift tab

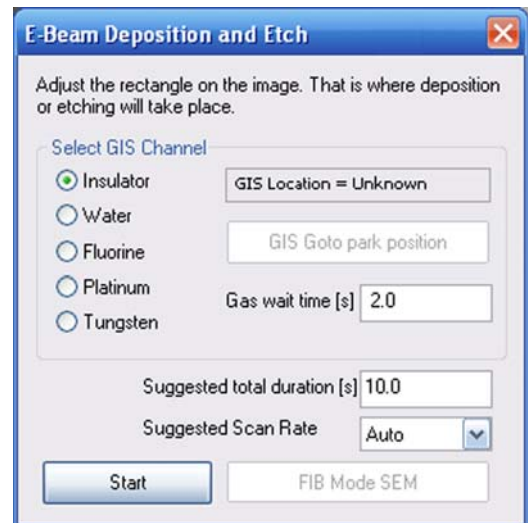
- **Position Marker**
Sets the position marker for cross milling.
- **Start Milling**
Begins the milling process.
- **Repeat Milling**
Repeats milling process.
- **Display Rectangle**
Shows the rectangle.
- **Hide Rectangle**
If activated, the rectangle is no longer shown.
- **Create Reference**
Creates the reference for drift correction.
- **Do FIB Drift Correction**
Starts the drift correction procedure.
- **Zero Beam Shift**
Sets the beam shift to zero.
- **Go to Reference**
Moves the specimen stage to the reference point.
- **FIB Drift Use Current BS**
If ticked, the current beam shift is used for the drift correction.
- **FIB Drift Field Search**
If ticked, the reference point is searched in a larger field. Recommended in case of stronger drift.
- **FIB Drift Auto Brightness**
If ticked, the Auto Brightness is activated to optimise image recognition.



7.2.2. E-Beam Deposition and Etching

A rectangle is displayed on the screen.

- **Select GIS Channel**
Selects the gas to be injected.
- **Suggested total duration**
Sets a time in seconds
- **Suggested Scan Rate**
Selects the scan speed from a drop-down list.
- **Start**
Starts the procedure.
- **FIB Mode SEM**
Change to **SEM** mode.



The screenshot shows a software dialog box titled "E-Beam Deposition and Etch". Inside the dialog, there is a text instruction: "Adjust the rectangle on the image. That is where deposition or etching will take place." Below this, there is a section titled "Select GIS Channel" containing five radio button options: "Insulator" (which is selected), "Water", "Fluorine", "Platinum", and "Tungsten". To the right of these options are two text input fields: "GIS Location = Unknown" and "GIS Goto park position". Below the radio buttons is a text input field for "Gas wait time [s]" with the value "2.0". Further down, there is a text input field for "Suggested total duration [s]" with the value "10.0", and a dropdown menu for "Suggested Scan Rate" currently set to "Auto". At the bottom of the dialog, there are two buttons: "Start" and "FIB Mode SEM".

7.2.3. FIB Aperture Calibration

Requires the **User Access Level Service**.

- **X Pos**
Indicates the X position.
- **Y Pos**
Indicates the Y position.
- **Aperture Steps**
Move the aperture.
- **Drop-down menu**
Sets the sensitivity.
- **Initialise**
Initialises the FIB apertures.
- **Backlash Correction**
Enables a better reproducibility of the aperture.
- **Aperture No.**
Selects the aperture.
- **FIB Focus Wobble**
If ticked, the focus is swept backwards and forwards through the focus.
- **FIB Obj Wobble Ampl**
Sets the wobble intensity.
- **Mouse FIB Mag/Focus**
Activates the mouse buttons FIB magnification/focus.

The screenshot shows the 'FIB Aperture Calibration' dialog box with the following sections and controls:

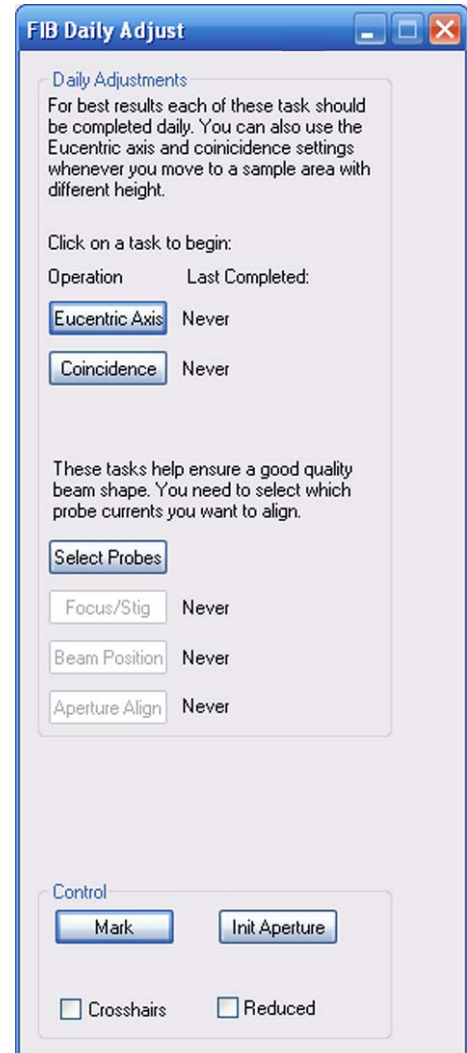
- Aperture Status:** Two tabs, 'Initialised' (selected) and 'Idle'. Below are input fields for 'X Pos' (0.000000) and 'Y Pos' (0.000000).
- Aperture Steps:** Four buttons: 'X-Left', 'Y-Up', 'X-Right', and 'Y-Down'. Below them is a dropdown menu set to 'Fine'.
- Actions:** Three buttons: 'Initialise', 'Calibrate', and 'Backlash Correction'.
- Aperture No.:** A dropdown menu set to '1'.
- Type:** Two radio buttons: 'Type A-7' (selected) and 'Type D-13'.
- Focus:** A checkbox for 'FIB Focus Wobble' (unchecked). Below it is a text field 'FIB Obj.Wobble Ampl = 1.0 %' with left and right arrow buttons. At the bottom is a button 'Mouse FIB Mag/Focus'.

7.2.4. FIB Daily Adjust

This function guides through a well-defined procedure to check the workstation against any drifts or misalignments and allows you to eliminate them.

Changing the beam shape parameters requires the *FIB alignment* privilege.

- **Eucentric Axis**
Starts the wizard for adjusting tilt eucentricity.
- **Coincidence**
Starts the wizard for setting the coincidence point.
- **Select Probes**
Allows to select a probe current.
- **Focus/Stig**
Adjusts focus and stigmator.
- **Beam Position**
Adjusts the beam position.
- **Aperture Align**
Sets the aperture position.
- **Init Aperture**
Initialises the FIB aperture.
- **Crosshairs**
If ticked, the crosshairs are shown.
- **Reduced**
If ticked, the reduced raster is shown.

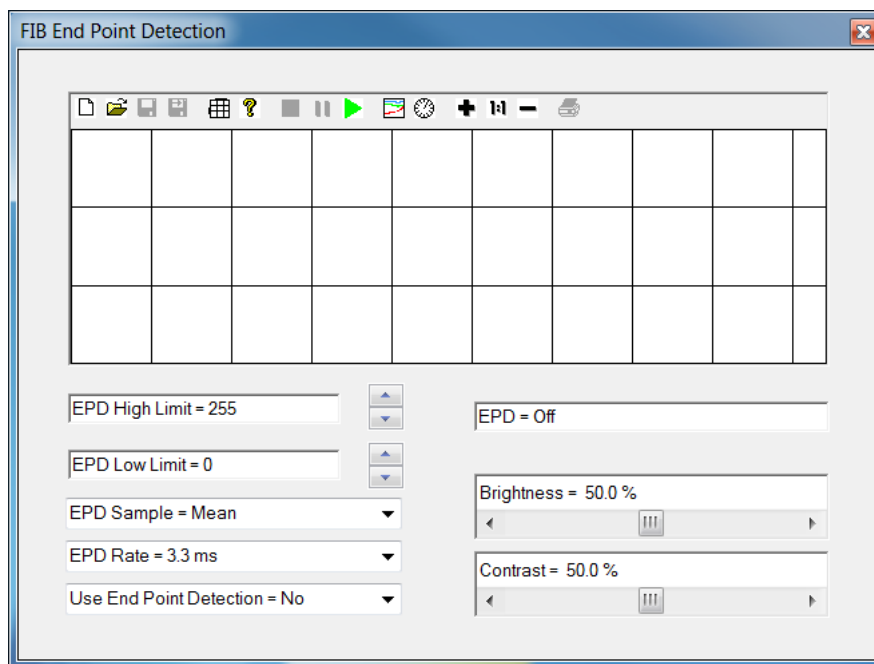


7.2.5. FIB End Point Detection

Requires the licence END-DETECTION.

This function is used to detect the point at which milling should be paused by detecting the signal changes generated during milling.

The **End Point Detection** settings dialog is used in setup mode to define criteria for detecting the end point experimentally and also to monitor the signal when in active use.



- If signal > High limit or signal < Low limit then status is triggered.
- If *Mode* = *setup* an audible beep is given when status is triggered, milling continues.
- If *Mode* = *On* milling is paused when status is triggered.

7.2.6. FIB Filament Heating

Requires the **User Access Level** *Expert* or *Service*.

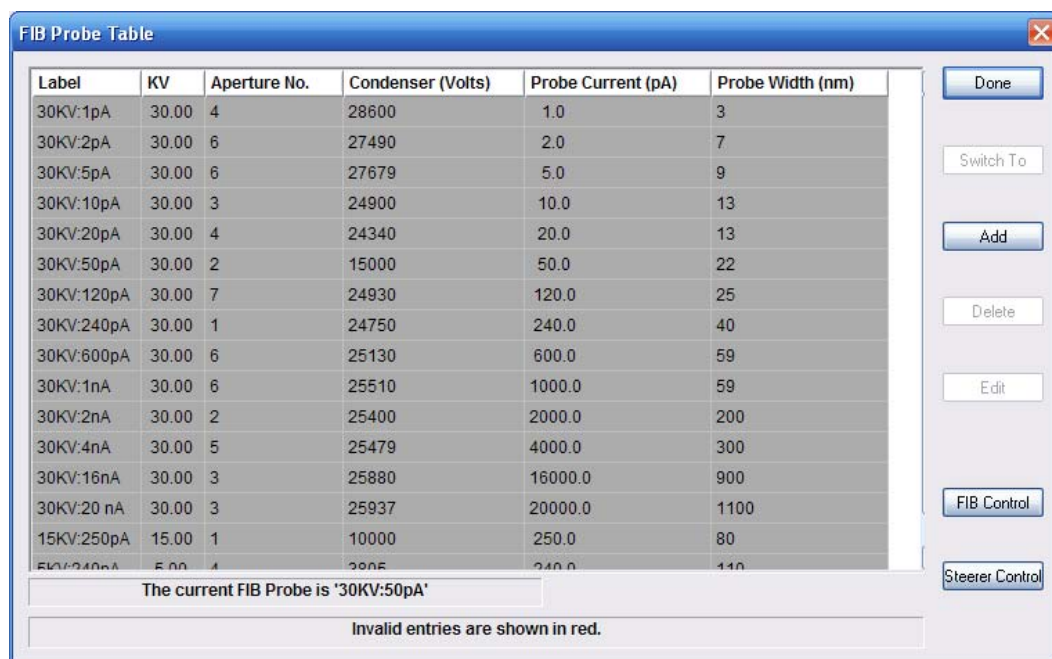
- **FIB Fil Current**
Indicates the FIB filament current.
- **FIB Fil Voltage**
Indicates the FIB filament voltage.
- **FIB Min Autoheat Current**
Defines the autoheat current.
- **Filament Status**
Shows the status of the filament (*on, off, ramping...*).
- **FIB Fil I Target**
Sets the desired FIB filament current.
- **FIB Auto Heating Limit**
Sets the limit.
- **Filment On**
Switches the filament heating on.
- **Filament Off**
Switches the filament heating off.

The screenshot shows a software window titled "FIB Filament Heating". It contains several input fields and controls:

- FIB Fil Current**: A text box showing "0 μ A".
- FIB Fil Voltage**: A text box showing "0.0 V".
- FIB Min..Autoheat Current**: A text box showing "0 μ A".
- Filament Status**: A dropdown menu currently set to "Off".
- FIB Fil I Target**: A slider control with a value of "0 μ A".
- FIB Auto Heating Limit**: A slider control with a value of "3.200 A".
- Filament On**: A button to turn the filament heating on.
- Filament Off**: A button to turn the filament heating off.

7.2.7. FIB Probe Table

Requires the **User Access Level** *Expert* or *Service*.

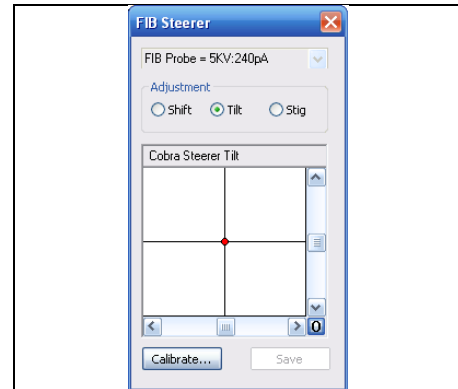


IMPORTANT

A probe current of 50 pA is used as reference. The other probe currents are dependent on this reference.

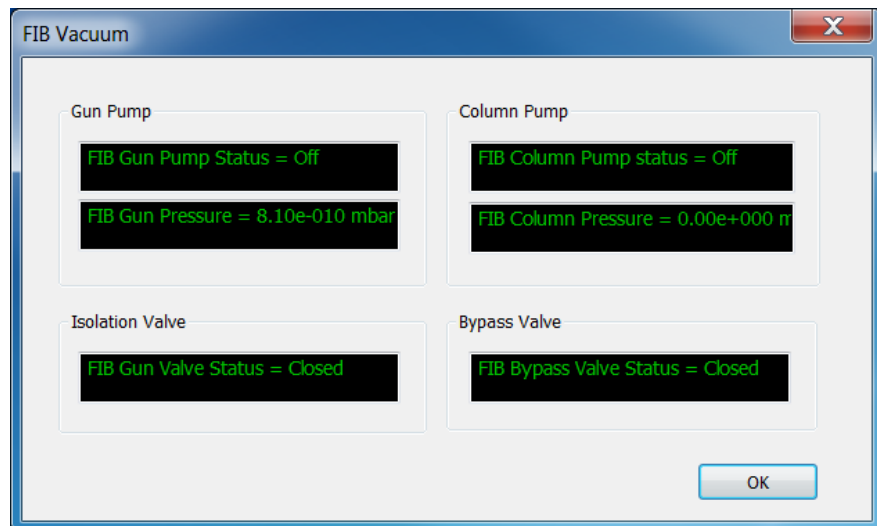
- **Done**
Closes the **FIB Probe Table**.
- **Switch To**
Sets the FIB to the selected values.
- **Add**
Inserts a new entry. Opens the **Select KV value to use** window.
- **Delete**
Removes an entry.
- **Edit/End Edit**
Allows you to change the settings.
- **Cancel**
Undoes the changes.
- **FIB Control**
Opens the **Align** tab of the **FIB Control** panel.

- **Steerer Control (Cobra column only)**
Opens the **FIB Steerer** window to adjust symmetric illumination of the image.



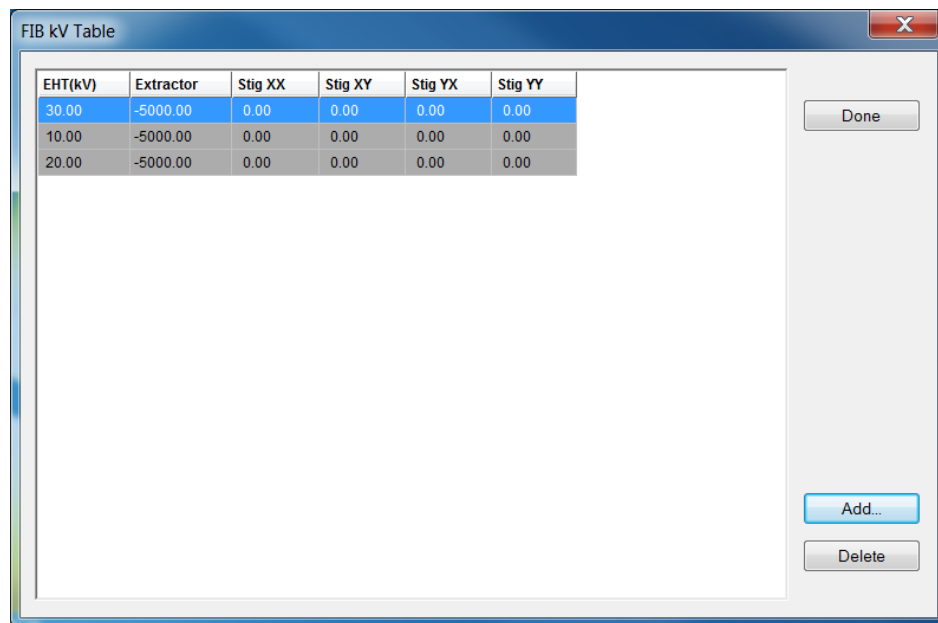
7.2.8. FIB Vacuum

Displays the current vacuum status of all FIB components



7.2.9. FIB kV Table

The FIB kV Table allows you to add and delete custom EHT values.

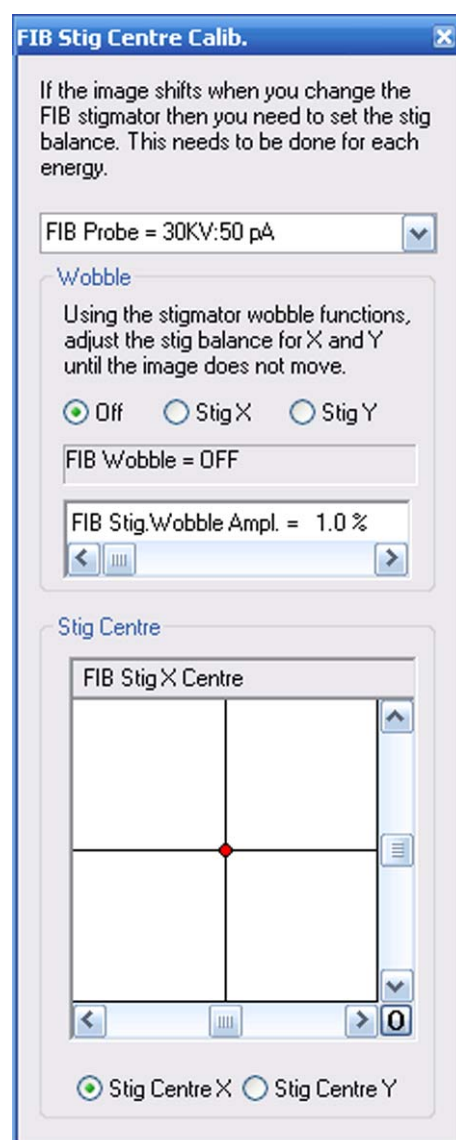


- **Done**
Closes the FIB kV Table
- **Add**
Inserts a new entry. Opens the **New EHT Value** window.
- **Delete**
Removes an entry.

7.2.10. FIB Stig Centre Calib.

Calibrates the FIB stigmator.

- **FIB Probe**
Select the FIB probe current
- **Wobble**
Off/StigX/StigY
- **FIB Stig Wobble Ampl.**
Sets the wobble intensity.
- **Stig Centre X**
Changes the stimator X.
- **Stig Centre Y**
Changes the stimator Y.



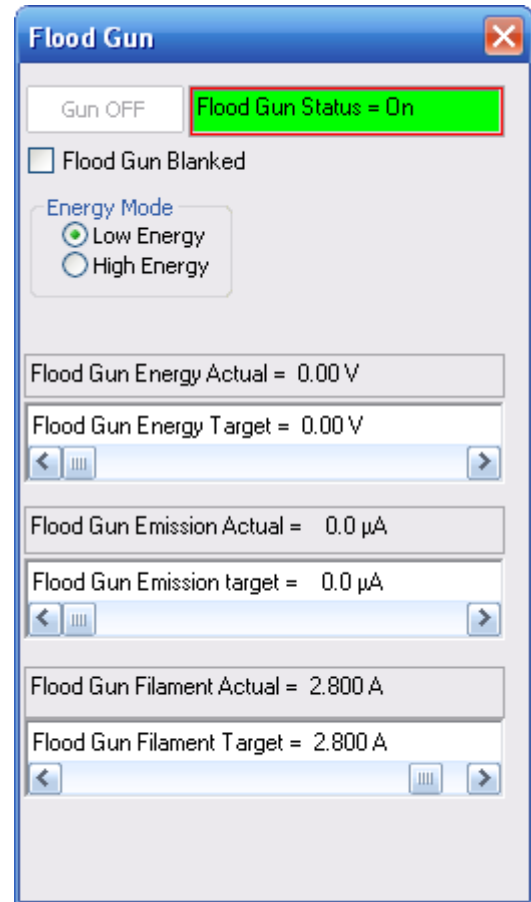
7.2.11. Flood Gun

Operates the optional Flood Gun.

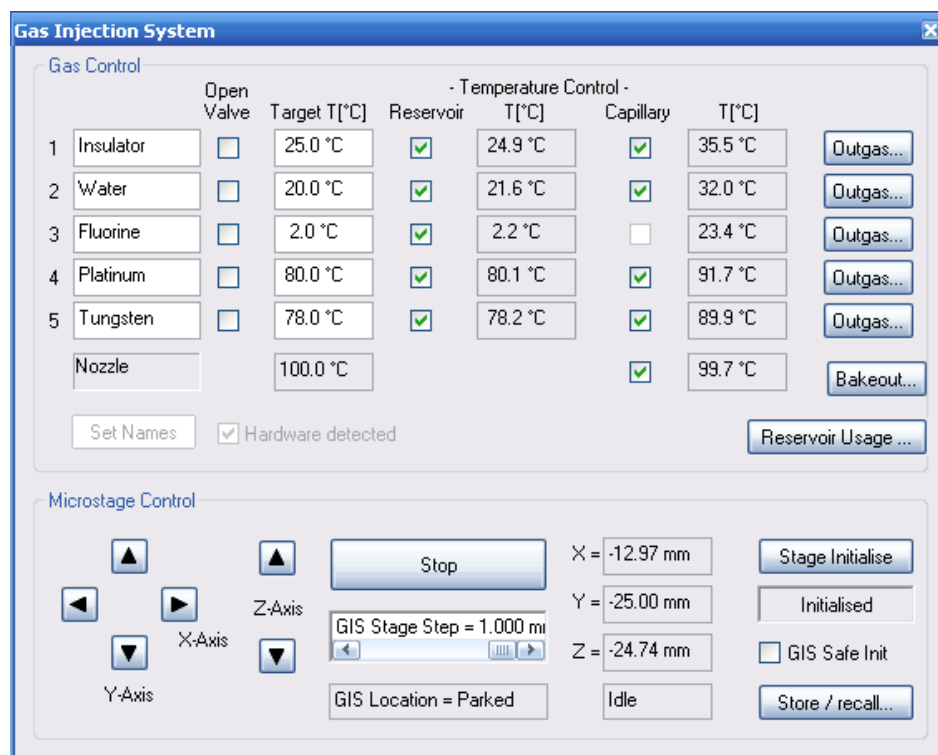
- **Gun ON/OFF**
Switches the Flood Gun on/off.
- **Flood Gun Status**
Indicates the current status of the Flood Gun.
Off = Flood Gun is switched off
On = Flood Gun is switched on
Blanked = electron energy is set to zero; emission current to 1.5 x the previous emission current or the highest emission current, whichever is lower

Interlocked = An interlock has been triggered and the Flood Gun cannot be used until the threshold which triggered the interlock has returned to normal working conditions.

- **Flood Gun Blanked**
Blanks/unblanks the Flood Gun.
When blanked, the Electron Energy of the Flood Gun will be set to zero and the Emission current will be set to 1.5 x Previous emission current or the highest emission current limit, whichever is lower.
- **Energy Mode**
Selects the energy mode. In most cases, **Low Energy** will be the suitable selection.
Low Energy =
The Flood Gun Energy Target is set 10 V
High Energy =
The Flood Gun Energy Target is set 500 V
- **Flood Gun Energy Actual**
Indicates the current Flood Gun energy.
- **Flood Gun Energy Target**
Sets a target value for the Flood Gun energy.
- **Flood Gun Emission Actual**
Indicates the current Flood Gun Emission.
- **Flood Gun Emission Target**
Sets a target value for the Flood Gun Emission.
- **Flood Gun Filament Actual**
Indicates the current Flood Gun filament current.
- **Flood Gun Filament Target**
Sets a target value for the Flood Gun Emission.



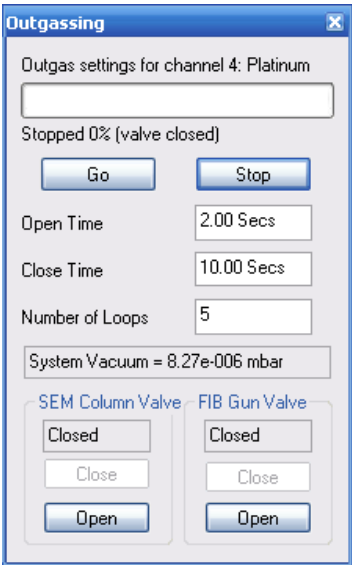
7.2.12. Gas Injection System (optional)



- **Open Valve**
If ticked, the valve of the precursor is open.
- **Target T (°C)**
Clicking in this field allows setting the target temperature of the gas line.
- **Temperature Control Reservoir**
If ticked, the reservoir is heated to the target temperature.
- **Temperature Control T (°C)**
Shows the current reservoir temperature.
- **Capillary**
If ticked, the capillary is heated.
- **T (°C)**
Shows the current capillary temperature.

7. Summary of software functions
Panels on the Panel Configuration Bar

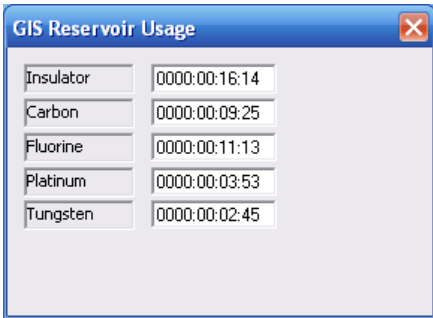
- **Outgas**
Opens the **Outgas** panel.



- **Bakeout**
Opens the **GIS Bakeout** panel.



- **Reservoir Usage**
Opens the **GIS Reservoir Usage** panel.
Shows the duration of the valve open status of the individual precursors.



- **Microstage Control**
Allows driving the GIS micro stage.
- **GIS Safe Init**
If ticked, the specimen stage is driven to a low Z before the GIS micro stage is initialised.

7.3. Shortcuts

Many functions and menus which are often used in the SmartSEM[®] user interface can also be opened using the keyboard.
The different CrossBeam[®] specific keys and key combinations in the SmartSEM[®] software are briefly explained in the table below.

Key/Key combination	Function
<F5>	Displays the FIB Align tab.
<F6>	Records a single frame.
<F8>	Toggles between SEM view and FIB view.
<F9>	Calls the help function for shortcut keys.
<Ctrl + Tab>	Calls the Centre Point function that allows to centre a point in the middle of the image area.

Table 7.1: Important keys and key combinations

8. Abbreviations

2D	Two dimensional
4QBSD	Four quadrant backscattered electron detector
ABCC	Automatic brightness and contrast control
ASP	Auto Sample Preparation
Auto BC	Auto brightness and contrast
AVI	Audio video interleaved
BC	Brightness and contrast
BMP	Bitmap
DB	Database
DLC	Diamond like carbon
EDX	Energy dispersive spectroscopy
EHT	Extra high tension
EM	Electron microscope
EsB	Energy selective Backscattered electrons
FCF	Frame Corrected Focus = Dynamic Focus
FESEM	Field emission scanning electron microscope
FIB	Focused ion beam
FTP	File transfer protocol
GAE	Gas assisted etching
GIS	Gas injection system
HV	High vacuum
I	Current
I ₂	Iodine
ID	Identification
JPEG	Joint Photographic Experts Group
LB	Left mouse button
LUT	Look-up table
Mag	Magnification
MB	Middle mouse button
PMCPs	2,4,6,8,10-Pentamethylcyclopentasiloxane
Pt	Platinum
SCM	Specimen current monitor
SE	Secondary electron

8. Abbreviations

SEM	Scanning electron microscope
Si	Silicon
TEM	Transmission electron microscope
TIF, TIFF	Tagged image format
UIF	User interface
V	Voltage
VOI	Volume of interest
VP	Variable pressure
W	Tungsten
WD	Working distance
XB	CrossBeam®
XeF ₂	Xenondifluoride

9. Glossary

Administrator	The SmartSEM® Administrator is part of the SmartSEM® program suite, which allows user management e.g. creating users and assigning them with certain privileges. The SmartSEM® Administrator is protected by an administrator password.
Annular milling	With the annular milling function you can mill circles more exactly because the ion beam scans the specimen surface following circle lines.
Auto Sample Preparation (ASP)	Routines that allow the automated FIB preparation of cross sections and TEM lamellas. All milling parameters for a particular sample preparation type are stored in a corresponding sample file and can repeatedly be applied to other specimen regions as often as required.
Chord	When using the feature milling function, the ion beam scans the specimen surface following horizontal lines which are called chords.
Chord list	When using the feature milling function, a chord list is created from all created objects which are indicated as red areas in the FeatureMill window.
Coincidence point	Point where electron beam and ion beam are crossed. Almost all CrossBeam® applications are done at the coincidence point with the specimen stage tilted to 54 degrees, because only at this location live imaging during milling is possible.
Crosshairs	A graphical object for assessing the relative position of objects in the image.
Deposition	Process that deposits material on the specimen surface. To start and maintain this process the ion beam is required.
Dongle	A device that is needed in order to use protected software.
E-beam deposition	Depositing with the electron is a suitable method for materials that cannot be processed with the focused ion beam, e.g. quartz masks.
EM Server	A server that implements the internal communication between control software and microscope hardware.
Emission current	The sum of electrons that have been emitted from the filament tip surface.
Etching	Process that removes material from the specimen surface.
Eucentric	Type of specimen stage, the rotation axes of which intersect in the same point. The specimen surface is located in the eucentric point, where the tilt axis meets the beam axis. This guarantees that the focus is maintained when the specimen is tilted at a certain working distance.
Expert	One of the SmartSEM® user levels, good for a person with special knowledge and training in operating a FESEM.
Feature milling	Function that allows you to mill any geometrical object, letters (texts) or image files (bmp or dxf).

FIB Server	A server that implements the internal FIB specific communication between control software and microscope hardware.
Gas assisted etching (GAE)	Type of etching that allows you to increase etching rates compared to etching with ion beam or electron beam alone. This is done by emitting a local flow of process gas.
Gas Injection System (GIS)	The GIS consists of precursor reservoirs for up to five different process gases, a capillary and a nozzle for each gas and a GIS micro stage for accurate positioning of the nozzles The GIS is essential for the deposition of metals and insulators as well as for etching.
Graticules	A grid displayed over the image.
High current	Mode which increases the active probe current obtained by a stronger activation of the condenser lens.
Licence	Licences are used to enable specific functionality in the SmartSEM [®] software.
Milling	Milling stands for the local removal of surface material by means of the focused ion beam
Milling object	A milling object defines the area to be scanned by the focused ion beam. Milling objects are geometrical patterns such as line, rectangular, and trapezium. Moreover, several milling parameters such as milling mode, milling current, width, and height characterise a milling object.
Novice	One of the SmartSEM [®] user levels, good for a person who is new and has little experience in operating a FESEM.
Probe currents	The current measured below the apertures. With CrossBeam [®] workstations the probe current can be continuously adjusted in the range between 1 pA and 50 nA. Among other things, the probe current depends on aperture size and condenser setting.
Service/Full	The highest SmartSEM [®] user level.
Supervisor	Privilege that permits to start the Administrator and - among others - enables to edit or create user directories and to start the bakeout function.
User preferences	Section that allows you to define user-specific pre-setting of the SmartSEM [®] user interface e.g. language or pressure units.
Zone	Part of the image area when displaying different detector signals or image areas.

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