ZEISS EVO®

Zeiss BSD User Manual

Operator Manual

Part Number: 3547500374004

Date: 26/09/05

Issue: 1

Printed in England

1 Table of Contents

2 Basic Information

2.1 About this Handbook

This Handbook is intended to serve as both an installation manual for the Carl Zeiss BSD and a user manual. It is divided into 3 main areas.

- Important Safety Information – Please ensure you are familiar with all the information in this section before installing or using the Carl Zeiss BSD.
- Operating Instructions
- Installation Instructions

2.1.1 Explanation of symbols

The safety instructions in this service-handbook follow a system of three risk levels, that are defined as follows:

DANGER
This symbol and signal word calls your attention to the threat of a life-endangering situation.
Disregarding this warning WILL lead to serious injury or death.

WARNING
This symbol and signal word calls your attention to the threat of a danger to health or life
Disregarding this warning CAN lead to serious injury or death.

CAUTION
This symbol and signal word calls your attention to possible danger to health or equipment.
Disregarding this warning can lead to injuries or damage to the instrument or equipment.

Moreover you will find the following type of information:

NOTICE
This symbol and signal word call your attention to important and useful additional information

2.1.2 Typographical conventions

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

Typography	Meaning
Type <**Ctrl + Alt + Del**>.	Jointly type Ctrl key, Alt key and Del key on the keyboard
Type <**key1, key2**>.	First type key 1, then type key 2 on the keyboard
Push <**ENTER**>	Push the ENTER key on the keyboard
Click on the **High Voltage** icon. Select **Aperture size** from the drop down list.	Icons, buttons and drop-down menus are printed in bold.
Select **Aperture size** *30µm* from the drop down list. Set **EHT Target** to *zero*	Values to be selected are printed in italics.

2.2 Fundamental safety information

2.2.1 Safety Instructions

Follow the safety instructions given in this handbook. This is essential to prevent damage and to protect yourself and other persons against accidents and unsafe practises. Do not deviate from the instructions provided in this service-handbook.

This section summarises possible hazards and recommended safety procedures.

DANGER

Danger of life: High-Voltage electrical currents occurring in the electron microscope can be fatal. Only NTS field service engineers specially trained and certified by NTS are allowed to service the electron microscope. Safety interlocks are built into the system to protect the operator and to safeguard the equipment. Do not override the interlocks.

Mains Voltage:

When the SEM is shut down, mains voltage will still be present both within the plinth and on some of the external cables.

ALWAYS SWITCH OFF THE SEM SWITCH AT THE REAR OF THE PLINTH TO ISOLATE THE INSTRUMENT FROM THE ELECTRICITY SUPPLY, BEFORE STARTING ANY MAINTENANCE WORK.
IN AN EMERGENCY, PRESS THE RED ILLUMINATED STOP BUTTON.

The emergency stop button is located on the right hand side of the console at the front. Pressing it will interrupt the distribution of the mains supply within the console.

Do NOT use this switch as a means of isolating the SEM from the electricity supply, because some parts of the instrument will still be live. To isolate the SEM use the switch at the rear of the plinth or disconnect the mains input

cable.

DO NOT REMOVE THE EARTH BRAID FROM THE EHT SET, OR THE CHASSIS WILL FLOAT AT HALF THE MAINS SUPPLY VOLTAGE.
DO NOT REMOVE THE EARTH BRAID FROM THE CHAMBER, OR THE COLUMN, CHAMBER AND THE EHT SET WILL FLOAT AT HALF THE MAINS SUPPLY VOLTAGE.

WARNING
Suffocation hazard when chamber door is opened due to lack of oxygen, since nitrogen may be used to ventilate the chamber. Inhaling nitrogen may cause unconsciousness.
Maintain a safe distance from the chamber door while it is open.
Ventilate the workspace well.

CAUTION
PCBs can be damaged due to electrostatic discharge (ESD).
When working on PCBs, take precautions to prevent electrostatic charge; wear wristbands and cotton clothes. Use grounding pad and special instruments to discharge.

CAUTION
Panels and covers: For safety reasons and to comply with EMC regulations, do not operate the SEM with any panel or cover removed.

CAUTION
When in use, the Backscattered Detector occupies a thickness of between 3 to 7 mm directly below the final lens. The BSD diode will be irreversibly damaged by a collision with a sample.

NOTICE
Fingerprints can cause virtual vacuum leaks. NEVER handle components and mechanisms that are subject to vacuum with bare hands.
Always wear lint-free gloves when handling inner parts of the vacuum system.

3 Zeiss BSD - Operation

3.1 Introduction

This chapter contains information about the day-to-day operation of the BSD system. It is split into the following sections:

- Quick Start – a guide on how to get the BSD up and running and obtaining an image;
- Maximising Performance – advice for the conditions for getting the best image quality out of the BSD system;
- Further Information – advanced information about the operation of the BSD system.

3.2 Quick Start

1 Position the BSD detector beneath the final lens. For the lens mounted BSD detector this is performed with the chamber vented to atmosphere. Ensure any fixed apertures are inserted into the end of the final lens before the diode is placed into position.

CAUTION

Never try to insert or remove fixed apertures with the BSD diode in position. Doing so will damage the BSD diode.

2 For flat samples, set the specimen tilt to 0° (for more details see 3.3.2).

3 Adjust the specimen height. The optimum specimen height is approximately 6 - 7 mm from the final lens under normal circumstances.

4 Obtain and focus a secondary electron image.

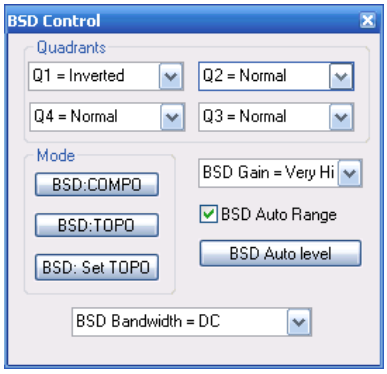
5 Select **QBSD** from the **Detection** ▸ **Detectors** submenu of SmartSEM™.

Selection of the QBSD detector.

6 Open the **BSD Control** dialog from selecting the **BSD Control…** option of the **Detection** menu.

Opening the BSD Control dialog.

7 Select **BSD:COMPO**, **BSD Gain = High** from the **BSD Control** dialog



The BSD Control dialog.

8 Set **Contrast = 0%**.

9 Set **Brightness = 53%** and click **BSD Auto Level**.

10 Adjust **Contrast** to get the desired image.

11 If the Contrast is very high or low it may be necessary to change **BSD Gain** to a different range. Go down a gain range if the contrast is very low or up a gain range if the contrast is very high.

3.3 Maximising Performance

The BSD image quality is dependent upon the signal to noise ratio of the detection system. As the electronics is operated in higher gain ranges the noise component of the amplifier will increase. To compensate for this it is necessary to maximise the signal entering the BSD amplifier.

Factors to maximise the signal include:

- Reducing the microscope scan speed, i.e. increase **Scan Speed =**
- Increasing the microscope Probe Current, i.e., increase **I Probe =**
- Increase the solid angle collection efficiency of the diode. For the Zeiss BSD the best solid angle collection is obtained with **WD =** 6 to 9 mm and 0° sample tilt.
- Increasing the accelerating voltage of the SEM, i.e., increase **EHT =**

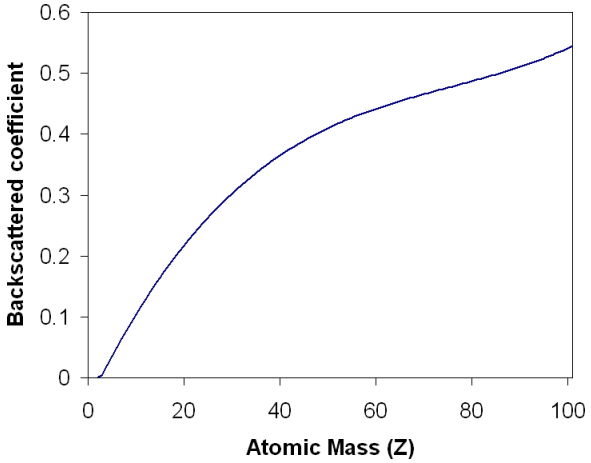
3.3.1 Atomic Number

It is also worth remembering that the Backscattered Electron coefficient often referred to as η is very sensitive to the Mean atomic number (Z) of the sample being examined where:

$$\eta = I_{BSE} / I_P$$

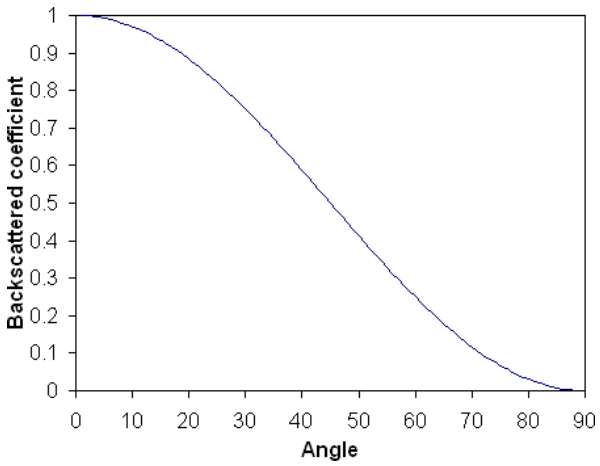
where I_{BSE} = current of Backscattered electrons and I_P = current of electrons in SEM probe.

A higher atomic number sample will give a greater signal. The variation in the Backscattered coefficient η as a function of atomic number Z is shown below.



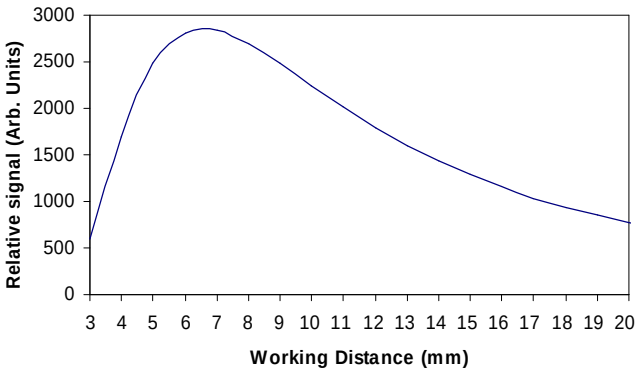
3.3.2 Specimen Tilt

Unlike Secondary electron collection, for the BSD detector the maximum signal is obtained when the sample surface is parallel to the BSD detector. If the sample is flat this corresponds to a sample tilt of 0°.



3.3.3 Working Distance

The working distance determines the solid angle collection efficiency of the BSD diode. For the Zeiss BSD detector the variation in collection efficiency as a function of working distance is shown below.



At the maximum signal is obtained in the range of working distances from 6 to 9 mm with the peak detection occurring at 7 mm. At shorter distances a higher percentage of electrons travel through the hole in the centre of the detector and are not collected. At longer working distances an increasing percentage of electrons miss the outer perimeter of the detector.

NOTICE

Increasing or decreasing the working distance from the optimum range will reduce the signal and reduce image quality.

If the backscattered image is to be used in conjunction with X-Ray analysis, the working distance should be set to 8.5 mm. This is dependant on the optimum working distance for the EDX detector.

3.3.4 Accelerating Voltage

The backscattered signal is a function of SEM accelerating voltage - the higher the voltage, the higher the energy of the backscattered electron signal. The accelerating voltage of the microscope is important to the detection of backscattered electron in 2 ways:

- A higher accelerating voltage will give a distribution of Backscattered electrons with higher energy that can be converted by the detector to more signal.
- At a particular low voltage < 1 kV for this diode then a cut-off threshold exists where no electrons in the backscattered signal have enough energy to penetrate into the active detection volume of the detector.

3.3.5 Probe Current

The probe current is also a function of backscattered signal. Once again the balance between probe current and resolution needs to be considered:

- The probe current should be set so it is high enough for the required image (high signal to noise ratio),
- The probe current should also be set that it is small enough to give the minimum electron probe spot size for the resolution required.

3.3.6 Light Sensitivity

Strong specimen Cathodoluminescence may affect the operation of the detector since the diode is light sensitive. If an Infrared Chamber scope is fitted to the SEM, it will be necessary to switch off the infrared illumination before operating the BSD.

3.3.7 EDX silicon signal

When the detector is fitted and an EDX spectrum is recorded it is possible that a small number of X-ray counts corresponding to silicon and aluminium can be recorded. These are from the interaction of the Primary electron beam and backscattered electron signal with the detector generating spurious X-ray signals. On the rare occasions that this causes problems, it may be best to remove the diode temporarily from the vicinity of the specimen.

3.3.8 Handling and Cleaning

Avoid handling the detector diode surface which may become contaminated and impair performance. When not fitted to the microscope, always store the diode safely in its original packaging in a secure location.

NOTICE

The following should only be performed by Carl Zeiss Electron Microscopy Engineers or an authorised agent:-

- ***Should finger marking occur, they may be removed by very careful wiping with a soft tissue.***
- ***Stubborn contamination can usually be removed by cautious use of solvents such as alcohol.***

3.4 Further Information

The Zeiss BSD is controlled by the SmartSEM® software. This section details the operation of the relevant parts of the user interface.

To open the **BSD control dialog** select '**BSD Control…**' from the **Detection** option found on the main menu of the SmartSEM® window.

Opening the BSD Control dialog.

The BSD Control dialog is labelled with the relevant sections to examine.

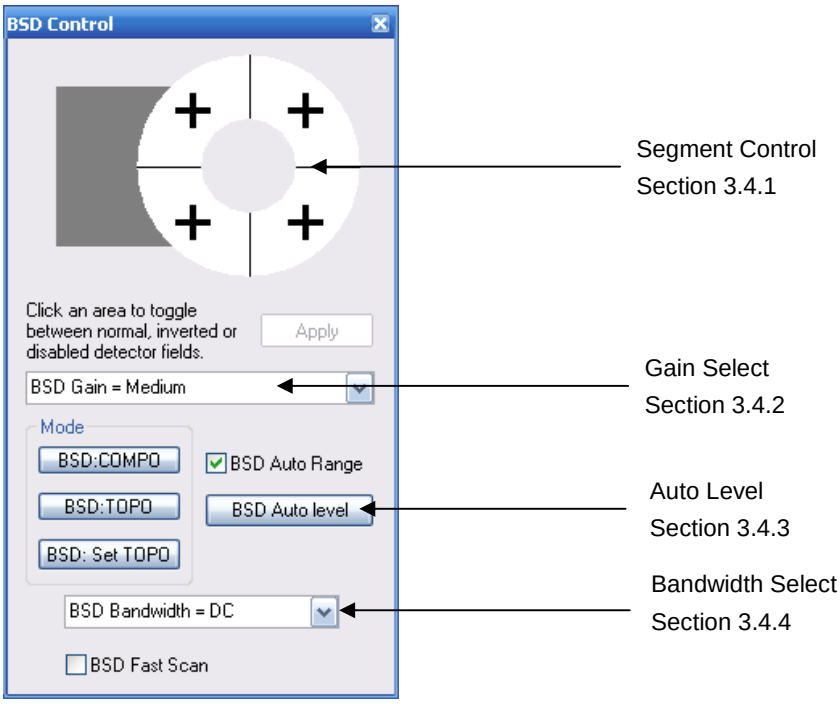


Image of the BSD Control dialog.

NOTICE
All buttons and dropdowns refer to this dialog unless otherwise stated.

3.4.1 Segment control

Each individual segment of the detector diode can be in one of three states. These states are represented by '**+**', '**-**' or ' '. The states are:

- **'+'** When selected this segment is arithmetically added to the total signal.
- **'-'** When selected this segment is inverted; the signal from Q1 is arithmetically subtracted from the total signal.
- **' '** When selected this segment is not used and has no influence on the total signal.

3.4.1.1 Atomic Number (COMPO) and Topographic Contrast (TOPO)

2 pre-defined configurations, or modes, of segments are available:

- Composition (**BSD:COMPO**), which highlights atomic number contrast.
- Surface topography (**BSD:TOPO**), which highlights changes of the sample surface angle.

To use the compositional mode click the **BSD:COMPO** button. All 4 segments will be set to '**+**' and an image that is high in atomic number contrast is obtained. This is the default setting of the BSD.

Select topography mode by clicking the **BSD:TOPO** button. The default setting for the **TOPO** mode is two diagonal segments are '**+**' the other diagonal segments are '**-**'. However this can be altered by the user. To store a new **TOPO** mode adjust the segments to the desired setting then click **BSD: Set TOPO**. This will save the current segment configuration and it can be recalled by clicking the **BSD:TOPO** button.

The signal from an individual segment will be a mixture of atomic number and topographic contrast. Various combinations of segment settings will give various mixes of composition and topographical representations, examples of which are shown below. As a general rule, high topographical detail will result from selecting a diametrically opposed pair of segments and summing them differentially, whereas pure atomic number contrast is obtained with all segments set to **Normal**.

Seg. 1	Seg. 2	Seg. 3	Seg. 4	Function
Normal	Normal	Normal	Normal	Composition
Normal	Off	Invert	Off	Topographic, illuminated from one particular angle.
Normal	Normal	Invert	Invert	Topographic, illuminated at 45 deg to angle obtained in set up above.
Normal	Normal	Normal	Invert	Composition on 1, 2 and 3 topographic on 1 and 4.

Some possible BSD segment arrangements to achieve different details.

In order to see the greatest detail it is advisable to experiment with different opposite pairs until the required result is obtained. The human eye/brain expects an object to be illuminated from the top of the presented image therefore many specimens when illuminated from below will appear inverted, with hills and valleys being transposed.

3.4.2 Gain Ranges

The gain range of the BSD is adjusted by using the **BSD Gain** drop down in the **BSD Control** dialog.

The BSD electronics can operate at 4 different gain ranges labelled:

- **BSD Gain = Low**
- **BSD Gain = Medium**
- **BSD Gain = High**
- **BSD Gain = Very High**

The **Contrast** control adjusts the gain within these ranges.

If an image is obtained at a low contrast, i.e., **Contrast** <15%, a superior image may be obtained by changing to a lower gain range. Changing to a higher gain range may also be advantageous if **Contrast >** 85%.

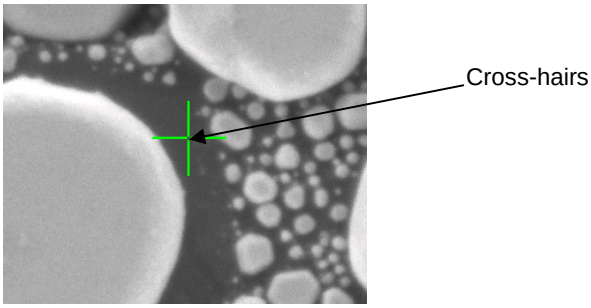
3.4.3 BSD Auto Level

The **BSD Auto Level** button is used to automatically trim the BSD electronics to the sample image. To get the best out of this function, set **Brightness = 53%** before selecting **BSD Auto Level**. An image should appear. Adjust the **Contrast** then **Brightness** and to get the desired image.

The **BSD Auto Level** function analyses the current BSD video signal and attempts to set a mid grey pixel level in the image to coincide with a brightness of 50%. A manual selection of pixel intensity can be achieved with the following procedure:

1 Select **Scanning** from the main menu bar and navigate and select **Spot**. This will put the scanning system into spot mode.

2 A set of green cross-hairs will appear as show below



3 Set the position of the cross hairs to the point of interest

4 Select the **BSD Auto Level** function

5 Set the scan mode back to normal (Select **Normal** from the **Scanning** option on the main menu).

3.4.4 BSD Bandwidth

The BSD Bandwidth is adjusted by using the **BSD Bandwidth** drop down in the **BSD Control** dialog at the bottom of the **BSD Control Panel**. In normal usage the QBSD Bandwidth should be left in the default **BSD Bandwidth = DC** mode.

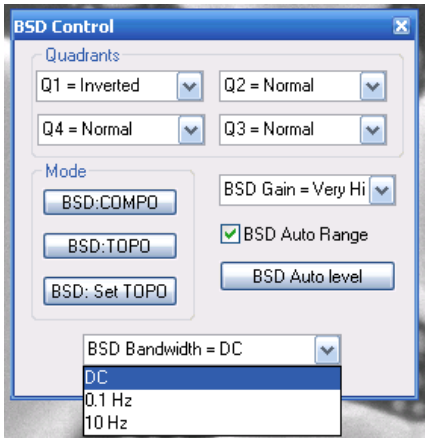


Image of the BSD Bandwidth drop down.

However, in some circumstances low frequency noise from the BSD diode and electronics may impair image quality. This will appear banding at low scan speeds, i.e., **Scan Speed = 10** or slower. The amount of disturbance may be reduced, or eliminated, by selecting **BSD Bandwidth = 0.1 Hz** or **BSD Bandwidth = 10 Hz**.

In the cases of **BSD Bandwidth = 0.1 Hz** and **BSD Bandwidth = 10 Hz** the BSD electronics is instructed to operate in an AC coupled mode. In this mode the DC component of the video signal is rejected and only the AC component is presented to the user. The 0.1 and 10 Hz values correspond to the time constant of the High pass filter.