Carl Zeiss Microscopy - Electron and Ion Beam Microscopy

AURIGA® series

Modular CrossBeam® workstation

Instruction Manual

ZEISS

AURIGA® series
Modular CrossBeam® Workstation

Original instructions

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1. About this manual

This instruction manual is considered to be part of the AURIGA® series workstation.

Read the instructions carefully. Keep the instruction manual nearby the workstation and hand it over to future owners of the instrument.

This instruction manual is designed for users who have been trained to operate the workstation by an authorised Carl Zeiss expert. Operators of the workstation must not deviate from the instructions provided in this document.

Reference to related documents

For detailed information regarding the operating software refer to

- Software Manual SmartSEM® for general information on FESEM operation (basic workstation)
- Software Manual SmartSEM® XB for CrossBeam® specific topics (FIB and GIS upgrade)

For details on technical data refer to the documents Product Specification and Installation Requirements.

For details on optional components of the workstation refer to the respective manuals delivered with the workstation. You will find these manuals in the document folder.

Models

The AURIGA® series includes the following models:

- AURIGA®
- AURIGA® 60

At a glance

This instruction manual contains the following chapters:

1. About this manual	Explains function and structure of this instruction manual
2. Safety	Summarises important safety details
3. Description	Describes structure and principle of operation of the workstation
4. Transport and storage	Gives details on transport and storage
5. Installation	Refers to Carl Zeiss service staff
6. Operation	Introduces fundamental operation procedures
7. Maintenance and repair	Describes preventive maintenance and repair tasks
8. Troubleshooting	Summarises clues to solve possible problems
9. Shutdown and disposal	Summarises notes on shutdown and disposal
10. Parts and tools	Lists consumables, spare parts, tools, and accessories
11. Abbreviations	Alphabetical list of abbreviations used in this instruction manual
12. Glossary	Alphabetical list of important technical terms
13. Declaration of conformity	Important declaration
14. Index	Alphabetical list of key words that are referred to in this instruction manual

1.1. Safety instructions in this manual

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

DANGER

This safety symbol and signal word indicates an imminently hazardous situation. Disregarding this warning WILL result in death or serious injury.

WARNING

This safety symbol and signal word indicates a potentially hazardous situation. Disregarding this warning COULD result in death or serious injury.

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.

IMPORTANT

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

1.2. 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 on the **Magnification** icon. Select **File/Exit** from the menu.	Icons, buttons, and menus are printed in bold.
Enter *10 kV* in the **EHT target** field.	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.

1.3. Definition of terms

The following terms are used in this instruction manual:

Workstation	The models of the AURIGA® series are CrossBeam® workstations, referred to as workstation.
AURIGA®	Includes the models AURIGA® and AURIGA® 60
SmartSEM®	Operating software for Carl Zeiss field emission scanning electron microscopes
Operator	A trained person, who is assigned to operate the workstation. *Basic operator:* Person who has been trained to perform fundamental operation sequences *Specially trained operator*: Electrically skilled person who has been trained to perform basic maintenance tasks
User	A person or organisation that uses products of Carl Zeiss.
Carl Zeiss service engineer, Carl Zeiss service staff	Specially trained service expert, either Carl Zeiss staff or authorised service partner of Carl Zeiss.
EMO box	Emergency off box; a safety device that contains the safety related electronics to switch off the workstation (and connected options) completely in case of an emergency.
EMO button	Emergency off button; to be pressed in an emergency to de-energize the workstation completely.
FIB	Focused ion beam
GEMINI® column	Electron optical column
Cobra column	Type of FIB column (optional)
Canion column	Type of FIB column (optional)
Coincidence point	Point where electron beam and ion beam are crossed.
GIS	Gas injection system (optional) Several different types of available

This instruction manual refers to the operating software SmartSEM® V05.04 (AURIGA®) and SmartSEM® V05.05 (AURIGA® 60).

2. Safety

2.1. Intended use

AURIGA® series instruments are CrossBeam® workstations that allow microscopic examination and modification of suitable specimens.

The workstation has been designed in a modular manner so that it can exist in different upgrade stages. At *maximum* upgrade stage, the workstation allows you to perform the full range of FESEM and CrossBeam® applications, which are:

- **SEM operation**
  A focused beam of electrons is scanned across the specimen to generate an image or to analyse the specimen.
  Suitable for the analysis of surface structures and near-surface structures of appropriate specimens.
- **FIB Imaging** (requires FIB column)
  A focused beam of ions is scanned across the specimen to generate an image or to analyse the specimen.
- **Milling** (requires FIB column)
  A focused beam of ions locally removes material from the specimen surface.
- **Gas assisted etching with ion beam** (requires FIB column and gas injection system)
  With the help of a process gas, the focused ion beam cuts into the specimen surface.
- **Gas assisted deposition with ion beam** (requires FIB column and gas injection system)
  With the help of a process gas, the focused ion beam deposits material onto the specimen surface.
- **Gas assisted etching with electron beam** (requires gas injection system)
  With the help of a process gas, the electron beam cuts into the specimen surface.
- **Gas assisted deposition with electron beam** (requires gas injection system)
  With the help of a process gas, the electron beam deposits material onto the specimen surface.

For all of these applications, the specimen has to be located in the evacuated specimen chamber.

IMPORTANT

Depending on the upgrade stage of your workstation, not all of theses features may be available.

Commercial use only

The workstation is to be used in a laboratory environment for commercial purposes only.

Using the workstation for any other purpose is not allowed and could be hazardous.

Gas injection system

If the workstation is equipped with a gas injection system (GIS), up to *five* different precursors out of the following can be available:

Reactive product	Precursor	Used for
Tungsten	$W(CO)_6$ Tungsten hexacarbonyl	deposition
Platinum	$C_9H_{16}Pt$ Methylcyclopentadienyl(trimethyl)platinum (IV)	deposition
Silicon dioxide (insulator)	$C_{12}H_{24}O_6Si$ Diacetoxydi-t-butoxysilane	deposition
Carbon	$C_{14}H_{10}$ Phenanthrene	deposition
Gold	Dimethyl(acetylacetonate)gold(III)	deposition
Fluorine	XeF_2 Xenondifluoride	gas assisted etching, selectively etches Si, SiO_x
Water (reactive product)	$MgSO_4 * 7\ H_2O$ Magnesium sulphate heptahydrate	gas assisted etching selectively etches hydrocarbon
Iodine*	I_2	gas assisted etching, selectively etches aluminum/ aluminum oxide

Table 2.1: Overview of available precursors

*Iodine is not available for the US market.

Using the GIS for any other purpose is not allowed and could be hazardous.

Likewise, it is not allowed to use the GIS in combination with any other precursor not mentioned in table 2.1.

For safety reasons, mixing of precursors is not possible due to technical measures.

2.2. Prevention of accidents and of improper use

CAUTION

Risk of injury or damage due to improper operation of the workstation.

Read the user documentation carefully.
Do not operate the workstation until you have completely read and understood this instruction manual and the entire user documentation delivered with the workstation.
You will find the user documentation in the document folder.

Operator training

Within the scope of initial start-up the Carl Zeiss service staff will perform a basic operator training. The basic operator training consists of fundamental operation procedures including safety instructions. Besides, an introduction to basic maintenance tasks will be given for an advanced operator, who has to be an electrically skilled person.
The training performed shall be documented appropriately.

Special application trainings are offered on request.

IMPORTANT

All pursuing tasks of maintenance, service, and repair not described in this instruction manual have to be performed by authorised Carl Zeiss service staff only.

2.3. Safety summary

Follow the safety instructions given in this instruction manual. This is essential to prevent damage and to protect yourself and others against accidents and unsafe practices. Do not deviate from the instructions provided in this instruction manual.

This section summarises possible hazards and recommended safety procedures.

2.3.1. Hazards related to personal injury

Service tasks

DANGER

Danger to life: Hazardous voltage inside the workstation.
Only service engineers trained and authorised by Carl Zeiss are allowed to service the workstation.

Radiation protection

X-rays are produced within the workstation during operation. This is unavoidable since accelerated electrons hit material thus generating radiation.

WARNING

Radiation hazard: X-rays are generated inside the workstation during operation.

Only authorised Carl Zeiss service engineers are allowed to service the workstation.
Do not remove any parts. Do not disable any parts of the interlock system.
Use genuine Carl Zeiss parts exclusively.
Observe all safety and X-ray protection regulations.

In Germany, the operation of the workstation is permission-free as the following requirements are fulfilled:

- The maximum acceleration voltage is limited to 30 kV.
- The local dose rate at a distance of 0.1 m from the accessible surface of the workstation does not exceed 1 µSv/h.
- A respective label is attached to the workstation.

Outside Germany, the user of the workstation has to comply with the local regulations of the country where the workstation is operated.

The workstation is equipped with several radiation protection devices, which ensure - under regular operation conditions - that the workstation operates in accordance with the German X-ray protection regulation (RöV) respectively the German radiation protection regulation (StrSchV) as well as with the EC Directive 96/29/EURATOM.

Electrical connections

CAUTION

High leakage current
Ensure proper grounding.
Do not operate the workstation without separate ground connection.

Gases

Gaseous dry nitrogen is used to ventilate the specimen chamber during specimen exchange. Compressed air is used to operate several valves and the auto levelling system.

CAUTION

Suffocation hazard due to lack of oxygen, since the specimen chamber is ventilated with gaseous nitrogen. Inhaling nitrogen may cause unconsciousness.
During specimen exchange, keep the chamber door open as short as possible.
Avoid inhaling the air from within the specimen chamber.
Ensure the area around the workstation is sufficiently ventilated.

IMPORTANT

Concerning the hazards of nitrogen installations and associated safety precautions refer to the current version of guideline IGC Doc 44/00/E: Hazards of inert gases, published by EIGA (European Industrial Gases Association) which can be found on the EIGA homepage www.eiga.org/Publications/Documents.

CAUTION

Risk of injury or damage due to the high internal pressure in gas cylinders (e.g. containing nitrogen or compressed air).
Observe all safety labels on the gas cylinders and all safety instructions given by the gas cylinder manufacturer.

CAUTION

Crushing hazard while load is being lowered.
Maintain a safe distance. Do not walk or place your hands or feet under the load while it is being lowered. Wear safety shoes and gloves.

Operation

CAUTION

Risk of injury
Fingers could be trapped in the moving specimen stage.
Always close the chamber door before you move the specimen stage.

CAUTION

If you work with aggressive or toxic chemicals there may be a risk of injury.
Wear suitable protective clothing, gloves and eye/face protection. Do not eat, drink or smoke at work. Refer to local safety regulations.

CAUTION

Risk of injury due to aggressive or toxic chemicals.
Risk of damage to environment.
When disposing of waste that has been generated during a service operation comply with all national and local safety and environmental protection regulations.

GIS

The optional gas injection system allows injecting process gases onto the specimen surface. During operation, the process gases are generated out of precursor substances.

CAUTION

Hazard due to irritant gases that might be released from the precursors.
Gases can cause irritation to eyes, skin, and respiratory system.

Do not remove a reservoir from the workstation.
Contact the Carl Zeiss service to have an empty reservoir replaced.
Never try to open a reservoir.

During operation, unknown reaction products may be generated, when specimen material, reactive precursor products, electron beam and/or ion beam get in contact.

CAUTION

Hazard due to dangerous reaction products that might be present in the specimen chamber during or after operation.
Wear personal protective equipment when touching the inner parts of the specimen chamber or the specimen.
Do not remove a reservoir from the workstation.
Contact the Carl Zeiss service to have an empty reservoir replaced.
Never try to open a reservoir.

Maintenance procedures

Baking out the gun head has to be performed as a regular maintenance procedure.
Only advanced operators are allowed to perform the bakeout procedure.

CAUTION

Burn hazard
Some parts inside the workstation will get hot during the bakeout procedure.
Do not place any combustible objects on the grids of the electron optical column.

2.3.2. Hazards not related to personal injury

CAUTION

Risk of property damage when opening the chamber door.
Workstation or specimen could be damaged if specimen stage is at short working distance.
Always move specimen stage to long working distance before opening the chamber door.

CAUTION

Risk of property damage
Connect Carl Zeiss approved equipment only.
Ensure the total load connected to the workstation does not exceed 10 A.

IMPORTANT

Fingerprints can cause virtual vacuum leaks.
Always wear lint-free gloves when touching the specimen or inner parts of the specimen chamber.

2.4. Safety equipment

2.4.1. Safety devices

In order to prevent any risk of hazard to human health or of property damage, the workstation is equipped with several safety and protective devices.

2.4.1.1. Protective cover panels

Plinth, electron optical column and specimen chamber are secured with protective cover panels.

WARNING

Hazardous voltage inside the workstation. Contact may cause burn or electric shock.
X-rays are generated inside the workstation during operation.
Do not remove any parts.
The workstation must not be operated with removed protective cover panels.

2.4.1.2. Interlock system

The interlock system includes several functions.

Chamber door interlock

The chamber door interlock is located at the inner bottom front side of the specimen chamber.

It ensures that the door of the specimen chamber is closed properly.
When this interlock is activated (i.e. no electrical contact) '*EHT Vac ready = no'* is indicated in the SmartSEM® user interface. EHT and detector voltages are blocked.

Gun head interlock

The gun head interlock is located at the top of the electron optical column.

It ensures that the high voltage interlock circuit is cut off when the gun head is opened.

When this interlock is activated (i.e. no electrical contact), gun and EHT cannot be switched on. All high voltages are blocked.

Vacuum interlock

The vacuum interlock is an internal interlock.

It ensures that Gun vacuum and System vacuum are better than the required thresholds.

If this interlock is activated gun respectively EHT cannot be switched on.

2.4.1.3. ON/OFF switch

The **ON/OFF SWITCH** is located at the rear of the plinth. It cuts off the mains power from the FESEM.

Without optional EMO box:
The ON/OFF switch has the function of a main switch.

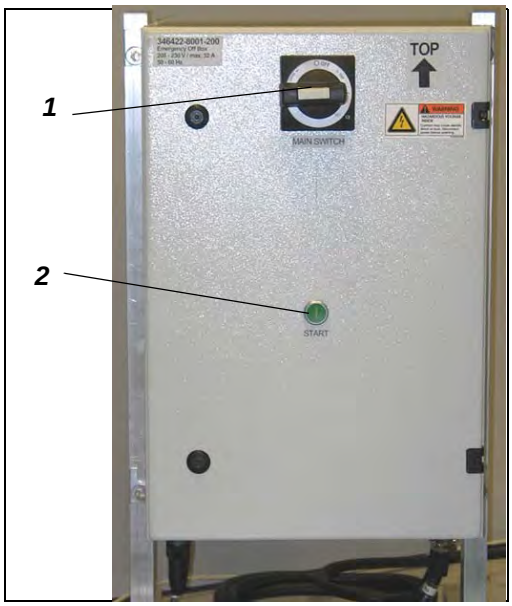
With optional EMO box:
The FESEM is switched off.
Other devices connected to the EMO box remain turned on.

2.4.1.4. EMO box with main switch (optional, but mandatory with FIB and/or GIS upgrade)

The **MAIN** switch (***1***) is located at the front panel of the EMO box.

It cuts off all devices connected to the EMO box from the mains power supply. The main switch can be secured against re-activation.

The main switch guarantees an ampere interrupting capacity (AIC) of at least 10000 A rms.



The **START** button (***2***) is located underneath the **MAIN** switch.

IMPORTANT

The EMO box with MAIN switch has an emergency off function.

2.4.1.5. EMO button (optional, but mandatory with FIB and/or GIS upgrade)

The emergency off button (EMO button) is located on the plinth.

The EMO button is to be pressed in an emergency to cut off power to all devices connected to the EMO box.
It must always be readily accessible and operable.

2.4.1.6. Main shut-off valves

The user is responsible for the installation of main shut-off valves at the site of installation. The following main shut-off valves are required:

- water supply
- water runback
- nitrogen supply
- compressed air supply

The main shut-off valves have to be easily accessible. They must close off the connections to the corresponding media when needed. The main shut-off valves have to be lockable in their OFF position in order to prevent accidental re-activation.

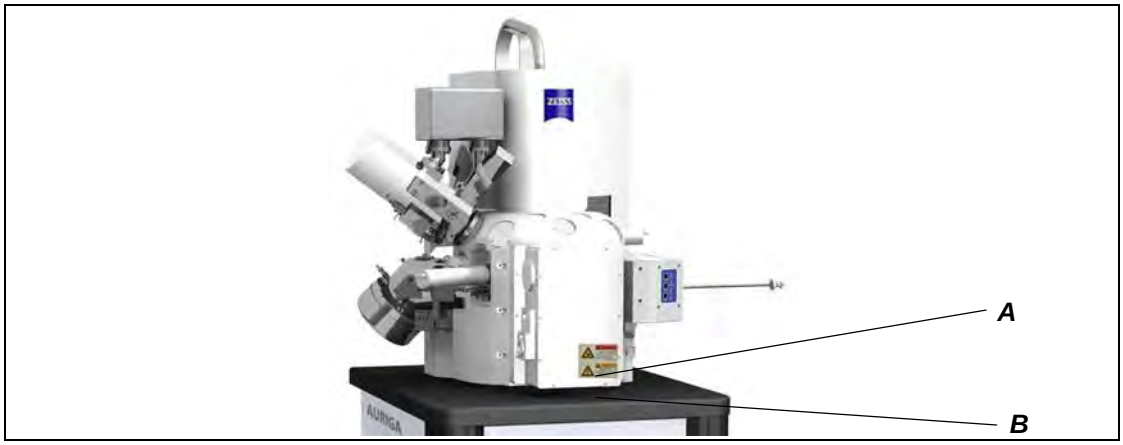
As the user is responsible for installing the main shut-off valves, he/she should also provide instructions how to operate the main shut-off valves properly.

2.4.2. Safety labels and labels

Appropriate safety labels on the workstation warn users of possible hazards. Each safety label is affixed close to the point where a particular hazard exists.

Moreover, you will find several labels which provide legal information.

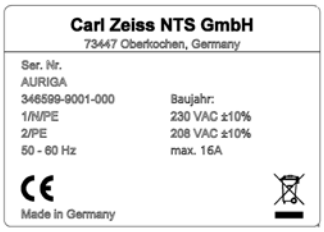
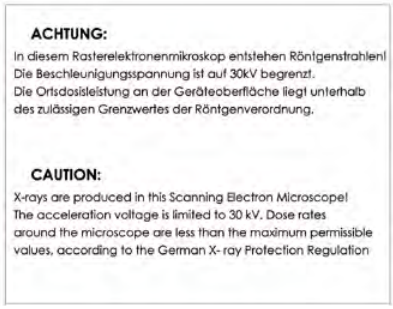
2.4.2.1. At the front of the workstation



Shown on AURIGA®
(AURIGA® 60 has a larger specimen chamber)

Position	Subject	Label	
A	Safety information		**WARNING** **Risk of injury** Fingers could be trapped. Always close the chamber door before you move the stage.
B	Safety information		**CAUTION** **Risk of damage** FESEM or specimen stage could be damaged if the specimen stage is at short working distance. Move specimen stage to longer working distance before opening the chamber door.
	Safety information	 	**CAUTION** **Avoid injury** Read and understand the instruction manual before operating this product.

2.4.2.2. At the rear of the workstation

Subject	Label	
Type plate		 Shown on AURIGA®.
Safety information		**CAUTION** **Radiation hazard** X-rays are generated inside the electron microscope during operation. Do not remove any parts. Use genuine Carl Zeiss parts exclusively. Observe local safety and X-ray protection regulations.
Legal information		
Safety information		**CAUTION** **High leakage current** Ensure proper grounding. Do not operate the electron microscope without separate ground connection.
Safety information		**CAUTION** **Suffocation hazard** Specimen chamber is ventilated with gaseous nitrogen. Ensure the area around the electron microscope is sufficiently ventilated.

2.4.2.3. At the rear of the electron optical column

Subject	Label	
Safety information		**WARNING** **Hazardous voltage inside** Contact may cause burn or electric shock. Only authorised service staff is allowed to service the equipment. Disconnect power before opening.
Safety information		**CAUTION** **Burn hazard** Hot surfaces inside during bakeout procedure. Do not place any combustible objects on the grids of the electron optical column. Only authorised service staff is allowed to service the equipment. Disconnect power and let surfaces cool before opening.

2.4.2.4. Inside the workstation

Underneath the cover panels of workstation there are some more safety labels, which are addressed to authorised Carl Zeiss service engineers. These safety labels are described in the documents for Carl Zeiss service staff.

2.4.3. Material Safety Data Sheets

Material safety data sheets (MSDS) of chemicals used in combination with the workstation are contained in the document folder delivered with the workstation.

2.5. Safety instructions for handling precursors (with GIS upgrade only)

WARNING

Hazard due to irritating and toxic gases.
Gases can cause irritation to eyes, skin, and respiratory system.
High concentrations may cause central nervous disorders.

Do not remove a reservoir from the workstation.
Contact the Carl Zeiss service to have the empty reservoir replaced.
Never try to open a reservoir.

For more information refer to the instruction manual of the GIS and the Material Safety Data Sheets (MSDS).

3. Description

3.1. Overview

AURIGA® series instruments are modular workstations. The basic workstation consists of a field emission scanning electron microscope with GEMINI® column. The following upgrade stages are possible:

	Upgrades			Possible applications
	FIB column	**GIS**	**Charge compensation (CC)**	
Basic workstation with GEMINI® column	-	-	-	SEM operation
	-	-	+[3]	SEM operation Imaging of non-conductive specimens
	-	+[2]	-	SEM operation Electron beam etching Electron beam deposition
	-	+[2 / 4]	+[3 / 4]	SEM operation Electron beam etching Electron beam deposition Imaging of non-conductive specimens
	+[1]	-	-	SEM operation, FIB imaging Milling
	+[1]	+[2]	-	SEM operation, FIB imaging Milling Gas assisted etching Gas assisted deposition Electron beam deposition Electron beam etching
	+[1]	+[2 / 4]	+[3 / 4]	SEM operation, FIB imaging Imaging of non-conductive specimens Milling Gas assisted etching Gas assisted deposition Electron beam deposition Electron beam etching

+[1] Canion column or Cobra column

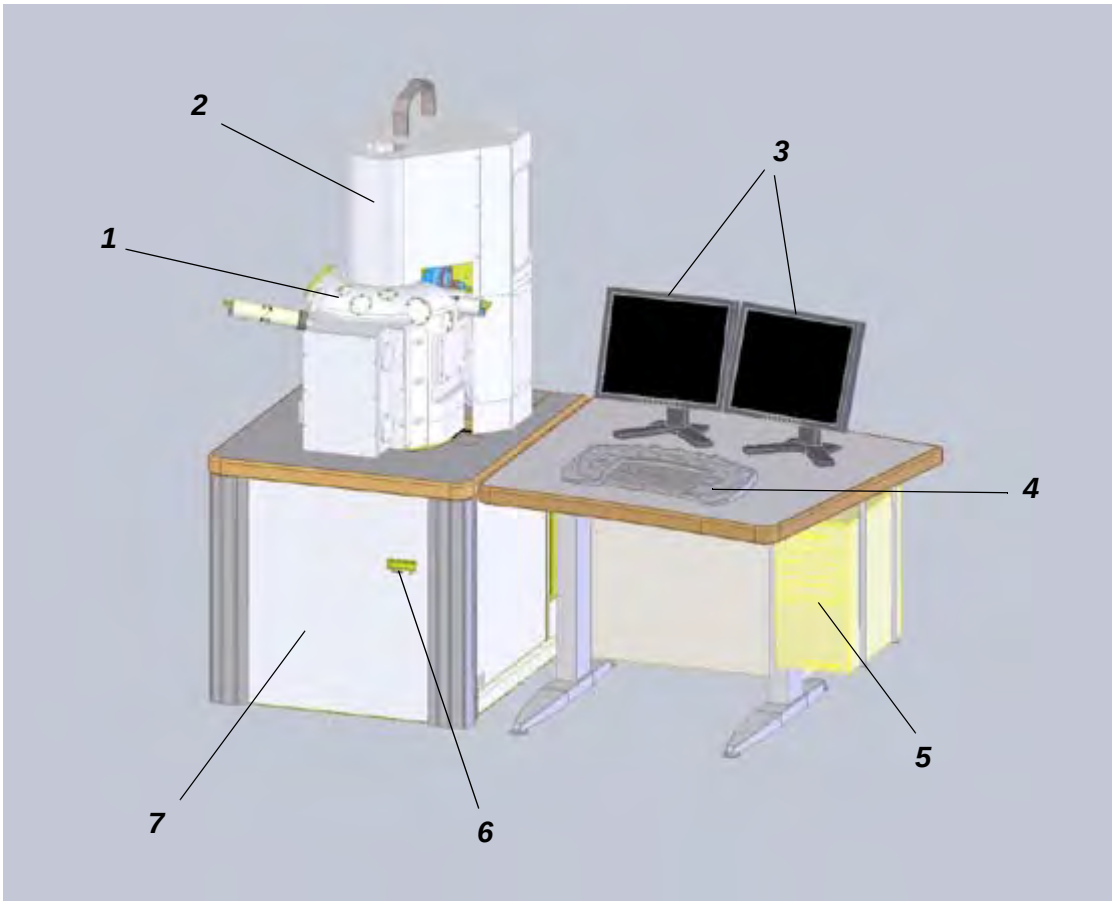
+[2] Five-channel GIS or Single GIS

+[3] Charge Compensator

+[4] Five-channel GIS with integrated charge compensation (CC)

3.2. Basic workstation

3.2.1. View



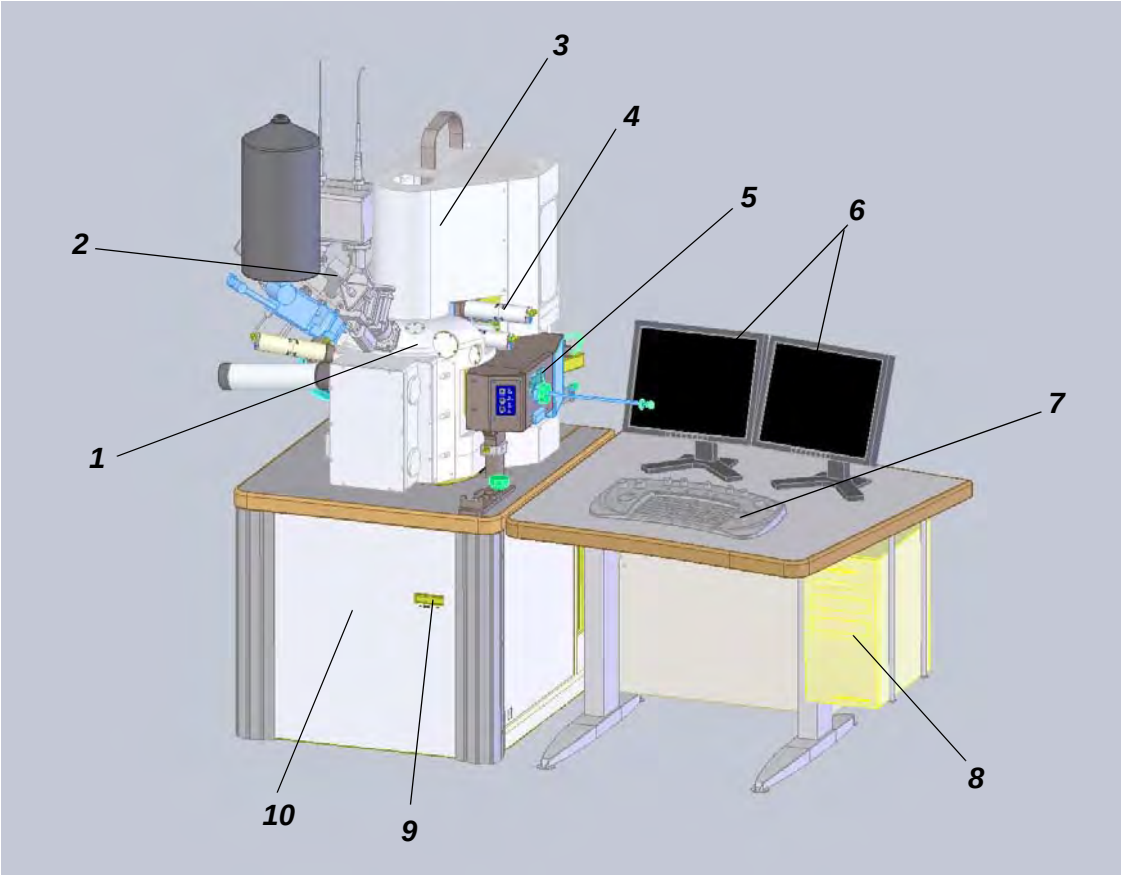
1	Specimen chamber	5	Personal computer (PC)
2	Electron optical column, GEMINI® column	6	ON/STANDBY/OFF button
3	Monitors	7	Plinth
4	Control panel (optional)		

Fig. 3.1: View of AURIGA® basic workstation

The **AURIGA®** 60 basic workstation has a larger specimen chamber.

3.3. Upgraded workstation

3.3.1. View



1	Specimen chamber	6	Monitors
2	FIB column	7	Control panel (optional)
3	Electron optical column, GEMINI® column	8	Personal computer (PC)
4	Detector	9	ON/OFF/STANDBY button
5	Airlock	10	Plinth

Fig. 3.2: View of AURIGA® upgraded workstation

The **AURIGA®** 60 upgraded workstation has a larger specimen chamber.

3.3.2. FIB upgrade

Two types of FIB columns are available:

- Canion column
- Cobra column

3.3.3. Gas injection system (GIS) upgrade

A gas injection system allows the injection of one or more process gases to the specimen surface.

3.3.3.1. Five-channel GIS

The five-channel GIS allows you to inject up to five different precursor gases.
For details refer to the respective Instruction Manual.

3.3.3.2. Single GIS

The one-channel GIS allows you to inject one precursor gas.
For details refer to the respective Instruction Manual.

3.3.4. Charge compensation upgrade

Charge compensation is a method to inhibit charging of non-conducting specimens by injecting a local flow of gaseous nitrogen onto the area of interest.

3.3.4.1. Charge Compensator

The Charge Compensator inhibits charging of non-conducting specimens by emitting a local flow of gaseous nitrogen onto the area of interest.

The pneumatic retraction mechanism allows you to quickly toggle between charge compensation mode and high vacuum mode.

For details refer to the respective Instruction Manual.

3.3.4.2. Five-channel GIS with integrated charge compensation

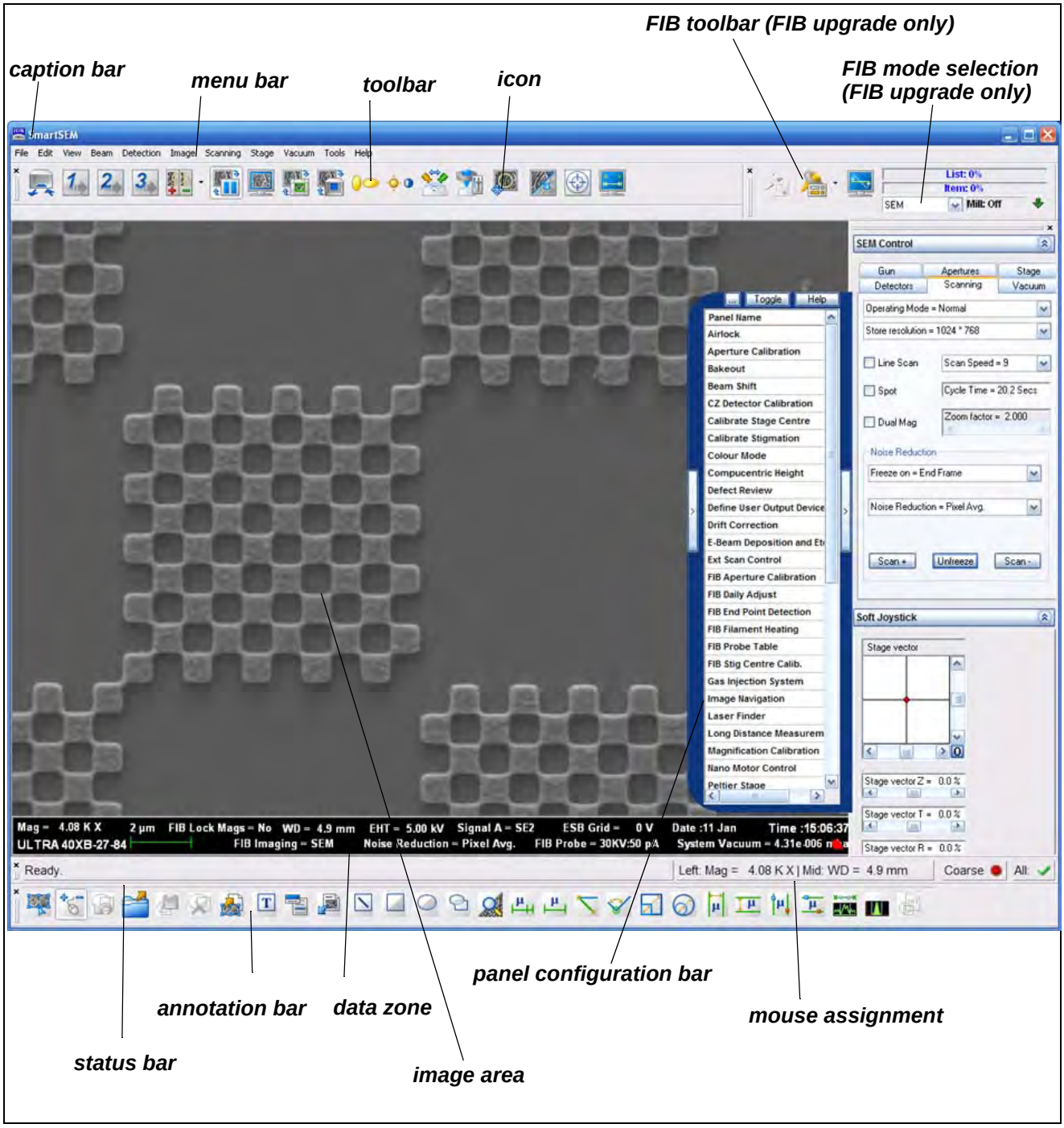
Alternatively, a five-channel GIS with integrated charge compensation function is available.

For details refer to the respective Instruction Manual.

3.4. Control elements

3.4.1. SmartSEM® user interface

The workstation is controlled by the SmartSEM® software. The software is operated via a graphical user interface.



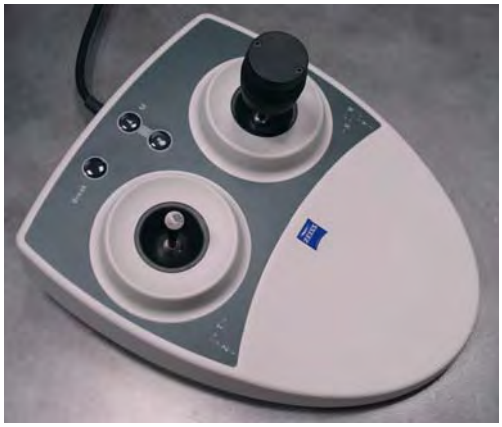
3.4.2. Dual joystick

The dual joystick is used for stage control and specimen navigation.

The big joystick on the right is used to drive X- and Y-axis. The stage rotation is controlled by turning the upper knob to the left or to the right.

The small joystick on the left is used to control the Z axis and the stage tilt (T).

The **Break** push button is an emergency stop for the stage.



All axes are deflection-compensated: When the joystick is only moved slightly, the respective axis will move slowly. However, major movements of the joystick will result in a faster movement of the stage.

Two **M** push buttons allow control of a second Z-axis (M) on super-eucentric stages to set the eucentric point of the specimen tilt on these stages.

The X-, Y-, Z- and M-axes are magnification-compensated. When working at a low magnification, the stage moves relatively fast. At higher magnifications the stage movement is slower.

The different axes can also be moved simultaneously.

3.4.3. Optional control panel

The control panel is optionally available. It integrates a full sized keyboard and allows direct access to 14 of the most frequently used functions on the workstation.

The following functions are available through:

Encoders

- Magnification
- Stigmator X
- Stigmator Y
- Aperture X
- Aperture Y
- Scan Rotate
- Shift X
- Shift Y
- Brightness
- Contrast
- Focus

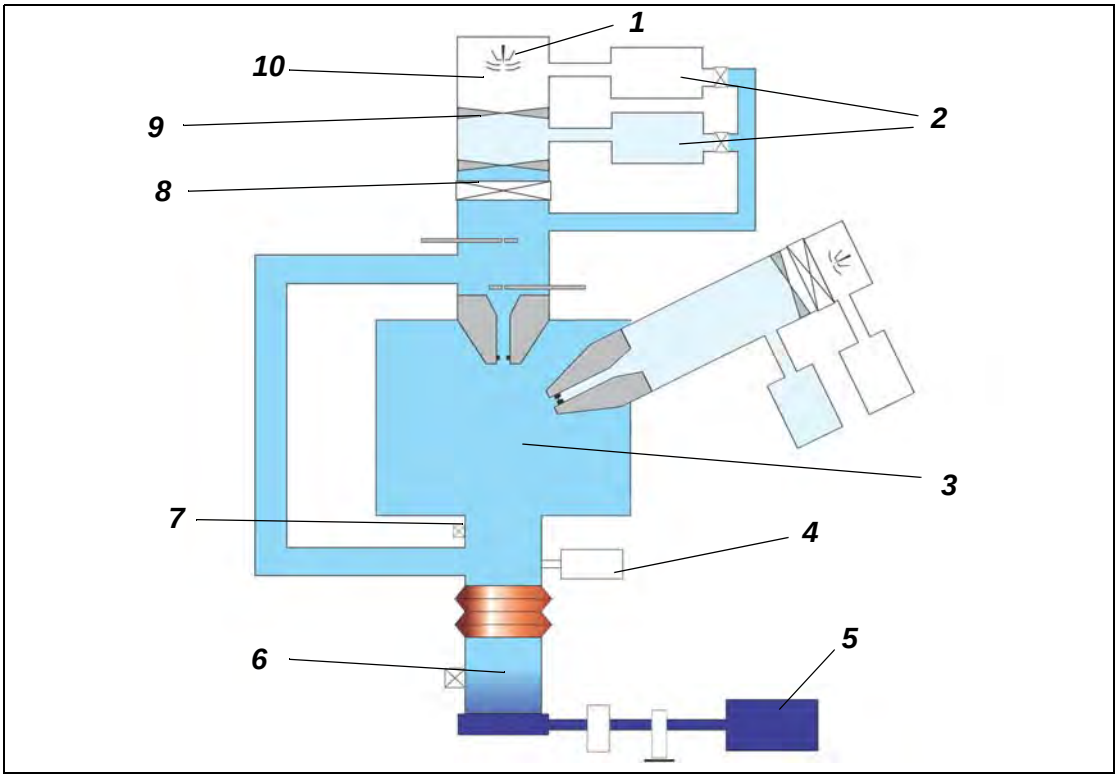
Push buttons

- Reduced
- Wobble
- Freeze
- Exchange
- Resume
- Camera
- Scan Speed +
- Scan Speed -

3.5. Principle of operation

3.5.1. Vacuum system

For operation of the workstation, gun head (***10***), column and specimen chamber have to be evacuated. The vacuum is essential to operate the gun and to prevent collision of electrons and/or ions with gas molecules.



1	Gun with filament	6	Turbo pump
2	Ion getter pumps (IGP)	7	Vent valve
3	Specimen chamber	8	Column chamber valve
4	Penning gauge	9	Multihole aperture
5	Pre-vacuum pump	10	Gun head

Fig. 3.3: Schematics of the vacuum system

System vacuum

Pre-vacuum pump (***5***) and turbo pump (***6***) evacuate the specimen chamber. The vacuum in the specimen chamber is measured by a Penning gauge (***4***). The detected vacuum values are shown as 'System vacuum' in the SmartSEM® user interface. As long as the detected pressure in the specimen chamber is not ready for operation, the column chamber valve (***8***) is closed in order to separate the specimen chamber from the column.

Gun vacuum

In the gun head is a ultra high vacuum, which is maintained by two ion getter pumps (***2***).
The vacuum in the gun head is called 'Gun vacuum'. It should be well below 1 x 10^{-8} mbar.

The specimen is located in the evacuated specimen chamber (***3***). To open the specimen chamber for specimen exchange, you have to break the vacuum in a controlled manner. This is done by the **Vent** command via the SmartSEM® user interface or by pressing the **Exchange** push button on the optional control panel.

Ventilating

When receiving the **Vent** command, the column chamber valve closes and gaseous nitrogen flows into the specimen chamber via the vent valve (***7***). As soon as the pressure equilibrium is obtained, the chamber door can be opened to change the specimen.

Evacuating

In order to continue operation, the **Pump** command makes pre-vacuum pump and turbo pump evacuate the specimen chamber.

As soon as the vacuum in the specimen chamber is ready for operation, the column chamber valve opens and the 'EHT Vac ready' message appears in the SmartSEM® user interface. Gun and EHT can be switched on.

Quiet Mode

The automatically controlled **Quiet Mode** is optionally available.
This option allows switching off the pre-vacuum pump after specimen exchange when the vacuum threshold is achieved.

3.5.2. Specimen stage

Standard specimen stage is a 6-axes motorised super-eucentric stage that is controlled by the SmartSEM® software. The stage can be operated by the dual joystick controller or by using the soft joystick in the SmartSEM® user interface.
The axes are called:

X	X-axis
Y	Y-axis
Z	Height
M	Height (eucentric)
R	Rotation
T	Tilt

The stage is an eucentric one, which means that all rotation axes 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.

When moving a tilted specimen, the specimen is also moved unintentionally in Z direction. The selected feature moves out of view. The so-called super-eucentric stage is equipped with the M-axis, which allows you to move the specimen surface into the tilting plane with the result that a selected feature stays in view and in focus when the stage is tilted at various working distances.

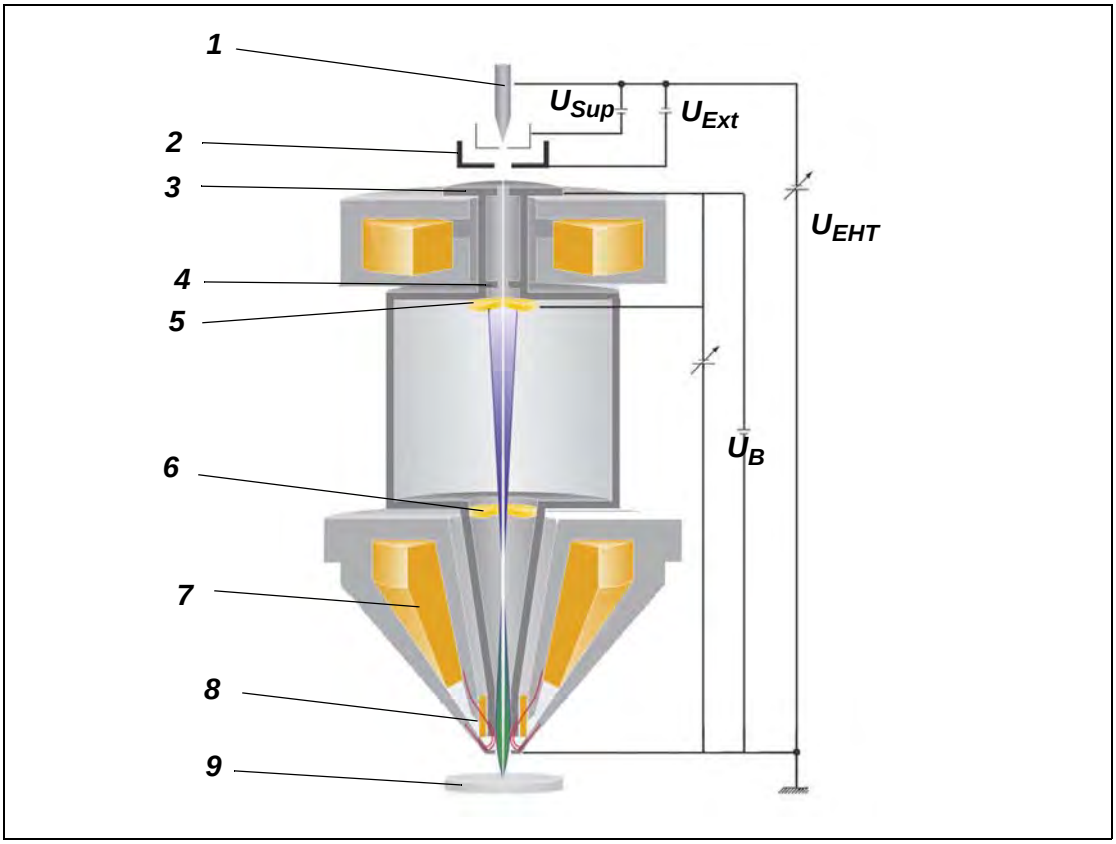
3.5.3. Electron optics (GEMINI® column)

The patented GEMINI® column is the area of the FESEM, where electrons are emitted, accelerated, bundled, focused, and deflected. Main characteristics of the GEMINI® optics are the so-called beam booster and an objective lens that consists of a combined electrostatic/electromagnetic lens doublet.

Gun

A Schottky field emitter serves as gun (***1***). The filament is heated by applying the filament current. Electrons are emitted from the heated filament while an electrical field, called extractor (U_{Ext}) voltage, is applied.

To suppress unwanted thermoionic emission from the shank of the Schottky field emitter, a suppressor voltage (U_{Sup}) is applied as well.



1	Gun	6	In-lens detector
2	Extractor	7	Objective lens
3	Anode	8	Scanning coils
4	Multihole aperture	9	Specimen
5	EsB® detector		

Fig. 3.4: Schematics of the electron optics

EHT

The emitted electrons are accelerated by the acceleration voltage (U_{EHT}).

The beam booster (U_B, booster voltage), which is always at a high potential when the acceleration voltage is at most 20 kV, is integrated directly after the anode. This guarantees that the energy of the electrons in the entire beam path is always much higher than the set acceleration voltage. This considerably reduces the sensitivity of the electron beam to magnetic stray fields and minimises the beam broadening.

Apertures

The electron beam passes through the anode aperture (***3***) first, afterwards through the multihole aperture (***4***). Standard aperture is the 30 µm aperture hole that is the central aperture. The aperture size is decisive for the probe current. Other aperture sizes are selectable to meet the requirements of a wide range of applications.

Stigmator

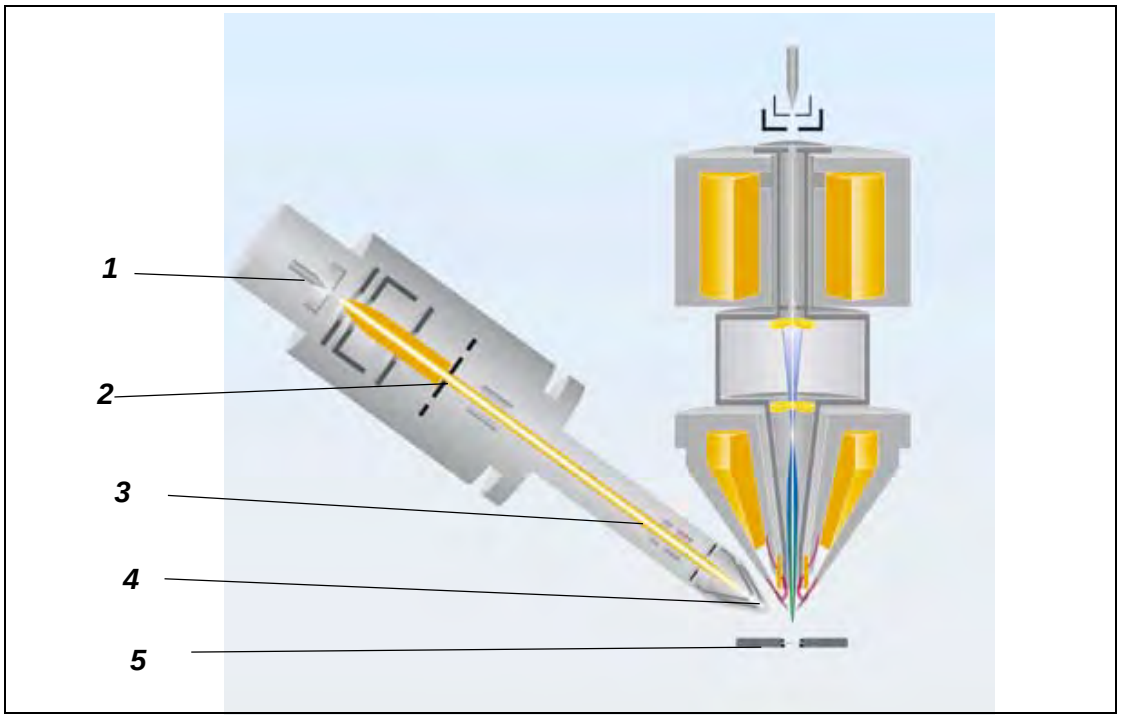
The stigmator compensates for astigmatism, so that the electron beam becomes rotationally symmetrical. The electron beam is focused onto the specimen while being deflected in a point-by-point scan over the specimen surface.

Before the electron beam exits the objective lens (***7***), the electrostatic lens creates an opposing field which reduces the potential of the electrons by + 8 kV. The energy of the electrons reaching the specimen surface (***9***) therefore corresponds to the set acceleration voltage (EHT).

Signal detection

When the primary electron beam hits the specimen, certain interaction products are released, which can be recorded by specific detectors.

3.5.4. Ion optics (FIB column)



1 Ion source (Ga^+)
2 Variable apertures
3 Ion beam
4 Objective lens
5 Specimen

Fig. 3.5: Schematics of the ion optics

The focused ion beam (FIB) column is the part of the CrossBeam® workstation, where ions are emitted, accelerated, focused and deflected.
The FIB column is tilted by 54°.

Two types of FIB columns available:

- Canion column
  7 mechanical aperture positions, 7 nm resolution
- Cobra column
  14 mechanical aperture positions, 2.5 nm resolution

A liquid metal ion source of gallium (Ga^+) serves as ion source (***1***).

Ion source

Gallium ions (Ga^+) are extracted from a liquid metal ion source. The ions are accelerated by the acceleration voltage to an energy of maximum 30 keV. The ion emission is regulated by the extractor and stabilised by the suppressor.

Gallium is used up during operation. Therefore, the gallium emitter cartridge is a consumable. Moreover, the gallium emitter has to be regenerated by heating from time to time; the heating procedure removes the gallium oxide, which has been created during operation.

Condenser The electrostatic condenser collimates and focuses the ion beam depending on the operating mode.

Probe currents After passing the condenser, the beam current is defined by a set of software-controlled mechanical apertures. By using the different apertures in combination with the different condenser settings, 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 settings.

The objective lens is designed as an electrostatic einzel-lens system. It focuses the beam onto the specimen surface.

3.5.4.1. Imaging modes

Provided the optional FIB column is installed, the following 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 signal 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 completely independently from each other.	Setting the coincidence point.
	Mill	No image Mills with the milling parameters 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.

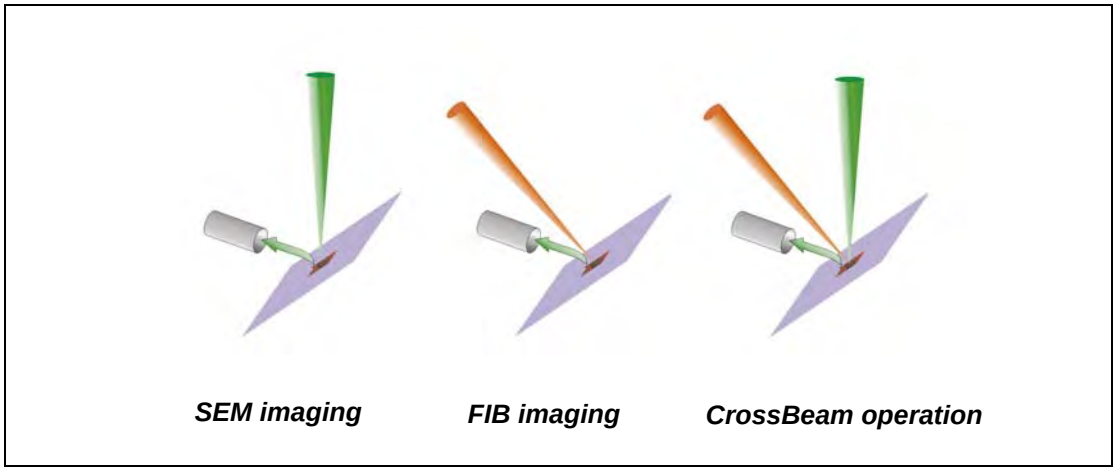


Fig. 3.6: Imaging modes

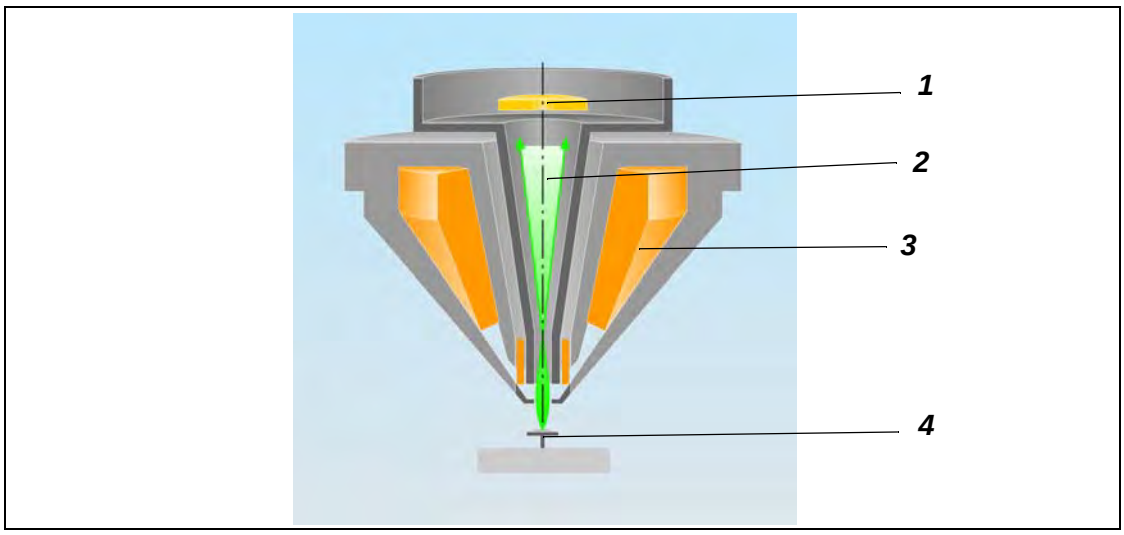
3.5.5. Signal detection

The interaction products most frequently used for the generation of images in scanning electron microscopy are secondary electrons (SEs) and backscattered electrons (BSEs). For the separation and detection of SEs and BSEs one has to consider two parameters: Energy and angle distribution. For that purpose an Energy selective Backscattered electron detector (EsB®) has been developed.

Detector type	Detected signals	Availability	Typical application	Reference
In-lens detector (annular SE detector)	SE	Standard	Surface structure	See section 3.5.5.1.
SE2 detector (Everhart-Thornley type)	SE2	Standard	Topography	See section 3.5.5.2.
EsB® detector with filtering grid (in-column detector)	BSE	Option	Pure material contrast	See section 3.5.5.3.
SESI detector	SE, SI, (BSE)	Option; requires FIB	Topography, material contrast	See section 3.5.5.4.
Further detectors on request.				

3.5.5.1. In-lens detector

The In-lens detector (***1***) is a high efficiency detector for high resolution SE imaging. It is located above the objective lens (***3***) and detects directly in the beam path (***2***). The detection efficiency of this detector results from its geometric position in the beam path and from the combination with the electrostatic/electromagnetic lens.



1	In-lens detector	3	Objective lens
2	Beam path	4	Specimen

Fig. 3.7: Schematics of In-lens detector

At an acceleration voltage of maximum 20 kV, the electrons of the primary electron beam are additionally accelerated by 8 kV, the so-called beam booster voltage.
To ensure that the electrons reach the specimen surface (***4***) with the energy set as acceleration voltage, an electrostatic field is generated at the end of the objective lens by 8 kV. This electrostatic field acts as acceleration field to the SE generated on the specimen surface.

At the In-lens detector, the electrons hit a scintillator generating flashlight that is guided out of the beam path by means of a light guide. The light information is multiplied in a photomultiplier and output as a signal which can be electronically processed and displayed on the monitor.

IMPORTANT

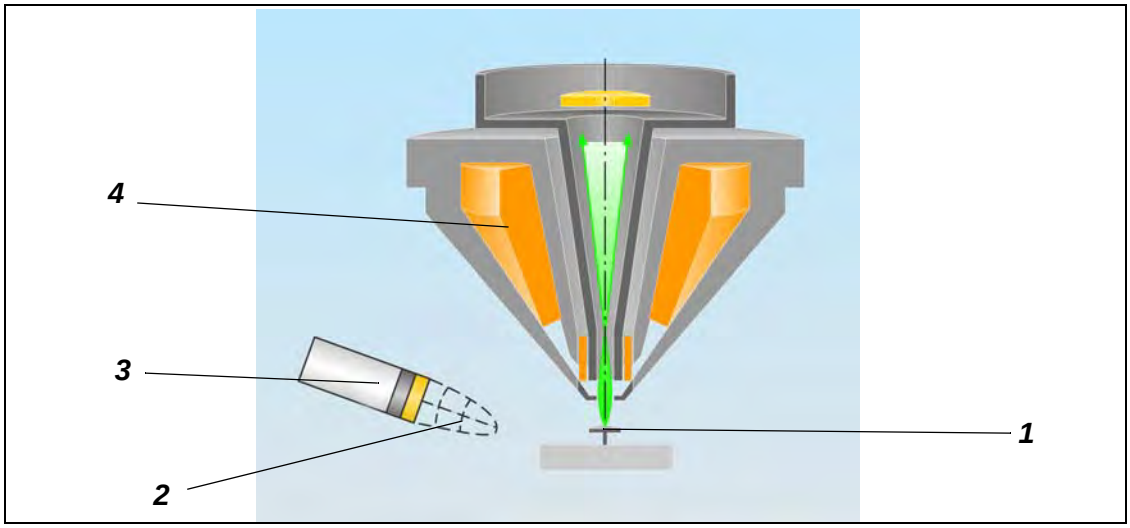
The In-lens detector can be used up to an acceleration voltage of 20 kV.
At higher acceleration voltages the beam booster and thus the field of the electrostatic lens are switched off. Therefore, the efficiency of the In-lens detector will be markedly reduced.

The efficiency of the In-lens detector is mainly determined by the electric field of the electrostatic lens, which is decreasing exponentially with the distance.
Thus, the working distance (WD) is one of the most important factors affecting the signal-to-noise ratio of the In-lens detector.
As the tilt angle of the specimen surface affects the emission angle of the electrons, you should avoid strong specimen tilting.

3.5.5.2. SE2 detector

The SE2 detector (***3***) is a Everhart-Thornley type detector. It detects SEs as well as BSEs.

Electrons moving to the detector are attracted by the collector grid (***2***) and directed to the scintillator. The collector voltage can be varied in the range between -250 V and + 400 V. This collector voltage generates an electrical field in front of the detector thus directing the low energy SEs towards the scintillator.
For all standard applications the collector voltage should be set to +300 V.



1	Specimen	3	SE2 detector
2	Collector grid	4	Objective lens

Fig. 3.8: Schematics of the SE2 detector

Negative collector voltage

Selecting a negative collector voltage generates a field deflecting the low energy SEs so that they cannot reach the scintillator and do not contribute to the signal. Only high-energy BSEs reach the scintillator contributing to the image generation.

This produces a so-called pseudo-backscattered image, which shows pronounced topography, but largely cancels surface properties (edge contrast).

3.5.5.3. EsB® detector (optional)

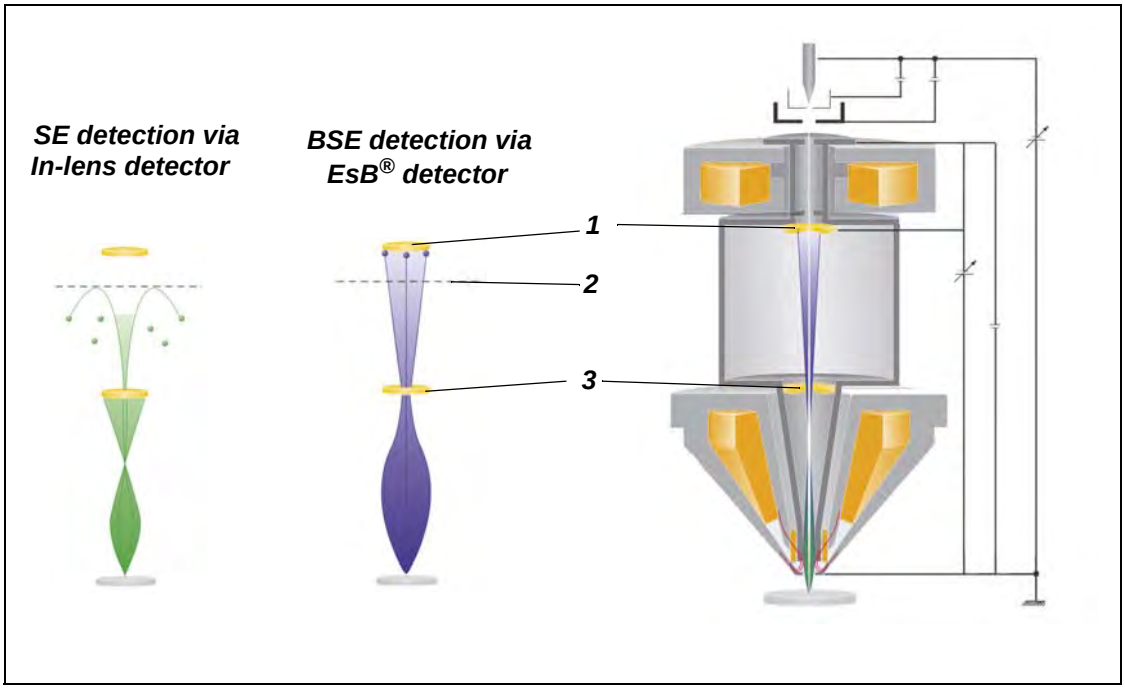
The **E**nergy **s**elective **B**ackscattered (EsB®) detector (***1***) is suitable for clear compositional contrast. It is an annular shaped in-column detector that is located above the In-lens detector (***3***). The EsB® detector detects BSEs and SEs.

The SEs and BSEs generated at the impact point of the primary electron beam are intercepted by the low electrical field of the GEMINI® column. These electrons are accelerated by the field of the electrostatic lens.

Filtering grid

A small amount of SEs pass through the hole of the In-lens detector and would be observed by the EsB® detector. To prevent detection of these SEs, a filtering grid (***2***) is installed in front of the EsB® detector. By switching on the filtering grid voltage, the SEs will be rejected and only BSEs will be detected.
Below a landing energy of 1.5 kV the filtering grid has the additional function of selecting the desired energy of the BSEs. The operator can select the threshold energy of inelastically scattered BSEs to enhance contrast and resolution.

The combination of In-lens detector and EsB® detector allows simultaneous imaging and mixing of a high contrast topography (SE) and a compositional contrast (BSE).

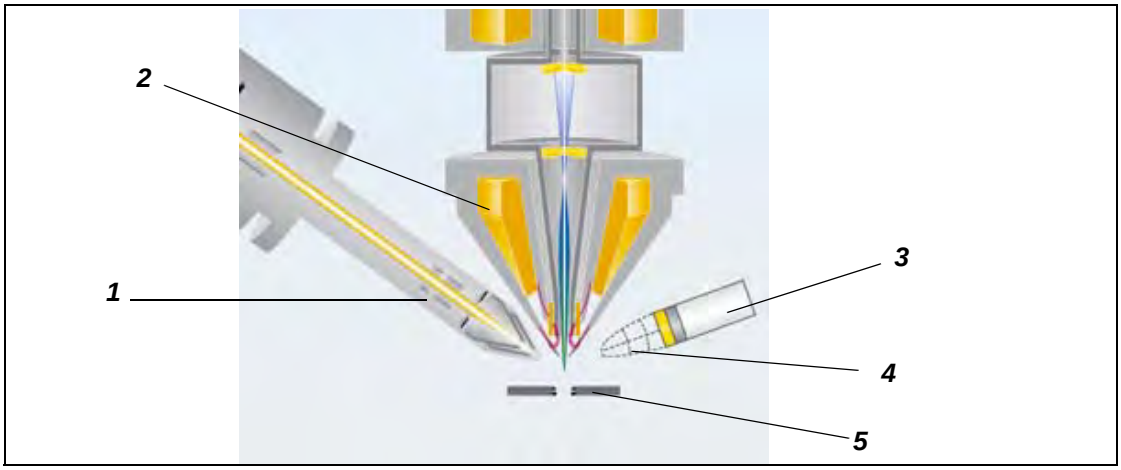


1 EsB® detector
2 Filtering grid
3 In-lens detector

Fig. 3.9: Schematics of the EsB® detector

3.5.5.4. SESI detector (optional, with FIB upgrade only)

The **S**econdary **E**lectrons **S**econdary **I**ons detector (SESI detector) (***3***) is suitable to detect secondary electrons as well as secondary ions. The SESI detector replaces the SE2 detector.



1 FIB column
2 GEMINI® column
3 SESI detector
4 Collector grid
5 Specimen

Fig. 3.10: Schematics of the SESI detector

Depending on the polarity of the collector voltage either electrons or ions scattered from the specimen (***5***) are attracted by a collector grid (***4***) and accelerated to the converter. In the converter, both electrons and ions are converted into secondary electrons which are used to generate an image.

The SESI detector can be operated in two modes: **SE** mode and **Ion** mode.

Operating mode	FIB mode	Detected signals	Typical application
SE mode (typical collector voltage +400 V)	SEM	Secondary electrons	Topography
	FIB		
Ion mode (typical collector voltage -4 kV)	-	Secondary ions	Crystal orientation contrast, material contrast e.g. imaging of corrosion/oxidation processes in metals
	FIB		

3.6. Specification

3.6.1. Basic workstation

Performance	
Resolution	1.0 nm at 15 kV at optimum working distance (WD) 1.9 nm at 1 kV at optimum working distance (WD)
Acceleration voltage	0.1 V - 30 kV
Probe current	4 pA - 20 nA with integrated High Current - Depth of Field module
Magnification	12 - 1.000.000 x

Electron optics (GEMINI® column)	
Electron source	Schottky field emitter
Lens control	Patented GEMINI® electromagnetic/electrostatic objective lens system (68° conical final-lens) with water cooling for best thermal stability and reproducibility
Stigmator	Eight pole electromagnetic
Apertures	Seven apertures with electromagnetic selection.
Beam shift	Width: max. 15 µm depending on EHT and WD Extended beam shift width: ±100 µm depending on EHT and WD

Specimen chamber and stage		**AURIGA®**	**AURIGA® 60**
Specimen chamber	Dimensions	330 mm inner diameter 270 mm height	520 mm inner diameter 300 mm height
Accessory ports		15	20
Specimen stage	Type	6-axes motorised super eucentric, controlled via SmartSEM® software	
	Specimen weight	Up to 0.5 kg	
	Movement	X = 100 mm Y = 100 mm Z = 55 mm M = 10 mm T = -10° to 60° R = 360° continuous	X = 150 mm Y = 150 mm Z = 43 mm M = 10 mm T = -10° to 60° R = 360° continuous

Standard detectors	
In-lens detector	High efficiency annular scintillator detector mounted in GEMINI® column with optically coupled photomultiplier.
SE2 detector	Everhart-Thornley type with optically coupled photomultiplier. Collector bias adjustable from -250V to +400 V.
Chamber viewing	a) Infrared CCD camera b) 2nd infrared CCD camera

3.6.2. Workstation with FIB upgrade

Two types of FIB column are available:

- Canion column
- Cobra column

Performance		
Resolution	Canion column	< 7.0 nm at 30 kV
	Cobra column	< 2.5 nm at 30 kV
Acceleration voltage	1 - 30 kV < 5 kV as an option	
Probe current	1 pA - 50 nA	
Magnification range	300 x - 500,000 x	

Ion optics		
Ion source	Gallium liquid metal ion source	
Lenses	Two electrostatic lenses	
Stigmator	Eight pole electrostatic	
Apertures	Canion column	7 apertures, motorized
	Cobra column	14 apertures, motorized
Beam shift	±7 µm	

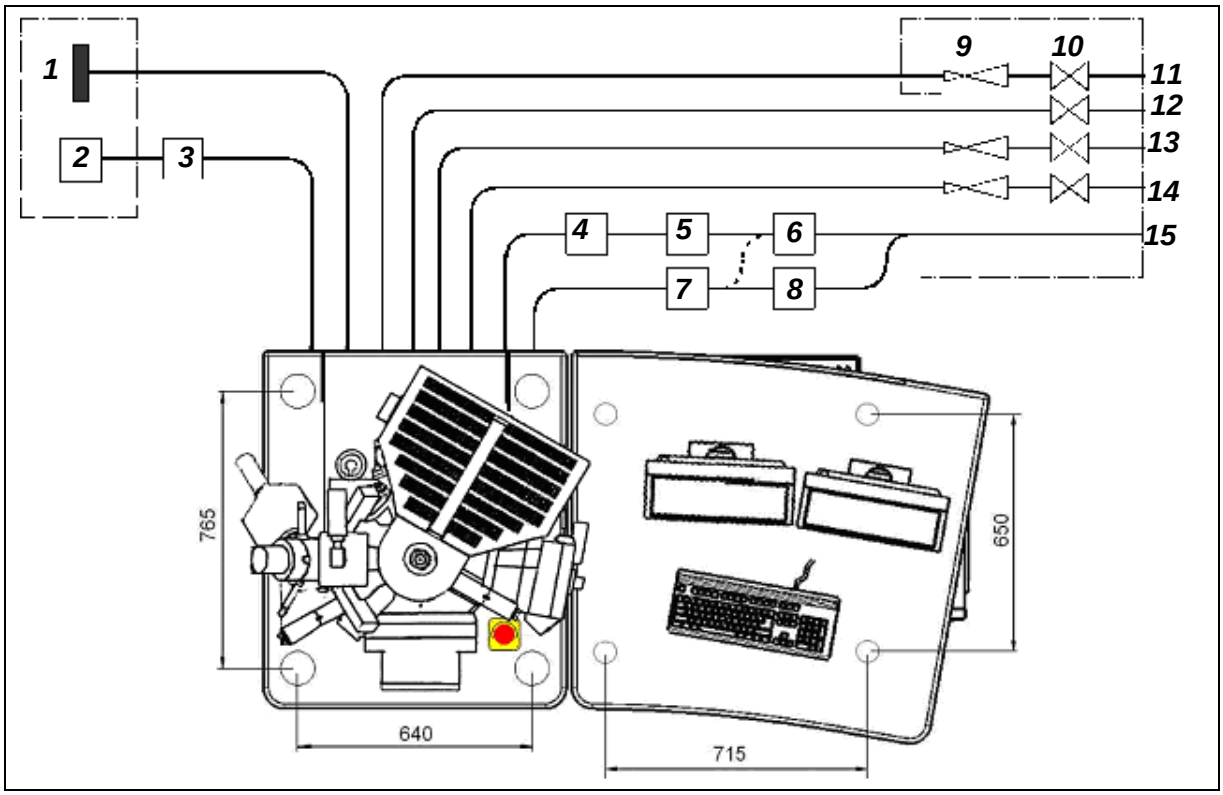
Optional detector	
SESI detector	Scintillator photomultiplier based system; easy change between secondary ion and secondary electron mode, alternative to SE2 detector
Other optional detectors on request.	

IMPORTANT

For more details refer to the document Product Specification AURIGA® / AURIGA® 60.

3.7. Technical data

3.7.1. Layout and connections



1 Equipotential bonding bar

2 Mains power supply 208…230V / 22A 1/N(L2)/ PE

3 EMO box (optional, but mandatory with FIB and/ or GIS upgrade)

4 Static vibration damper

5 Quiet mode reservoir (optional)

6 Pre-vacuum pump

7 With optional airlock:
Static vibration damper

8 Pre-pump for optional 200-mm airlock

9 Pressure reducers for water, nitrogen, and compressed air

10 Main shut-off valves for water, nitrogen, and compressed air

11 Water supply

12 Water runback

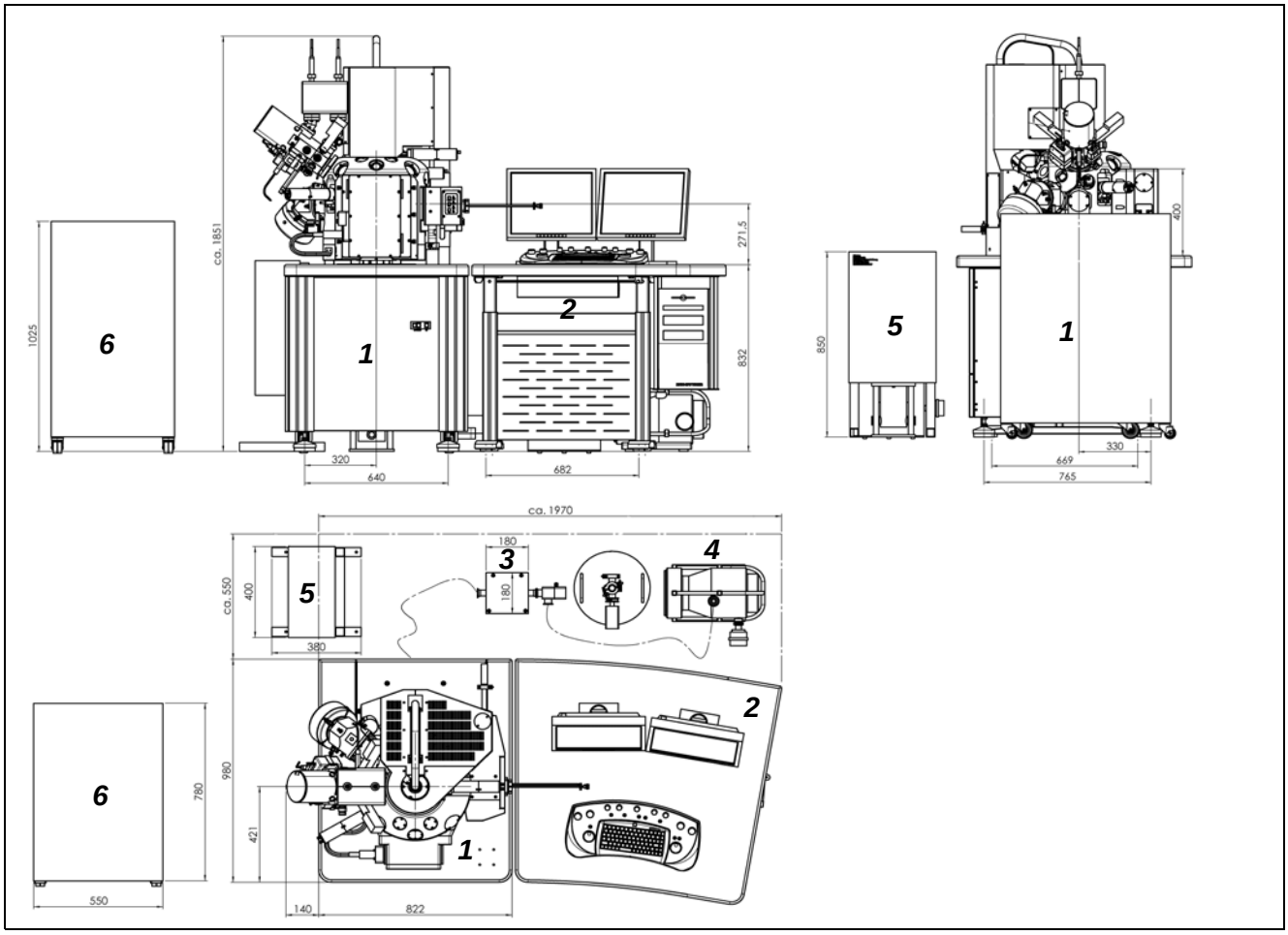
13 Nitrogen supply

14 Compressed air supply

15 Exhaust line

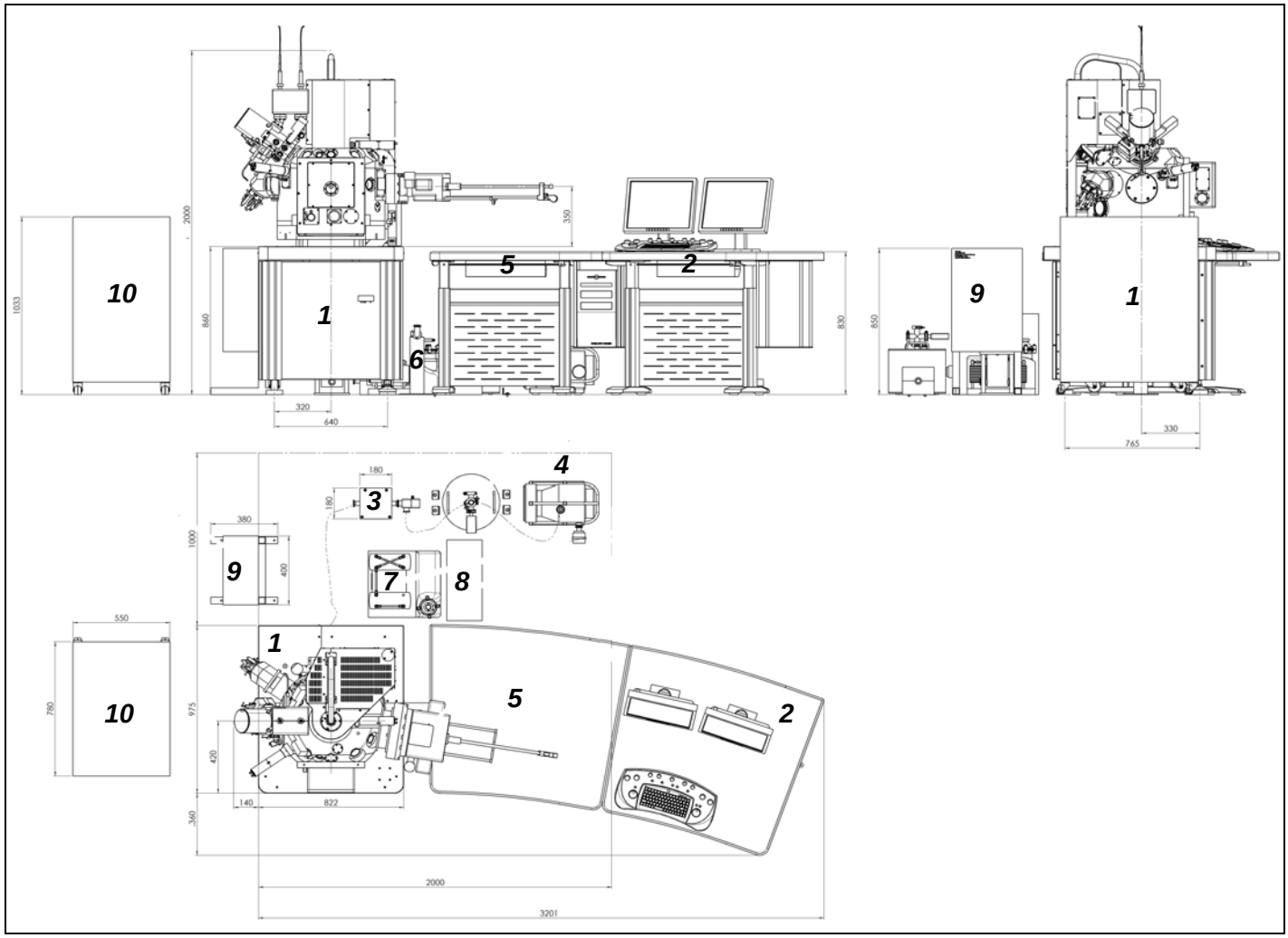
3.7.2. System layout

3.7.2.1. AURIGA®



No	Description	Size (mm) approx.	Weight (kg) approx.	Distribution of load	Footprints
1	Plinth + column (without airlock)	822 x 980 x 1851	860	4 x 215 kg	4 x Ø 100 mm
2	Table + Monitor + PC	1150 x 980 x 1350	104	4 x 26 kg	4 x Ø 50 mm
3	Static damping block	180 x 180 x 160	37	1 x 37 kg	-
4	Pre-vacuum pump	427 x 250 x 290	26	1 x 26 kg	-
Upgrades					
1	Plinth + column + FIB column + GIS	962 x 980 x 1851	972	4 x 243 kg	4 x Ø 100 mm
5	EMO box (with FIB or GIS upgrade)	380 x 400 x 850	35	4 x 8,75 kg	-
6	FIB/GIS electronics rack (with FIB or GIS upgrade)	550 x 780 x 1025	120	4 x 30 kg	-

3.7.2.2. AURIGA® 60



Shown with 200 mm airlock
(80 mm airlock has no second table (**5**))

No	Description	Size (mm) approx.	Weight (kg) approx.	Distribution of load	Footprints
1	Plinth + column (without airlock)	822 x 975 x 2000	970	4 x 242,5 kg	4 x Ø 100 mm
2	Table + Monitor + PC	1150 x 980 x 1350	104	4 x 26 kg	4 x Ø 50 mm
3	Static damping block	180 x 180 x 160	37	1 x 37 kg	-
4	Pre-vacuum pump	427 x 250 x 290	26	1 x 26 kg	-
With 200 mm airlock					
1	Plinth + column	1700 x 975 x 2000	1005	4 x 251,25 kg	4 x Ø 100 mm
5	Second table	1150 x 980	85	4 x 21,25 kg	4 x Ø 50 mm
6	Static damper	Ø 80	16	1 x 16 kg	-
7	Airlock pump	410 x 390 x 400	26	4 x 6,5 kg	-
8	Airlock controller	200 x 460 x 470	14	4 x 3,5 kg	-
Upgrades					
1	Plinth + column + FIB column + GIS (without airlock)	822 x 975 x 2000	1020	4 x 255 kg	4 x Ø 100 mm
9	EMO box (with FIB or GIS upgrade)	380 x 400 x 850	35	4 x 8,75 kg	-
10	FIB/GIS electronics rack (with FIB or GIS upgrade)	550 x 780 x 1033	120	4 x 30 kg	-

3.7.3. Installation requirements

Location requirements	
Installation site	Exclusively inside buildings
Room size	AURIGA®: Min 3.5 m x 5.0 m x 2.3 m (W x D x H)
	AURIGA® 60: Min 4.0 m x 6.0 m x 2.3 m (W x D x H)
Service area	Min 1 m at each side
Installation category	II
Exhaust line	An exhaust line is required to remove the wate gas of the pre-vacuum pump and to transmit it to the outside.

Electrical supplies		
Nominal AC voltage		208 V - 230 V (±10%), 1/N (L2) / PE
Protection class		I
Nominal frequency		50 - 60 Hz
Power consumption		Max. 3.5 kVA, dependent on upgrade stage and installed options
Current input		Max. 16 A
Circuit breaker	25 A, switch off behaviour K on installation site A special emergency-off circuit is available (part no. 340002-0167). The EMO box is mandatory for the upgrade of FIB and/or GIS. The EMO box should be mounted close to the system. Wiring that runs outside the workstation should be laid and protected in appropriate cable ducts or trays. Moreover, it is recommended to protect the complete room by installing a power switch next to the door of the room.	
Ampere interrupting capacity AIC	With EMO box	At least 10000 A rms
Protective ground	The workstation must be connected via a separate protective ground. An exclusive grounding connection to earth must be provided, i. e. the grounding terminal must not be common to other electrical equipment. A grounding wire AWG10 (5 m long) is delivered with the workstation.	
Cross section		> 4 mm^2
Ground resistance		< 0.1 Ω

Cooling water supply	
Water flow rate	75 - 85 l/h
Input pressure	0.2 - 0.3 MPa (2 - 3 bar)
Water temperature	20 - 22°C
Stability	0.5°C/10 min

Gas supplies	
Nitrogen	
Quality	4.6 with nitrogen content <99.996 %
Flow rate	Approx. 40 l/min for ventilation of specimen chamber with chamber door open
Pressure	0.30 - 0.35 MPa (3.0 - 3.5 bar)
Compressed air	
Flow rate	Less than 1l/min
Pressure	0.6 - 0.8 MPa (6 - 8 bar)
Quality	Oil-free

Environmental requirements		
Ambient Temperature		Approx. 21°C ±4°C
	Stability	0.5°C/h
Relative humidity		Less than 65 %
Altitude	To guarantee an undisturbed operation, do not operate the workstation at sites higher than 2000 m above sea level.	
Pollution degree	2 According to EN 61010-1: Safety requirements for electrical equipment for measurement, control, and laboratory use. Part 1: General requirements.	

IMPORTANT

Also refer to the documents Product Specification AURIGA® / AURIGA® 60 and Installation Requirements AURIGA® / AURIGA® 60.

3.8. Options

There is a variety of further options available. For details please contact your local Carl Zeiss service engineer or sales representative.

3.8.1. Airlock

An airlock allows you to quickly transfer the specimen into the specimen chamber without breaking the system vacuum. Moreover, the use of an airlock minimises possible contamination of the specimen chamber and reduces pumping times thus speeding up the specimen exchange procedure.

Workstation	Airlock	Configuration
AURIGA®	80-mm	One of these airlocks can be chosen.
	100-mm	
AURIGA® 60	80-mm	One of these airlocks has to be chosen.
	200-mm	

For details on operation refer to the respective instruction manual.

3.9. Customer service

For customer service please contact your local Carl Zeiss service engineer.

A list of Carl Zeiss locations and authorised service partners can be found at:

http://www.zeiss.com/microscopy

In case of questions regarding radiation protection please contact the Carl Zeiss Radiation Safety Officer

Dr. Wolfgang Sold, Carl Zeiss AG, 73447 Oberkochen, Germany
phone: +49 (0) 7364 202951
e-mail: sold@zeiss.de

IMPORTANT

To maintain best possible performance of the workstation it is essential to perform preventive maintenance on a regular base.
Moreover, it is recommended that you conclude a service contract with your local Carl Zeiss service organisation or representative. This will ensure a continuous trouble-free operation of the workstation.

4. Transport and storage

4.1. Transport

CAUTION

Crushing hazard while load is being lowered.
Maintain a safe distance. Do not walk or place your hands or feet under the load while it is being lowered. Wear safety shoes and gloves.

CAUTION

Risk of damaging the workstation.
The workstation may only be transported in air-suspended vehicles. Moving parts must be secured during transport to prevent them from slipping or tipping over.
Avoid rocking the crates back and forth.
Devices for transporting the workstation must be rated to handle its full weight and dimensions. Note the weight information on the package and on the shipping document.

In order to avoid damage of the workstation by shock, the workstation has to be exclusively transported in air-suspended vehicles.
Temperature during transport has to be between +10° C and +70° C.

The workstation is delivered in two crates:

Microscope plinth	Wrapped with recyclable polyethylene-foil and shipped in a reusable box Dimensions and weight of box: AURIGA® 1310 x 1060 x 2020 mm³ (W x D x H), appr. 1150 kg AURIGA® 60 1422 x 1300 x 2390 mm³ (W x D x H), appr. 1450 kg
Microscope console and accessories	Console, valve, damper, monitors, cables, pipes etc. are wrapped with recyclable polyethylene-foil or packed in separate cartons and shipped in a reusable box. Dimensions and weight of box: 1450 x 1360 x 1180 mm³ (W x D x H), appr. 400 kg
FIB	Dimensions and weight of box: 960 x 720 x 1100 mm³ (W x D x H), appr. 180 kg

If required there are additional boxes for optional equipment.

Check that none of the items has been damaged during shipment.

4.2. Storage

The packed workstation has to be stored in a dry place.
Temperature during storage has to be between +10° C and +70° C.

5. Installation

Unpacking, installation and first start-up are carried out by authorised Carl Zeiss service staff.

6. Operation

At a glance This chapter contains information about:

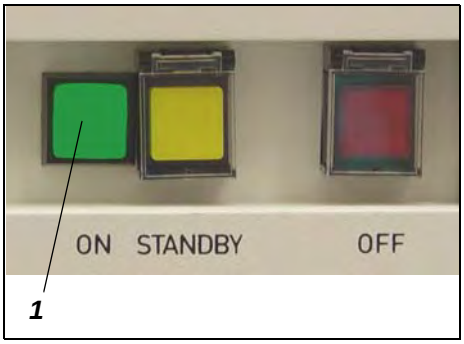
- Switching on the workstation
- Starting the SmartSEM® user interface
- Finding your way in the SmartSEM® user interface
- SEM operation (basic workstation)
- Electron beam deposition or etching (with GIS upgrade only)
- CrossBeam® operation (with FIB upgrade only)
- Using the help functions
- Closing the SmartSEM® user interface
- Switching off the workstation as a matter of routine
- Emergency off
- Switching off the workstation completely

6.1. Switching on the workstation

Preconditions:

- Workstation is in **STANDBY** mode

1 Press the green **ON** button (***1***) that is located at the front of the plinth.



6.2. Starting the SmartSEM® user interface

Preconditions:

- The workstation is switched on.
- The Windows® operating system has been loaded.

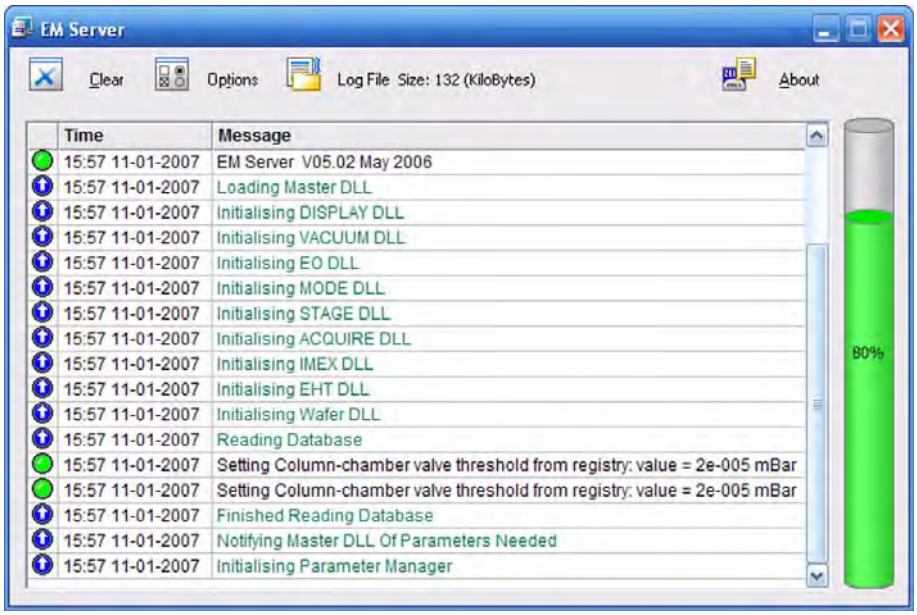
IMPORTANT

To receive the Windows® login data contact your Carl Zeiss service engineer.

1 Double-click on the Carl Zeiss SmartSEM icon.

Alternatively, select **Start/Programs/Smart-SEM/SmartSEM User Interface**.

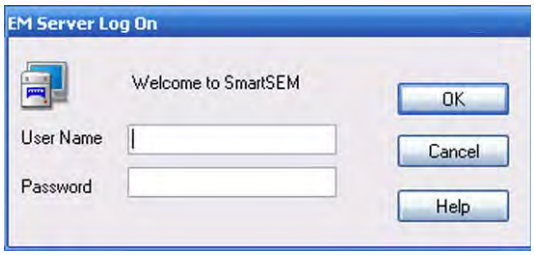
The **EM Server** opens, loading various drivers. The function of the EM Server is to implement the internal communication between the SmartSEM® software and the hardware of the workstation.



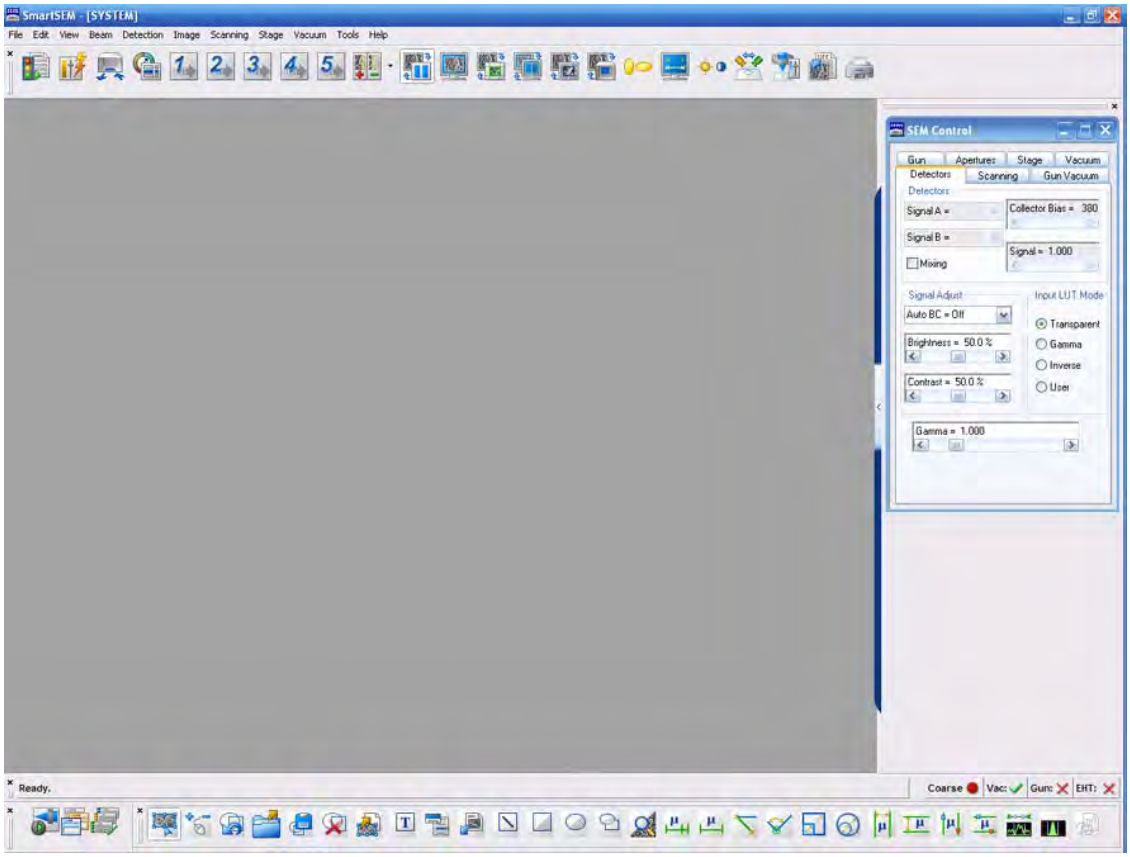
The **EM Server Log On** dialogue appears.

2 Enter your user name and password.

3 Confirm by clicking on **OK**.



The SmartSEM® user interface opens.



The **EM Server** is minimised to a small element (icon) on the right side of the Windows® task bar.

The SmartSEM® software is ready to operate the workstation.

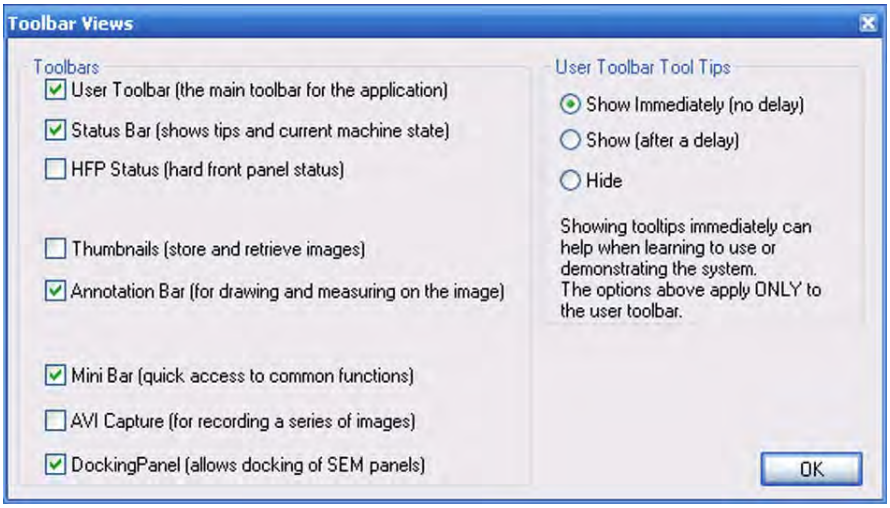
6.3. Finding your way in the SmartSEM® user interface

6.3.1. Showing or hiding toolbars

Several toolbars such as user toolbar, status bar, and annotation bar are available for easy access to the SmartSEM® functions.

1 Select **View/Toolbars**.
Alternatively, type **<Ctrl+B>**.

The **Toolbar Views** panel is shown.



2 If you wish to show a toolbar, tick the respective checkbox.
3 To change the tooltip features of the user toolbar, select the respective radio button on the right hand side of the panel.
4 Confirm by clicking on **OK**.

6.3.2. Showing or hiding the data zone

The data zone is a special group of annotation objects which are used to display current parameters. You can also include a µ-marker to show the base magnification.

1 Select **View/Data Zone/Show Data Zone** from the menu.
A tick is shown to indicate that the function is activated.

Alternatively, type **<Ctrl+D>** to toggle the data zone.

6.3.3. Showing a full screen image

To take advantage of the full monitor size to display the microscopic image, show a full screen image.

1 Select **View/Toggle Full Screen Image** from the menu.
Alternatively, type **<Shift + F3>**.

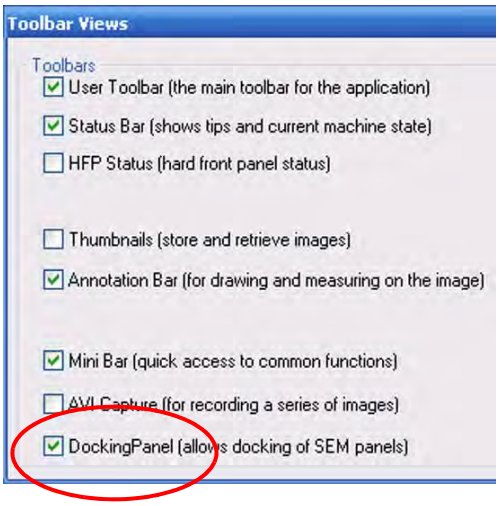
To undo the function, type **<Shift + F3>**.

6.3.4. Docking panels

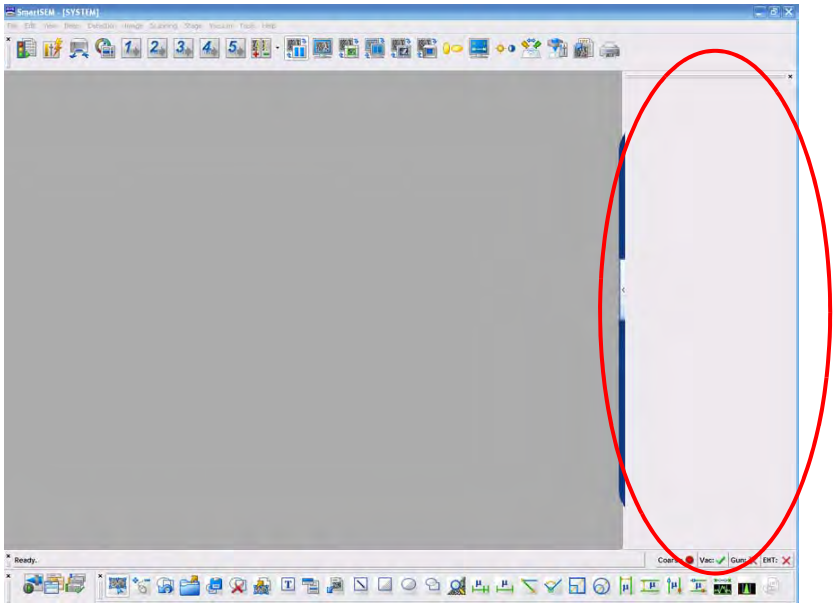
It is possible to dock various panels onto the main window. The purpose of the docking panel is to keep the area of the image completely clear, as the docking panel is outside the main window.

1 To show the docking panel select **View/Toolbars** from the menu.

2 Tick the **Docking Panel** checkbox.



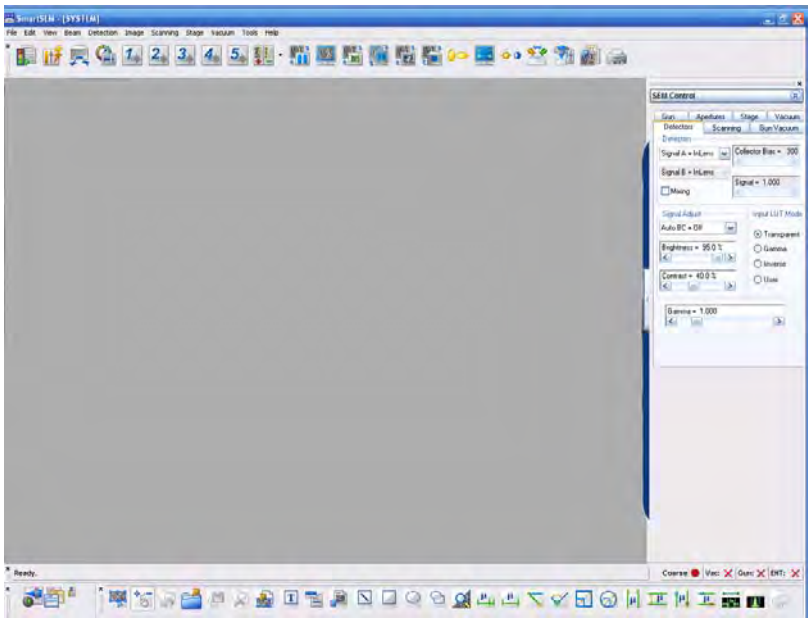
The docking panel is shown on the right hand side of the image area.



3 To move the docking panel to the left hand side, pick up the panel by clicking on the title bar and drag it to the other side of image area.

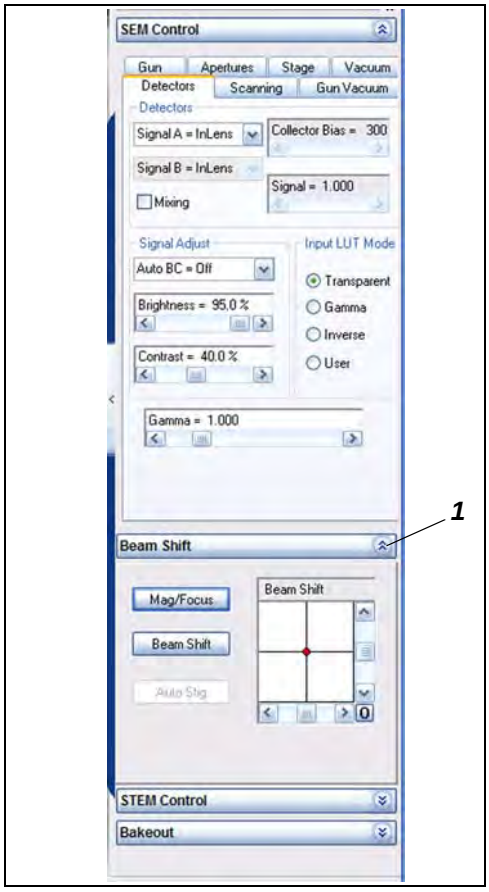
4 To stick a control panel to the docking panel, click on the title bar of the control panel and drag it to the docking panel.

The panel becomes integrated into the docking panel.



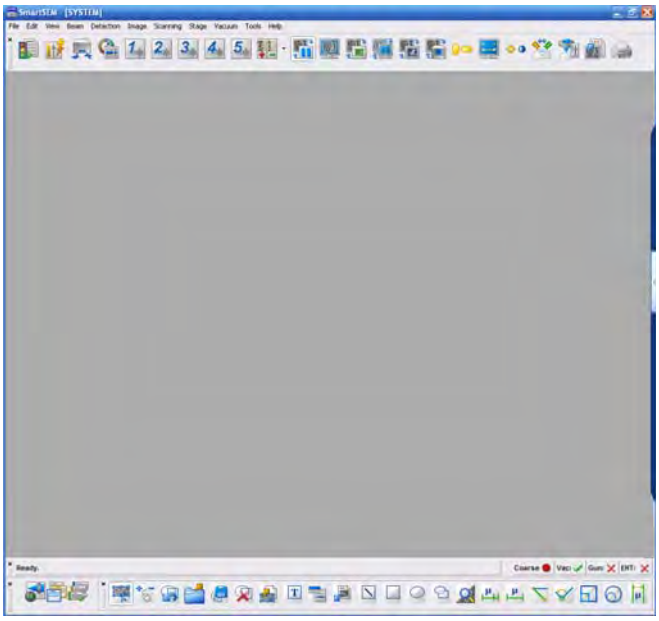
You can stick several control panels to the docking panel.

5 To minimise a panel, click on the **arrow** button (***1***) in the title bar.



6 To hide the docking panel untick the **Docking Panel** checkbox.

The docking panel is hidden.



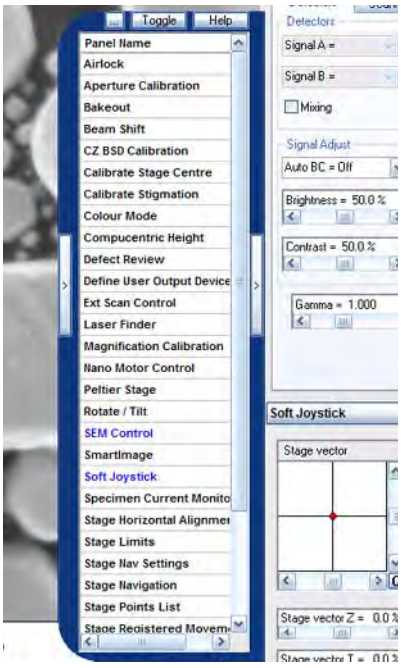
6.3.5. Opening the Panel Configuration Bar

1 Select **Tools/Goto Panel** from the menu.

Alternatively, click on the arrow button at the side of the image area.

The **Panel Configuration Bar** opens showing an alphabetical list of functions.

2 To select a function, double-click on it.



6.4. SEM operation (basic workstation)

6.4.1. Obtaining a first image

The following section summarises basic sequences to quickly obtain an image using the SE2 detector. To simplify the procedure, the method described mainly uses **SEM Control** panel and status bar functions.

Preconditions:

- SmartSEM® has been started and is ready to control the workstation.

Parts required	No.
Allen wrench, 1.5 mm	delivered with the workstation
Stub	delivered with the workstation
Tweezers for specimen	delivered with the workstation
Specimen holder	delivered with the workstation
If necessary: carbon tape, conductive carbon, adhesive metal tape or similar	-
Appropriate specimen (with conducting properties e.g. gold on carbon)	-
Lint-free gloves	-

At a glance

The complete sequence includes:

- Preparing the sample holder
- Loading the specimen chamber via chamber door

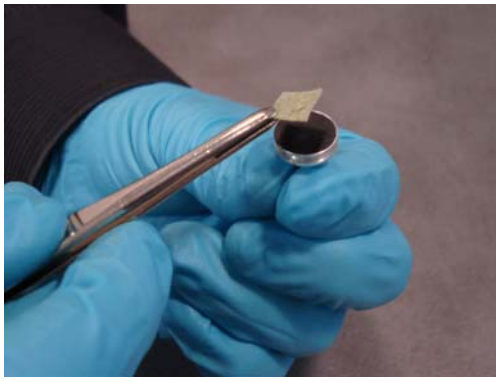
  Alternatively:
  Loading the specimen chamber via airlock (optional)
- Locating the specimen
- Switching on the gun
- Switching on the EHT
- Generating an image
- Optimising the image
- Saving the image

6.4.1.1. Preparing the sample holder

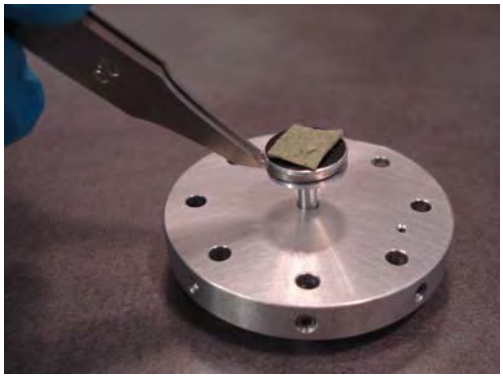
IMPORTANT

Contamination caused by fingerprints can lead to vacuum deterioration or prolonged pumping times. Always wear lint-free gloves when touching specimen, sample holder or stage.

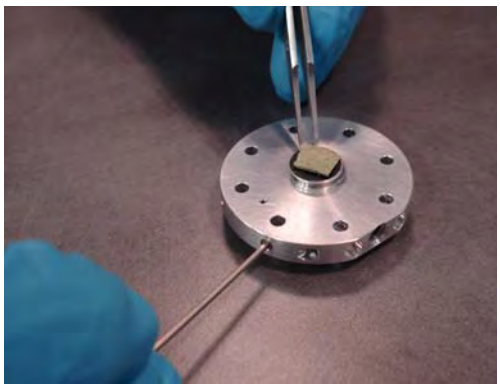
1 Attach the specimen to the stub by using conductive carbon, adhesive metal or carbon tape etc.
Ensure that the specimen area to be analysed is in proper contact with the stub.



2 Use the tweezers to insert the stub into the sample holder.



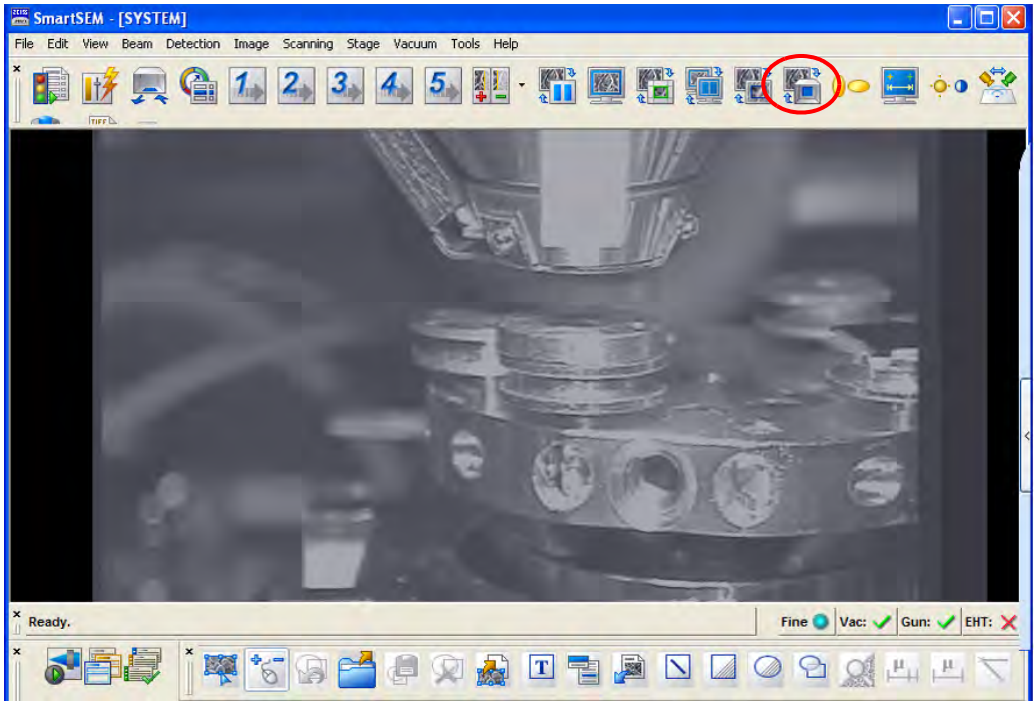
3 Properly fix the stub to the sample holder.
Use the Allen wrench to tighten the location screw.



6.4.1.2. Loading the specimen chamber via chamber door

1 Click on the **ChamberScope** icon in the toolbar.

A TV view inside the specimen chamber is shown.



CAUTION

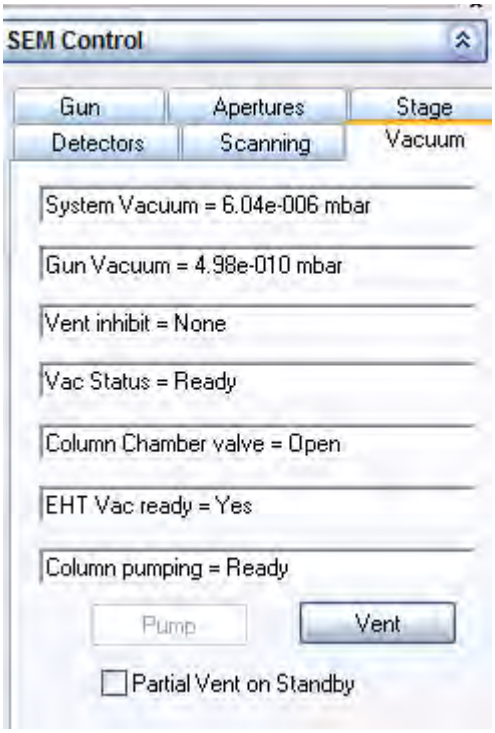
Risk of damaging the objective lens and/or your specimen
Ensure not to hit the objective lens while driving the stage. Change to TV mode to observe the moving stage.

2 Select **Tools/Goto Control Panel** from the menu.

The **SEM Control** panel opens.

3 Go to the **Vacuum** tab.

4 Click on the **Vent** button to ventilate the specimen chamber.



A message appears asking: 'Are you sure you want to vent?'.

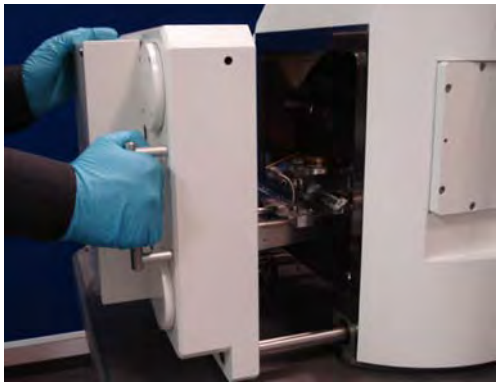
5 Confirm by clicking on **Yes**.

The specimen chamber is filled with gaseous nitrogen.

CAUTION

Suffocation hazard due to lack of oxygen, since the specimen chamber is ventilated with nitrogen.
After the specimen exchange, keep the chamber door open as short as possible.
Avoid inhaling the air from within the specimen chamber.
Ensure the area around the workstation is sufficiently ventilated.

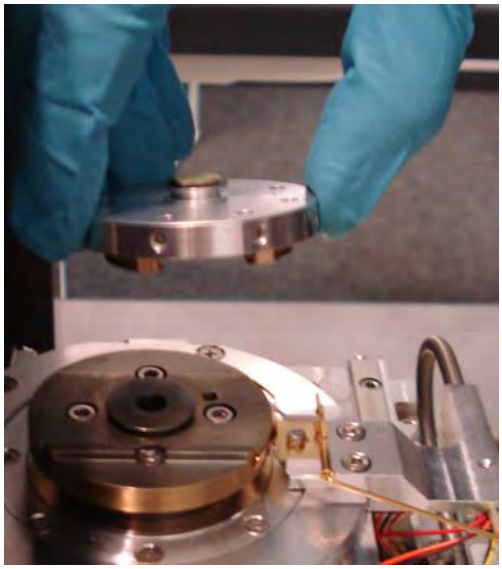
6 Slowly open the chamber door.



IMPORTANT

Contamination caused by fingerprints can lead to vacuum deterioration or prolonged pumping times.
Always wear lint-free gloves when touching specimen, sample holder or stage. Keep the chamber door open as short as possible.

All sample holders are equipped with a dovetail so that the position of the sample holder is exactly defined.



7 Mount the sample holder:
   a Ensure that you place the dovetail in the correct orientation onto the holding device on the specimen stage.
   b Make sure that the flat side of the dovetail of the sample holder is flush with the milled edge of the stage.

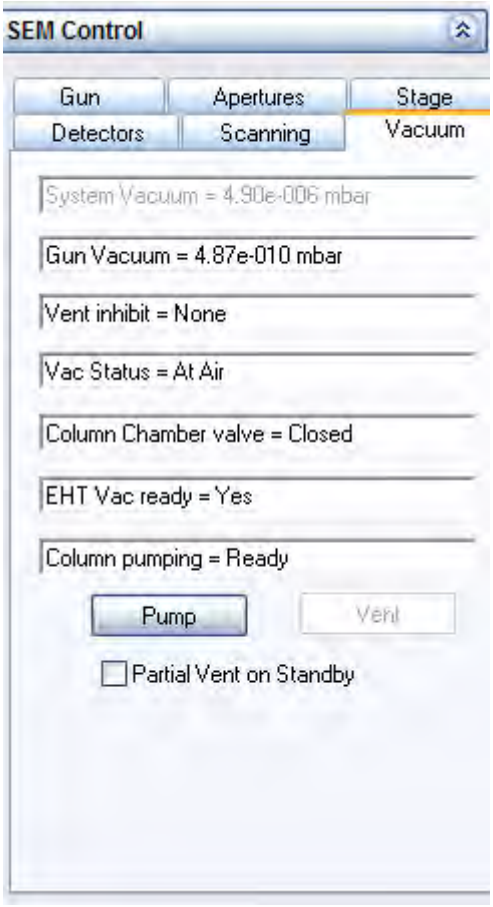
8 Look into the specimen chamber to ensure that the specimen cannot hit any components when it is introduced into the specimen chamber.

CAUTION

Pinch hazard when closing the chamber door.
Ensure not to get your fingers caught in the chamber door gap.

9 Carefully close the chamber door.

10 Click on the **Pump** button in the **SEM Control** panel.



The vacuum status messages show the current vacuum levels achieved.

6.4.1.3. Loading the specimen chamber via airlock

An airlock is

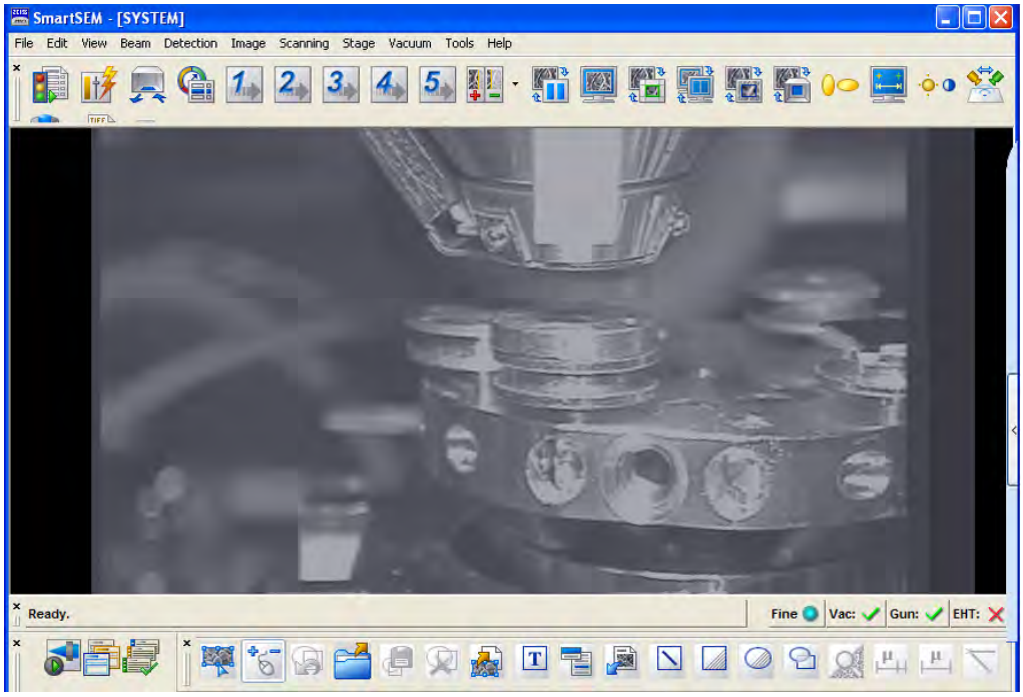
- optional with AURIGA®
- standard with AURIGA® 60

Several airlocks are available.

For details on the operation of the airlock refer to the respective instruction manual.

6.4.1.4. Locating the specimen

1 In TV mode (ChamberScope), look into the specimen chamber.



CAUTION

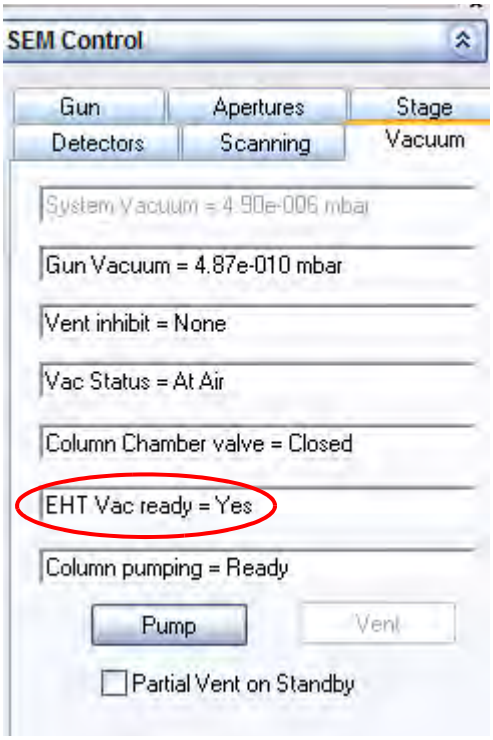
Risk of damaging the objective lens and/or your specimen.
Ensure not to hit the objective lens while driving the stage. Change to TV mode to observe the moving stage.

2 Move the specimen by using the dual joystick (optional) or by calling the Soft Joystick via **Tools/Goto Panel/Soft Joystick**.

3 Carefully move the specimen closer to the objective lens.
The distance between objective lens and specimen surface should be less than about 10 mm.

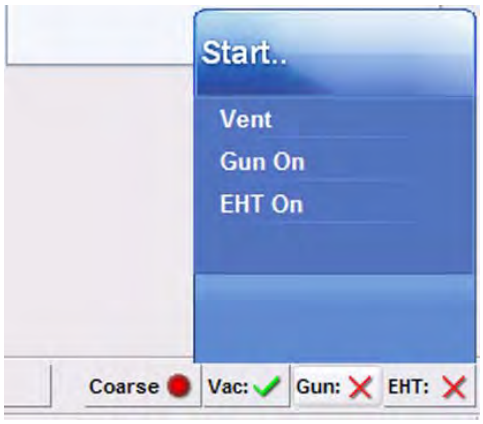
6.4.1.5. Switching on the electron gun

1 In the **Vacuum** tab:
Check that *EHT Vac ready=Yes* is indicated.



2 Click on the **Gun** button in the status bar.
3 Select **Gun On** from the pop-up menu.

The gun is being run up.

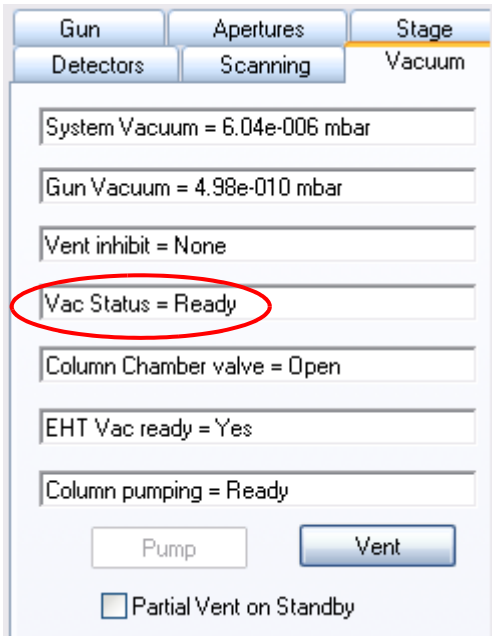


6.4.1.6. Switching on the EHT

'EHT' stands for acceleration voltage. This voltage has to be applied to the gun in order to make it emit electrons.

1 Watch the vacuum status messages on the **Vacuum** tab of the **SEM Control** panel.

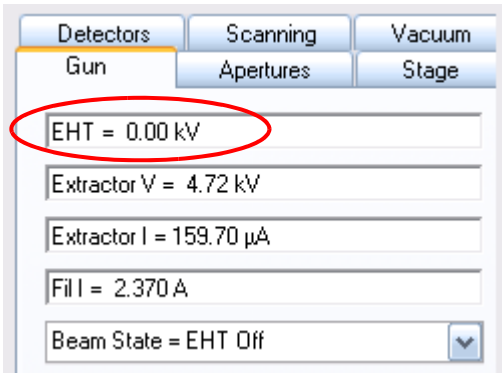
When the required vacuum has been reached you will see the message 'Vac Status = Ready'.



2 Go to the **Gun** tab.

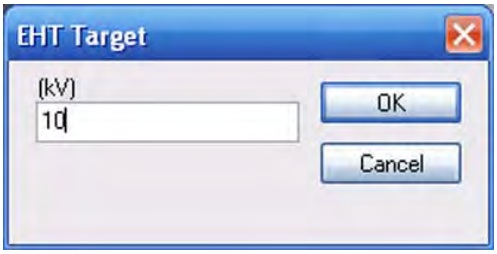
3 Set the acceleration voltage:

a Double-click in the **EHT=** field.



b Enter the desired acceleration voltage in the **EHT Target** field, e.g. *10 kV*.

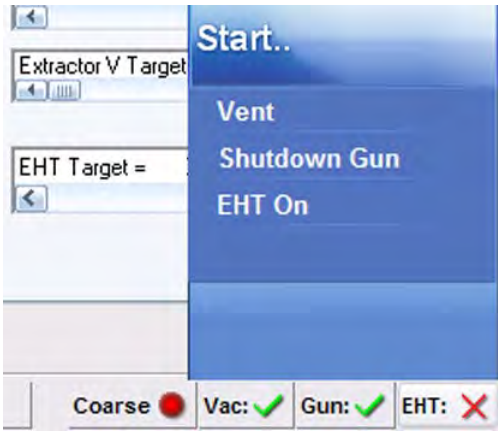
c Confirm by clicking on **OK**.



4 Switch on the EHT:

a Click on the **EHT** button in the status bar.

b Select **EHT On** from the pop-up menu.



The EHT is running up to 10 kV.

The status bar buttons are merged, and the **All:** button appears.

Now, the electron beam is on.

6.4.1.7. Generating an image

1 Go to the **Detectors** tab.

2 Select *SE2* from the **Detectors** drop-down list.

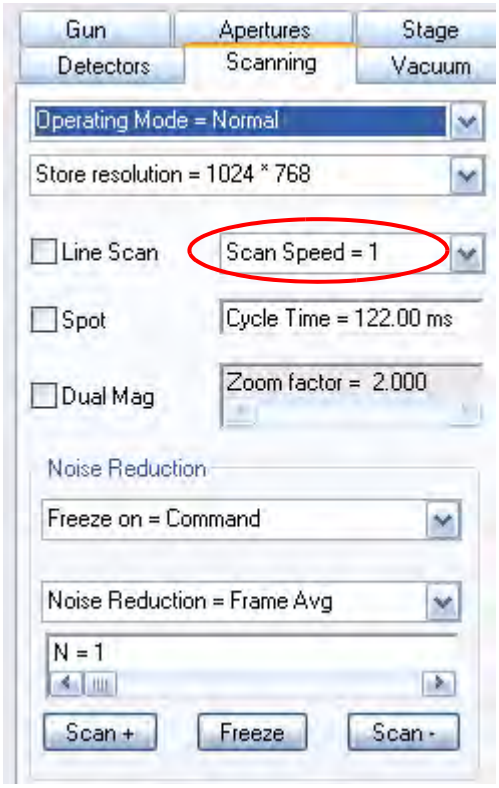
It is recommended that you select the SE2 detector to obtain the first image, as this detector provides a good signal-to-noise ratio even at large working distances.

3 Go to the **Scanning** tab.

Select a fast scan speed, e.g.

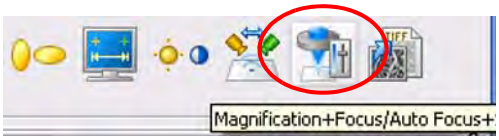
Scan Speed = 1 from the drop-down list.

The lower the scan speed number, the faster the scan of the specimen by the electron beam. *Scan Speed = 1* allows you to get an image quickly.



4 Set a low magnification e.g. *Mag = 500 x*:

a Click on the **Magnification/Focus** icon in the toolbar.



b Press the left mouse button and drag the mouse to adjust the magnification of *500 x*.

The current magnification is indicated in the status bar.

5 Set the focus:

a Press the middle mouse button and drag the mouse to focus.

The current working distance (WD) is indicated in the status bar.

6 Adjust contrast and brightness.

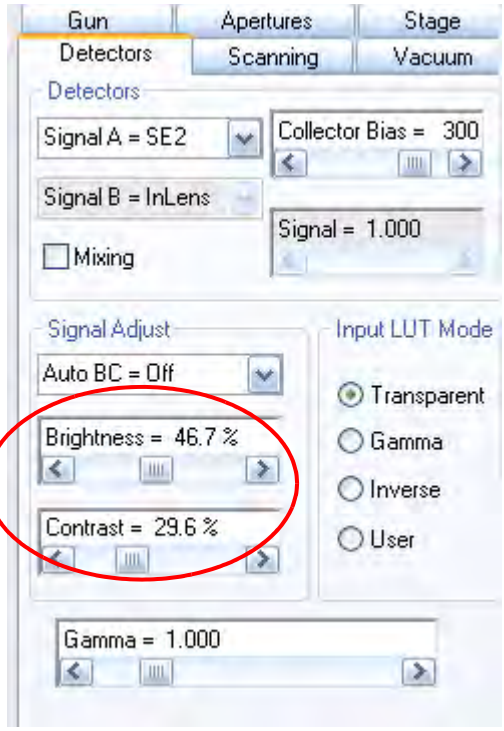
a Go to the **Detectors** tab.

b Use the **Brightness** and **Contrast** sliders.

7 Select a detail on the specimen surface.

8 Focus the detail.

9 Adjust contrast and brightness again.



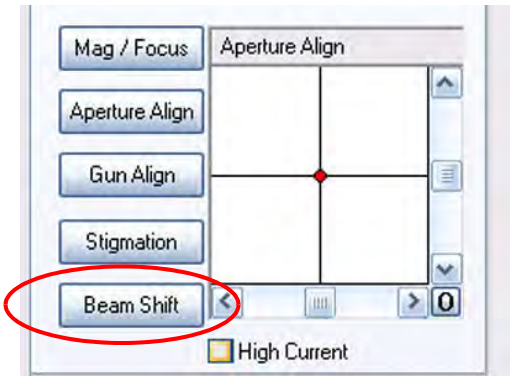
6.4.1.8. Optimising the image

1 Set *Coarse* by toggling the **Coarse/Fine** button in the status bar.

2 Step by step, set a high magnification,
e.g. Mag *50.000 x*.
Focus in between.

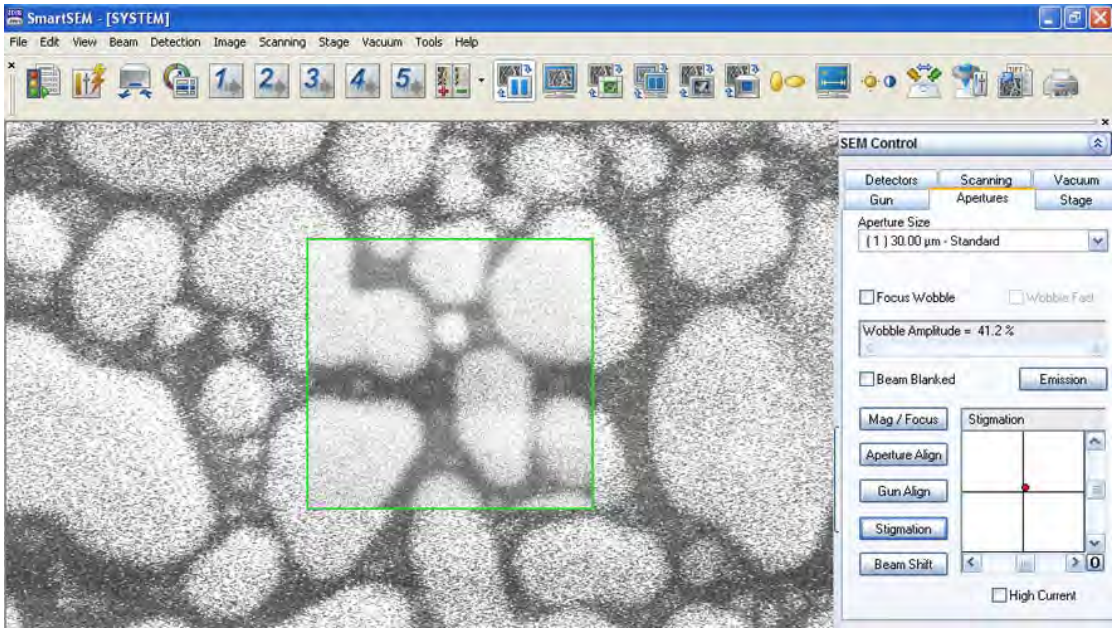
When selecting high magnifications it is recommended that you move the specimen by using the beamshift function instead of driving the stage.

3 Use the Beam shift function:
- a Go to the **Apertures** tab.
- b Click on the **Beam Shift** button.
- c Use the slider or the red marker to shift the beam.



4 Click on the **Reduced Raster** icon.

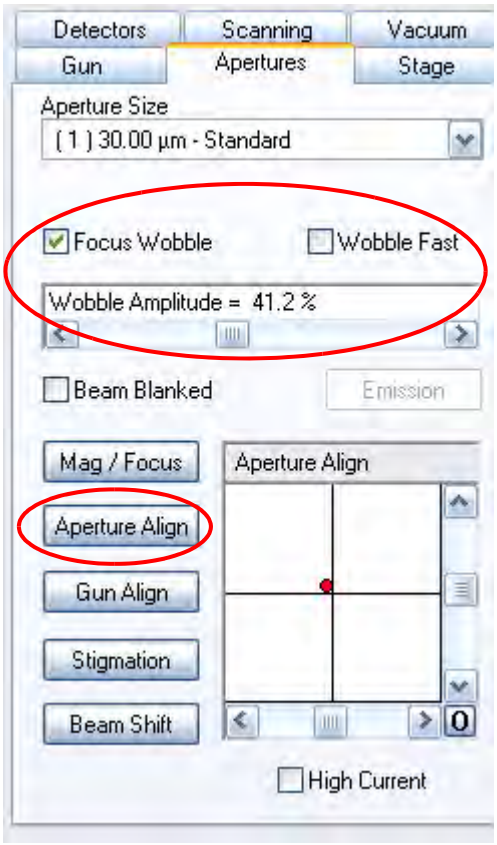
A small scan frame is shown.
The image outside the scan frame is frozen. Size and position of the scan frame can be changed by dragging and dropping.



5 Focus the image in the reduced raster.

6 Align the aperture:

a In the **Apertures** tab, tick the **Focus Wobble** checkbox.



The Focus Wobble is a function that sweeps the focus of the objective lens backwards and forwards through the focus on the specimen plane. If the aperture is slightly misaligned, a lateral shift can be observed.

Intensity of wobble can be adjusted by using the **Wobble Amplitude** scroll bar.
Wobble speed can be accelerated by ticking the **Wobble Fast** checkbox.

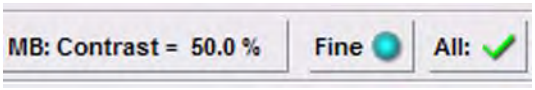
b Click on the **Aperture Align** button.
Use the left and right slider of the **Aperture Align** box until there is no movement of the detail in X- and Y- direction.
The specimen detail should just be pulsating without shifting.

c Untick the **Focus Wobble** checkbox.

7 In the **Scanning** tab, set *Scan Speed* = *7*.

8 Bring the image into focus.

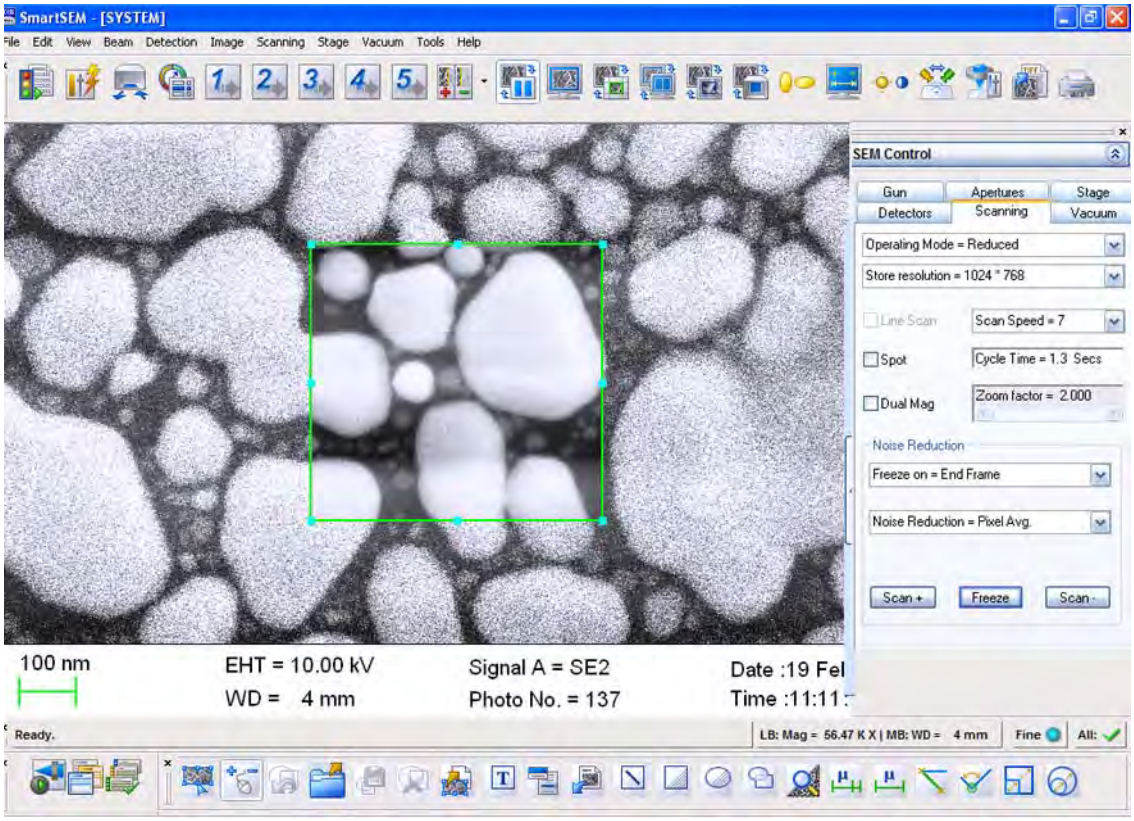
9 Toggle to **Fine** in the status bar.
Use **Coarse** and **Fine** mode of adjustment where appropriate.



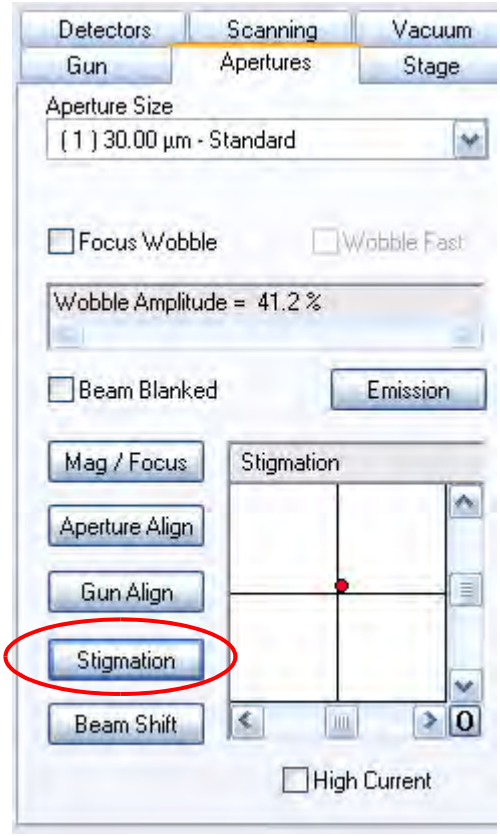
10 Correct astigmatism:

a Select a detail (e.g. a mark or an edge) on the specimen surface.

b Click on the **Reduced Raster** icon.
Ensure the selected detail is in the raster.



c In the **Apertures** tab:
Click on the **Stigmation** button.



d In the **Stigmation** box, use the arrow buttons or the left and right slider to obtain the sharpest possible image.

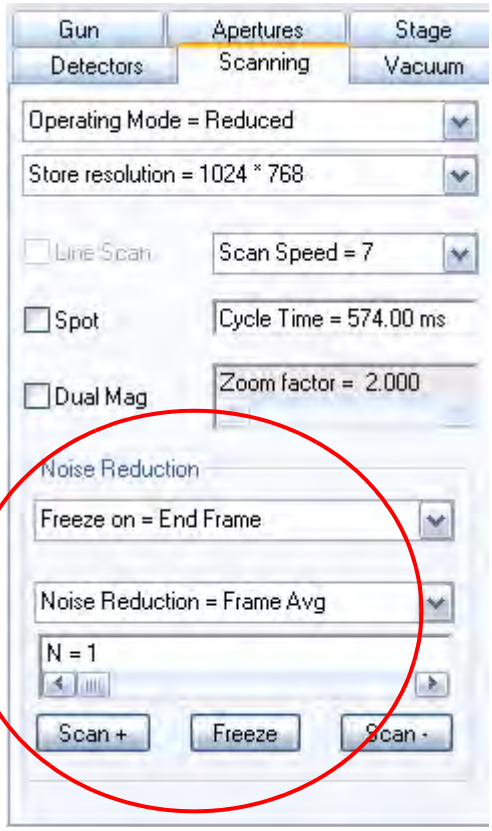
11 Deactivate the reduced raster.

12 In order to reduce image noise, select a slower scan speed, e.g. scan speed *6* to *8*.

6.4.1.9. Saving the image

1 Stop the scan:

a Go to the **Scanning** tab.

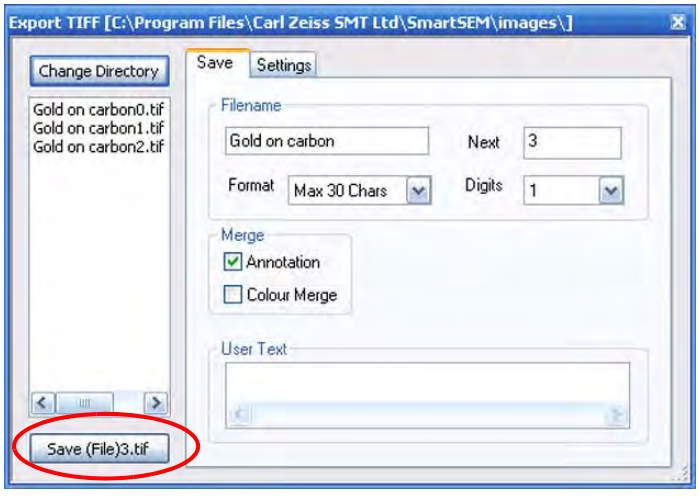


b In the **Noise Reduction** section, select *Freeze on = End Frame* from the drop-down menu.

c Click on the **Freeze** button.

A red dot at the right bottom of the image area indicates that the image is frozen.

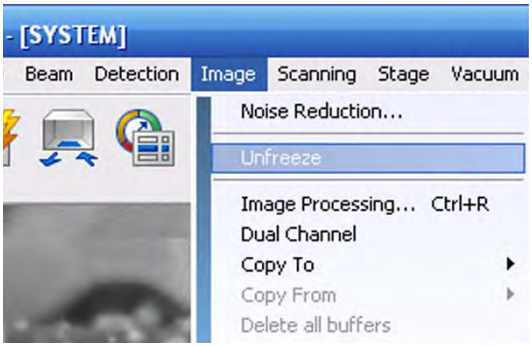
2 Select **File/Save Image** from the menu.



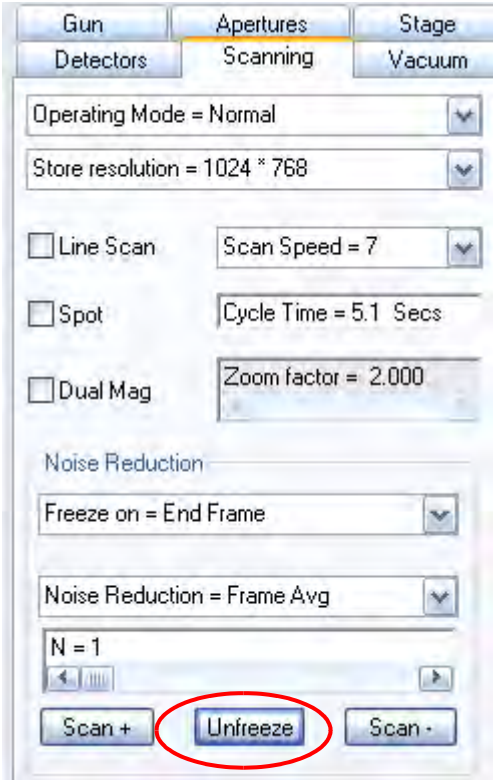
3 Enter a path and a file name.

4 Confirm by clicking on the **Save....tif** button.

To continue imaging, unfreeze the image by selecting **Image/Unfreeze** from the menu.



Alternatively, you can click on the **Unfreeze** button in the **Scanning** tab.

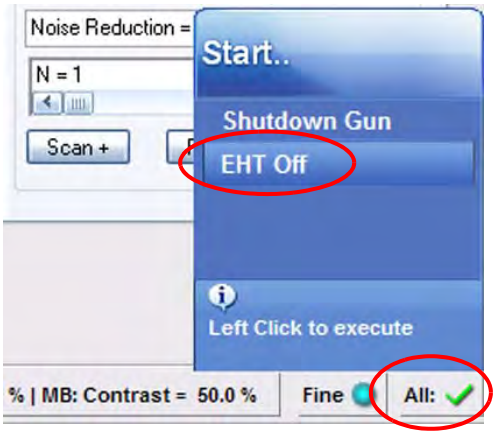


6.4.1.10. Finishing the work session

To finish your work session, switch off the EHT:

a Click on the **All:** button in the status bar.

b Select **EHT Off** from the pop-up menu.

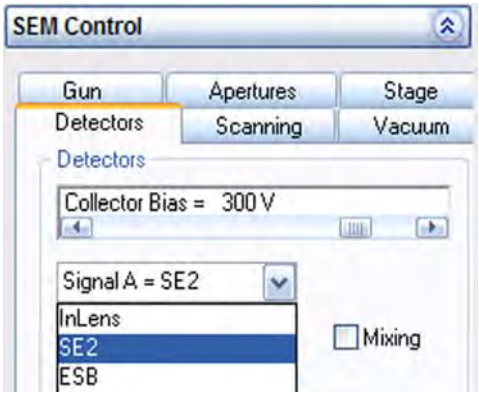


It is recommended that you leave the gun on during the working week. This should help to optimise lifetime of the cathode.

6.4.2. Setting detection parameters

6.4.2.1. Selecting a detector

1 Go to the **Detectors** tab of the **SEM Control** panel.
2 Select the detector from the **Detectors** drop-down menu.

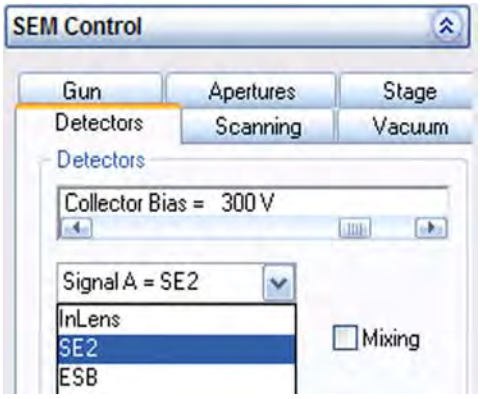


The following table should serve as a help to find the required settings for your application.

Detectors	EHT	Typical WD	Detector settings	Remarks
In-lens	3 kV - 20 kV	3 - 6 mm	None	
	100 V - 3 kV	2 - 3 mm		
	100 V	max. 4 mm		
SE2	1 - 30 kV	min. 4 mm	Collector voltage (= bias) adjustable from -250 V to + 400 V Standard applications: +300 V Pseudo BSE image: -150 to 0 V	Select the settings as described in section 6.4.2.2.
	1 kV - 5 kV	4 - 6 mm		
	5 kV - 30 kV	min. 6 mm		
EsB®	1 kV - 5 kV	max. 4 mm	EsB grid adjustable from 0 to +1500 V Value depends on type of electrons to be detected: less than approx. 800 V: SE + BSE more than approx. 800 V: BSE	Select the settings as described in section 6.4.2.3.
	100 V - 1 kV	1-2 mm		

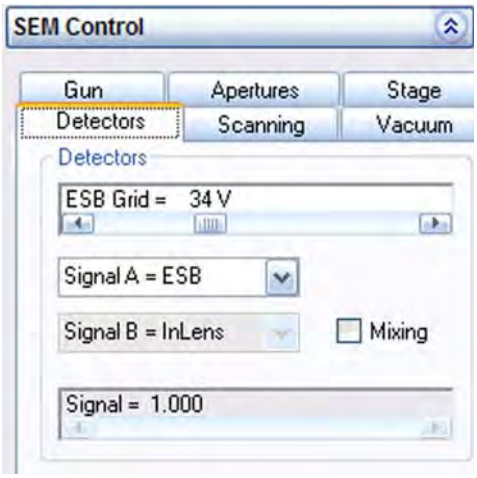
6.4.2.2. Using the SE2 detector

1 Select the SE2 detector.
2 Set the collector bias (voltage) in the **Detectors** tab of the **SEM Control** panel.



6.4.2.3. Using the EsB® detector (optional)

1 Select the EsB® detector.
2 Set the **EsB Grid** voltage in the **Detectors** tab of the **SEM Control** panel.



6.5. Electron beam deposition or etching (with GIS upgrade only)

Requires a gas injection system (GIS).

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

Precursor/gas	**Application**
Insulator, SiO_2	Deposition
Platinum, Pt	Deposition
Water (reactive products)	Etching of material that contains carbon e.g. diamond like carbon layers (DLC)
Fluorine, XeF_2	Etching of Si-containing materials
Tungsten, W	Deposition

6.5.1. Heating the reservoirs

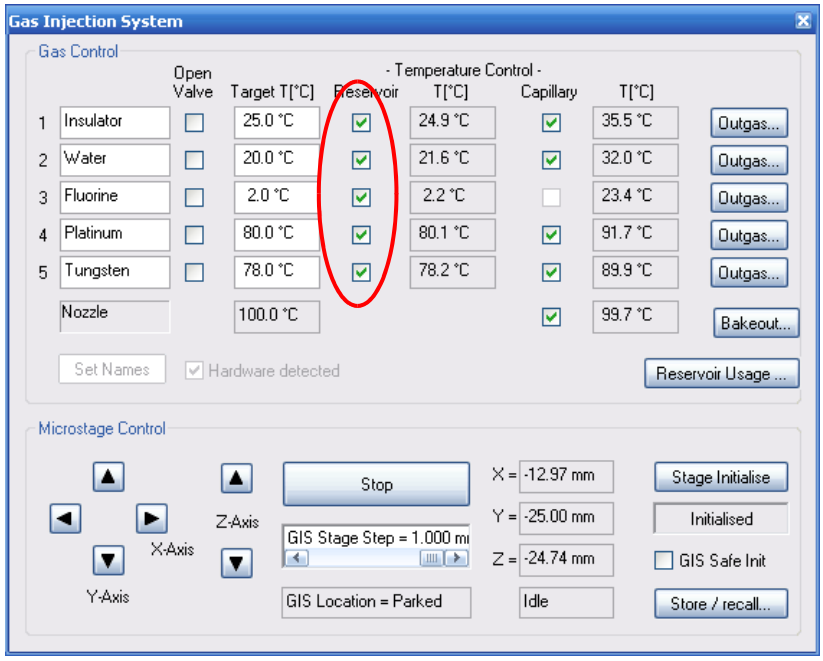
The reservoirs - except for the fluorine precursor (XeF_2) - are heated in order to liberate the process gases from the precursor substances and to improve their reactivity.
The fluorine precursor (XeF_2) is never heated, but cooled, because this substance is volatile at room temperature.

Procedure:

1 Open the **Panel Configuration Bar**.

2 Double-click on **Gas Injection System**.

The **Gas Injection System** panel opens.



3 Click on 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 all the time to ensure stable conditions, because it can last 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 x 10^{-5} mbar.

6.5.2. Depositing or etching with the electron beam

CAUTION

Danger of damaging GIS micro stage or specimen.
Make sure to position the specimen surface at a safe working distance.

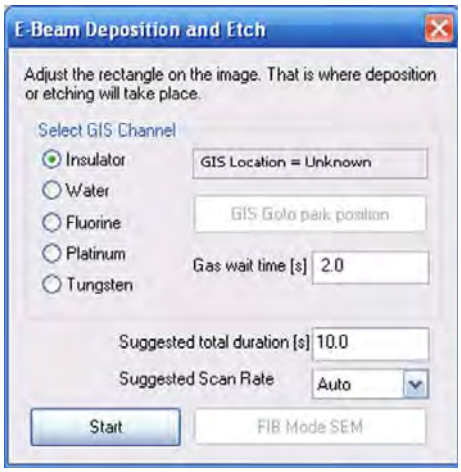
Procedure

1 Open the **Panel Configuration Bar**.

2 Double-click on **E-Beam Deposition and Etch**.

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

A deposition object is shown in the image area.



3 Resize the deposition object to the appropriate size.

4 Select the required precursor.

5 Set a **Gas Wait Time**.

6 Set a **Total Duration Time**.

7 Set a **Scan Rate**.

8 Click on **Start**.

6.6. CrossBeam® operation (with FIB upgrade only)

Requires FIB column.

It is assumed that the operator is already familiar with general functions of SmartSEM® and the operation of the FESEM.

IMPORTANT

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

6.6.1. Preparing the workstation

Before you can make use of the CrossBeam® functions, you have to prepare the workstation.

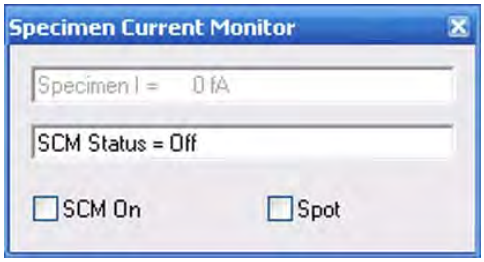
At a glance

The complete sequence includes:

- Getting started
- Adjusting tilt eucentricity
- Switching on the ion beam (FIB)
- Setting the coincidence point

6.6.1.1. 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 on **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.

6.6.1.2. Adjusting tilt eucentricity

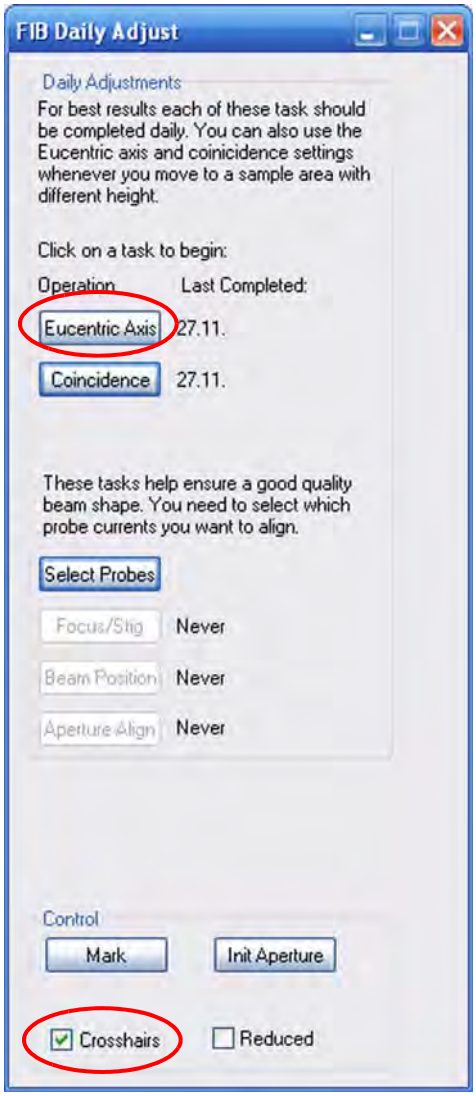
Before you can start imaging or milling, it might be necessary to adjust tilt eucentricity. By adjusting the eucentricity, the specimen surface is moved into the tilting plane of the super-eucentric stage. That is why the image does not shift out of the screen when the stage is tilted.

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 on **FIB Daily 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 on **Eucentric Axis**.
6 Click on **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.

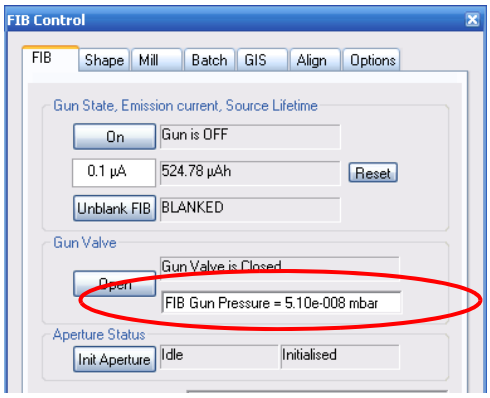
How to continue

Continue with switching on the ion beam (FIB).

6.6.1.3. Switching on the ion beam (FIB)

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

2 Ensure the **FIB Gun Pressure** is better than *5 x 10^{-7} mbar.*



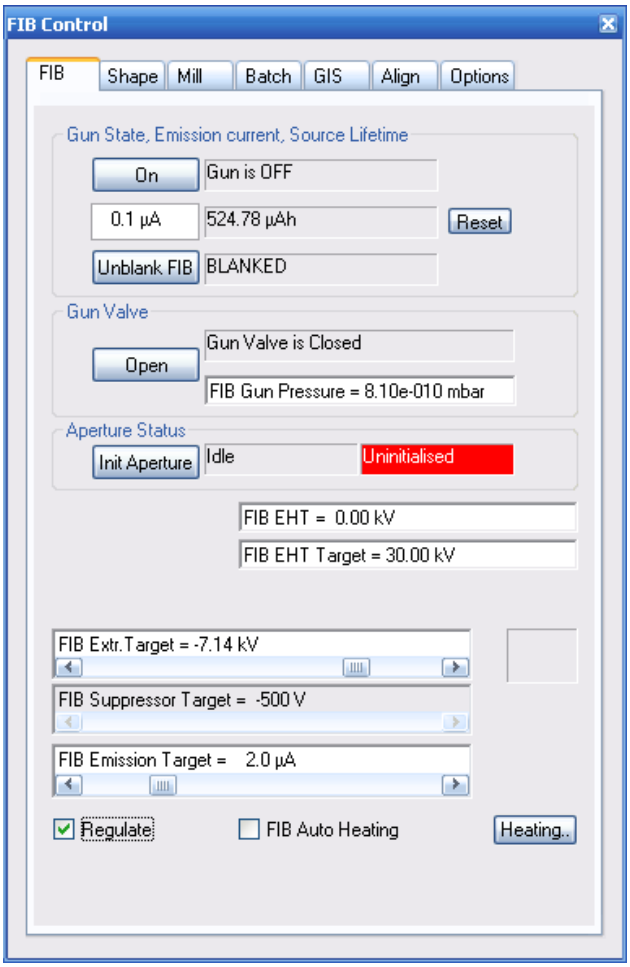
CAUTION

Danger of arcing. Danger of damaging the ion source.
Before switching on the ion beam, ensure the FIB gun pressure is better than 5x10^{-7} mbar.

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

4 Click on the **FIB** icon.

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



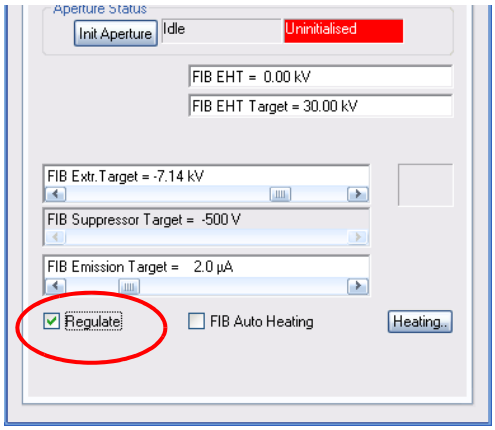
IMPORTANT

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

5 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

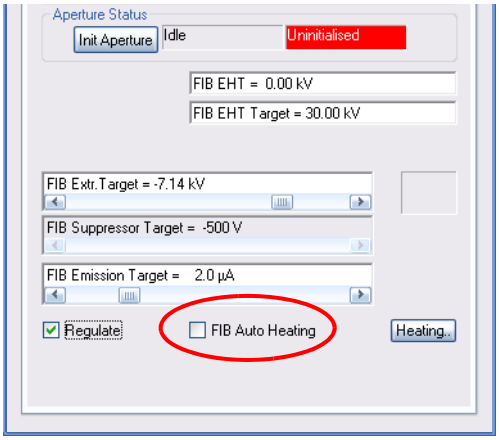
From time to time, the gallium emitter has to be regenerated by heating. The heating procedure removes the gallium oxide which has been created during operation or during longer breaks.

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:

Heating automatically

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



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.

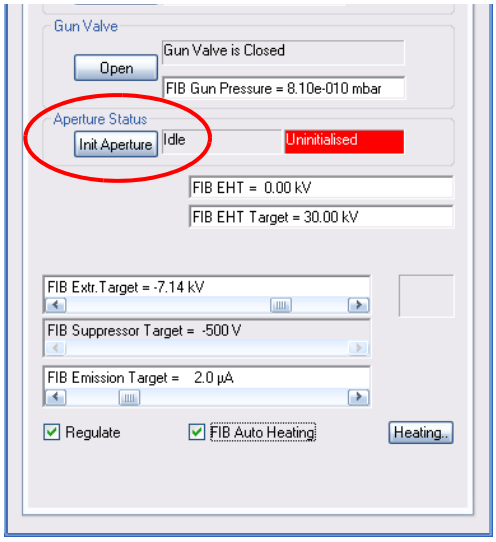
The manual heating will be required after having performed the Auto Heating for about 5 times, i.e. about every 2 - 3 weeks. However, this interval is dependend on the usage of the workstation. All Auto Heating cycles are listed in the log file of the EM Server.

Heating manually

a Check the number of Auto Heating cycles in the EM Server.

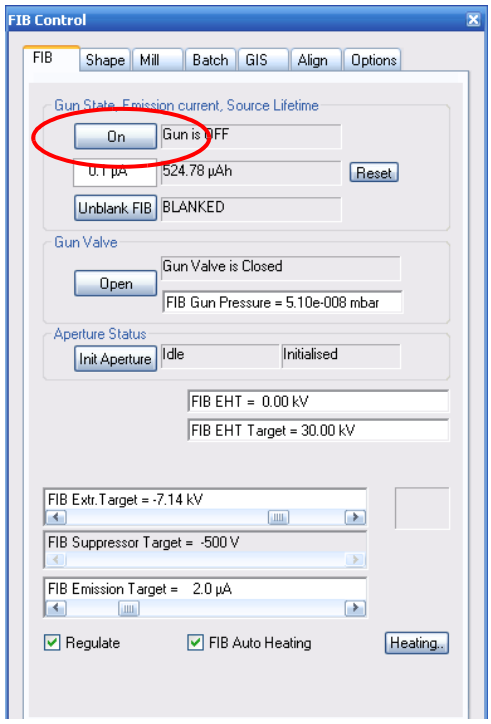
b After every fifth Auto Heating cycle heat manually.
Refer to section 8.3.2.2. regenerating the ion source by heating manually.

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



The aperture initialisation may require several seconds.

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



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

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

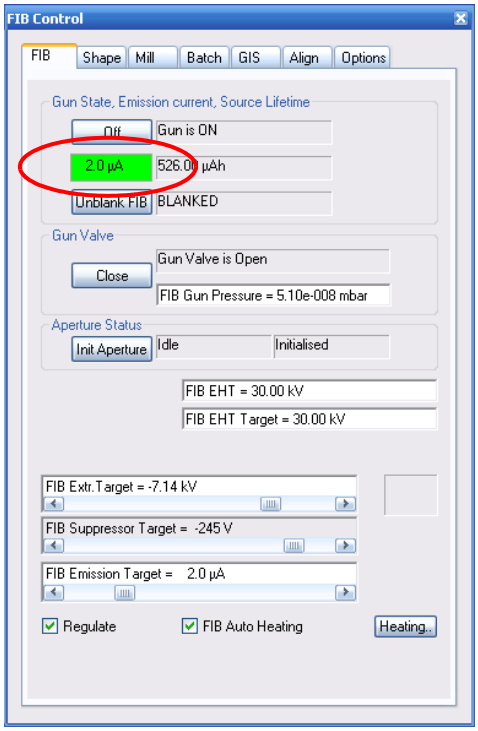
The emission current should be about *2 µA*.

The background of the button can have several colours.

Green background:
The emission current equals the target (+/- 0.1 µA).

Yellow background:
The emission current differs from the target by more than 0.1 µA.

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 6.6.4.1.

How to continue

Continue with setting the coincidence point.

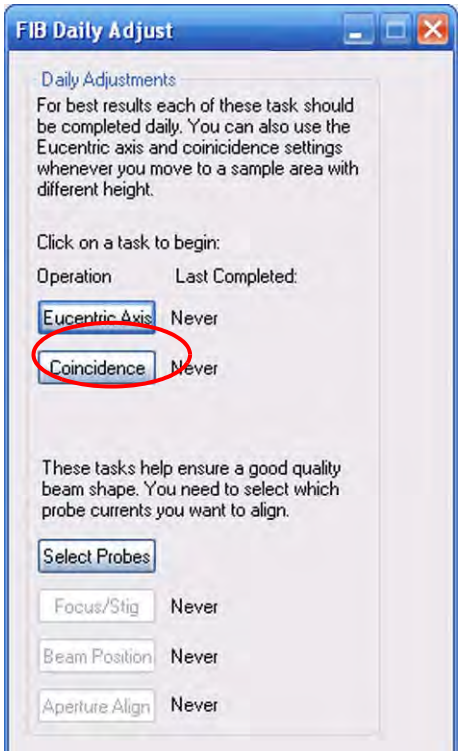
6.6.1.4. Setting the coincidence point

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 Configuation Bar**.
7 Double-click on **FIB Daily Adjust**.
8 Tilt the stage to *54°*.

The **FIB Daily Adjust** panel opens.



9 Click on **Coincidence**.
10 Follow the instructions in the wizard.

11 Click on **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.

Now, the workstation is ready to apply the Cross-Beam® functions.

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.

6.6.2. 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 a given depth.

At a glance

The complete sequence includes:

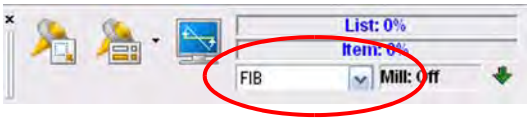
- Selecting milling conditions
- Starting the milling procedure

Preconditions:

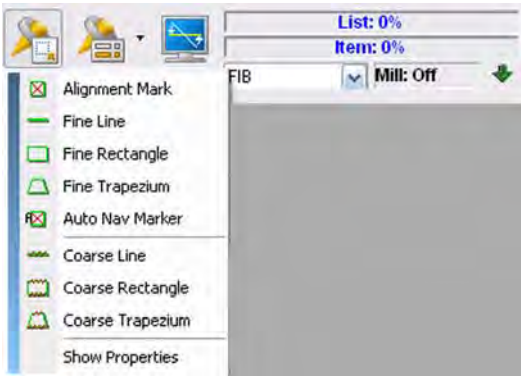
- Electron beam has been switched on
- Ion beam has been switched on
- Tilt eucentricity has been adjusted
- Specimen has been moved to the coincidence point

6.6.2.1. Selecting milling conditions

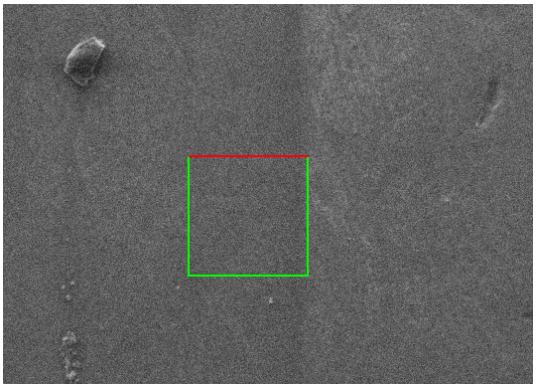
1 Select **FIB** mode from the drop-down list.



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



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

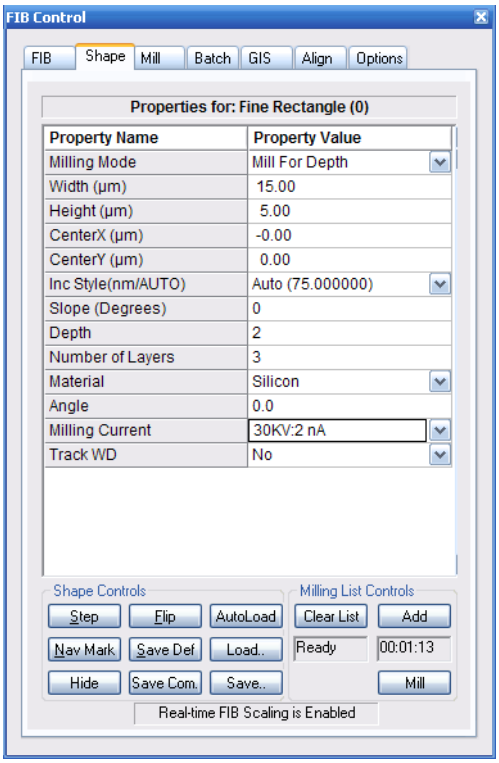


The milling object is displayed on the screen.

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 on the markers of the milling object and drag.

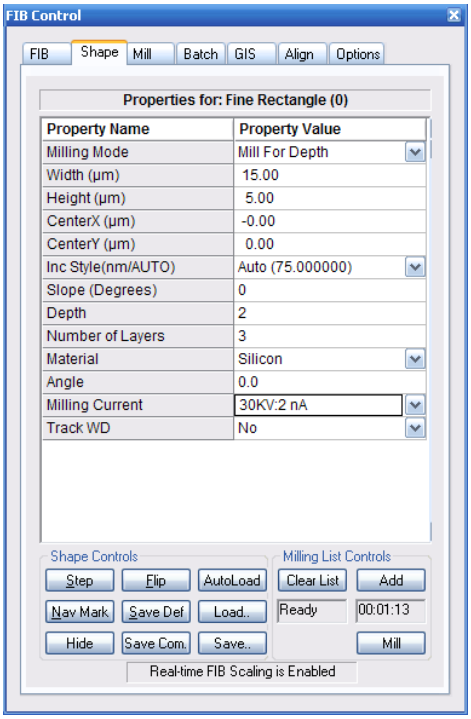
c Set the position of the milling object:
Enter values for **CentreX** and **CentreY**.

Alternatively, select the milling object.
Click on 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**.

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.

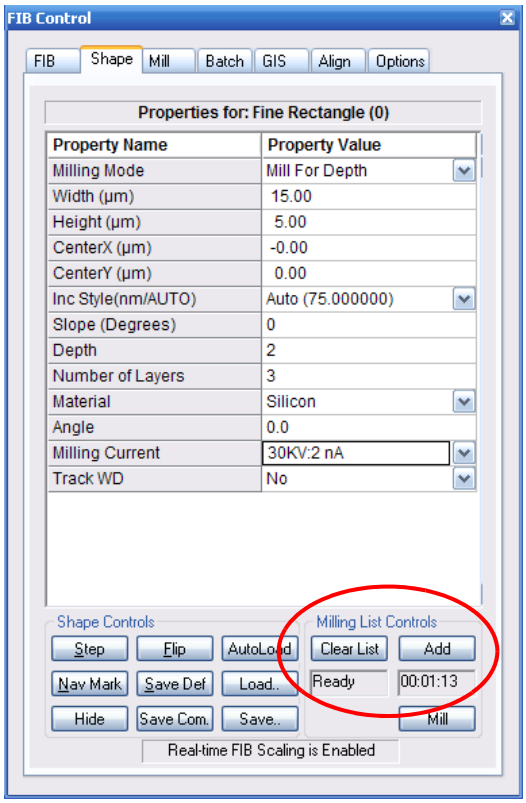
6.6.2.2. Starting the milling procedure

1 Click on **Clear List**.

All previous milling objects are deleted from the milling list.

2 Click on **Add**.

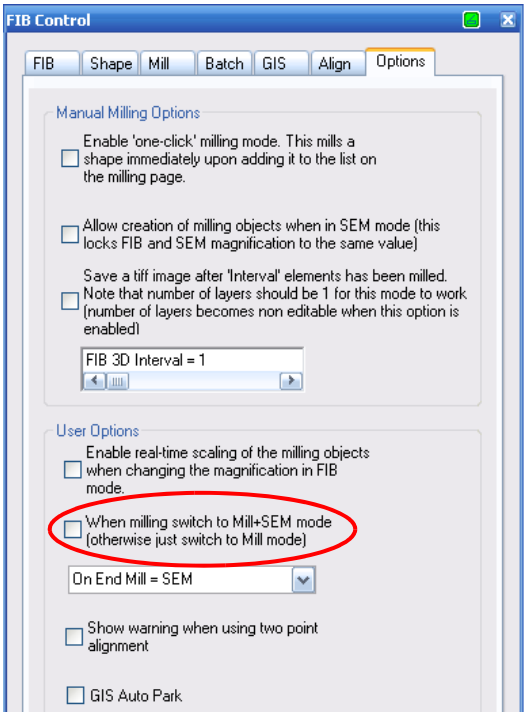
The current milling object is - together with the selected milling conditions - added to the milling list.



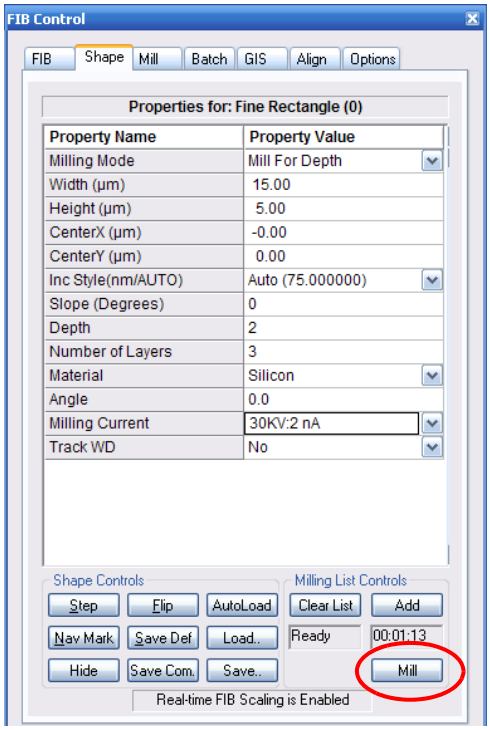
The time needed to process the object is shown under the **Add** button.

3 Go to the **Options** tab.

4 Tick the **When milling switch to Mill+SEM mode**... checkbox.

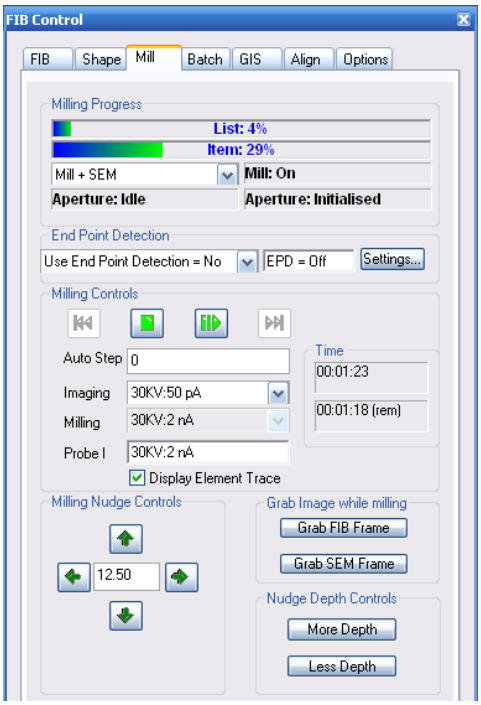


5 To start the milling, go to the **Shape** tab and click on **Mill**.



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.

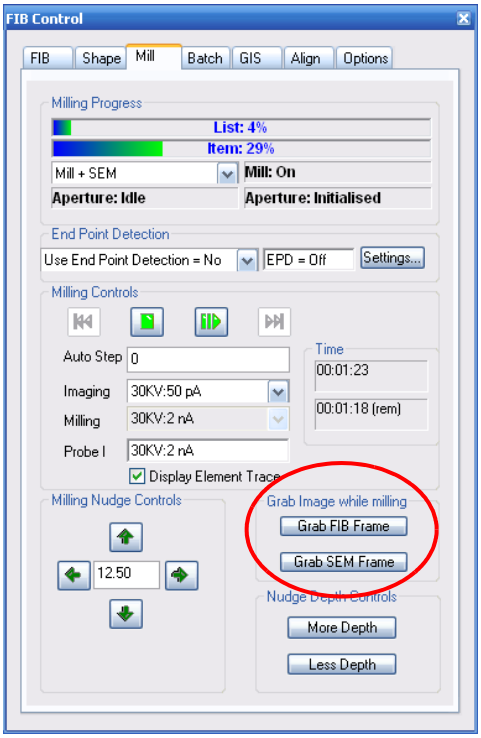
6.6.3. Recording images during milling

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 on **Grab FIB Frame**.
Grabbing a FIB image provides an orthogonal view onto the specimen surface.

2 To record a SEM image, click on **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 on **Unfreeze**.

6.6.4. Gas assisted deposition: Platinum (with GIS upgrade only)

Requires FIB column and GIS.

A common ion-beam induced deposition is the deposition of platinum, which serves e.g. as a surface protection layer. This section summarizes the procedure for the platinum depsition as a model.

IMPORTANT

For details on the deposition of other materials, refer to the Software Manual SmartSEM® XB.

At a glance

The complete sequence includes:

- Heating the platinum precursor
- Outgassing the platinum precursor
- Selecting deposition conditions
- Starting the deposition procedure

Preconditions:

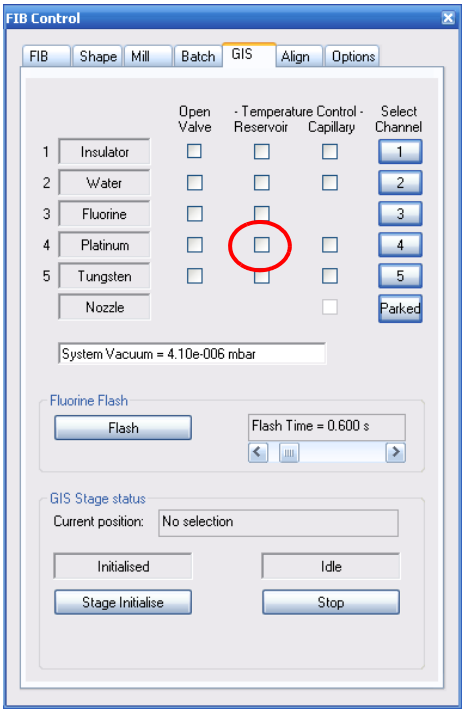
- Workstation has been prepared
- Stage is tilted to 54°

6.6.4.1. Heating the platinum reservoir

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.

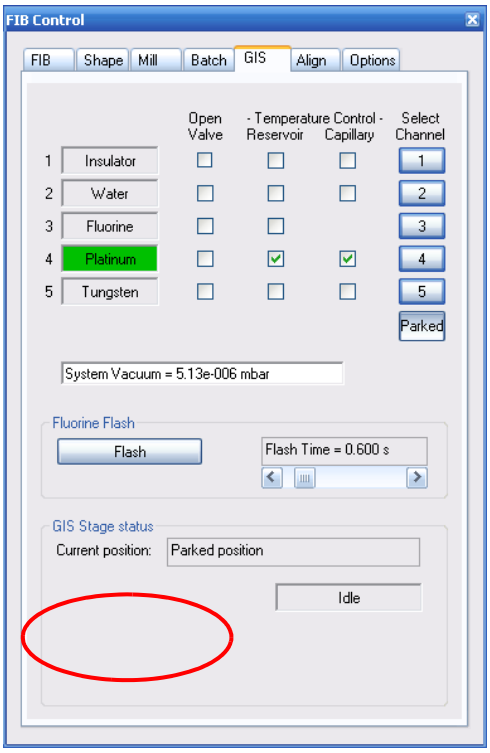
IMPORTANT

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

2 If required, initialise the GIS micro stage:

a Go to the **GIS** tab.

a Click on **Stage Initialise**.



How to continue

Continue with outgassing the platinum precursor.

6.6.4.2. Outgassing the platinum reservoir (only with five-channel GIS)

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:

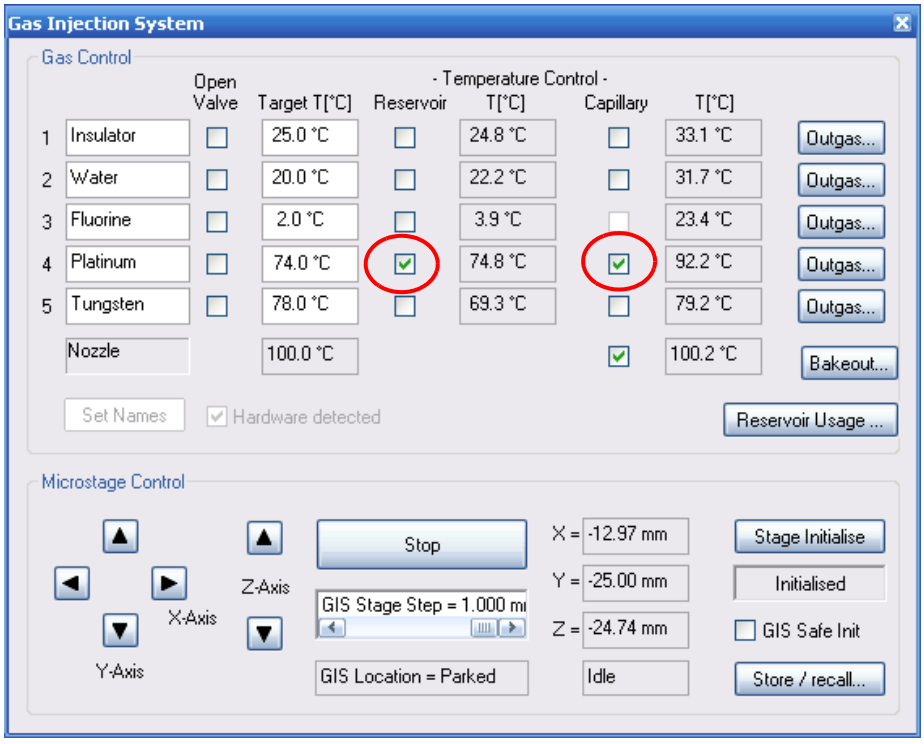
1 Switch off the SEM EHT.

2 Switch off the FIB EHT.

3 Open the **Panel Configuration Bar**.

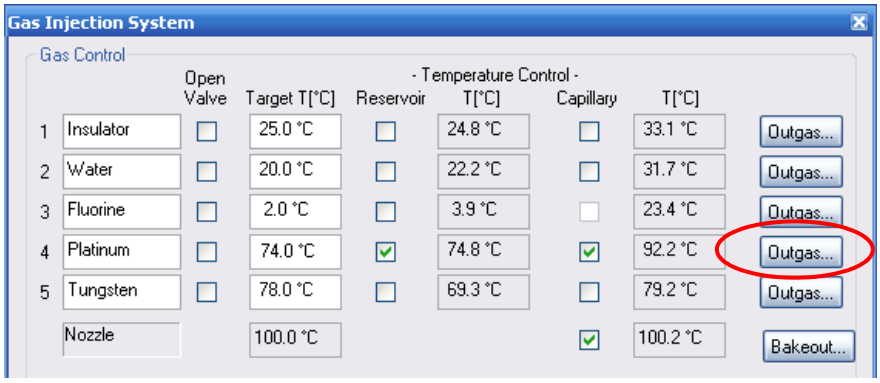
4 Double-click on **Gas Injection System**.

The **Gas Injection System** panel opens.

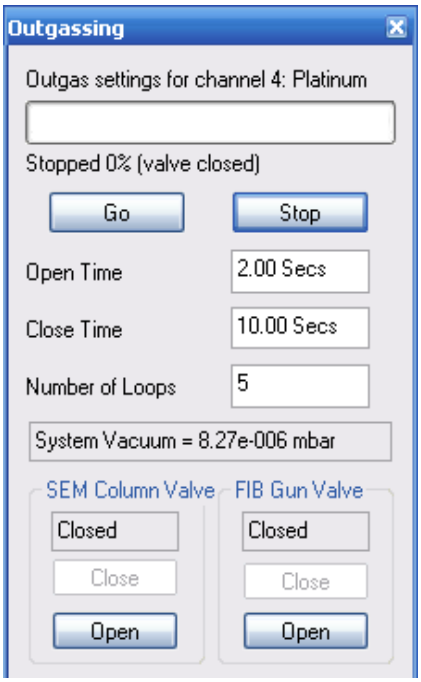


5 Ensure that the **Temperature Control** checkboxes for **Reservoir** and **Capillary** of *Platinum* are ticked.

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



The **Outgassing** panel opens.



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

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

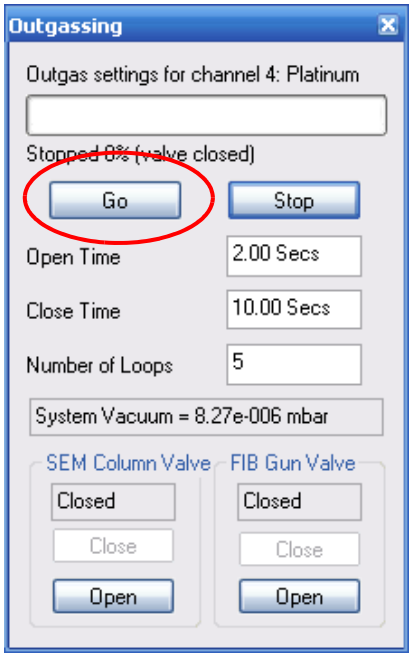
8 Click on the **Open Time** field and enter *2 seconds*.
9 Click on the **Close Time** field and enter a value of about *5 to 10 seconds*.
10 Click on the **Number of Loops** field and enter *5*.

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 Gun Valve" are closed.

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 x 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 on **Stop**.

How to continue

Continue with selecting deposition conditions.

6.6.4.3. Selecting deposition conditions

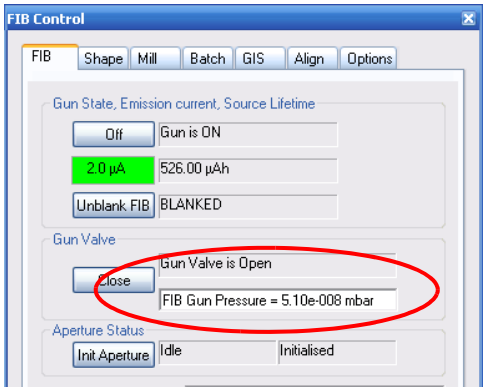
Preconditions:

- 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 x 10^{-7} mbar.



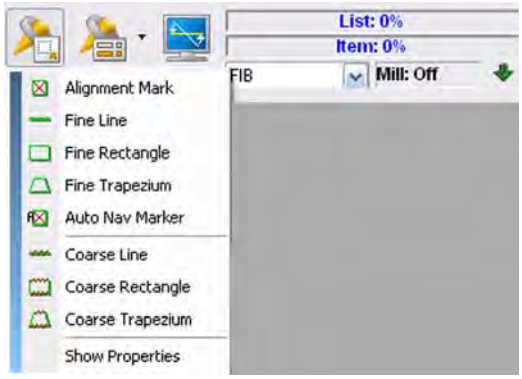
CAUTION

Danger of arcing. Danger of damaging the ion source.
Before switching on the ion beam, ensure the FIB gun pressure is better than 5 x 10^{-7} mbar.

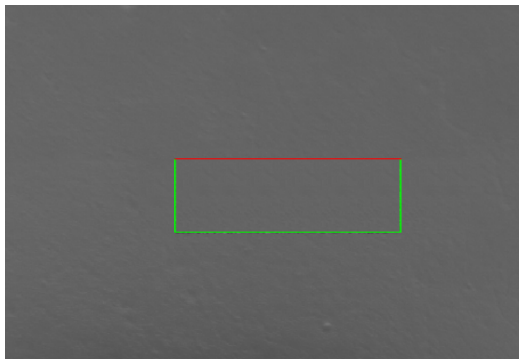
4 Switch on the ion beam:
   a Go to the **FIB** tab of the **FIB Control** panel.
   b Click on **On**.

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.

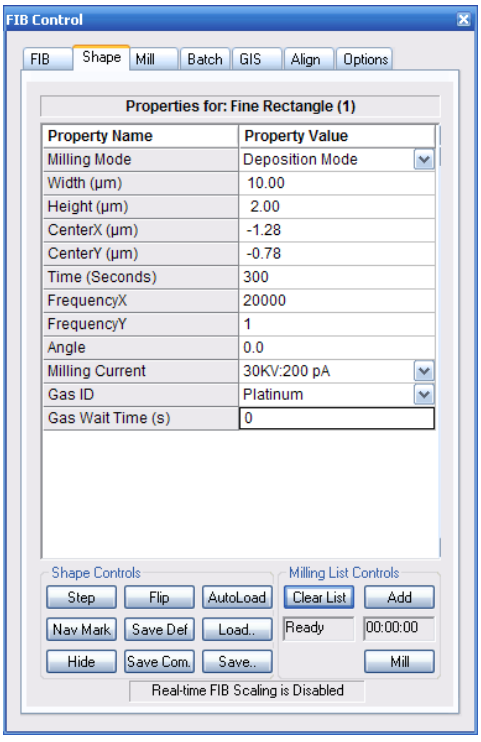


The milling object is displayed on the screen.

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*



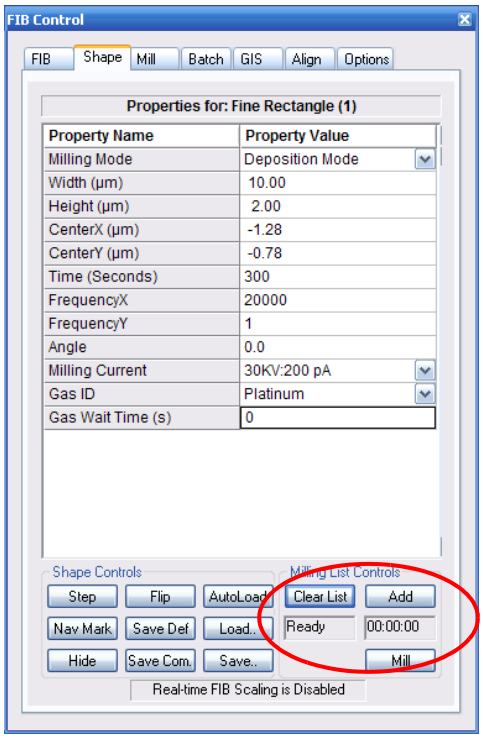
6.6.4.4. Starting the deposition procedure

1 Click on **Clear List**.

All previous milling objects are deleted from the milling list.

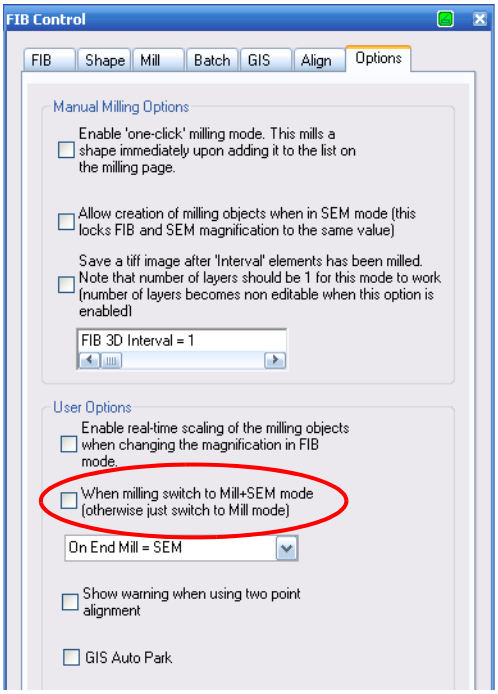
2 Click on **Add**.

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



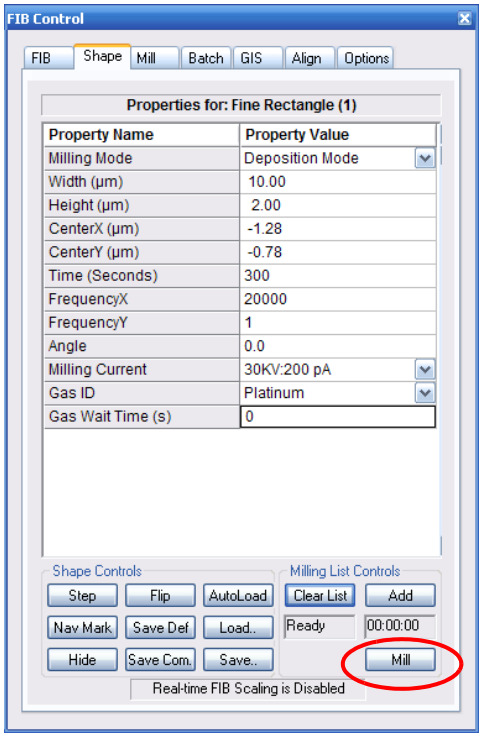
The time needed to process the object is shown under the **Add** button.

3 Go to the **Options** tab.



4 Tick the **When milling switch to Mill+SEM mode**... checkbox.

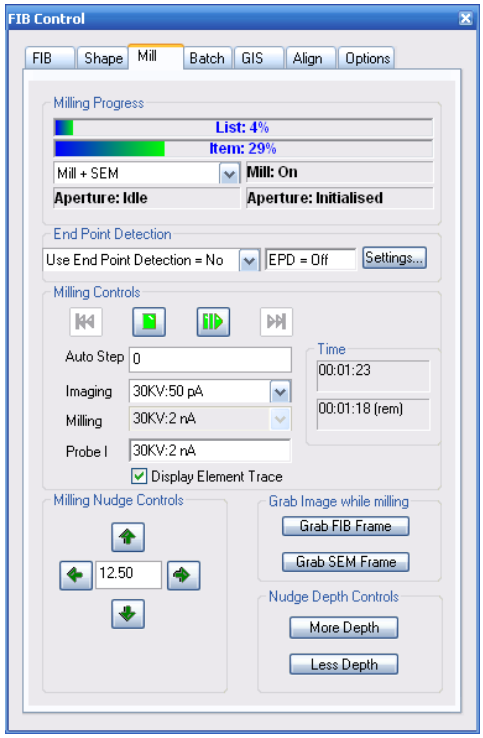
5 To start the deposition, go to the **Shape** tab and click on **Mill**.

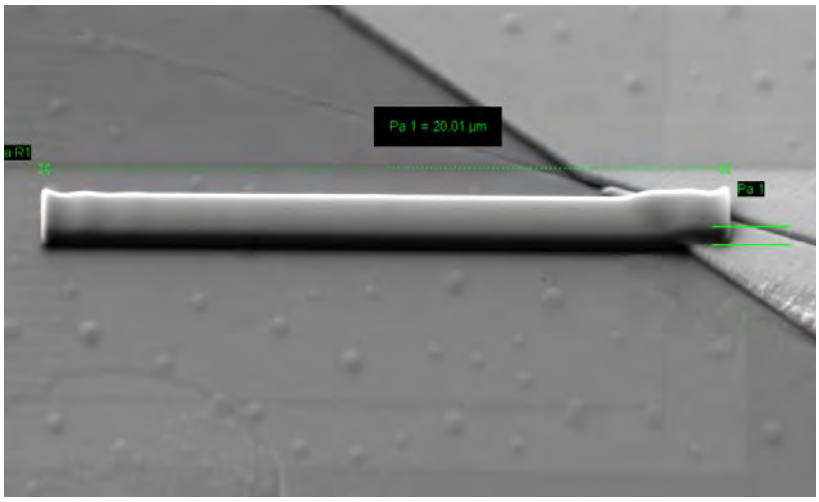


The GIS micro stage is moved automatically to the pre-defined position, which has been assigned to *Platinum.*

The deposition process starts.

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



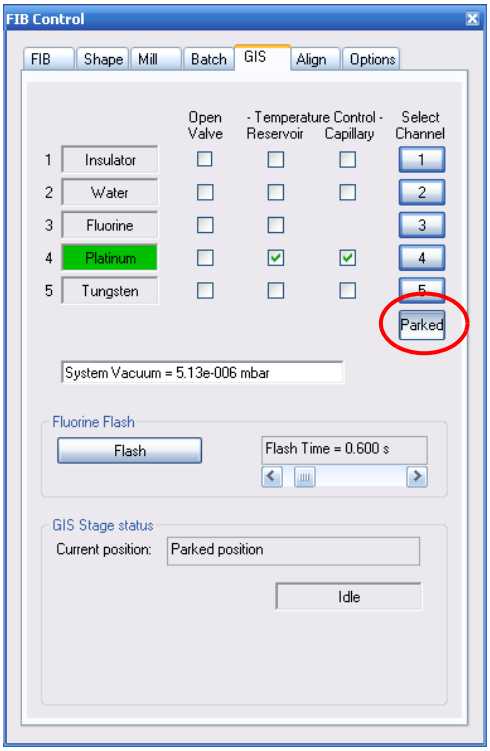


The deposition process ends automatically.

6 Move the GIS micro stage to the park position:

a Go to the **GIS** tab.

b Click on **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.

6.6.5. Setting detection parameters

6.6.5.1. Using the SESI detector (optional)

The SESI detector allows the acquisition of FIB secondary ion images and electron images.

The following table should serve as a help to find the required settings for your application.

Operating mode	Detected signals	FIB mode	EHT	Typical WD	Detector settings
SE mode	Secondary electrons	SEM	100 V to 30 kV	max. 5 mm	Collector voltage: 0 V to + 1500 V Best detection: +300 V to + 400 V
		FIB	2 kV to 30 kV	coincidence point	Collector voltage: 0 V to + 1500 V Best detection: +300 V to + 400 V
Ion mode	Secondary ions	FIB	2 kV to 30 kV	coincidence point	Collector voltage: - 5 kV to 0 kV Best detection: around - 4 kV

Preconditions:

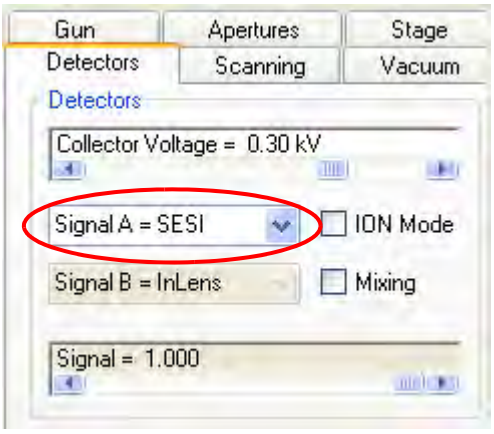
- Gun and EHT are on
- Suitable specimen is located

Procedure:

1 Select an imaging mode, e.g. **FIB mode SEM**.

2 Go to the **Detectors** tab of the **SEM Control** panel.

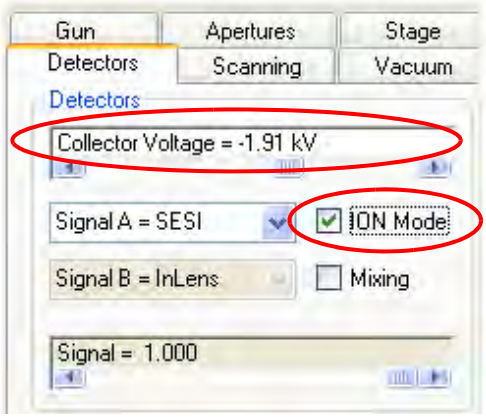
3 Select *SESI* from the drop-down menu.



The SESI detector is operated in **SE mode**.

4 In order to toggle between **SE Mode** and **Ion mode**, tick/untick the **ION Mode** check-box.

5 Set the **Collector Voltage**.

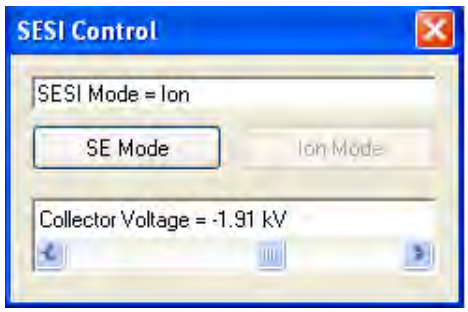


SESI Control panel

Alternatively:

1 Open the **Panel Configuration Bar**.
2 Double-click on **SESI Control.**

The **SESI Control** panel opens.



3 Select the desired settings.

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

6.6.6.1. 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 6.1: 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.

Cobra FIB

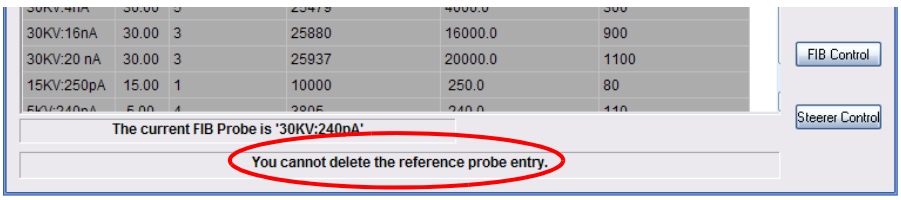
Range	FIB probe currents	Aperture diameter	Aperture No.
Low probe currents	Currently not in use	10 µm	14
	1, 2 pA	10 µm	13
	Currently not in use	20 µm	12
	10 pA	30 µm	11
	Currently not in use	50 µm	10
	20 pA	50 µm	9
	50 pA	80 µm	8
	80, 140 pA	100 µm	7
	275 pA	150 µm	1
	600	200 µm	6
High probe currents	1 nA	200 µm	6
	2 nA	300 µm	2
	4 nA, 8 nA, 12 nA	400 µm	5
	16 nA	500 µm	3
	30 nA	800 µm	4

Table 6.2: 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	NTS part no.
Faraday cup	348342-8055-000
Piece of silicon wafer (bulk)	-

6.6.6.2. Adjusting a low probe current (pA)

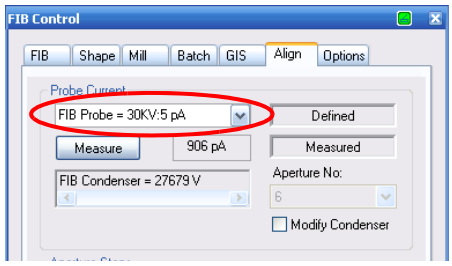
Procedure:

1 Load the Faraday cup.

2 Go to the coincidence point at 54°.

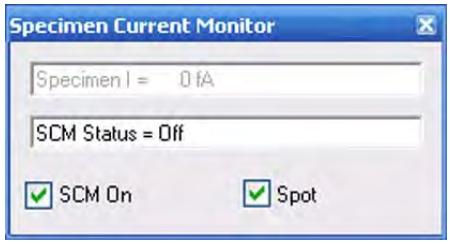
3 Ensure that the emission of the ion beam is stable.

4 Go to **FIB Control/Align** and select a probe current.



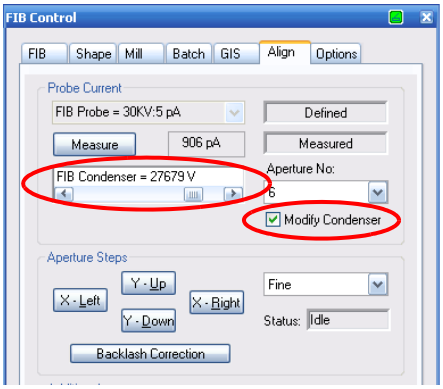
5 Start measuring the specimen current by using the Specimen Current Monitor (**Panel Configuration Bar/Specimen Current Monitor**).

6 Tick the **SCM On** and the **Spot** checkbox.

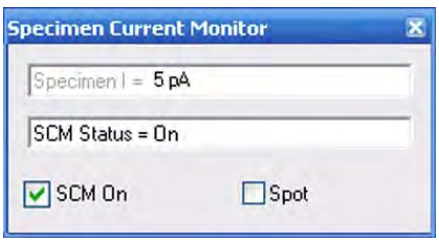


7 Go to **FIB Control/Align**.

8 Tick the **Modify Condenser** checkbox.



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**.

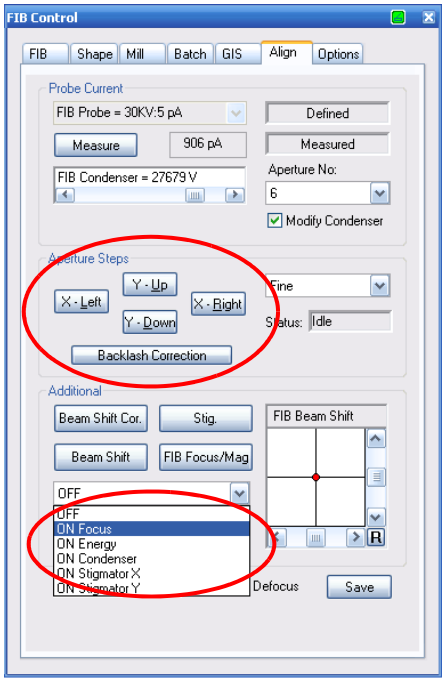


10 Focus the specimen surface: Use **Focus** and **Stigmation**.

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*.



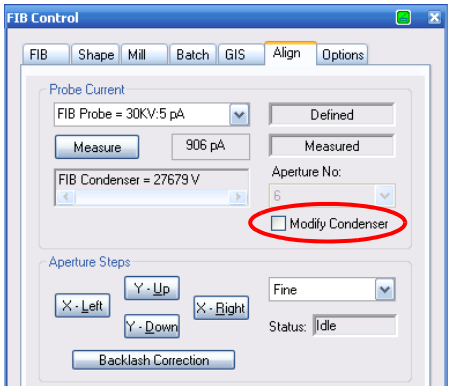
The aperture has been aligned correctly when the image does not shift any more during the focus/un-focus cycle.

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

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

14 Repeat the procedure for all other probe currents.

15 In the **Align** tab, untick the **Modify Condenser** checkbox.



How to continue

Adjust the Beam shift correction (refer to section 6.6.6.5.).

6.6.6.3. Adjusting a high probe current (nA)

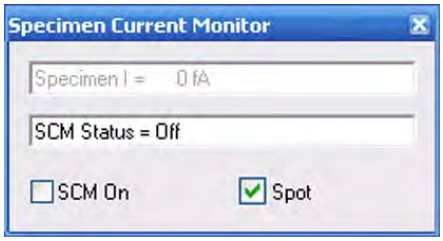
For the higher currents (nA range) usually the largest apertures need to be selected. It is very difficult to achieve a circular beam profile without halo by using the Focus wobble procedure.

Precondition:

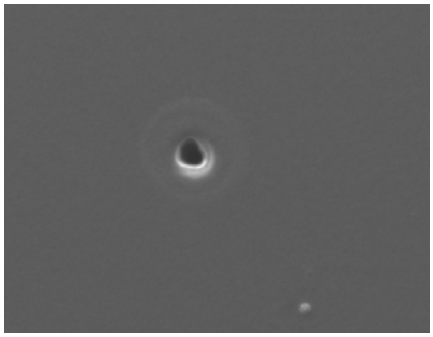
- Piece of silicon is loaded
- Probe currents have been adjusted roughly as described for pA probe currents (see previous section).

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.



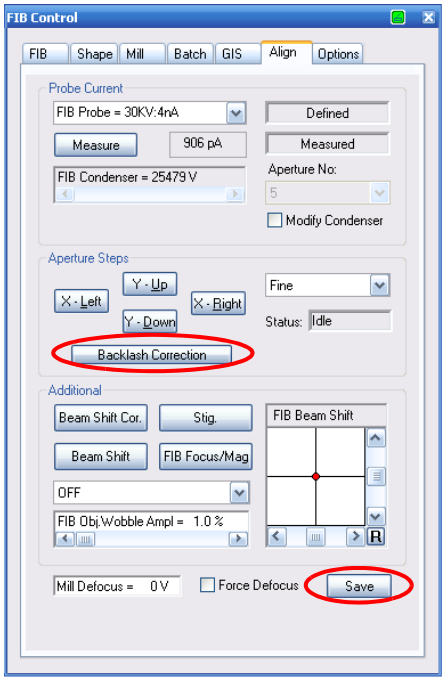
5 If the halo is reduced, continue moving the aperture in this direction.
If the halo is increased, move the aperture in the opposite direction.

6 Repeat steps 4 to 5 until the burned spot is round.

7 In the **Align** tab of the **FIB Control** panel: Click on **Backlash Correction**.

8 Check the spot shape.

9 Click on **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 6.6.6.4.).

How to continue

Adjust Beam shift correction (refer to section 6.6.6.5.).

6.6.6.4. 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.

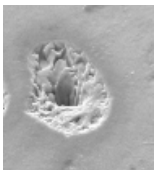
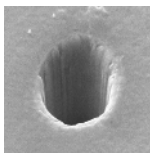
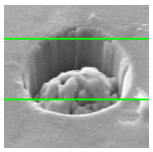
Image	Comment
	The ion beam is focussed, resulting in - an optimum imaging resolution but - the sputter rate is low due to the large halo.
	The focus voltage is reduced by -60 V resulting in - poor image quality, but - the sputter rate is increased due to the elimination of the halo and - high current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

Table 6.3: Spot files

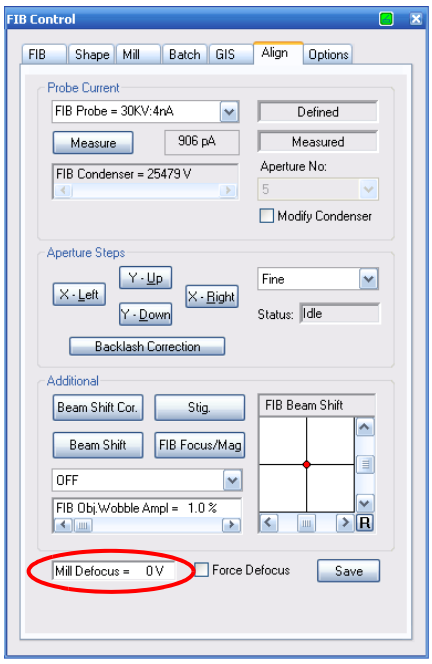
Procedure:

1 Adjust the probe current as described in section 6.6.6.3.

2 Go to **FIB Control/Align**

3 Set the defocus value:

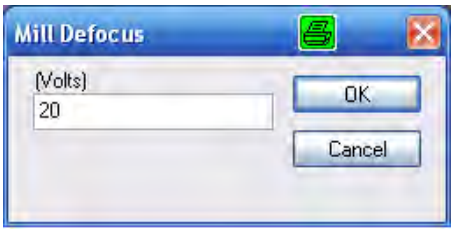
a Double-click in the **Mill Defocus =** field.



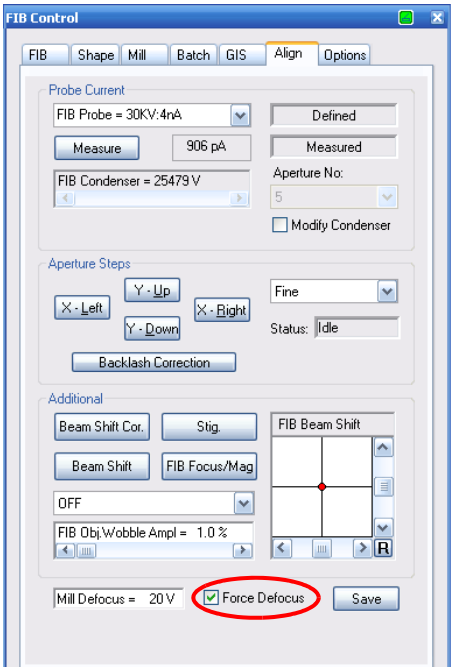
IMPORTANT

The defocus value is different for each current.

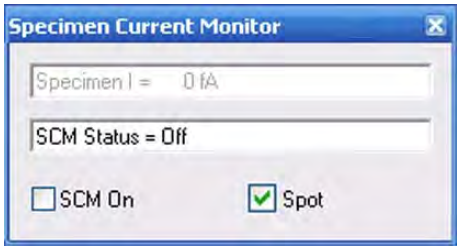
b Enter a defocus value, e.g. *20V* in the **Mill Defocus** window



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



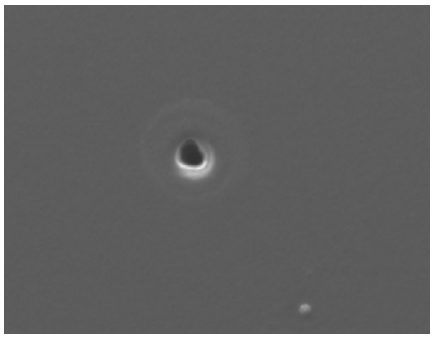
5 Burn a spot into the specimen for about *5 s* to evaluate the spot quality:
Use the **Spot** mode.



6 Check the halo.

7 Slowly increase the defocus value in *10 V* steps.

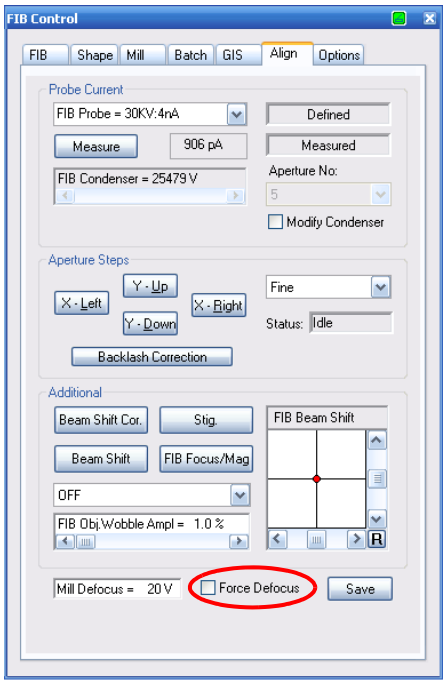
8 Repeat steps 5 to 7 until the burned spot is round.



9 If the correct defocus voltage is reached, click on ***Save***.

10 Untick the **Force Defocus** checkbox.

Now, the adjustment is complete.



6.6.6.5. 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.

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.

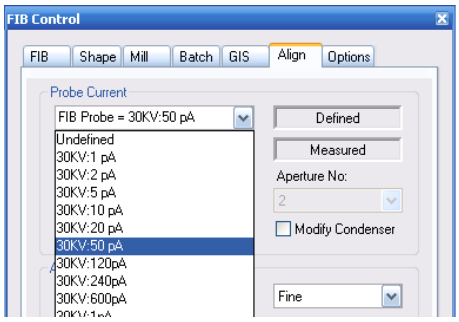
IMPORTANT

The Beamshift correction has only a limited range.

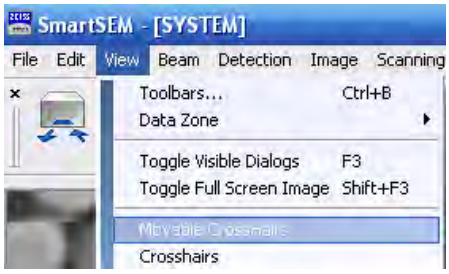
Procedure:

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.

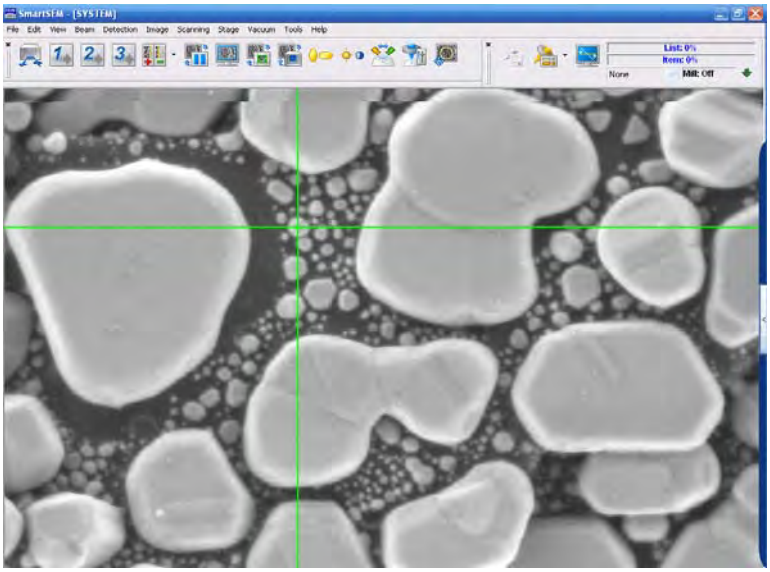


3 Select **View/Movable Crosshairs** from the menu bar.

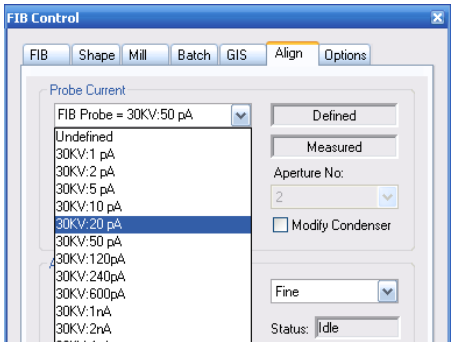


Crosshairs are displayed in the image area.

4 Move the crosshairs to a selected position. To move the crosshairs, click on the square in the centre and drag.

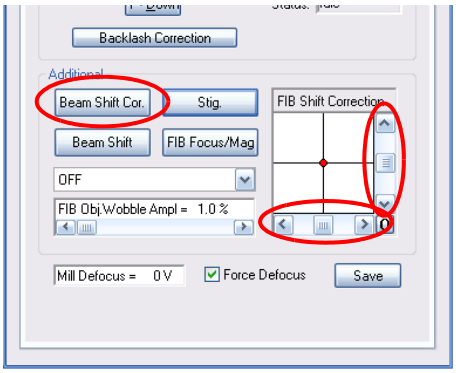


5 In the **FIB Control/Align** tab, select the next smaller probe current from the drop-down menu.

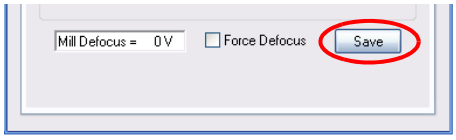


The crosshairs are shifted to another position

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

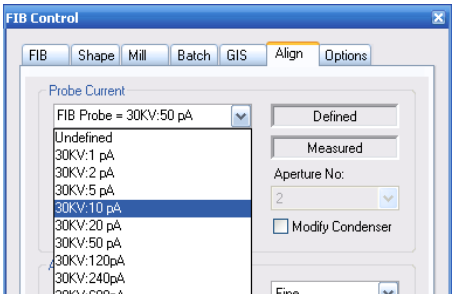


7 Click on **Save** to save the adjustments.

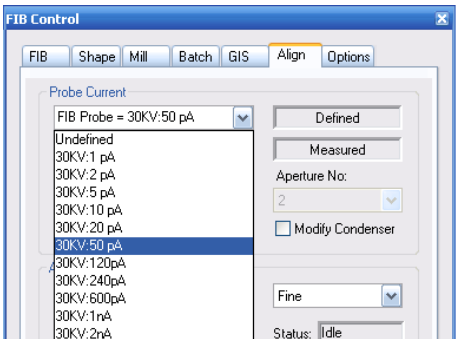


8 Repeat steps 5 to 7 with the next smaller probe current.

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.

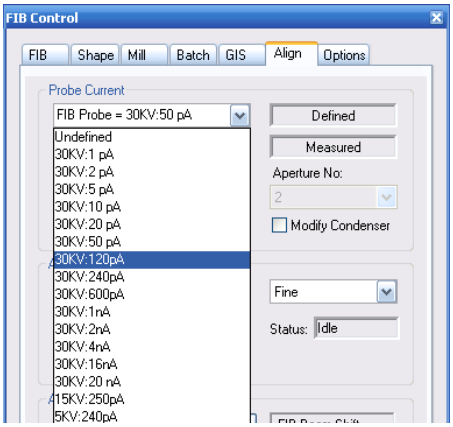


CAUTION

Danger of damaging the specimen
Ensure not to damage the specimen while working with high currents.

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.

6.7. Using the help functions

The SmartSEM® user interface offers a multitude of help texts containing information on the operation of the workstation, the optimization of the images and the handling of accessory options.

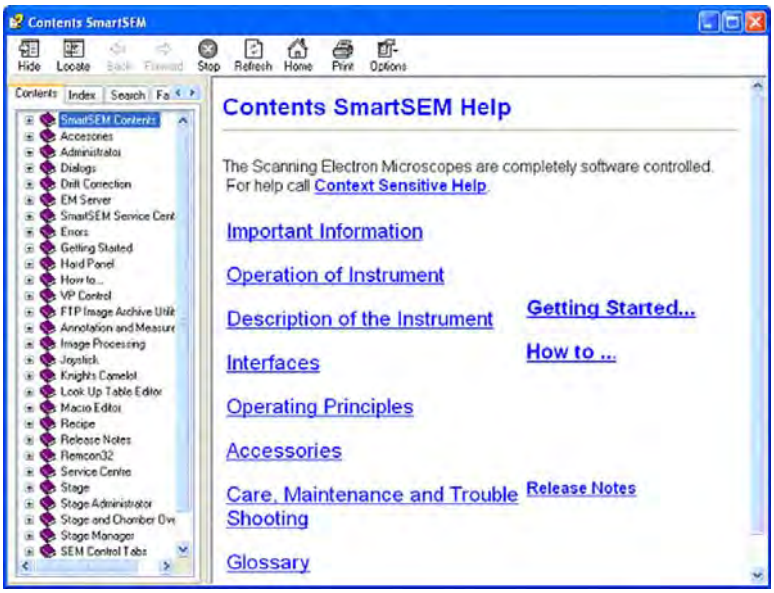
6.7.1. Calling the SmartSEM® help

1 Press <**F1**>.

Alternatively, select **Help/SmartSEM help** from the menu.

The SmartSEM® help start window opens.

If menus are opened in the SmartSEM® user interface, pressing <**F1**> will open the help text for the respective menu. This allows explaining the menu while the workstation is being operated.



6.7.1.1. Printing help texts

1 Click on the printer icon in the help window.

If a printer is installed, the help text is printed.

6.7.1.2. Bringing help texts to the foreground

1 Select **Help/Help Always On Top** from the menu.

The displayed help texts remain in the foreground.

6.7.2. Calling the context-sensitive help

1 Press <**SHIFT+F1**>.
Alternatively, select **Help/What's This** from the menu.

The mouse cursor is equipped with a question mark.

2 Move the cursor to the area of interest on the screen.

3 Click on the left mouse button.

The help text is shown.

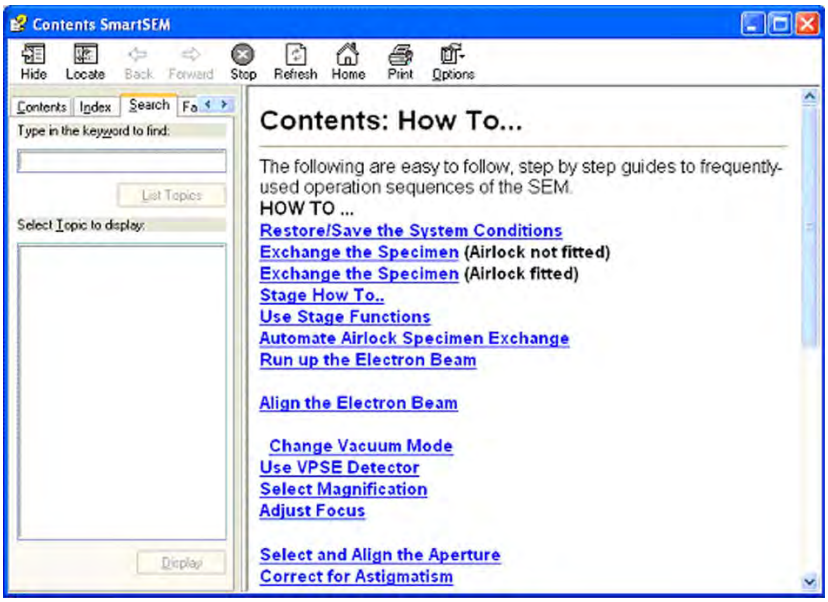
4 To disable the context-sensitive help, press <**ESC**>.

6.7.3. Searching for a topic

1 Select **Help/Search** from the menu.

2 Click on the **Search** tab.

3 Search for the desired topic.



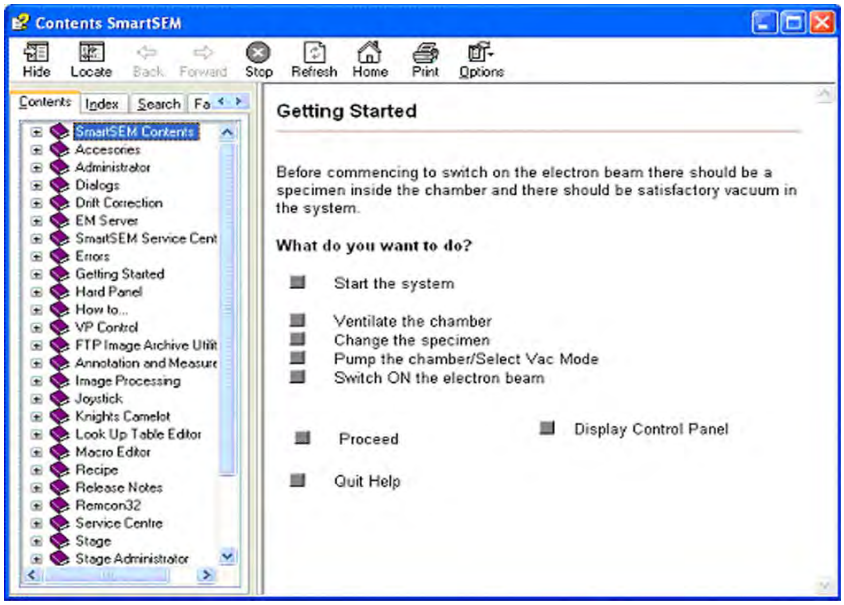
6.7.4. Using the step-by-step guides

The step-by-step guides provide quick information on important operation sequences.

6.7.4.1. Getting started

1 Select **Help/Getting started** from the menu.

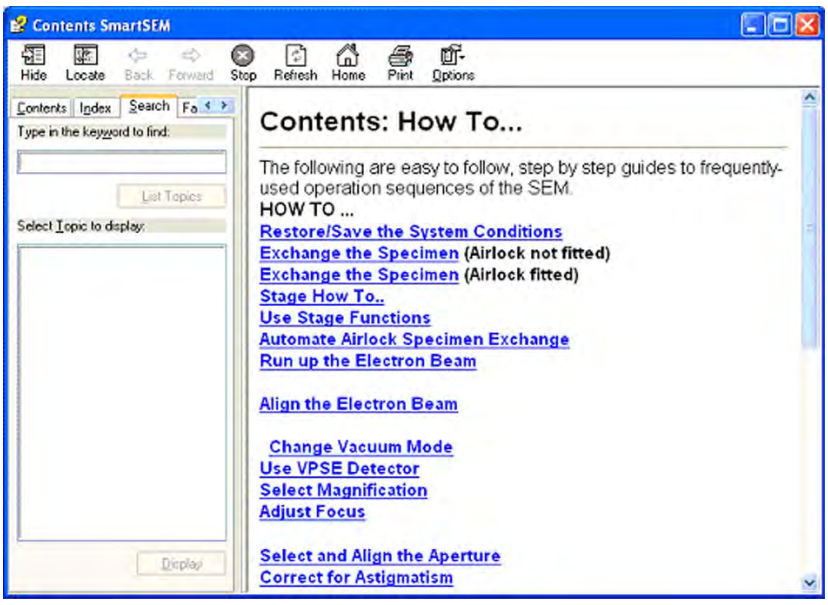
2 Click on the topic of interest.



6.7.4.2. Frequently used operation sequences

1 Select **Help/How To** from the menu.

2 Click on the topic of interest.

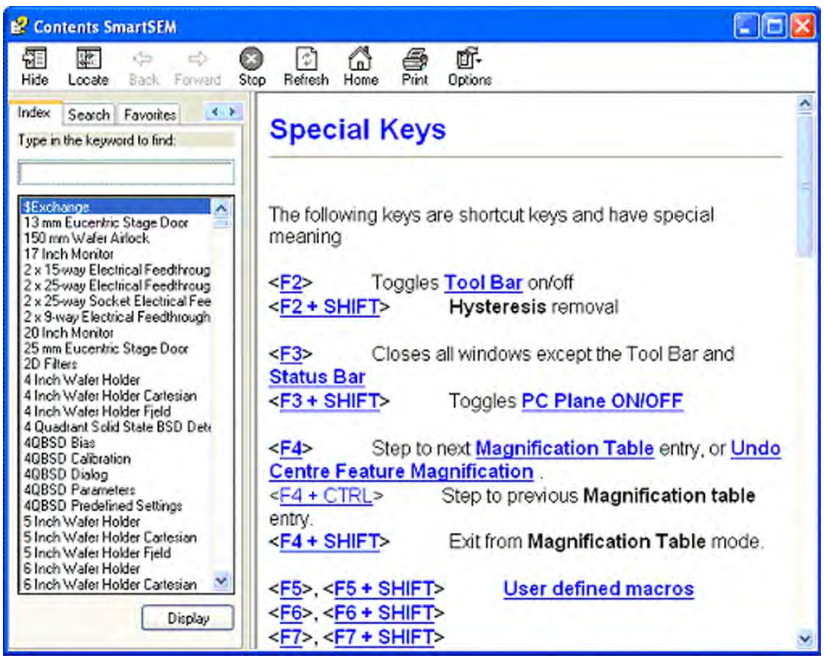


6.7.5. Calling the short cuts help

Many functions and menus which are often used in the SmartSEM® user interface can also be opened using the keyboard. A list of short cuts (key combinations) can be displayed in the SmartSEM® help.

1 Press < **F9**>.

Alternatively, select **Help/Keys help** from the menu.

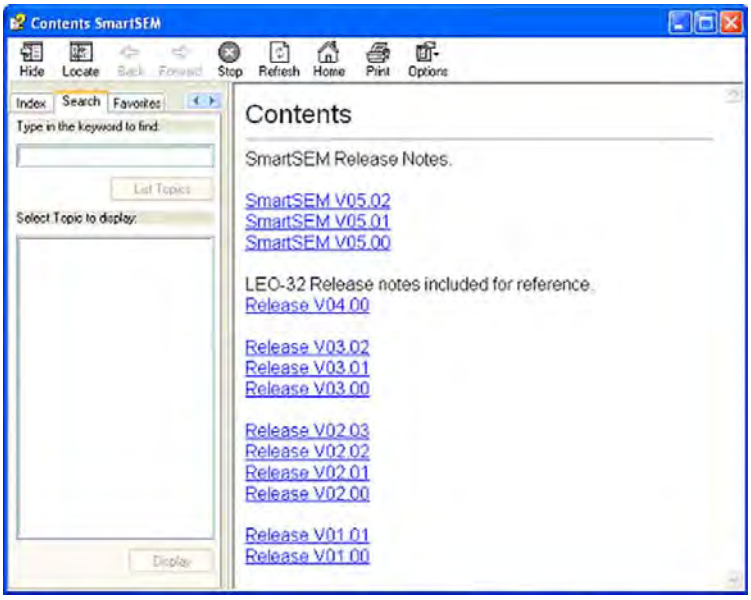


6.7.6. Showing information about SmartSEM®

6.7.6.1. Version history

The Release Notes summarise important information about the software version history. New functions, bug fixes and special features of the different versions are explained.

1 Select **Help/Release Notes** from the menu.



6.7.6.2. About SmartSEM®

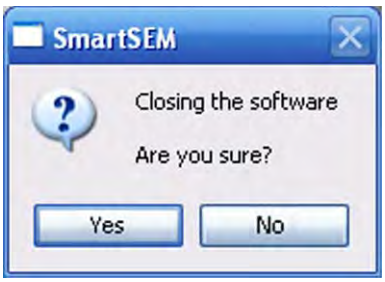
1 Select **Help/About SmartSEM** from the menu.

6.8. Closing the SmartSEM® user interface

6.8.1. Logging off

1 Select **File/Log Off** from the menu.

A window appears asking for confirmation to close the session.



2 Confirm by clicking on the **Yes** button.

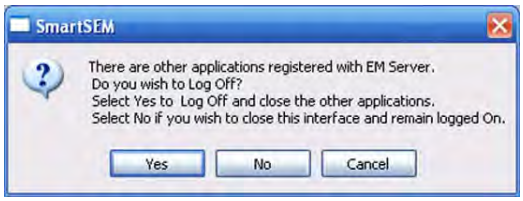
The electron-optical parameters are filed in a macro in the individual user directory.

The EM Server remains active.

6.8.2. Exiting

1 Select **File/Exit** from the menu.

A window appears asking for confirmation to close the session.



2 Confirm by clicking on the **Yes** button.

The electron-optical parameters are filed in a macro in the individual user directory.

6.9. Switching off the workstation as a matter of routine

6.9.1. Changing to STANDBY mode

Change to STANDBY mode when the workstation is not operated, even for longer periods.

The SEM filament will continue to be heated, and the vacuum in electron optical column, ion column and specimen chamber will be maintained.

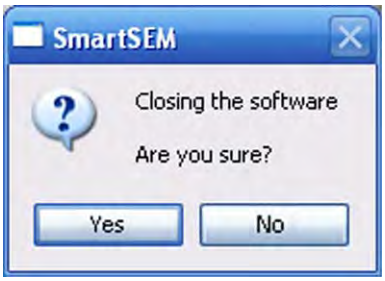
STANDBY mode is also the recommended mode to store the workstation.
In this case, tick the **Partial Vent on Standby** checkbox in the **Vacuum** tab of the **SEM Control** panel.

1 Switch off the EHT.

2 Close SmartSEM® :

a Select **File/Exit** from the menu.

The SmartSEM® Close UIF window appears asking for confirmation to close the session.



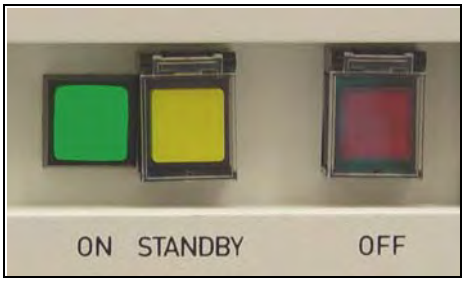
b Confirm by clicking on the **Yes** button.

The electron-optical parameters are filed in a macro in the individual user directory.

3 Shut down the PC.

4 Press the yellow **STANDBY** button.

The yellow **STANDBY** button lights.



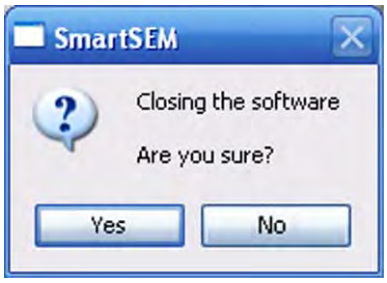
6.9.2. Changing to OFF mode

Change to OFF mode in case the workstation needs to be reset.

1 Switch off the EHT.

2 Close SmartSEM® :

a Select **File/Exit** from the menu.



A window appears asking for confirmation to close the session.

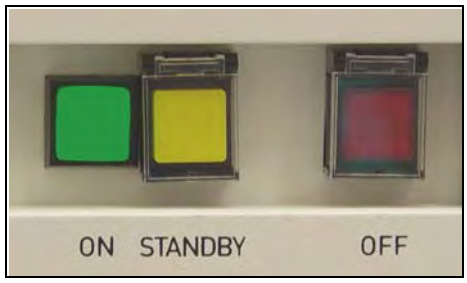
b Confirm by clicking on the **Yes** button.

The electron-optical parameters are filed in a macro in the individual user directory.

3 Shut down the PC.

4 Press the red **OFF** button.

The red **OFF** button lights.



Computer, electronic components and vacuum system are switched off. The electron optical column is partially ventilated. A 24 V auxiliary voltage is still present to restart the workstation.

6.10. Emergency off (EMO)

The emergency off procedure depends on the type of installation (with or without optional EMO box).

6.10.1. With EMO box (optional, but mandatory with FIB and/or GIS upgrade)

6.10.1.1. Switching off in an emergency

1 Press the EMO button (***1***).

All power is cut off from the workstation.

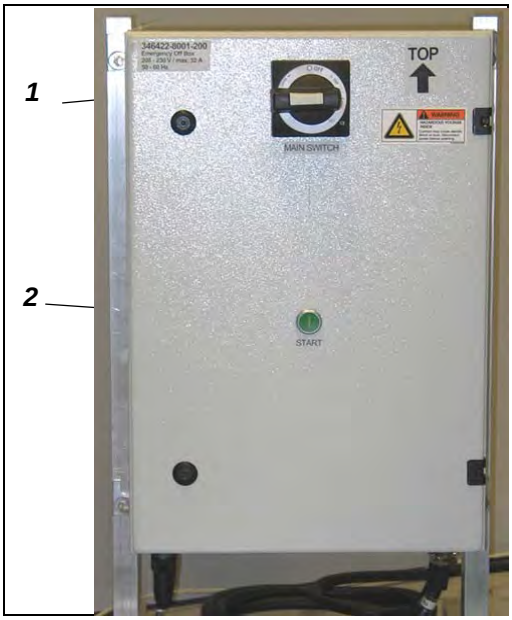
The EMO button will remain in its depressed position.

6.10.1.2. Switching on again after an emergency off

IMPORTANT

Before switching on the workstation, ensure that the reason for the emergency off does not exist any more and that it is safe to switch on the workstation.

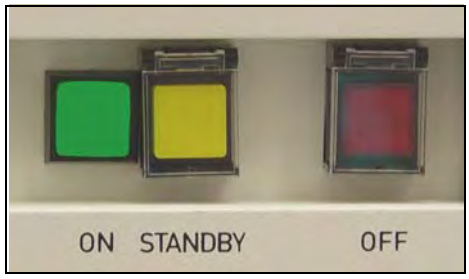
1 Release the EMO button by pulling it.
If several EMO buttons are installed, ensure that all EMO buttons have been released.
2 Turn the **MAIN** switch (***1***), which is located at the EMO box, to position *RESET*.
3 Turn the **MAIN** switch (***1***) to position *ON*.
4 Press the **START** button (***2***) which is located at the front of the EMO box.



5 Turn the **ON/OFF** switch, which is located at the back of the plinth, to position *ON (*unless it is already in this position)..

6 Open the main shut-off valve for cooling water (unless it is already open).
7 Open the main shut-off valve for compressed air (unless it is already open).
8 Open the main shut-off valve for gaseous nitrogen (unless it is already open).

9 Press the yellow **STANDBY** button at the front of the plinth.
10 Press the green **ON** button at the front of the plinth.



11 Start the SmartSEM® software.
12 Initialise the stage.

6.10.2. Without EMO box

6.10.2.1. Switching off in an emergency

1 Turn the **ON/OFF** switch, which is located at the back of the plinth, to position *OFF*.

6.10.2.2. Switching on again after an emergency off

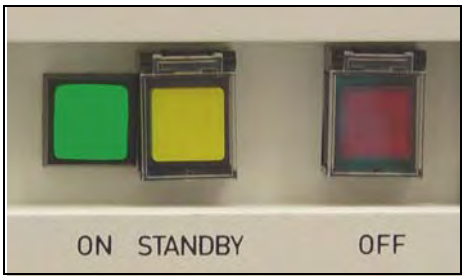
IMPORTANT

Before switching on the workstation, ensure that the reason for the emergency off does not exist any more and that it is safe to switch on the workstation.

1 Turn the **ON/OFF** switch, which is located at the back of the plinth, to position *ON*.

2 Open the main shut-off valve for cooling water (unless it is already open).
3 Open the main shut-off valve for compressed air (unless it is already open).
4 Open the main shut-off valve for gaseous nitrogen (unless it is already open).

5 Press the yellow **STANDBY** button at the front of the plinth.
6 Press the green **ON** button at the front of the plinth.



7 Start the SmartSEM® software.
8 Initialise the stage.

6.11. Switching off the workstation completely

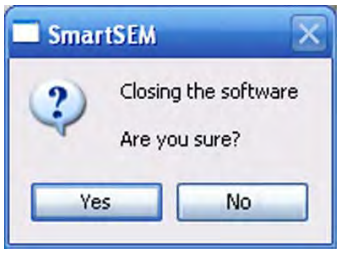
This procedure completely cuts off the workstation from the electrical main supply.

1 Switch off the EHT.

2 Close SmartSEM®

a Select **File/Exit** from the menu.

The SmartSEM® Close UIF window appears asking for confirmation to close the session



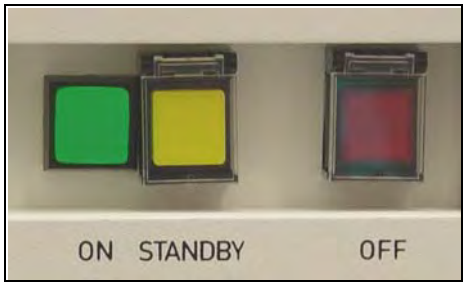
b Confirm by clicking on the **Yes** button.

The electron-optical parameters are filed in a macro in the individual user directory.

3 Shut down the computer.

4 Press the red **OFF** button.

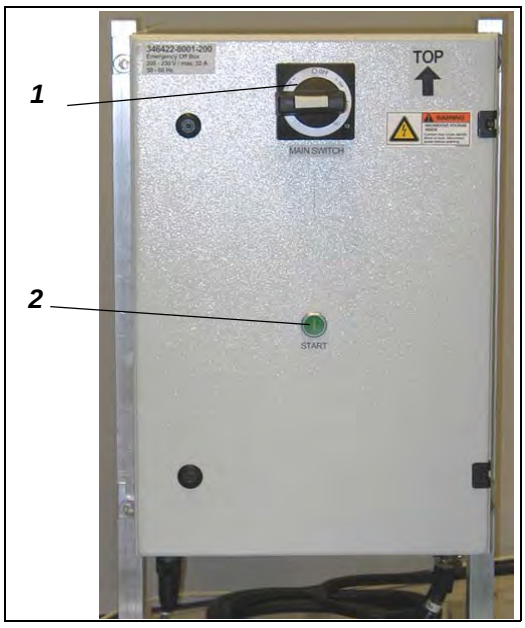
The red **OFF** button lights.



5 Turn the **Main SWITCH** (***1***), which is located at the EMO box, to position *OFF*.

The workstation is completely cut off from the mains power supply.

6 Check that the **START** (***2***) button at the EMO box as well as the **ON/STANDBY/OFF** buttons at the front of the plinth are switched off.



7. Maintenance and repair

To maintain best performance of the microscope it is essential to perform preventive maintenance at regular intervals.

7.1. Maintenance work

The preventive maintenance is performed by the ZEISS service representative and includes the following items:

- Inspection
- Preventive maintenance work
- Change of consumables and chemicals
- Equipment test
- Verification run

IMPORTANT

The mainenance work will be accomplished according to standardized maintenance plans and will be recorded by the ZEISS service representative.

7.2. Maintenance intervals

The maintenance intervals depend on the period of application of the device:

- 24/7: annually
- 8/5: semiannually

IMPORTANT

Plan maintenance work and order the ZEISS service representative early.

A list of ZEISS locations and authorised service partners can be found at:

http://www.zeiss.com/microscopy

7.3. Change of consumables and chemicals

The change of consumables and chemicals have to be done by a ZEISS service representative in mandatory intervals.

The times scheduled are designed for the maximum equipment performance level:

Interval	Component/Part
Basic workstation	
Every 6000 h[1] (filament on)	Gun (cathode)[1]
As required or yearly (and after cathode exchange)	Standard multihole aperture Anode aperture Extractor aperture Anode aluminium seal Copper seal at gun head
Yearly or as required	Pre-vacuum pump
Yearly	SE2 detector In-lens detector EsB® detector
Upgraded workstation	
As required	Ion source
With every ion source replacement	FIB apertures
If used up	Precursors

Table 7.1: Time schedule

[1] There is no warranty on cathodes; cathode manufacturers do not guarantee any lifetime.

8. Troubleshooting

8.1. Overview

The following table gives some clues to solve problems.
If you cannot solve the problem or if you are feeling unsure do not hesitate to get in contact with your local Carl Zeiss service engineer.

DANGER

Danger to life: Hazardous voltage inside the workstation .
Only service engineers trained and authorised by Carl Zeiss are allowed to service the workstation and to perform work on the electrical system of the workstation.

Keyword	Symptom	Possible reason	Recommended action/s
Vacuum	„Vac ready = OK“ is not shown after specimen exchange.	System vacuum is bad due to a vacuum leak at the chamber door.	Check the chamber door seal for cleanliness. If required, replace the chamber door seal.
	„Vac ready = OK“ is shown very late after specimen exchange.	Gas ballast at rotary pump or scroll pump is activated.	Deactivate gas ballast at the pre-vacuum pump.
Vacuum	workstation does not vent.	No nitrogen. No compressed air.	Check nitrogen supply. Check compressed air supply.
System vacuum	„Vac ready = OK“ is indicated abnormally fast.	Penning gauge has not been identified correctly.	Restart the workstation: If this does not solve the problem, call your local Carl Zeiss service engineer.
System vacuum	Bad system vacuum.	Chamber door seal does not seal tightly.	Check chamber door seal for particles. Replace the chamber door seal. Refer to section 8.2.2.
Gun vacuum	Gun vacuum is worse than 8 to 9 x 10^{-9} mbar.	Gun has been switched off for safety reasons since gun vacuum is too bad.	Bakeout the gun head. Refer to section 8.3.1.
Specimen stage	Stage does not move.	Stage needs to be initialised.	Initialise the stage. Refer to section 8.2.1. If this does not solve the problem, call your local Carl Zeiss service engineer.
Specimen stage	Stored position cannot be approached correctly.	Stage needs to be driven to a well-defined position.	Initialise the stage. Refer to section 8.2.1.
Specimen stage/ PC	Stored position cannot be approached correctly.	PC has crashed. Stage needs to be driven to a well-defined position.	Initialise the stage. Refer to section 8.2.1.

Keyword	Symptom	Possible reason	Recommended action/s
Drift	Specimen seems to be moving.	Charging effects. Non-conducting specimen.	Ensure proper conduction of the specimen. Optimise specimen preparation. Apply a charge compensation method (e.g. Charge Compensator or GIS with Charge Compensation)
Gun	Gun is switched off automatically. Gun vacuum worse than 2 x 10^{-8} mbar	Gun has been switched off for safety reasons since gun vacuum is too bad.	Bakeout the gun head. Refer to section 8.3.1.
Image quality	Image quality gets worse, but there is no change in total emission current.	Cathode has been damaged due to arcing.	Call the local Carl Zeiss service engineer to have the cathode replaced.
Image quality	Image is noisy. Noise reduction methods do not remedy.	Cathode is used up.	Call the local Carl Zeiss service engineer to have the cathode replaced.
Image quality	Image is bad at low EHT (e.g.1 kV)	Working distance is too long.	Reduce working distance.
In-lens image	In-lens image is noisy.	Working distance is too long.	Reduce working distance.
In-lens image	No In-lens image	EHT exceeds 20 kV.	Reduce EHT to a maximum of 20 kV.
SE2 image	SE2 image is noisy	Scintillator is used up.	Call the local Carl Zeiss service engineer to have the scintillator replaced.
Optional specimen current meter	Specimen current is low.	Cathode is used up.	Call the local Carl Zeiss service engineer to have the cathode replaced.
After emergency off or power failure	Stored position cannot be approached correctly.	Stage needs to be initialised.	Initialise the stage. Refer to section 8.2.1.

8.2. Chamber

8.2.1. Initialising the stage

If a stored stage position cannot be approached or if absolute stage movement is required, the stage needs to be initialised.

Prerequisite

- Executing this function requires the *Stage initialise* privilege in the user profile.
- Specimen chamber has been evacuated.

Procedure

1 On the menu, select **Stage/Stage initialise**.
2 In the window **SmartSEM**, click **Yes**.

IMPORTANT

If initialisation of the stage does not solve the stage problem, contact your local Carl Zeiss service engineer.

8.2.2. Replacing the chamber door seal

Reasons

- Chamber door does not close tightly, bad chamber vacuum

CAUTION

Suffocation hazard due to lack of oxygen, since the specimen chamber is ventilated with nitrogen.
Avoid inhaling the air from within the specimen chamber.
Ensure the area around the microscope is sufficiently ventilated.

IMPORTANT

Contamination caused by fingerprints can lead to vacuum deterioration or prolonged pumping times.
Always wear lint-free gloves when touching specimen, sample holder or stage. Keep the chamber door open as short as possible.

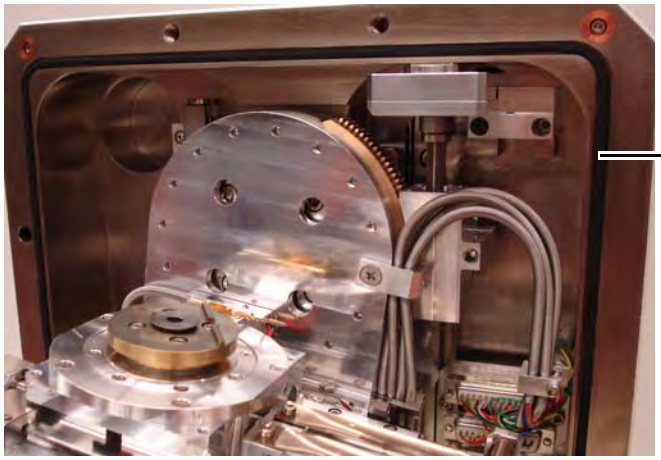
Procedure

1 Ventilate the specimen chamber.
2 Open the chamber door.

CAUTION

Risk of damaging the sealing surface when using metallic tools.
If required, use a plastic or wooden tool to remove the chamber door o-ring.

3 Remove the chamber door o-ring (***1***).



4 Insert the new chamber door o-ring.

5 Close the chamber door.

Pump the specimen chamber.

8.3. Column

8.3.1. Baking ot the gun head

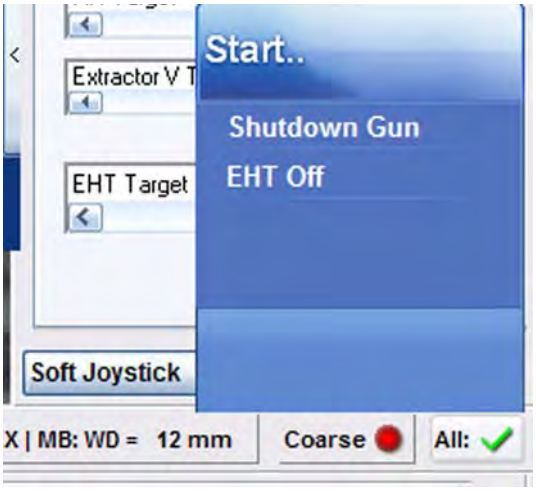
The pumping capacity of the ion getter pump decreases in the course of time, thus deteriorating the 'Gun vacuum'. This can be remedied by an ion getter pump bakeout as a regular maintenance procedure.

Prerequisite

- Only advanced operators are allowed to perform the bakeout procedure.
- Baking out requires *Supervisor* privilege and user access level *Service*.

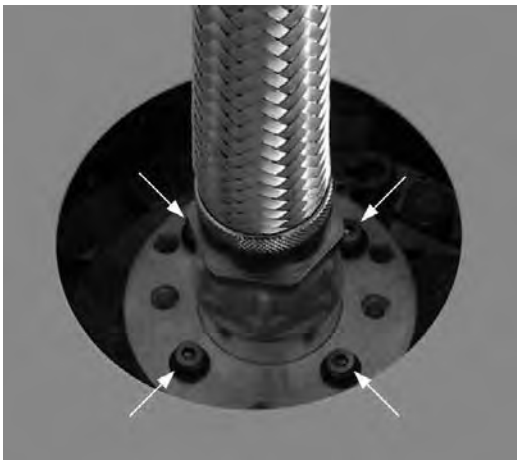
Procedure

1 Select **All/Shutdown Gun** from the status bar in order to switch off EHT and Gun.



2 Wait until the Gun has ramped down.

3 Use a 3 mm Allen key to remove the four screws at the gun head.



Shown on SUPRA® /

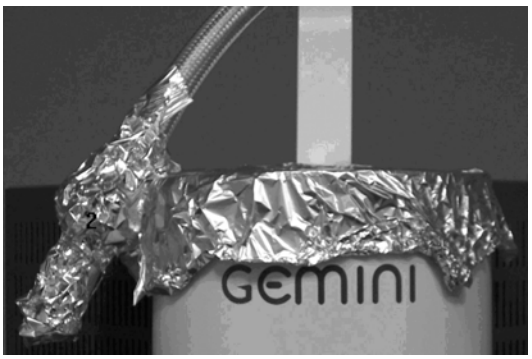
CAUTION

Danger of misaligning the gun head
Ensure not to apply any lateral force when removing the high voltage plug.

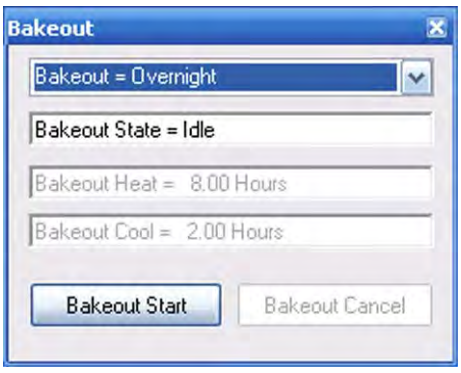
4 Remove the high voltage plug:
   a Take hold of high voltage line and high voltage plug.
   b Pull it upwards.

CAUTION
Danger of contamination
Ensure to properly cover gun head area and high voltage plug.

5 Cover the gun head area with aluminium foil.



6 Wrap the high voltage plug in aluminium foil or in an antistatic bag to avoid contamination.
7 In the SmartSEM® user interface, select **Tools/Goto panel** from the menu. The **Panel Configuration Bar** opens.
8 Double-click on **Bakeout.** The **Bakeout** dialogue is shown.
9 Select one of the different bakeout cycles:
Quick: 2 hours heating / 1 hour cooling
Overnight: 8 hours heating / 2 hours cooling
Weekend: 40 hours heating / 3 hours cooling
User: To be defined by the operator



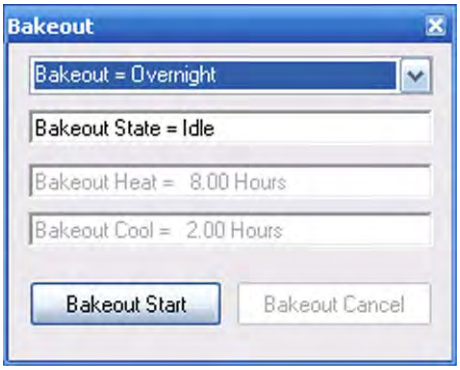
CAUTION

Risk of injury from hot surfaces during bakeout
Parts of the enclosure in the upper range of the column may become hot during bakeout, particularly after a long bakeout cycle.
Do not touch any parts of the cover panel or place any combustible objects on the grid of the electron optical column.

IMPORTANT

You may switch to STANDBY mode while the bakeout procedure is running.
Before you do so, ensure that the 'PARTIAL VENT ON STANDY' checkbox is UNTICKED in the SEM Control panel.

10 To start the bakeout procedure, click on **Bakeout Start**.



After having finished the bakeout procedure:

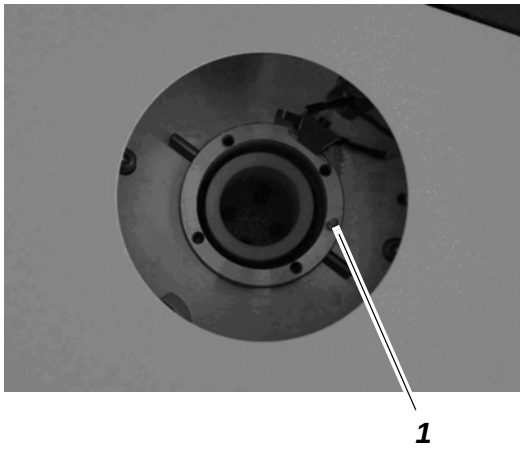
1 Remove the pieces of aluminium foil.

CAUTION

Danger of misaligning the gun head
Ensure not to apply any lateral force when reconnecting the high voltage plug.

2 Reconnect the high voltage plug.
Note the pin (***1***) at the gun head.
It fits into the bore hole at the high voltage plug in order to ensure correct orientation.

3 Tighten the screws.



4 Switch on the gun to continue working with the workstation.

8.3.2. Ion source (Workstation with FIB)

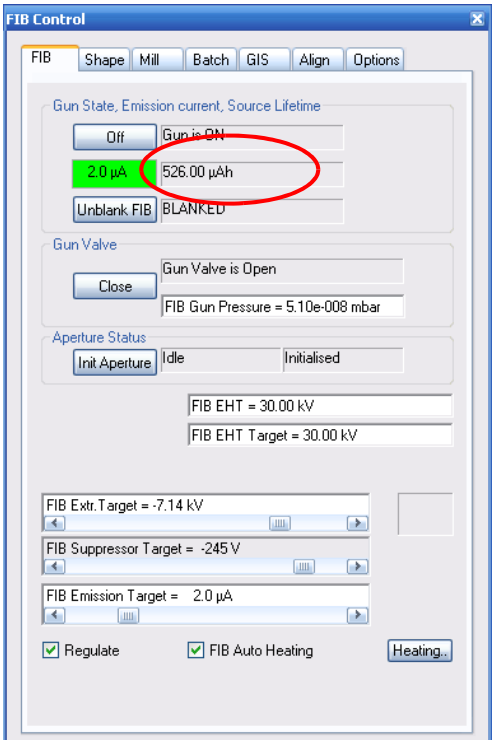
8.3.2.1. Checking the lifetime

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.

Procedure

1 Select **FIB** from the **FIB** drop-down menu.
The **FIB** tab of the **FIB Control Panel** opens.
The life of the ion source is indicated as *µAh*.



IMPORTANT

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

8.3.2.2. Regenerating by heating

The heating procedure is used

- if the suppressor voltage has reached 0 V while a probe current of 2 µA cannot be maintained any more or
- if the ion source does not start emitting.

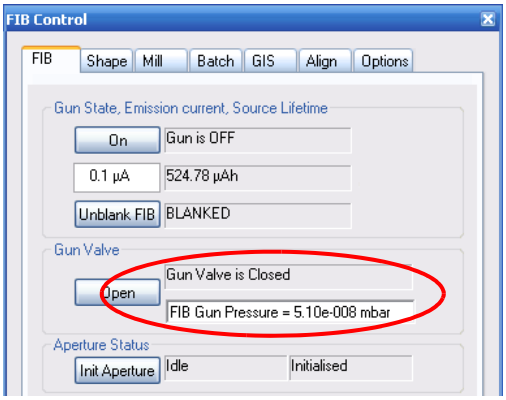
Prerequisite

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

Procedure

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

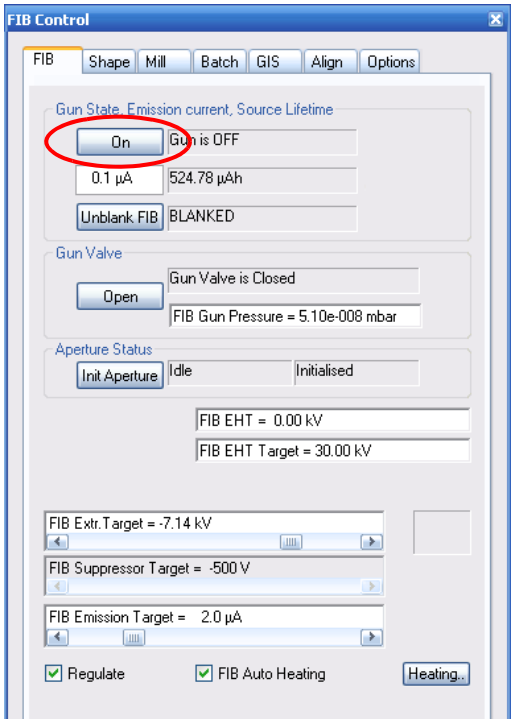
The **FIB Gun Presssure** must be better than *5 x 10^{-7}* mbar.



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 x 10^{-7}mbar.

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



CAUTION

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

3 Click on **Heating**.

4 The **FIB Filament Heating** panel opens.

5 Enter **FIB Fil I Target** = *2.5* A.

6 To start the heating procedure, click on **Filament On**.

7 While watching the emission, wait about 10 seconds.

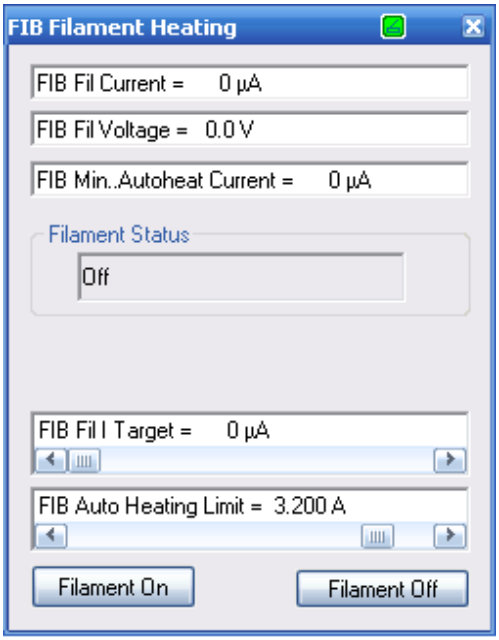
8 If there is no emission, slowly increase the **FIB Fil I Target** by *100 mA* steps until the emission begins and the suppressor target starts regulating towards *0*.

9 When the suppressor voltage is well between *0* and *-1000 V,* or when the emission is increasing rapidly, stop the procedure:
Click on **Filament Off**.

10 Notice the **FIB Fil Current** value at which the ion source starts emitting.

11 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.

12 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 6.6.1.3. step 7).

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

- Contact the local Carl Zeiss service if the emission current does not increase again.

8.4. Power circuit

8.4.1. Checking the circuit breakers

DANGER

Danger to life: Hazardous voltage inside the workstation.
Checking and changing fuses may only be carried out by an electrically skilled person in accordance with national safety regulations.

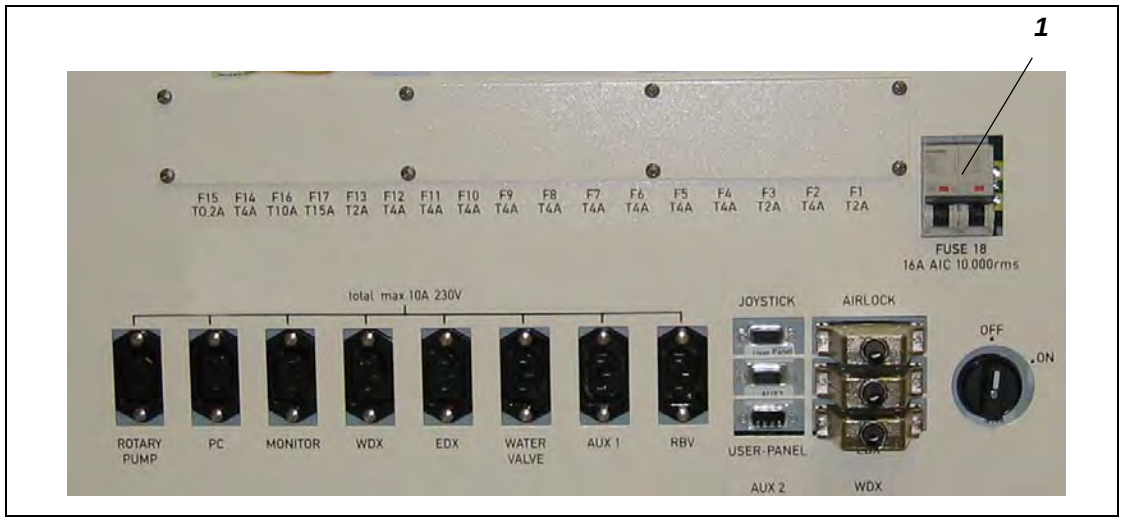
Turn off and lock out the workstation before opening the protective cover.

Reasons

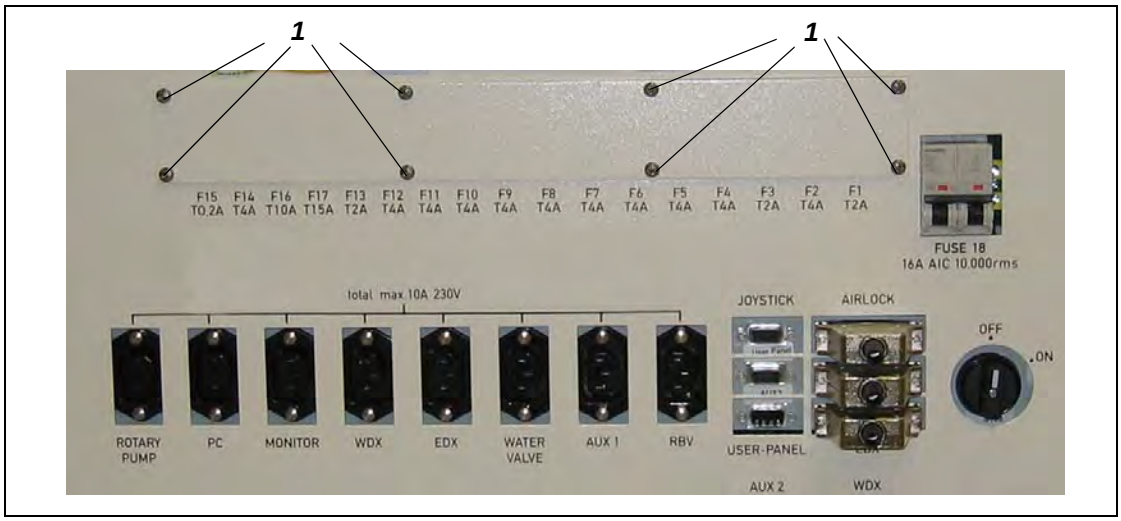
- Circuit breaker is tripped (lower position)

Procedure

1 Switch off the workstation completely.
   a Turn the ON/OFFswitch to OFF position.
   b Unplug the power cord.
2 Check the miniature circuit breaker (***1***).
   F18 (main fuse): 16 A, AIC 10,000 rms, ON/OFF switch



3 Remove the screws (***1***).



4 Remove the protective cover.

5 Check the fuses.

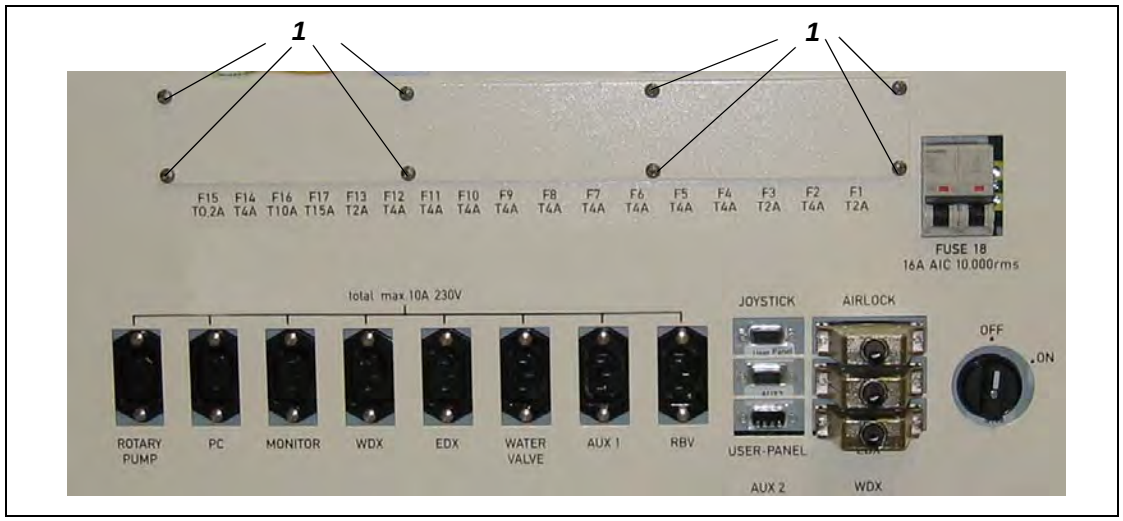
Replace as necessary.

No.	Value	Circuit	No.	Value	Circuit
F1	T2A	Water magnetic valve	F10	T4A	WDX
F2	T4A	IGP power supply	F11	T4A	Res 1 (spare)
F3	T2A	Bakeout heater 1	F12	T4A	Res 2 (spare)
F4	T4A	Bakeout heater 2	F13	T2A	Mains PSU: Vac supply voltage
F5	T4A	Spare VP microscope: RBV	F14	T4A	Turbo pump power supply and angle valve
F6	T4A	EHT	F15	T0.2A	Main input 230/24 V
F7	T4A	PC	F16	T10A	Rotary pump and fuse F14
F8	T4A	Not connected	F17	T15A	Mains PSU: stage and EO supply voltage
F9	T4A	EDX			

Table 8.1: Circuit breakers

6 Mount the protective cover.

7 Tighten the screws (***1***).



8 Plug in the power cord.

9 Turn the ON/OFF switch to ON position.

10 Restart the workstation.

9. Shutdown and disposal

9.1. Putting the workstation out of operation

If the workstation will not be used for an extended period of time e.g. several months, it should be put out of operation.

Contact your local Carl Zeiss service engineer to have the workstation put out of operation. The service engineer will see to that the cooling water is completely removed from the interior of the FESEM.

9.2. Disposal

9.2.1. Disposing of solid waste (consumables)

The operator must ensure that solid waste (consumables) is disposed of and recycled in a responsible manner.

Description	Material	Disposal
Schottky field emitter, gun	Tungsten, ceramics	To be returned to Carl Zeiss.
Apertures	Platinum, iridium, gold	Very small amounts. May be disposed of in accordance with local/regional regulations.
Ion source (gallium)	Gallium	To be returned to Carl Zeiss.

9.2.2. Disposing of the workstation

The operator must ensure that waste products are disposed of and recycled in a responsible manner.

Refer to EC directive 2002/96/EC on waste electrical and electronic equipment (WEEE).

The workstation consists of several modules. Be careful to separate the materials properly when you dispose of the workstation.

- Materials: e.g. metals, non-metals, composite materials, process materials
- Electronic scrap material: e.g. transformers, circuit boards, cables
- Comply with national and regional waste disposal ordinances.

10. Parts and tools

CAUTION

Risk of injury or property damage
Use genuine Carl Zeiss parts only.
Order parts and tools at your local Carl Zeiss service organisation.

10.1. Important consumables

Item	Part no.
Schottky field emitter By DENKA By FEI	 0302-460 0302-102
Thin film aperture (standard multihole aperture)	348520-0586-000
Anode aperture, 40 µm	348520-0084-001
Extractor aperture	348520-0097-001
Anode aluminum seal	348520-0609-000
Copper seal gun head (single use)	340002-0382-000
Tip seal for pre-vacuum pump BOC Edwards XDS 10	113-898
Scintillator for SE2 detector	348306-8142-000
With FIB upgrade: Ion source (gallium)	 346700-8011-000
With GIS upgrade: Precursors	 On request

10.2. Important spare parts

Item	Part no.
Set of fuses	348200-8801-000
Chamber door o-ring	113-880

10.3. Tools and accessories

Item	Part no.
3 mm Allen key	0015-247
1.5 mm Allen key	151-883
Small pliers	-
Sample holders	Refer to sample holder catalogue.
Stubs	-
Tweezers	-
TEM oil 300	0484-955
Isopropanol	-
Cloth, lint-free	-
Gloves, lint-free	-
Aluminium foil or antistatic bag	-

11. Abbreviations

AC	Alternating current
AIC	Ampere interrupting capacity
BSE	Backscattered electron
CC	Charge Compensator
CCD	Charge coupled device
D	Depth
EC	European community
EHT	Extra high tension
EIGA	European Industrial Gases Association
EMC	Electromagnetic compatibility
EMO	Emergency off
EsB®	Energy selective backscattered
FESEM	Field emission scanning electron microscope
GUI	Graphical user interface
H	Height
IGP	Ion getter pump
M	M-axis
MSDS	Material safety data sheet
NTS	Nano Technology Systems
PC	Personal computer
PE	Protective earth
R	R-axis
SE	Secondary electron
SESI	Secondary Electrons Secondary Ions
SI	Secondary ion
SMT	Semiconductor Manufacturing Technologies
T	T-axis
U	Voltage
UIF	User interface
W	Width
WD	Working distance
WEEE	Waste electrical and electronic equipment
X	X-axis

Y	Y-axis
Z	Z-axis

12. Glossary

Aperture	Small opening in the beam path that forms and limits the electron or ion beam.
Astigmatism	Lens aberration that distorts the shape of the electron beam, compensated by the stigmator.
Backscattered electrons	High energy electrons that are liberated from the specimen surface when the specimen is hit by the primary electron beam.
Bakeout	Degassing of surfaces of a vacuum system by heating during pumping process.
Beam booster	Anode and liner tube of the GEMINI® column are connected mechanically and electrically forming the beam booster. A booster voltage (U_B, liner voltage) of +8 kV is applied to the beam booster, so that a high beam energy is maintained throughout the entire column. The beam booster technique has two main advantages: It minimises beam widening, that may occur due to stochastic electron-electron interactions. Consequently there is almost no loss in beam brightness, even at low acceleration voltages. Secondly, the beam booster technique enhances protection against external stray fields.
Charging	Effect of the electron beam building up an electric charge within a non-conducting specimen. Effects: poor imaging, physical movement of the specimen.
Charge Compensator	Equipment that allows you to minimise charging effects by emitting a local flow of gaseous nitrogen onto the area of interest on the specimen surface.
Emission image	Special beam profile mode used to adjust the cathode. The emission image is a shadow image (In-lens image) of the multihole aperture holes generated by scanning the electron beam above the multihole aperture. In this process, the true size of the holes is masked, while parts of the specimen can be visible through the aperture holes.
Extractor	Positive electrode that attracts electrons from the cathode.
Focus wobble	Function that sweeps the focus of the objective lens backwards and forward through the focus on the specimen plane. When the aperture is misaligned a lateral shift is observed.
Penning gauge	Device for measuring high vacuum in the vacuum system.
Pre-vacuum pump	A pump for generating a pre-vacuum.
Secondary electrons	low energy electrons that are liberated from the specimen surface when the specimen is hit by the primary electron beam. Secondary electrons are generated by inelastic scattering.
Suppressor	Electrode (anode) that suppresses unwanted thermoionic emission from the shank of the Schottky field emitter.
Stigmator	Compensates astigmatism (lens aberration), so that the electron beam becomes rotationally symmetrical.
Schottky field emitter	Component that produces electrons (electron source).

Scintillator	Substance that absorbs electrons and in response, fluoresces photons while releasing the previously absorbed energy.
Primary electrons	Narrowly bundled beam of accelerated electrons that hit the specimen surface.
X-ray	Type of ionising radiation that is generated during the operation of electron microscopes

13. Declaration of conformity

Denomination:	**CrossBeam® workstation**
Model:	**AURIGA® / AURIGA® 60**
Manufacturer	**Carl Zeiss Microscopy GmbH** **Carl-Zeiss-Str. 56** **73447 Oberkochen** **Germany**

This is to declare that the machinery mentioned above fulfils all relevant provisions of the

- Directive 2006/42/EC

Moreover, the machinery fulfils the following directives and standards:

- Directive 2004/108/EC
- Standard EN 60204-1
- Standard EN 61000-6-4
- Standard EN 61000-6-2
- Standard EN 61010-1
- Standard EN ISO 12100-1/2

Unauthorised modifications of the machinery will cancel this declaration.

CE marking The CE conformity marking is located on the type plate of the machinery.

14. Index

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