Rev 8/27/03

Hitachi S4700 Field Emission SEM

1 Introduction

The Hitachi S4700 SEM is a cold field emission SEM with very high resolution, integrated backscatter detector, EDAX X-Ray attachment, 5 motor stage, sample exchange chamber (load-lock) for quick pump down and a infra-red chamber scope for stage viewing at 1x. Although the machine is easy to operate, only trained approved users may use the SEM and only properly mounted and baked samples with low out-gassing characteristics may be used. Maintaining good vacuum is mandatory for proper operation of this tool.
Machine specifications are included in this section, a quick spec with an abbreviated procedure in section 2 and the detailed procedure in section 3. Machine figures are in the appendix.
Companion documents which may be needed include the EDAX X-Ray spec and the PCI graphics software spec.

Specifications for Hitachi Model S-4700, Field Emission Scanning Electron Microscope

1. Resolution:

Accelerating voltage 15 kV
Working distance = 12 mm 1.5nm
Accelerating voltage 1 kV
Working distance = 1.5 mm.....2.1nm

2. Magnification:

High magnification mode. .....x to 500,000x
Low magnification mode .....x to 2,000x

3. Electron Optics:

(1) Electron gun..... Cold cathode field emission type
(2) Extracting voltage (Vext)..... to 6.5 kV
(3) Accelerating voltage (Vacc) ..... 0.5 to 30 kV (in 100 V steps)
(4) Lens.....….3-stageelectromagneticlens, reductiontype

(5) Objective lens aperture.....……...Movable aperture (4 openings selectable/. alignable outside column). Self-cleaning thin aperture

(6) Astigmatism correction coil (stigmator) ..... Electromagnetic type

(7) Scanning coil .....….2-stage electromagnetic-deflection type

4. Specimen Stage

Motion	Model S-4700, Type II
X Traverse	0 to 100 mm (continuous)
Y Traverse	0 to 50 mm (continuous)
Z Traverse	1.5 to 30.0 mm (continuous)
Tilt	-5° to +60°
Rotation	360° (continuous)
Specimen size	Max. 150 mm (diameter) (airlock type specimen exchange)

5. Display Unit

(1) Display type..... Flicker-free image on PC monitor
(full scanning speeds)

(2) Viewing monitor..... Type 17, color (1024 x 768 pixels).

(3) Photo CRT (Option)… ..... Not available

(4) Scanning modes..... Normal scan,
Reduced area scan,
Photo scan,
Split/Dual magnification,
Line scan, Position setting,
Spot, MF (Analysis Area Finder),
SM (Selected Area Analysis).

(5) Scanning speeds… ..... Fast, Slow: 0.5 to 40 sec per frame for viewing
20/17, 40/33, 80/67, 160/167, 320/333 sec per frame for photo mode
Value of (50 Hz)/(60 Hz)
Fast: NTSC or PAL signal

(6) Signal processing modes…..... Automatic brightness control,
Gamma control,
Automatic focus,
Automatic stigmator

(7) Automatic data display ..... Film number, accelerating voltage, magnification,
micron bar, micron value, date/time and working

distance can be printed on the film.

(8) Data entry..... Alphanumeric characters, numbers, and marks can be written on the image from the keyboard.

(9) Electrical image shift..... +/-15 microns (WD=12mm)

6. Evacuation System

(1) System….....Fully automatic pneumatic-valve system

(2) Ultimate vacuum levels..... Specimen chamber : 7 x 10^{-4} Pa
Electron gun chamber:
IP-1 2 x 10^{-7} Pa or better
IP-2 2 x 10^{-6} Pa or better
IP-3 7 x 10^{-5} Pa or better

(3) Vacuum pumps .....…….....Electron optical system: 3 ion pumps
Specimen chamber : Oil diffusion pump
2 oil rotary pumps

7. Protection Devices

Warning devices.....……Power failure, Cooling-water interruption, Inadequate vacuum

8. Others

(1) Acoustic noise. ..... Less than 65 dB (the microphone position is 1 m. away from front of the display unit and 1 m above floor.)

(2) Dielectric voltage-limit…..... 1500 V AC/1 min

2 Quickspec for Hitachi S4700 Field Emission SEM

The following section is an abbreviated description of the operating procedure for using the Hitachi S4700 SEM in UCLA's Nanoelectronics Research Facility. Refer to section 3 for a detailed procedure with explanations.

SEM Standby Checklist

1 Check the standby checklist to make sure the machine is safe to run:
- a Last user in Log book had no problems
- b Write your name and the date on logbook
- c IP1, 2 &3 lamps are lit with vacuum better than:
  IP1< 2×10^{-7} Pa
  IP2< 2×10^{-6} Pa
  IP3< 7×10^{-5} Pa
- d DP/TMP, water and Air Press lamps are lit
- e High lamps of SC Vac and SEC Vac are lit
- f OBJ. APT. switch is set at HEAT
- g GUN Valve switch is closed and AUTO lamp is flickering
- h HV lamp is off, SEM application is closed.

Specimen Loading and Initial Instrument Setup

2 Turn on the chamber scope and verify that no other sample is in the specimen chamber.

3 Turn on the DISPLAY switch in the computer cabinet to turn on the computer and its monitor (if it is not already on).
- a Select Windows NT Workstation 4.0 (Default) when the selection is visible.
- b Press CTRL, ALT, DELETE when prompted to do so. Login name is S4700, Password is left blank
- c Double click PC-SEM.exe when the Windows desktop and icons are visible.
- d Login name and Password are as in 2b.
- e Open the Stage Control Dialog window  and click the **Go to Home** button. The stage is then moved to the specimen exchange position, and the color of the indicator button turns green.

4 Specimen Preparation: Wearing clean gloves and face mask, mount your sample onto the appropriate stub or chuck. Use the metal tape OR carbon paste but use as little as possible and make sure your sample covers the adhesive. Bake the mounted sample to remove solvent fumes (or let air dry for an hour). You can also use carbon conductive tabs.

5 Specimen Loading: Always wear clean gloves and face mask whenever venting and loading exchange chamber:

a Verify that SC/SEC switch is set to SEC and the black exchange valve closed, press the AIR switch on the column vacuum control panel.

b After 5-10 seconds, the exchange chamber is at atmosphere. Open the exchange chamber by grabbing the sides of the door and swinging out. **Do NOT open the door by using the ROD.**

c Screw your sample stub onto the stud and verify sample height is within .5mm of height gage gap.

d Screw sample holder back onto the loading rod in the exchange chamber, pull rod out completely til it locks, close door and press EVAC on the column vac control panel while pressing gently on the chamber door.

e Wait until High lamp on SEC Vac is lit and the SEC/Pi reads 2×10^{0} or less. This should not take more than a minute.

f Open Exchange valve and push the exchange rod fully into the main chamber until it slides into the holder fork. Unscrew black knob and withdraw the knob fully out until it locks into position.

g Close the Exchange valve and switch vacuum readout to SC/Pe and wait until chamber pressure is $L \times 10^{-3}$

h Flip the gun valve switch on the vacuum console to AUTO.

6 Input the z value to be used (ie working distance) as well as the sample size in the stage dialog box. This will affect the allowable tilt and range of x-y movement. Samples up to 6 inch can be accommodated although the NRF currently is limited by its 4 inch chuck. Tilt can be adjusted at this point if desired as well.

7 Flash the tip if necessary. Note that it may take up to an hour before the emission current stabilizes.

8 Set the High Voltage and Emission current to the desired values in the HV Control dialog window . Click the On button to turn on the High voltage and verify that the HV light on the back of the column is on.

9 The column aperture should be set at position 2 or 3 which are equivalent. If the aperture is not set to either of these values, contact nanolab staff.

Specimen Imaging Pointers

10 Select the operation mode (usually ultrahigh resolution), working distance (usually 3mm for low energy operation), detector mode (upper/lower or backscatter for instance) and ABCC (if desired) in the **Column Setup**  window.

11 If operating conditions have been saved from a previous run, go to File Operating Conditions to open a selection dialog box and load the saved conditions. (Always save the conditions under a descriptive name eg 5KV8WD).

12 In the low mag mode, make sure you can see your sample and the approximate location of interest. Adjust brightness, contrast and focus to get a good image. Progressively zoom in on the area of interest while re-focussing and adjusting the image. Use the track ball to position your sample according to your needs.
If no image can be seen, try going directly to beam alignment first and align the beam to the target.

13 Select the high mag mode and adjust focus, stigmation, contrast and brightness.

14 Turn on the Beam monitor and periodically adjust as needed the emission current.

15 Perform the beam alignment by clicking on the  icon and using the console alignment knobs to center the beam within the target.

16 Perform aperture alignment so that minimal wobbling is seen while the image's focus is varied. Use a high enough magnification say >25,000X.

17 If the image shifts during stigmation adjust, perform stigma alignment in both x and y. Use a fairly high magnification, say 50,000X or so.

18 If desired low mag position adjustment can be made as in section 3.4.2.4. This is only needed if you are switching back and forth between modes.

19 Move the stage if necessary to the point on the sample to be photographed (actually image captured). At high magnifications, use the image shifter on the console to move the image as this is more controlled than stage movement.

20 Adjust focus and stigmation at a magnification higher than you intend to photograph.

21 For very high magnifications, you may need to turn on stage lock if vibrations in the image are seen (wavy, undulating lines). This should be tur ned on 5 minutes before taking pictures and before doing high magnification work since the stage lock affects focus and has a 5 minute settling time. Sample refocus and reposition may be required after locking the stage. Note that Z and Tilt may <u>not</u> be changed when the stage is locked but x and y may be adjusted.

22 Choose a slower scan speed that gives the nicest looking image and averages out line scan noise (typically speed 3 or 4).

23 When the image desired is seen it may be frozen or captured by clicking the capture icon. To start Image Capturing, click the Capture  button in the **Scanning Image** window, or select the **Capture** command in the **Scan** menu.
Set the capture parameters as discussed in section3.6.3 and 3.6.4.

24 Save the image to the hard drive as discussed in section 3.6.5. The hard drive can not be used for long term storage as images will be periodically purged.

25 Transfer your images to a writeable CD or FTP the images to your server as described in section 3.6.1.5. Caution: Do NOT use the SEM computer for email or web surfing and do NOT leave the Internet connection hooked up when you are done. We do not want the machine exposed to viruses.

Specimen Unload and Machine Shutdown

26 Shut the machine down:

a Turn off HV
b Click on **Go To Home** in stage dialog box
c Flip gun valve switch back to close.
d Open Exchange Valve and unload the specimen holder from the specimen chamber using rod. Close Exchange valve all the way.
e Unload your sample from exchange chamber.
f Exit SEM program. Exit Windows if no one else is going to use the machine.
f Turn off chamber scope and its display.
g Remove specimen from stub or chuck. Do not take stubs away.
h Fill out Log book completely.

Quick Spec Appendix-Selecting the Proper SEM Mode

There are many set-up parameters for the SEM which will determine the image quality and resolution for your sample. It is strongly recommended that you experiment a little after reading the following discussion:

Energy

The S4700 allows energies between 0.5-30 KEV and although higher energies give better resolution in theory, it is recommended that lower energies be tried first (1-5 KEV). This reduces sample charging and damage and produces images which are usually acceptable.
Higher energies may be desirable to minimize "sample burning" (hydrocarbon redeposition) since they penetrate this thin surface layer. Higher energies may also be more desirable for backscatter mode since there will be a stronger backscatter signal than at lower energies.

Working Distance

The working distance, distance between the surface of the sample to the pole piece (visible in the chamber scope) is one of the most important parameters that you will select. Although the allowable range is from 1.5-30 mm with 12 mm being nominal, smaller distances will give a stronger signal and better image. For lower energies of 3 KEV or less, a working distance of 1.7-2mm may be used **as long as no sample tilt is required.** At higher KEV, however, working distances must be greater than 4 mm (another reason to use lower energy).
If the lower detector is to be used, than a longer working distance may be desired to get a stronger signal. Also a longer working distance allows for sample tilt and greater depth of field. The working distance can also be used in conjunction with the mixed signal mode to balance the output between the two. This can give the illusion of a 3D image for instance.

Emission Current

The emission current is chosen from a selectable menu and can be varied from 1 microA to 50 microA. On samples sensitive to charging or electrostatic damage, lower currents should be used (say 10 microA or less). For samples with weak signals (eg cross-sections or into higher aspect ratio structures) higher emission currents should be used. Likewise for the backscatter mode, use of the lower detector or the analysis (EDAX) mode will likely require a larger emission current.

Detector

There are 3 detector modes, upper, lower and mixed. For high resolution surface imaging, the upper detector is used with a smaller working distance. For some backscatter sensitivity, where subsurface imaging is desired, either lower or mixed detector mode is used. The lower detector 's sensitivity to backscattered electrons is about half that to secondary emission electrons so that higher beam energy or longer working distance may be needed to get enough of a backscatter signal. The lower detector does not "see" sample burning as strongly as the upper detector does.

Finally the mixed mode is useful for giving a composite surface and subsurface image which can take on a 3D-like image.

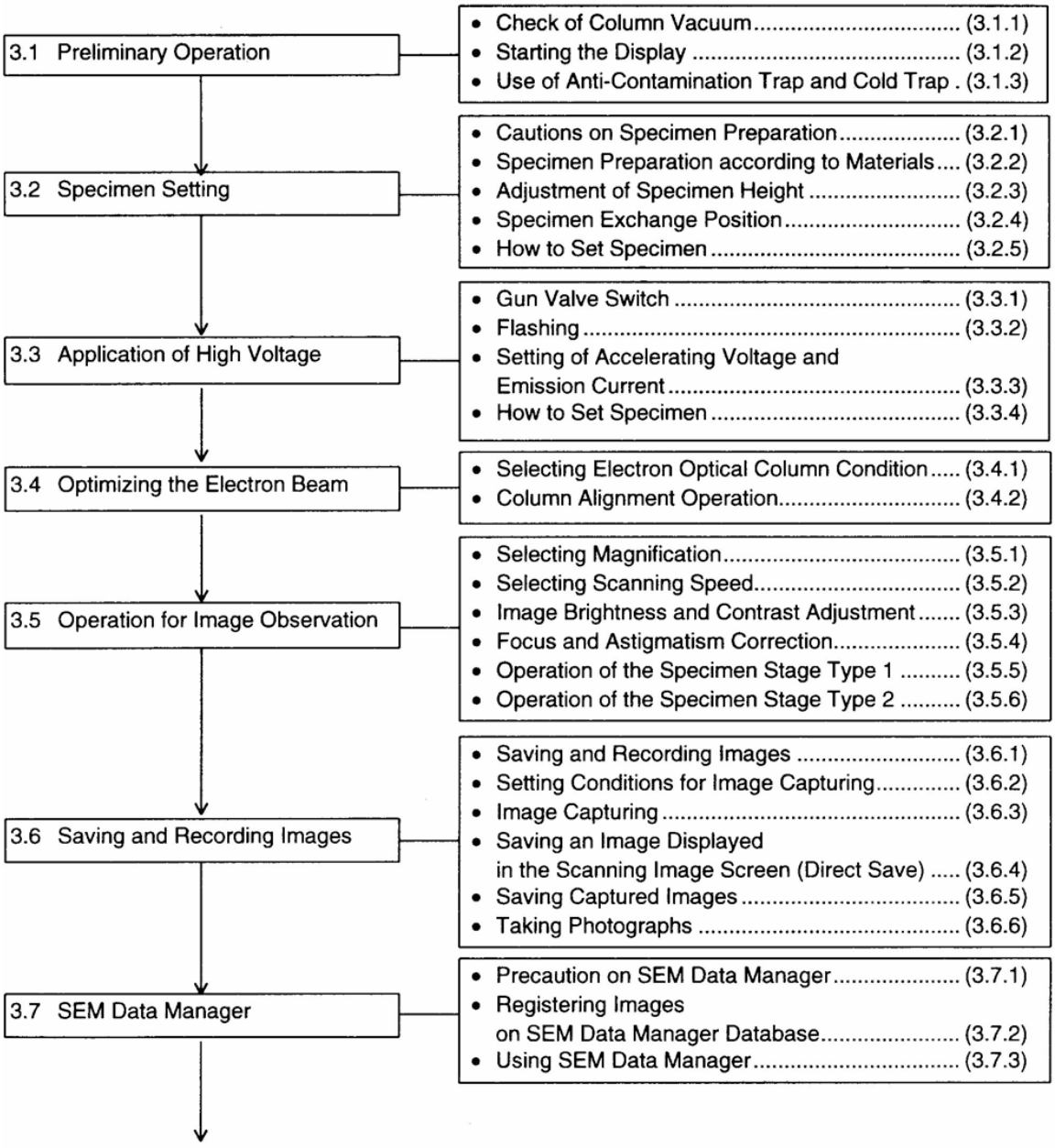
Back Scatter Mode The backscatter mode is selected to image deeper into the sample-to penetrate surface films eg sample-burning, to see microcracks, subsurface graininess and other features not visible at the surface. The upper detector is used in conjunction with a variable grid voltage to image the backscatter electrons. Consequently the working distance is kept small commensurate with the energy used. (Remember higher KEV requires longer working distances.) A user selectable negative bias voltage is used to "turn off" the secondary emitted electrons so that 0V corresponds to no backscatter mode and -150V corresponds to full backscatter mode with voltages in between representing a ratio of the two modes. A higher beam current may also be required to produce a strong enough signal. Another possible benefit to this mode is to reduce sample charging on difficult samples since charging is a surface effect which is not imaged in the backscatter mode.

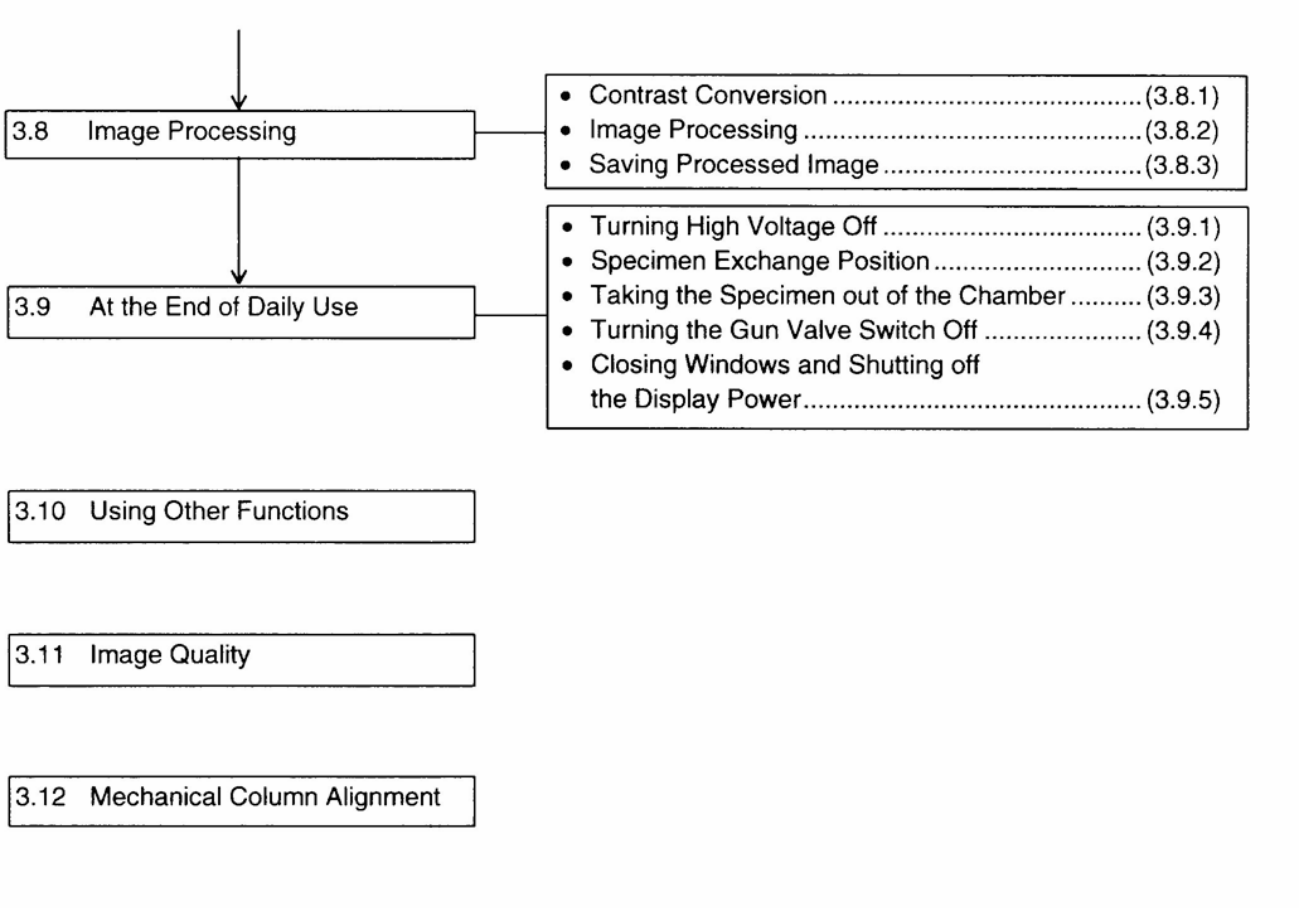
Resolution Mode Usually the ultra high resolution mode (UHR) is selected since this gives the smallest beam size even at smaller working distances. Normal mode gives more beam but is limited to 6 mm working distance. For cases where a lot of signal is required (eg EDAX), use another mode such as analysis.

Mag Mode Usually the high magnification mode is used after using the low mag mode to navigate around on the surface. For low resolution requirements, however such as MEMs structures, the low mag mode mixes detectors automatically and can give a 3D appearance to your structures. However, this mode is not calibrated for dimensions or working distance and cannot be used for measurement.

3. OPERATION

Shown below is the procedural flow of typical SEM operations. For details, refer to each subsection.





3.1 Preliminary Operation

3.1.0 Log Book Verification

Verify from log book that the previous user had no problems.

3.1.1 Check of Column Vacuum

At the beginning of SEM operation, check the evacuation control panel. The following conditions must be met:

(1) IP1, IP2 and IP3 lamps are lit.

(2) Ion pump readings are better than the following.

IP1: 2×10^{-7} Pa

IP2: 2×10^{-6} Pa

IP3: 7×10^{-5} Pa

If vacuum readings do not satisfy the above conditions, gun baking is required. Call lab management to report this condition.

(3) EVAC POWER switch is set at 1 (ON).

(4) DP/TMP, WATER and AIR PRES lamps are lit.

(5) HIGH lamps of S.C VACUUM and S.E.C VACUUM are lit.

(6) GUN VALVE switch is at CLOSE and AUTO lamp is flickering.

(7) OBJ. APT. switch is set at HEAT. *(Degas mode is used by lab staff or approved superusers only.)*

Keep the OBJ. APT. switch on the evacuation control panel at HEAT. If the objective lens aperture is contaminated, charging will degrade image quality and the image will drift because of micro discharge. Such problems are noticeable at low accelerating voltages. The aperture is heated to about 150 °C to remove contaminants to one tenth or less of what it would be at room temperature.

The switch should be turned OFF only when introducing air into the specimen chamber. **SPECIMEN CHAMBER IS VENTED ONLY BY LAB STAFF OR QUALIFIED SUPERUSERS.**

Note that when you have first turned the switch to ON, image drift may be observed for about half an hour.

3.1.2 Starting the Display

Note: If the Display is already on go to step 4 below

(1) Ensure that the EO CONTROL switch is set to 1 (ON), and then turn the DISPLAY switch to 1 (ON). During routine operation, EO CONTROL SHOULD BE KEPT ON (1).

(2) The PC should boot up when the DISPLAY switch is turned on.

(3) Select Windows NT Workstation Version 4.00 for the booting up selection. A dialog window for logging on will appear. Press Ctrl, Alt and Delete keys simultaneously. S-4700 appears as your login name and the password is left blank. Windows NT will start up.

(4) Double-click the PC-SEM short-cut icon on the desktop. The S-4700 system will start and the initial log-in dialog window appears. Login name and password are as in the previous step. The SEM main window will open.

(5) Flip the gun valve switch up to Auto on the vacuum console.

3.1.3 Use of Anti-contamination Trap and Cold Trap

(This will not be necessary for many SEM users)

For image observation at high magnifications or low accelerating voltages, the use of the anti contamination trap and cold trap may be used to prevent specimen contamination by hydrocarbon build -up. The trap to the right of the column may be filled with liquid nitrogen to

reduce sample burning. It takes about 20 minutes however for the trap to stabilize. **Contact lab staff if you need this option.**

The anti-contamination trap is a plate above the specimen that adsorbs gas around the specimen. The capacity of the liquid nitrogen dewar is about 0.9 liters and is usable for about 5 hours at an ambient temperature of 24 °C. For initial filling, about 1.3 liters of liquid nitrogen is required.

CAUTIONS:

Before using liquid nitrogen, be sure to put on leather gloves and safety glasses. If liquid nitrogen splashes on your skin, you may suffer frostbite.
Never introduce air into the specimen chamber while the anti contamination trap is filled with liquid nitrogen. The anti contamination trap will frost up and the vacuum will deteriorate. Before introducing air into the specimen chamber, wait for a few hours after the liquid nitrogen dewar has completely emptied. The air introduction valve does not have a protection link with the cold trap.

3.2 Specimen Settings

3.2.1 Cautions on Specimen Preparation

During specimen preparation, observe the following:

(1) Use clean gloves and wear a face mask when exchanging specimens.

(2) Avoid using an excessive amount of conductive paste to fix a specimen on the specimen stub. Ensure that the paste has dried before placing the specimen in the chamber. Make sure the paste is completely covered by your sample to prevent contamination.

(3) Select the correct specimen stub for each specimen. Note that the Nanolab provides 2 stub sizes (15mm and 1 inch) as well as a 70° tilted piece holder and a 4 inch wafer chuck. Always demount your sample and clean the stub with alcohol when you are through.

(4) When using double-sided adhesive tape to fix a specimen to the stub, use the least amount to minimize out-gassing. The use of double -sided adhesive tape may also cause specimen drift. As in step 2, sample must completely cover the tape.

3.2.2 Specimen Preparation according to Materials

The method of specimen preparation varies with materials. Below are preparation methods for typical types of specimens.

(1) Conductive Specimens such as Metals

These types of specimens can be observed without preparation. However, coating with heavy metals by using a vacuum evaporator, an ion sputtering or magnetron sputtering unit may result in better contrast.

(2) Non-conductive Specimens such as Semiconductors, Fibrous Specimens and Polymeric Materials

Coating with conductive materials is recommended. To observe these kinds of specimens without a conductive coating use low accelerating voltages (1 kV or lower). However, coated particles may be more visible at higher magnifications.

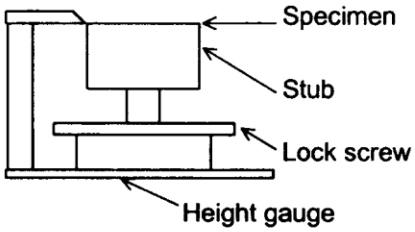
(3) X-ray Analysis Specimens

Generally, polish the surface of the specimen, then fix it to the specimen stub using carbon paste. Non-conductive specimens should be coated with carbon using a vacuum evaporator.

Note: The sample mounting assembly consisting of the base, stud and lock ring is stored in the exchange chamber when not in use. Always store this assembly in the exchange chamber after you have removed your sample with the specimen stub.

3.2.3 Adjustment of Specimen Height

Put the specimen stub on the specimen holder and adjust it to the proper height using the specimen height gauge as shown in the figure. To adjust, loosen the lock screw and adjust the specimen height so that the highest point of the specimen is the same as the bottom of the height gauge. Then, tighten lock screw.



⚠ CAUTION

Specimen height must be adjusted carefully. It must not be 0.5 mm higher than the bottom of the height gauge. If it is higher than this, the specimen may strike the objective lens and cause damage when operating at a short working distance or at a high tilt angle.
Also, accurate setting of specimen height minimizes image shift during specimen tilting.

Note: The height gauge is stored on top of the chamber exchange chamber door.

3.2.4 Specimen Exchange Position

Verify that no sample is still in the SEM chamber by turning on the chamber scope by pressing the white button on the camera power supply (see Fig 1) and then depressing the power on the LCD Display. This will also enable you to see inside the chamber as you load and unload your sample.
Before loading the specimen, remove the mounting assembly from the exchange chamber and screw the specimen stub with your sample onto the mounting assembly.
The window in the exchange chamber will allow you to see the sample mounting assembly.
Make sure your sample and the adhesive are clean and dry. Your sample must cover the entire adhesive or tape.

The UCLA SEM uses a Type ll , 5 -axis motorized stage with X,Y,? ,Z and tilt capability.

Open the Stage Control Dialog window and click the **Go to Home** button. The stage is then moved to the specimen exchange position, and the color of the indicator button turns green. To open the **Stage Control** dialog window, click the Stage operation area of the

Scanning Image window, or click the icon on the toolbar. Selecting the **Stage Control** command from the **Operate** menu can also access the **Stage Control** dialog window.
Specimen e xchange positions: X: 25.0 mm Y: 25.0 mm
R: 0° T: 0° Z: 12.0 mm

*NOTE: Do not repeat clicking the **Go to Home** button. Otherwise the **Stop** button may become ineffective.*
CAUTION: Do NOT start specimen exchange UNTIL the indicator window turns green.

3.2.5 How to Set Specimen

Before setting a specimen on the specimen stage, make sure that the height of the specimen is aligned with the height gauge mark.
Note: The sample holder assembly is kept in the exchange chamber when not in use.

(1) Confirm that the EXCHANGE VALVE is at C (Close) position. Verify that SC/SEC switch is set to SEC and press the AIR switch on the column vacuum control panel.

(2) After the specimen exchange chamber has reached atmospheric pressure (It takes about 5-10 secs), open the specimen exchange chamber. Open by grabbing both sides of the door and gently swinging towards you. **Do NOT open the door by using the Rod.**

(3) Remove sample holder assembly from the exchange chamber by unscrewing rod (CCW) while holding assembly with other hand. You must be wearing gloves and face mask.

(4) Mount specimen stub with your sample onto base stud by screwing stub onto stud tightly. Loosen locking ring and adjust specimen height by screwing/unscrewing stud into base. Do not adjust height by loosening stub. Verify sample height is +/- 0.5 mm of height gauge arm. Retighten locking ring.
Also verify that the stud does NOT stick out from the base as this will prevent sample from loading successfully.

(5) Push the specimen exchange rod slightly to unlock it, and screw it into a threaded hole of the specimen holder. (Do not screw in the rod with too much force. Threads may be crushed.) *Note winged portion of the base should be facing downwards.*

(6) Pull the rod and make sure it is locked. Then, close the specimen exchange chamber.

(7) Press the EVAC switch on the column vacuum control panel while gently pressing on exchange chamber door. Wait until vacuum in the specimen exchange chamber is improved enough and the HIGH lamp of S.E.C VACUUM is lit and SEC/Pi reads $2x10^0$

or less. ***Caution: Do NOT allow sample to sit in the exchange chamber for long periods of time as backstreaming can occur.***

(8) Turn the EXCHANGE VALVE to O (Open) position.

(9) Looking into the specimen chamber, push in the exchange rod and set the specimen holder into the stage by sliding it along the guide rails. The chamber scope may also be used to verify correct loading. Resistance will be felt as the holder slides into the fork.

(10) Turn the exchange knob counterclockwise until it is separated from the threaded portion of the specimen holder, and pull out the rod fully until it locks into place.

(11) Turn the EXCHANGE VALVE to C (CLOSE). Switch chamber vacuum readout to SC/Pe and wait until the specimen chamber pressure is at L X 10^{-3}

3.3 Application of High Voltage

3.3.1 Gun Valve Switch

GUN VALVE switch should already be set to AUTO at the beginning of operation. The gun air-lock valve opens by HV ON operation and closes by HV OFF operation. Turn this switch to CLOSE at the end of operating the machine.

3.3.2 Flashing

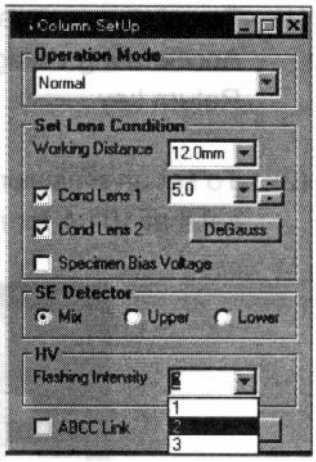
Flashing is a procedure for removing gas molecules which have been adsorbed on the surface of the cathode (FE tip) in the electron gun. Flashing is needed as follows.

(1) Flash once everyday before use or when the emission current becomes unstable.
(2) Flash once at the end of daily operation
(3) When the on-screen prompt asks you to flash.
(4) When the emission current becomes unstable.

Flashing Procedure

Use the following procedures for flashing.
(1) Check and set the flashing intensity as follows.

Open the Column Setup dialog window by clicking the icon on the toolbar or selecting the Column command from the Setup menu. Set flashing intensity at 2 in HV-Flashing Intensity list box.



(2) Open the HV Control dialog window by clicking in the HV indication area on the toolbar or selecting HV command from the Setup menu.

(3) Click the **Flashing** button in the **HV Control** dialog window. Click the **Execute** button.

The emission current during flashing is indicated in the Ie (emission current) part of the HV indication area for two seconds. Write this number in the log book along with IP1 (ion pump 1 pressure).

For normal flashing operation, use intensity 2. However, when the stable stage of the emission current is short, or the emission current begins to increase 1 hour after applying HV (in that case a large quantity of gas molecules are absorbed on the cathode), use intensity 3. Flash twice following the above procedure.

After flashing, the emission current decreases for a while, then becomes stable. (Even in the stable period, the emission current continuously decreases slightly.) The emission current becomes unstable and increases after 5 to 10 hours of operation. Noise (bright or dark lateral stripes on the image) may appear in the initial period, but will disappear in the stable period. When there is a large amount of noise and the emission current becomes unstable, turn HV Off, and flash again. A message will appear when 8 hours of cumulative operation time or 24 hours of total time have passed after flashing, as a reminder to flash the tip again. If the tip is not flashed within 30 minutes, the HV will be turned off a utomatically. These time periods can be set at other values if necessary.

Input the sample (chuck) size and height (usually standard) in the stage dialog box BEFORE turning on the high voltage. Typical sizes are 15 mm for the small stub, 1 inch (25mm) for the

larger stub and 3 and 4 inch for the sample chucks. It is important to choose the correct size since the software will limit movement in x, y, z and tilt for the larger sizes.

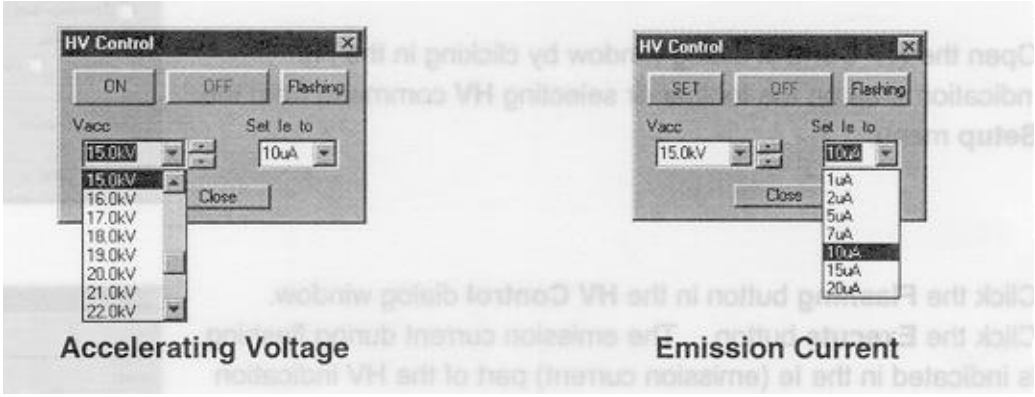
3.3.3 Setting of Accelerating Voltage and Emission Current

NOTE: BEFORE turning on the high voltage, input the sample size and height in the stage control dialog box. Sample size actually refers to stub size (15mm, 1 inch etc)

To set the accelerating voltage and emission current, use the **HV Control** dialog window.

(1) To set an accelerating voltage, select a voltage from the **Vacc** listbox.
Accelerating voltage can also be set by using the keyboard to input a value followed by the Return key. A click can be heard and the HV light comes on at the top rear of the machine

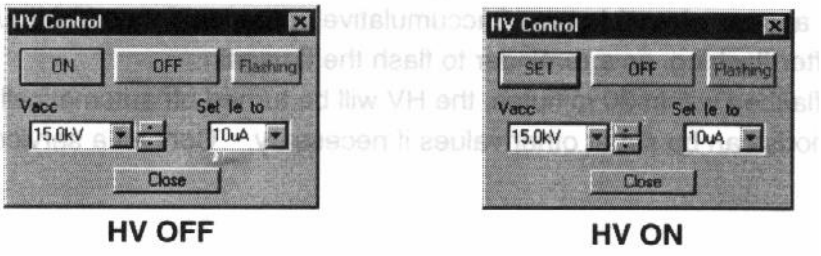
(2) To set an emission current, select a current in the **Set Ie to** listbox. It is recommended to set it at 10 uA for normal operation.



Note the emission current will decrease as you use the SEM especially right after flashing. Periodically readjust the emission current by clicking in the HV dialog box and reselecting the current. Both accelerating voltage and emission current are adjusted immediately upon changing them if the HV is on and may be monitored in upper right hand display.

3.3.4 Application of High Voltage

Click the **ON** button in the **HV Control** dialog window. Accelerating voltage (Vacc) and extracting voltage (Vext) are then applied with the values indicated in the HV display area. The gun airlock-valve is opened automatically if the **GUN VALVE** switch is set at **AUTO**. The **ON** button is changed to read **SET** when the high voltage is applied. You can set emission current to a selected value in the **Set Ie to** box by clicking this button.



HV OFF HV ON

You can turn On and Off HV using the ON and OFF buttons on the tool bar when you do not need to change the high voltage value.

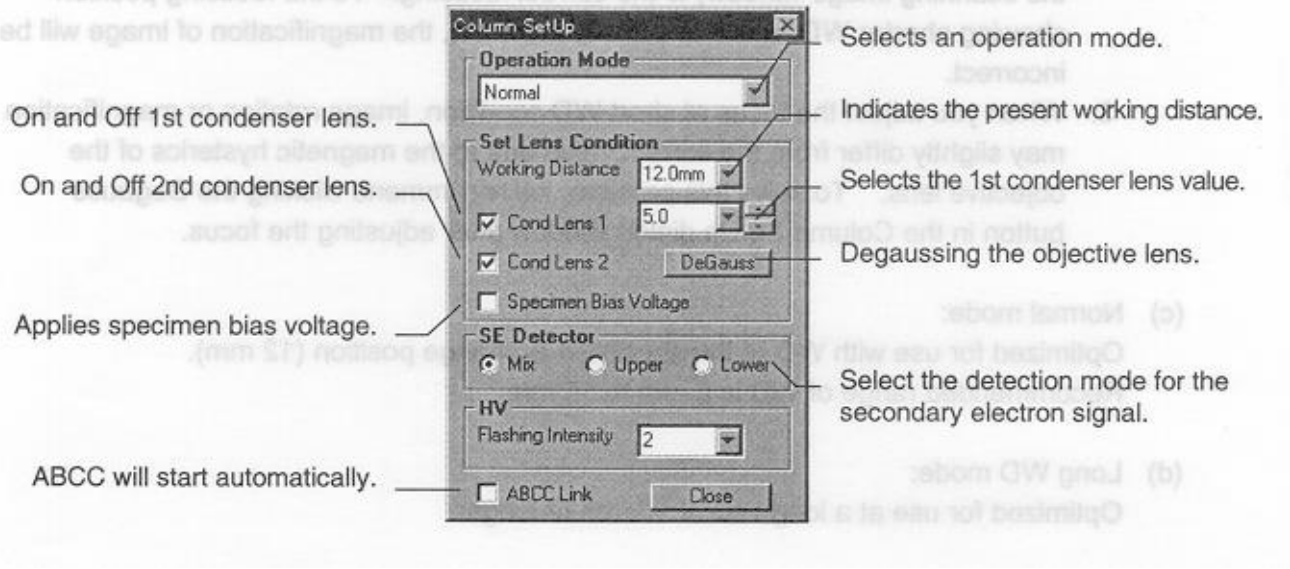
Note: A Sample size warning is displayed as a reminder to correctly set the sample height and size BEFORE turning on the HV. Click OK to acknowledge.

3.4 Optimizing the Electron Beam

3.4.1 Selecting Electron Optical Column Condition

NOTE: If setup conditions have been saved from a previous run, these conditions may be reapplied by restoring them from File Operating Conditions

Electron optical column conditions need to be selected before a lignment and operation of the SEM begins. Click the Column Setup icon on the toolbar or select the **Column** command from the **Setup** menu and open **Column Setup** dialog window.



(1) Operation Mode

The S-4700 has 5 operation modes listed below. Select a mode of interest to suit the specimen and the purpose of microscopy (usually UltraHigh Resolution.)

(a) Ultra High Resolution mode:

Highest resolution is attainable. Use it for high-resolution observation at a short WD of 6 mm or shorter. This mode can be operated at longer WD than 6 mm and provides the smallest spot size.

(b) UHR-A mode:

It is used when observing images at a short WD of less than 6 mm and with large probe current. This mode is effective when observing the BSE image by using the Signal Control function.

NOTES:

1. When using Ultra-high resolution mode or UHR-A mode, focus will be more sensitive to the focus knob when observing images at WD < 6 mm. At working distances longer than 6 mm, use the Normal mode or Long WD mode depending on the necessary WD or use Analysis mode when large probe current is necessary.
2. If you use Ultra-high resolution mode or UHR-A mode at longer WD such as WD >3.5 mm, two different focusing positions will be found at the same WD. In this case, the focusing position showing longer WD (displayed on data display of the scanning image window) is the correct focusing. At the focusing position showing shorter WD, which is actually incorrect, the magnification of image will be incorrect.
3. When you adjust the focus at short WD condition, image rotation or magnification may slightly differ from the correct value due to the magnetic hysterics of the objective lens. To solve this problem, click the Degauss button in the Column SetUp dialog window after adjusting the focus.

(c) Normal mode:

Optimized for use with WD at the specimen exchange position (12 mm). Recommended range of WD is 6 mm to 15 mm.

(d) Long WD mode:

Optimized for use at a long WD of 15 mm or longer.

(e) Analysis mode:

Large probe current is attainable. Use it for X-ray analysis (EDAX), or when a large probe current is required.

(f) Magnet Sample mode:

Astigmatism correction range is enlarged. Use it for observation of ferromagnetic specimens such as iron that make astigmatism correction difficult.

Pulverized ferromagnetic specimens shouldn't be introduced into the specimen chamber. If particles from such a material are attracted to the objective lens due to its strong magnetic field , the microscope performance will be degrad ed. Because ferromagnetic samples strongly interact with the magnetic field of the objective lens, they must be firmly attached to the specimen stub.

NOTE 1: If a ferromagnetic sample is large in volume, Magnetic Sample mode may fail to achieve complete astigmatism corrections, or may not provide an adequate brightness in the field of view. In such a case, decrease the size of the specimen, use a longer WD, or lower the accelerating voltage in order to correct the astigmatism.

NOTE 2: If the ABCC Link check box in the Column Setup dialog window has been checked, ABCC will start automatically when the Operation Mode is changed. Image brightness will be adjusted to adequate value.

(2) Set Lens Condition

(a) Working Distance (WD):

Working Distance (WD) is the distance between the bottom face of the objective lens and the surface of the specimen. At a shorter WD, higher resolution is attainable. At a longer WD, a larger tilt angle and a greater depth of focus is attainable. When a WD is selected in the **Column Setup** dialog window, the objective lens current is adjusted in order to focus an image at a specified WD.

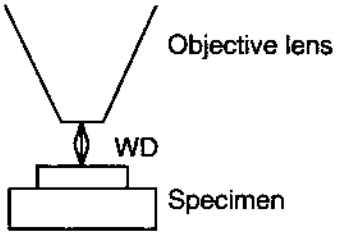
This function is useful for:

1) Obtaining focus of the specimen surface quickly after introducing a specimen.
2) Focusing the specimen at a specific WD.

For X-ray analysis, the same WD (12 mm) should be used in order to maintain the X-ray take-off angle. In that case, set WD on Column Setup dialog window and adjust Z position of the specimen stage to focus the image. (Use standard focusing operation only for fine adjustment.) Available WD value is limited for each Operation Mode and accelerating voltage.

The following table shows available value and recommended range of WD.

	Short	← WD →	Long
Resolution	High	←	Low
Depth of focus	Shallow	←	Deep
Specimen tilt angle	Small	←	Large



Available and Recommended WD Value for Each Operation Mode

Mode	WD: Type I (Type II)	Recommended Range (WD: mm)
UHR-A	1.5* to 15 (15)	less than 6
Ultra High Resolution	2.5* to 15 (15)	less than 6
Normal	6* to 26.5 (30)	6 to 15
Long WD	6* to 26.5 (30)	more than 15
Analysis	6* to 26.5 (30)	more than 6
Magnet Sample	6* to 26.5 (30)	more than 6

*: The minimum WD varies with accelerating voltage.

(b) Cond Lens 1 (First Condenser Lens):
It is possible to adjust probe current by setting Condenser Lens 1 value in the **Column Setup** dialog window. Only advanced users should adjust this setting. In general use the default value of 5.0. Probe current increases if a small number is set.

(c) Cond Lens 2 (Second Condenser Lens):
Condenser lens 2 can only be turned ON or OFF on **Column Setup** dialog window. Normally, it is set to ON. Select OFF only for mechanical alignment of electron optical axis (staff only).

(d) Specimen Bias Voltage:
Normally, it is set to OFF (un-check the box). Select ON (check the box) when non uniformity of brightness appears on the CRT at low magnifications in high mag. mode under the conditions where the sample is tilted at high angles of 40 degrees or higher. Additionally select on especially when observing at high accelerating voltage such as10 kV or higher. When the specimen bias voltage is on, -15 V is applied to the sample.

NOTES:

1. *When the Specimen Bias Voltage is turned on at low accelerating voltages, SEM image may become dark because the detection efficiency of the SE signal is decreased. Set the Specimen Bias Voltage at OFF in order to correct this problem. To improve the non-uniformity of brightness in the image which may appear at high sample tilt condition, at low magnifications and at low accelerating voltages, use the Low mag. mode.*
2. *Turning Specimen Bias Voltage ON and OFF may cause changes in the contrast of the image depending on the application.*
3. *Turning Specimen Bias Voltage ON and OFF may cause changes and require adjustment of the focus, astigmatism and aperture alignment.*
4. *If the **ABCC Link** check box **in the Column Setup** dialog window has been checked, ABCC will start automatically when Specimen Bias Voltage is changed.*

Image brightness will be adjusted to adequate value.

(e) Degauss Operation:

The Degauss operation eliminates hysteresis of the magnetic field in the objective lens. When focus is changed greatly, accuracy of magnification or alignment of the electron optical axis may degrade due to hysteresis of the focusing magnetic field.
Click **Degauss** button in the **Column Setup** dialog window under the following conditions:

- After changing focus significantly.
- Before making the electron optical axis alignment.

Degaussing is automatically effected when WD is changed in the **Column Setup** dialog window, when the accelerating voltage is changed, or when a new operation mode is selected.

(3) Secondary Electron Detector

The S4700 has two secondary electron detectors.: the upper and the lower detectors. The upper secondary electron detector is placed above the objective lens and secondary electrons are detected through the magnetic field of the lens. The lower secondary electron detector is placed in the specimen chamber, where a large amount of the signal is due to backscattered electrons. Signals from these two detectors can be selected individually, or mixed together. The image contrast of these detector signals is unique in that each has its own special characteristics.
To select a detection mode, open the **Column Setup** or **Signal Select** dialog window and select upper, lower, or mixed. Try upper detector first for normal secondary emission mode.

(a) Upper Detector Signal:

Using the upper detector, only high-resolution secondary electrons are detected, forming an image with high spatial resolution. A strong edge contrast due to the secondary electron signal may appear, as well as a flat overall contrast not carrying topographic information. An abnormal contrast may appear if a specimen is charged. Note that the signal intensity of the upper detector gradually decreases as the WD becomes longer.

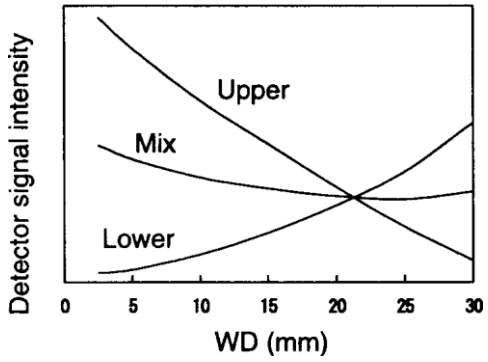
(b) Lower Detector Signal:

Images formed with the lower detector signal show a natural surface topography with less edge contrast. These images show a normal contrast even when a specimen is charged. Both secondary and backscattered electrons are detected at a long WD condition, while backscattered electrons are detected exclusively at a short WD condition. Spatial resolution is generally lower than that given by the upper detector because backscattered electrons are generated from a wider and deeper specimen area. The lower detector signal is advantageous for observation of specimens that are charge-sensitive at relatively low magnification. The lower detector also is less sensitive to "sample-burning".

(c) Mixed Signal of Upper and Lower Detectors:

The upper and lower detector signals can be mixed to show characteristics of both detectors. The intensity of this signal does not vary much for a change of WD; however, the signal of the upper detector is dominant at shorter working distances while that of the lower detector is best at longer working distances.

A mixed signal can give a "3D" appearance to high aspect ratio structures such as MEMs devices but the optimum working distance and emission current must be experimentally determined.



NOTE: If the **ABCC Link** check box in the **Column Setup** dialog window has been checked, ABCC will start automatically when detector selection is changed. Image brightness will be adjusted to an adequate value.

(4) Setting of ABCC Link

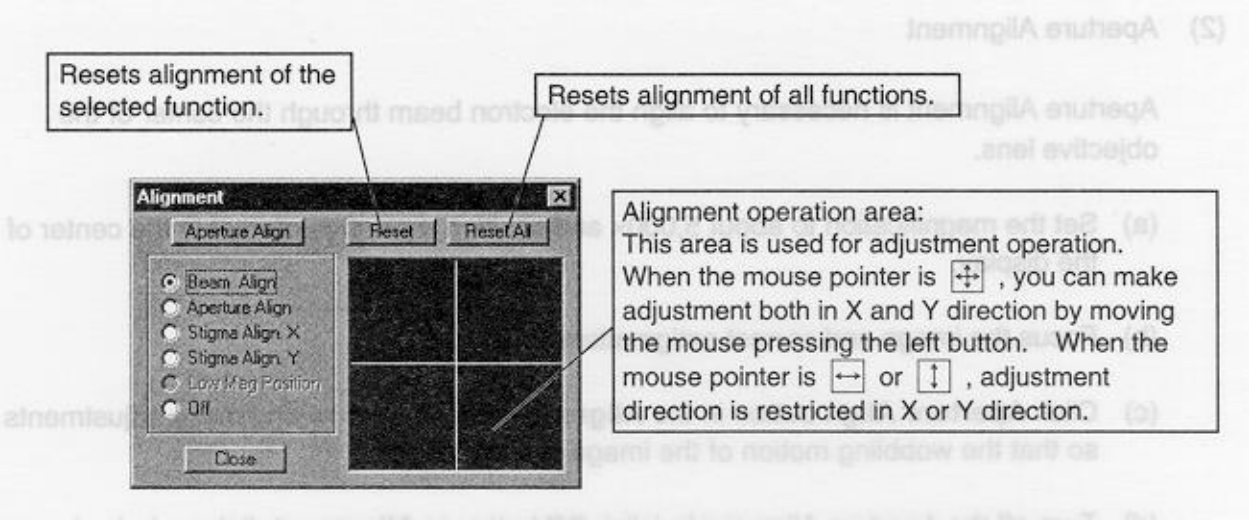
Used for setting whether or not to automatically adjust brightness and contrast (ABCC) upon changing the following status.

(a) Operation mode
(b) Specimen bias voltage
(c) Detector setting
(d) Magnification mode (High Mag/Low Mag)

3.4.2 Column Alignment Operation

For the best performance, alignment of the electron optical column axis is necessary. Generally, an electromagnetic alignment is sufficient, while a mechanical alignment (done by Hitachi or staff only) may be needed for more critical applications. Perform the following alignment when you change the accelerating voltage, operation mode, or setting of Cond Lens1. If you notice the image moving while focusing or correcting astigmatism, perform an Aperture Alignment or Stigma Alignment only, respectively. The S-4700 allows alignment conditions to be saved for each combination of accelerating voltage and operation mode. After performing an alignment, go to **File-Operating Condition** and name a file to save the

particular settings. The operating mode, accelerating voltage, detector, and condenser lens, plus any additional comments will be saved alo ng with the alignment information. If an alignment operation has been made at a particular combination of settings, only a slight adjustment (usually Aperture Alignment) is necessary when you return to that condition. For all electromagnetic alignments, either drag the mouse in the grid area of the **Alignment** dialog window or adjust the STIGMA/ALIGNMENT X and Y knobs on the control panel.



NOTE: To save operating conditions effectively, perform a Degauss operation after focusing and before column alignment.

(1) Beam Alignment

Beam Alignment is necessary in order to align the electron beam down the center of the electron optical column and through the center of the objective lens aperture.

NOTE: There are 4 apertures numbered from 1 to 4 on the SEM column with the following sizes: #1=100µm, #2=50 µm, #3=50 µm, #4=30 µm. Most of the time aperture 2 or 3 will be selected but for severe charging or very large depth of field, the smallest aperture may be used. If you're having problems getting a strong signal or finding the beam, or need a large probe current eg for X-Ray analysis, the largest aperture can be used.

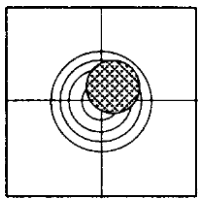
(a) Open the **Alignment** dialog window by clicking the icon on the toolbar or Monitor icon in the **Scanning Image** window, or by selecting the **Alignment** command from the **Operate** menu.

(b) Click the **Beam Align** button in **Alignment** dialog window. A circular image will appear along with a target in which to center it.

(c) Make adjustments with the console alignment knobs (X and Y) or the mouse so that the circular image appears in the center of screen.

(d) Turn off the Beam Align mode (click Off button in **Alignment** dialog window).

NOTE: If a circular image does not appear even under the highest contrast setting, change the first condenser lens to 16, and then carry out beam alignment. Afterwards, change the first condenser lens to



Circular image

the desired value (normally, 5) and repeat the beam alignment. If the electron beam is not focused near the specimen surface, the circular image may be distorted or partially blocked. In such a case, release the beam alignment (click Off button in the Alignment dialog window) and roughly adjust focus. If the circular image does not appear at all, perform a mechanical alignment (staff only).

(2) Aperture Alignment

Aperture Alignment is necessary to align the electron beam through the center of the objective lens.

(a) Set the magnification to about 5,000x and position a point of interest in the center of the display.
(b) Focus the image and correct astigmatism. This should be done at a higher magnification, say 50,000 or so. Use the x and y astigmatism knobs on the console to get an unsmeared image.
(c) Click Aperture Align button in the Alignment dialog window and make adjustments on the console knobs so that the wobbling motion of the image is minimized.
(d) Turn off the Aperture Align mode (click Off button in Alignment dialog window).

NOTE: You can access Aperture Alignment mode directly by clicking the Wobbler  *button on the Scanning Image window.*

(3) Stigma Alignment X, Y

Stigma Alignment is necessary to minimize image drift seen when correcting the astigmatism.

(a) Set the magnification to about 5,000x and position a point of interest in the center of the display.
(b) Focus the image and correct astigmatism.

(c) Click Stigma Align X button in the Alignment dialog window and make adjustments so that the wobbling motion of the image is minimized.
(d) Click the Stigma Align Y button in the Alignment dialog window and repeat the same adjustment as above (c).
(e) Turn off the Stigma Align mode (click Off button in the Alignment dialog window).

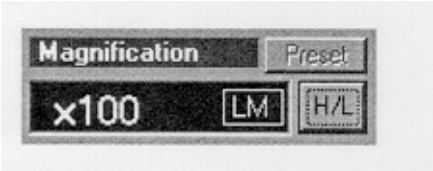
NOTE 1: Stigma Alignment may not completely stop image movement. Use up to 50,000 x magnification for this adjustment.
Note 2: Auto stigmation may be used on samples with sufficient numbers of edges or borders (eg film with highly defined grains) BUT the aperture alignment must be carefully performed first.

(4) Adjustment of Low Mag Position

The S-4700 has two magnification modes: High Mag mode and Low Mag mode. Low Mag Position adjustment is necessary to minimize a shift in the field of view for the two magnification modes. Perform the following procedure to keep the area of interest centered when going between Low Mag and High Mag modes.

(a) In High Mag mode, go to the minimum magnification allowable and place a point of interest in the center of the display. It is recommended to display the cross hair cursor by checking the **Area Marker** box in the **Scanning Image** window.

(b) Go to Low Mag mode by clicking H/L button in the magnification display area.



(c) Focus the image and correct astigmatism.

(d) Click the **Low Mag Position** button in the **Alignment** dialog window and make adjustments so that the point of interest on the specimen is in the center of the display. (Drag the mouse holding down the left button in the Alignment operation area, or adjust STIGMA/ALIGNMENT knobs on the operation panel).

NOTE: Complete Beam Alignment and Aperture Alignment before starting Low Mag Position mode. Low Mag Position adjustment is necessary for each Operation mode. When you have changed Operation mode, you need to adjust it again.

WD (mm)	Min. Magnification in High Mag Mode	Min. Magnification in Low Mag Mode
1.5	3500×	35×
2.0	2000×	35×
2.5	1500×	35×
5	700×	35×
12	250×	30×
20	130×	25×
25 or more	100×	20×

NOTE: If the ABCC Link check box in the Column Setup dialog window has been checked, ABCC will start automatically when magnification mode is changed. Image brightness will be adjusted to adequate value.

3.5 Operation for Image Observation

Follow the operation below for observation of a scanning image.

3.5.1 Selecting Magnification

There are several ways to select a magnification.

(1) Dragging the Mouse in the Magnification Indication Area

To increase magnification, drag the mouse to the right. To decrease magnification, drag the mouse to the left. For coarse changes, press the right button and for fine changes, the left button.

(2) Clicking the Mouse Button in the Magnification Indication Area

Magnification increases in incremental steps by clicking the right button and decreases by clicking the left button.

(3) Set Preset Magnifications

Click **Preset** button. The three preset magnifications are toggled through with each click of the left mouse button. To set preset magnifications, open the **Image Setup** dialog window and input a desired value in the three **Preset Magnification** boxes. Refer to: 2.3.25 Image Setup Dialog Window

(4) Using Low Mag Mode

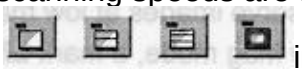
To observe images at low magnifications of a few hundred times or lower, click H/L button. In Low Mag mode, a mark LM is indicated in the Magnification indicator window. To return to High Mag mode, click H/L button again.

NOTE 1: If the preset magnification is lower than the minimum possible magnification for present WD value, magnification is set at the minimum value by Preset operation.

Note 2: Low Mag mode does NOT give the true working distance of the sample . It also mixes detector modes and can be used to get a "3D" effect for high aspect ratio images at lower magnifications.

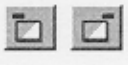
WD (mm)	Minimum Magnification
1.5	3500×
2.0	2000×
2.5	1500×
5.0	700×
12.0	250×
20.0	130×
25.0 or more	100×

3.5.2 Selecting Scanning Speed

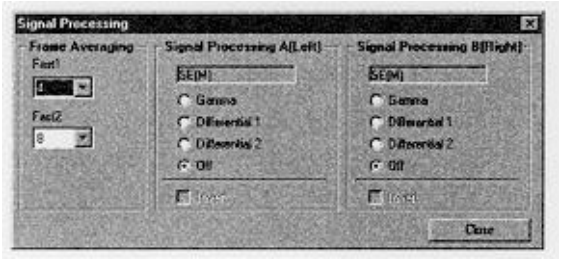
Eight scanning speeds are available. To select a scanning speed, click one of the Scan speed icons  in the **Scanning Image** window.

1. Fast 1/2
   Fast scanning in TV rates with frame averaging and integration. Use it for searching the field, coarse focus and astigmatism correction, and observation of charge sensitive samples.
2. Slow 1 to 4
   Slow speed scanning. Use it for observation, fine focus, and astigmatism correction.
3. Reduce Area 1/2
   Scan area is reduced to allow better image quality than Fast Scanning and a flicker free image for easy viewing. Use it for searching the field, focusing, and astigmatism correction.

The **Run/Freeze**  button on the **Scanning Image window** changes run (irradiate and scan electron beam on the specimen, and continuously acquire image) and freeze (blank electron beam and stop image acquisition) status alternately.

(1) Fast Scanning: 

Fast Scanning of flicker-free images is convenient for a field search of the specimen, coarse focus, etc. The quality (S/N ratio) of the image is improved by frame averaging. Two Fast Scanning speeds, TV1 and TV2, operate at the same speed but allow different number of frames to be averaged for each. To set the number of frames to be averaged, open the **Signal Processing** dialog window by clicking on the Signal Processing icon  on the toolbar, or select the **Signal Process** command from the **Image** menu. Select a number of frames for TV1 and TV2 in the Frame Averaging area. Recommended numbers are 4 for TV1 and 8 or 16 for TV2. The higher the number of frames, the better the attainable image quality.



NOTE:
In Fast scanning speed, there may be partial magnification unevenness in horizontal direction. Use slow scanning speed for applications that need partial magnification accuracy such as CD measurement.

Or you can use 2 or 4 times slower horizontal scanning speed for FAST scanning speed and FAST scan capturing. It is also effective for finer image quality. (Refer to 2.3.23 Environment Setting dialog window-Fast Scan Speed tab)

(2) Slow Scanning:

Four slow scanning speeds are available.
Slow 1: about 0.5 sec/frame
Slow 2: 8.3 sec (10 sec)/frame
Slow 3: 16.7 sec (20 sec)/frame
Slow 4: 33.4 sec (40 sec)/frame
(Power line frequency 60 Hz (50Hz))

(3) Reduced Area Scanning:
Two reduced area scanning speeds are available.

(a) Reduce 1:
Frame speed is about the same as the fast scanning. It is, therefore, suitable for searching the field, focus and astigmatism correction.
To move the scanning area box, place the mouse cursor on the border of the scanning image area. While the mouse cursor is changed to the Move indicator (intersecting arrows), press the left button and drag the scanning area box to a desired place.

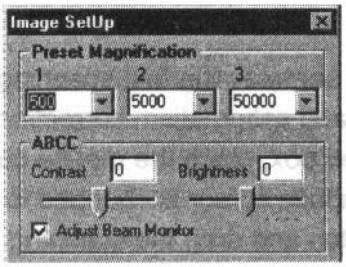
(b) Reduce 2:
Scanning speed is the same as Slow2 while the frame speed is 4 times faster. It is suitable for final focus and astigmatism correction. The scanning area can be moved with the same operation as mentioned above.

3.5.3 Image Brightness and Contrast Adjustment

Image brightness and contrast can be adjusted both manually and automatically. BC Monitor mode is also available for manual adjustment. The Beam Monitor function is provided to reduce the tip noise.

(1) Auto Adjustment (ABCC)

Click the ABCC icon in the **Scanning Image** window or select the **ABCC** command from **Operate** menu to start auto-adjustment. If the results of ABCC are not adequate, you can change the reference brightness and contrast in the **Image Setup** dialog window.



NOTE: Beam Monitor adjustment (adjustment of a reference voltage) is activated automatically at the start of ABCC function if **Adjust Beam Monitor** is checked in the **ABCC** area of the **Image Setup** dialog window. Normally, set this to ON (checked box). Set it OFF in special cases such as when the Beam Monitor reference signal needs to trace the drift of the emission current; for example, during quantitative X -ray analysis using a probe current drift cancellation function, etc. ABCC may fail to operate if started when contrast is too high, especially in Analysis mode where the probe current is high. In such a case, adjust the contrast manually, and then use the ABCC function.
When the Dual Screen Display mode is used, ABCC is applied to;
A screen image when A is running or both A and B are running.
B screen image when B is running and A is frozen.

(2) Manual Adjustment

Move the mouse cursor to the top right quadrant of the image where the mouse cursor changes to the B/C cursor. Drag the mouse while holding down the left button to adjust brightness; or while holding down the right button to adjust contrast. Drag it to the right to increase and to the left to decrease brightness and contrast. Sensitivity of mouse operation can be adjusted in the **Environment Setting** dialog window. Additionally, you can adjust the brightness and contrast using the scroll bars. Checking the **Scroll Bar** box in the **Scanning Image** window enables these scroll bars. Refer to: 2.3.23 Environment Setting Dialog Window-Mouse Tab Strip

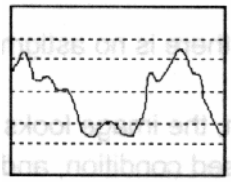
The BC Monitor mode can be used to monitor and adjust the brightness and contrast by observing a signal waveform in the **Scanning Image** window.

(3) BC Monitor Mode

A waveform and reference lines are displayed for monitoring contrast (amplitude of the waveform) and brightness (vertical level of the waveform).

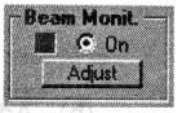
To start BC Monitor mode, click the Monitor button in the **Scanning Image** window or select the BC **Monitor** command from the **Operate** menu. When the maximum and minimum

values of the waveform are adjusted to fit within the upper and lower reference lines, appropriate brightness and contrast is obtained.



To terminate BC Monitor mode, click the Cancel button in the BC Monitor mode message or click the Monitor button again.

(4) Beam Monitor Function



The Beam Monitor function is provided to reduce the tip noise, which is a low frequency noise caused by fluctuations of the emission current. Dividing the image signal by a reference signal that is proportional to probe current can stabilize it. Keep Beam Monitor ON for normal operations. When the Beam Monitor button in the **Scanning Image** window is ON and the indicator is green, the beam monitor function is working. If it is OFF or the indicator is blinking in red, click **Adjust** button to turn it back on. Beam Monitor adjustment (adjustment of the reference voltage) is activated automatically at the start of ABCC function if **Adjust Beam Monitor** is checked in the **ABCC** area of the **Image Setup** dialog window. Normally, check this box. Uncheck this box in special cases such as when the Beam Monitor reference signal needs to trace the drift of the emission current; for example, during quantitative X-ray analysis using a probe current drift cancellation function, etc.

NOTE: If Beam Monitor indicator does not stop blinking in red or remains in gray color (turned OFF) after an Adjust operation, the fo llowing causes can be assumed.
Take corrective measures as required.

- Emission current has decreased.
  Set emission current again.
- The optical axis of electron beam is not aligned correctly.
  Carry out column alignment.
- The objective lens aperture or the beam monitor aperture is not adjusted properly.
  Set the objective lens aperture in position.
  Set the beam monitor aperture in position.
- Beam current is unstable because a long time has passed since the last flashing.
  Carry out flashing again.

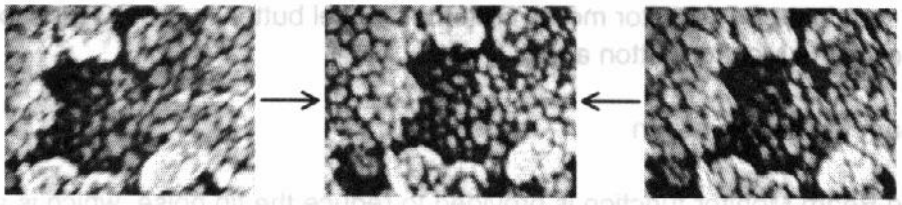
3.5.4 Focus and Astigmatism Correction

Focus and astigmatism correction can be done manually and automatically. Focus Monitor mode is available for manual focusing.

(1) General Method for Focusing and Astigmatism Correction

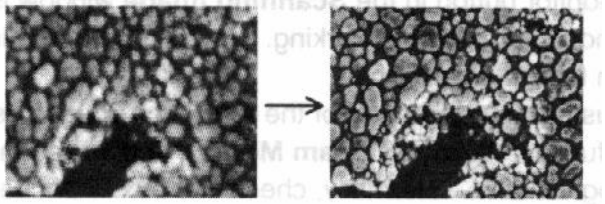
Focusing and astigmatism corrections are related to each other and need to be repeated alternately. Use the following process to complete adjustments.

(a) Focus the image. When there is no astigmatism, the sharpest image is obtained at the best focus point.
When there is astigmatism, the image looks like it is stretching in one direction at an over-focused or under-focused condition, and uniformly focused at the best focus point.



uniformly focused

(b) Adjust the stigmators X and Y alternately for the sharpest image.



(c) Focus again and check image drift and sharpness.

(d) Repeat steps (a) to (c) until adjustments are completed.

NOTE: If it takes a long time to focus and correct astigmatism, you may end up with specimen damage due to electron beam irradiation and/or contamination. If the specimen is beam-or contamination-sensitive, use one of the following techniques:

1. Reduce probe current.
2. Use another area on the specimen for focusing purposes. After focusing, return to the area of interest, adjust the final focus quickly, and then capture or record the image.

(2) Auto Focus Function

Click Auto icon in the **Scanning Image** window or select the **Auto Focus** command from the **Operate** menu to start Auto Focus. When magnification is lower than 5,000x, coarse focus (search using a wide focus range) is carried out. Fine focus (search using a narrow focus range) is carried out at magnifications higher than 5,000x. The working distance range searched by coarse focus is 1.5 mm to 12 mm in Ultra High Resolution mode and 6 mm to 35 mm in other operation modes. Fine focus works correctly under conditions where the image is not clear but visible. The result of Auto Focus depends on the surface structures of the

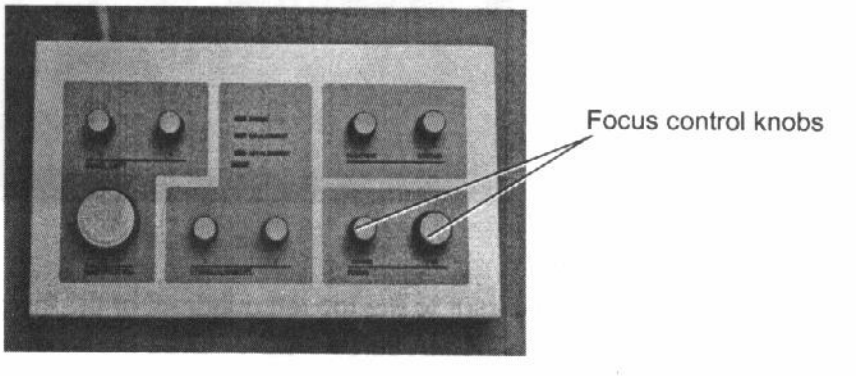
specimen. When there is little or no surface detail on the specimen, or when the specimen is charged, Auto Focus does not operate properly.

(3) Manual Focus

Manual focusing can be done using the control knobs on the operation panel or the mouse in the **Scanning Image** window.

(a) Knob Operation

Use Focus control knobs COARSE and FINE on the operation panel.



(b) Mouse Operation

Move the mouse cursor to the lower half of the image, where the mouse cursor is changed to the Focus cursor. Move the mouse while holding down the left button for fi ne focus or the right button for coarse focus. Move to the right for a shorter focal length and to the left for a longer focal length.

Sensitivity of mouse operation can be adjusted in the Environment Setting dialog window.

Alternately, focus can be adjusted with the Coarse and Fine scroll bars.

Checking the Scroll Bar box in the Scanning Image window enables these scroll bars. The Focus Monitor mode is available for monitoring focus.

(4) Auto Stigma Function

Click on the Auto icon in the **Scanning Image** window or select the **Auto Stigma** command from Operate menu to start Auto Stigma function. Use this function at magnifications higher than 5,000x. The results of Auto Stigma depend on the surface structure of the specimen. When the specimen is charged up or when there is no surface detail on the specimen, Auto Stigma does not operate properly.

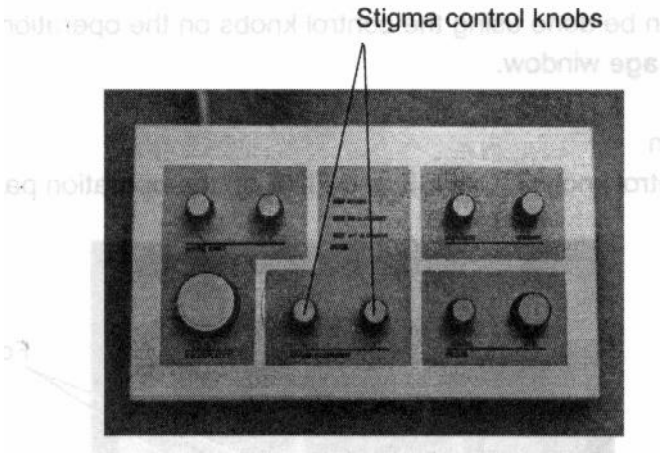
The aperture must be carefully aligned before using this option.

(5) Manual Astigmatism Correction

Manual astigmatism correction can be done using the knobs on the operation panel or with the mouse operation in the **Scanning Image** window.

(a) Knob Operation

Use Stigma control knobs X and Y on the operation panel.



(b) Mouse Operation

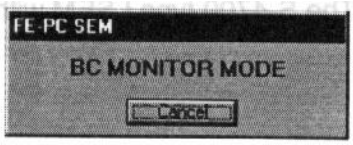
Move the mouse cursor to the top left quadrant of the image, where the mouse cursor is changed to the STIGMA cursor. Drag the mouse while holding down the left button for X or the right button for Y correction. Repeat X and Y corrections, and focus, for a final result. Sensitivity of mouse operation can be adjusted in the **Environment Setting** dialog window.

Astigmatism corrections can be done with the X and Y scroll bars as well.

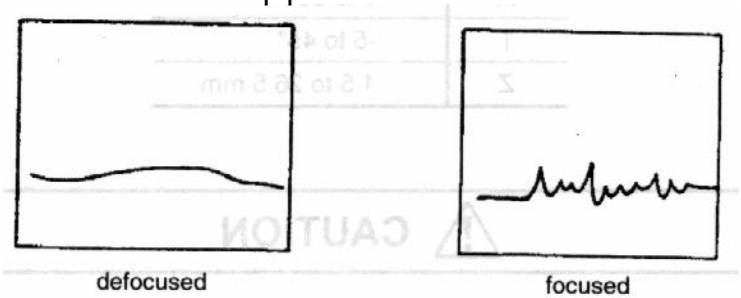
Checking the **Scroll Bar** box in the **Scanning Image** window enables these scroll bars.

NOTE: If image drifts by astigmatism correction, carry out Stigma Alignment. (Refer to 3.4.2 (3).)

(6) Focus Monitor Mode



A waveform is displayed for monitoring the focus. The magnification is set at 1,000x. To start the Focus Monitor, click the Monitor icon in the **Scanning Image** window and focus the image so that the waveform shows sharp peaks.



To close the Focus Monitor, click the **Cancel** button in the Focus Monitor or click Monitor button again.

3.5.6 Operation of the Type 11- 5-Axis Motorized Stage

The S4700 type SEM with a 5-axis motorized stage can be operated using the mouse in the Scanning Image window and in the **Stage Control** dialog window. Stage operation can also be done using the trackball unit. However, stage operation is not available using the knobs on the optional SEM operation panel.

	Movable Range
X	0 to 100 mm
Y	0 to 50 mm
R	0 to 360°
T	-5 to 60°
Z	1.5 to 30 mm

Allowable range of X, Y, Z and T axes: The allowable range for each axis is dependent on the specimen size and optional detectors put in the specimen chamber. Motion of each axis is limited within the allowable ranges, by computer control. There is no risk of striking the objective lens if the correct specimen size and height, and detectors being used are input correctly.

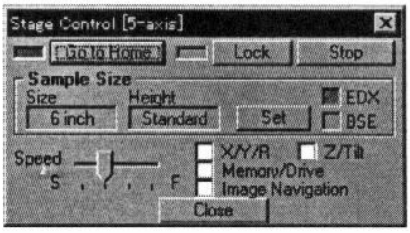
• Stage Lock mechanism

For high magnification work, use of the Stage Lock function is recommended for improved mechanical stability and minimization of vibration. Set the stage lock by clicking on the square at the top in the Stage Control Dialog box. Set the lock at a lower magnification before adjusting final focus and stigmation .

Z and T axis controls in the **Stage Control** dialog window are disengaged while the stage is locked. Refocusing will be necessary and the stage may drift up to 5 minutes before locking is achieved.

3.5.6.1 Stage Control Dialog Window

To open the **Stage Control** dialog window, click the Stage Control button on the toolbar or click the **Stage Control** button on Stage area in Scanning Image window. Selecting the **Stage Control** command from the **Operate** menu can also open the dialog window.



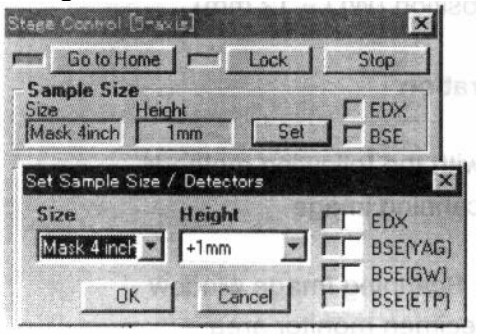
Checking each of **X/Y/R, Z/T**, **Memory/Drive, Image Navigation** check box opens corresponding operation areas.

3.5.6.2 Setting the Specimen Size

The specimen size and height and optional detectors built in the specimen chamber need to be set correctly to keep the motion of each axis within allowable range. Use the following process.

(1) Set the stage at the home position. The specimen size and height can be set only at the home position.

(2) Open **Set Sample Size/Detector** dialog window by clicking **Set** button in the **Sample Size** area of the Stage Control dialog window.



(3) Select a specimen stub size in the Size pull-down list (15 mm to 6 inches) and select a difference from the standard specimen height in the Height pull-down list (-2 mm to +5 mm).

(4) Check the appropriate boxes for the detectors being used (retracted detectors need not be checked).

(5) Click the OK button.

NOTE: Motion of Z and T axes is limited by EDX detector as follows.
Allowable range of Z axis is 11 mm or longer. If Z axis is at a position shorter than 12 mm, Z axis moves to 12 mm automatically when the EDX detector is set at operating position.

1. If Z axis is at a position shorter than 12 mm, Z axis moves to 12 mm and T axis to 0° automatically when BSE detectors are set at operating position.
2. When the specimen size is larger than 5 inches, X axis moves to 25 mm automatically if it is out of allowable range when the YAG BSE detector is set at operating position.

3. If the specimen height exceeds more than 2 mm of the height gauge, do not use EDX and BSE detectors. The specimen stage moves to 12 mm of Z axis when the **Go to Home** button is clicked for specimen exchange and may strike these detectors.
4. For EDX analysis, the specimen height should be within +1 mm of the height gauge. If it is less than -1 mm, it is not possible to set specimen surface at the analyzing position (WD= 12 mm).

3.5.6.3 X and Y Axes Operation

X and Y axes can be driven with **the following** methods.

Mouse operation on the scanning image

- Using RISM function
- Using stage buttons in the Scanning Image window

Mouse operation in the specimen monitor area

- Entering absolute coordinates of the specimen stage
- Using Image Na vigation function

the Specimen Monitor area.

NOTE
The stage motion is compensated for raster rotation angle so the image moves just in the operation direction. The mechanical motion does not coincide with the operation direction even if the raster rotation angle is just 0° because of a compensation function for image rotation that occurs due to objective lens magnetic field. If you need to coincide the mechanical movement direction with the operation direction, you can disable the compensation function.

When the mouse cursor in the Scanning Image area is turned into the Stage-Hand mark  , the stage can be driven in two ways. To turn the mouse cursor to the Stage-Hand mark, click the mouse icon  in the Stage area of the **Scanning Image** window, or double click the mouse at the center of the image display (where the mouse cursor turns into Hand mark )

(a) Stage Dragging
Place the mouse cursor at a start point on the scanning image. Move the mouse to an end point while holding down the left button (a red line is drawn), and release it. The stage is then driven so that the image at the start point moves to the end point.
When the **Over Drive** check box is checked, stage is overdriven 3 times the mouse movement.

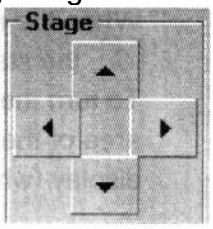
(b) RISM Function
If the end point of the above operation is near the center of the image, the red line is changed to a yellow line and the end point is positioned at the center of the image. When the left mouse button is released, the stage is driven so that the image at the start point moves to the center of the viewing screen with help of the electrical image shift.

When the cursor represents the Stage-Hand mark  , it changes to the Beam-Hand mark  by double clicking the mouse. The electrical image shift is now available with the same operation as mentioned above. The Stage-Hand mark and the Beam-Hand mark appear alternatively by double clicking the mouse. To cancel stage movements by mouse, click the  icon in the Stage control area again, or click the right button of the mouse. At high magnifications such as 50,000x or more, the stage may not move correctly. In such a case, use the electrical image shift or move the stage by step driving using Stage buttons.

NOTE: The RISM (Rapid Image Shift Mode) function moves a point of interest to the center of the viewing screen. The stage motion and electrical image shift are combined for better positioning accuracy. When the distance from the point of interest to the center of the image display is within a range of the electrical image shift, beam shift is used and the

stage is not driven. RISM function is useful for going to higher magnification without losing the field of interest once selected. RISM operation is available with both the electrical image shift and the stage mouse operation.

(2) Using Stage Buttons in the Scanning Image Window

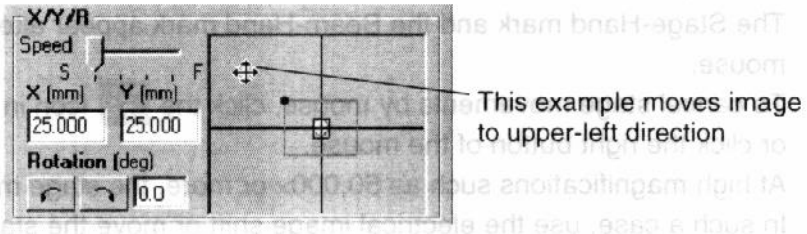


The stage is driven continuously while one of Stage buttons is pressed. Click a button to drive the stage in incremental steps, in the direction indicated by the arrow marks on the buttons. The direction of image movement can be reversed, if necessary, by setting the Reverse Mode option in the **Environment Setting** dialog window.

The width of the step is linked with magnification; however, the minimum step of the stage is limited to about several hundred nanometers. There may be some unexpected motion at high magnifications due to mechanical friction. The step traverse, for example, may vary depending on the stage position, and there may be some backlash right after the step driving. In such a case, repeat step driving several times. The stage motion should then become normal.

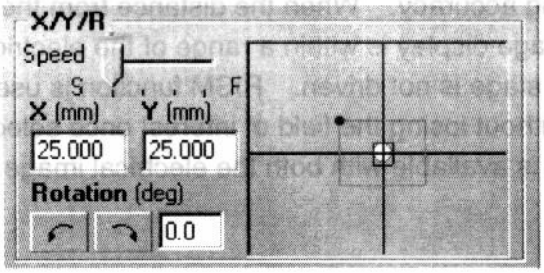
(3) Mouse Operation in the Specimen Monitor Area

Place the mouse cursor in the specimen monitor area a nd press the left button of the mouse. The direction of stage motion is determined referring to the center of the area. The driving speed is set according to the distance from the center of the area. In the specimen monitor area, the mouse cursor is changed to  . The stage is driven continuously while the left button of the mouse is held down. The driving speed can be selected **with Speed** slider and also changed according to the distance between the mouse cursor and the center of the area.



(4) Entering Absolute Coordinates

Enter coordinates for X and Y axes, and then press ENTER key.

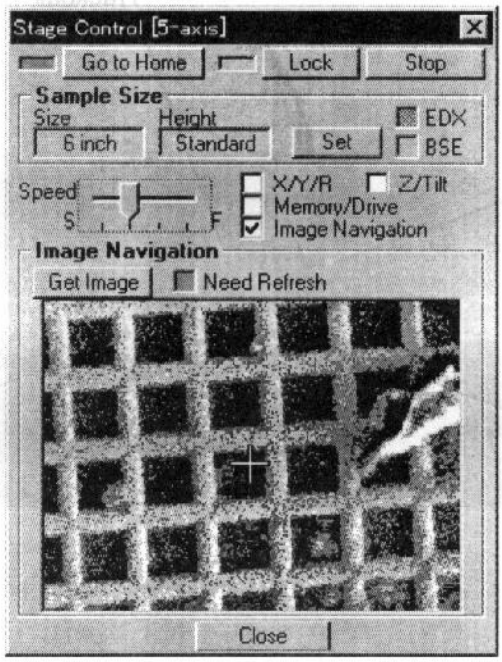


(5) Using Image Navigation Function

The Image Navigation function drives the stage to a position pointed on the low magnification image. Use this function with the following procedure.

(a) Set magnification at 1,000x or lower.
(b) Click **Get Image** button in the **Image Navigation** area. The scanning image is memorized and displayed in the **Image Navigation** area. The color of **Need Refresh** indicator is green while the image is effective. If it blinks in red color, repeat the above operation.

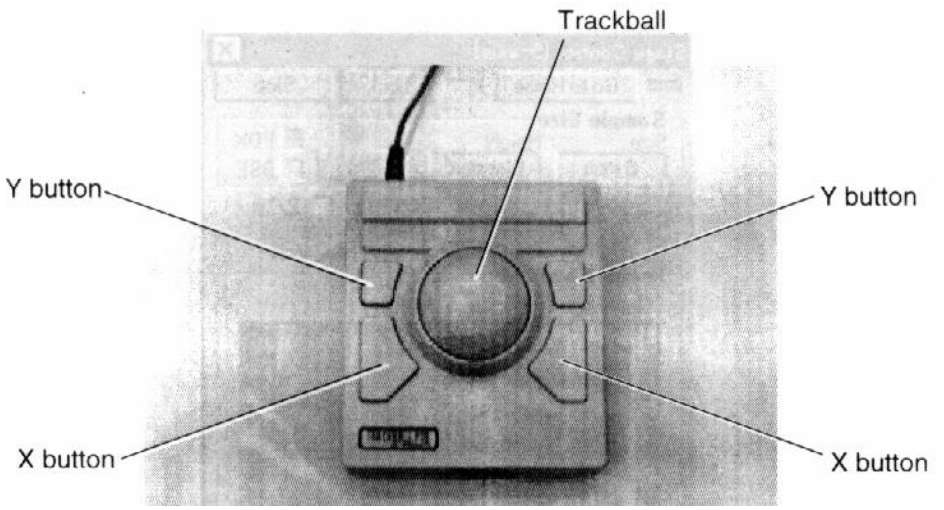
(c) Place the fine cross-hair cursor on a point in the image to be centered and click the mouse.



The stage is then driven to center this point.

NOTE: **Need Refresh** button begins blinking when any one of the R, T or Z axes of the stage; the accelerating voltage; or the lens mode is changed.

(6) Using Trackball Unit



The stage is driven in X and Y direction by rotation of the trackball. While the X or Y button is pressed, the stage is driven in only the X or Y direction. When the specimen moves in T/Z/R, stage operation by trackball is available.

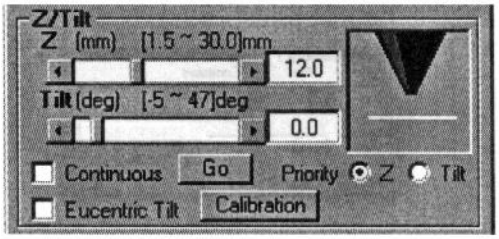
NOTE: When trackball is reversed at high magnification observation, the stage often is not driven for awhile because of stage backlash. In this case, by continuing to rotate the trackball or using a lower magnification, the stage will be driven normally.

3.5.6.4 R Axis Operation

The R axis is driven with the Rotation buttons on X/Y/R area in the **Stage Control** dialog window. Press or button to drive the R axis continuously or click the buttons to drive stepwise. A driving speed can be selected using the **Speed** slider in four steps. It is also possible to enter angles in the Rotation indication box, followed by the Enter key. The size, position and rotation angle of the specimen is indicated in the specimen monitor area.

3.5.6.5 Z and Tilt Axes Operation

Use controls on Z/Tilt area in the Stage Control dialog window for operation of the Z and Tilt axes.



(1) Mode of Operation

Two modes of operation, "Set values and Go" and "Continuous driving" are possible. When the Continuous mode is selected, the stage moves following the slide bar operation for each axis. It is recommended to press or click the arrow buttons of the slide bars, as the mechanical motion (of the stage) is relatively slow compared to the slider operation. When the Continuous mode is off (unchecked box), the stage begins its motion after clicking the Go button. In this mode of operation, select Z and Tilt movement with the sliders and then click the Go button. Blue numerals on the sliders indicate the movable range of each axis. These values are adjusted according to the input specimen size and all axes conditions.

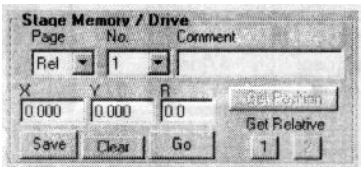
(2) Priority of Z or Tilt Axes

The movable range of the Z and T axes is limited by all other axes conditions. Maximum tilt angle is limited to 4° when the Z is 2.5 mm, or minimum Z is limited to 27 mm when the tilt angle is 60°. The **Priority** button selects which axis has priority when moving the stage (available with non-continuous movement). When **Priority-Z,** the WD can be set within a full range. If Tilt is out of its movable range, it is changed to be within its movable range automatically. **When Priority-Tilt** button is selected, Tilt can be set within a full range. If Z is out of its movable range, it is cha nged to be within its movable range automatically. This priority selection is available only when the **Continuous** checkbox is Off.

NOTE: 1. The specimen size and height, and detectors being used must be set correctly to allow motion of each axis in the proper ranges. If this is not done, the specimen may strike the objective lens and cause damage to the specimen and objective lens.
2. When the stage is locked, controls in Z/Tilt area are disabled. Release the stage lock to operate Z or Tilt axis.
3. Do not repeat clicking the Go button while the stage is moving. It may cause the stage to not stop its motion by the Stop button.
4. The allow buttons located at both ends of the scroll bar for positioning Z and Tilt must be clicked with step-like. Do not keep pressing the allow buttons. It may cause a stage error.

3.5.6.6 Position Memory Function

The stage coordinates, both absolute and relative, can be memorized and recalled. 100 absolute coordinates (10 points on each of the 10 pages) and 10 relati ve coordinates can be saved in total.



(1) Registration of Absolute Stage Coordinates at the Present Stage Position

Select a coordinate number and page, then click **Get** Position. The present coordinates are then indicated in the **X**, **Y** and **R** boxes. Input any comments in the **Comment** box, and click **Save.**

(2) Registration of Absolute Stage Coordinates by Direct Input

Select a coordinate number and page, and input values to the **X**, **Y** and **R** boxes using the keyboard, followed by the Enter key. Input any comments i n the **Comment** box, and click **Save.**

(3) Registration of Relative Stage Coordinates of the Present Stage Position

Registration of relative stage coordinates at the present stage position.

(a) Select Page **Rel** and Number.

(b) Move the stage (using RISM) to the first position and click **Get Relative-1.**

(c) Move the stage to the second position and click **Get Relative-2**.

The relative coordinates between the first and the second positions are calculated and indicated in **X**, **Y** and **R** box.

(d) Input comments in the **Comment** box and click **Save.**

(4) Registration of Relative Stage Coordinates by Direct Input

(a) Select Page **Rel** and Number.

(b) Input coordinates in **X**, **Y** and **R** boxes using the keyboard followed by the Enter key. Input any comments in the **Comment** box and click **Save.**

(5) Moving the Stage to a Memorized Position

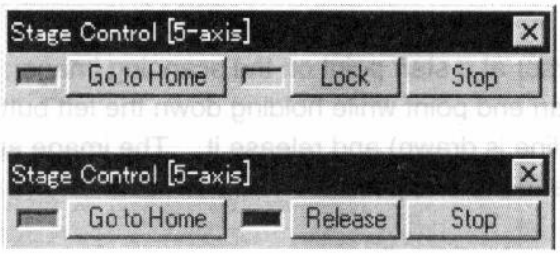
To move the stage to a memorized position, select Page and Number, and click **Go**.

(6) Moving the Stage by Relative Movement

To move the stage by a relative movement from the present position, select a page **Rel** and click **Go**.

3.5.6.7 Stage Lock Function

For high magnification work, the Stage Lock function is recommended for better mechanical stability. The Z and T axes are locked or released by clicking **Lock/Release** button in the **Stage Control** dialog window. When the box is red the stage is in a locked position.



Z and T axes operation is disengaged while the stage is locked.

3.5.6.8 Setting the Stage at Specimen Exchange Position

To exchange a specimen, click the **Go to Home** button in the **Stage Control** dialog window. The specimen stage is then moved to the specimen exchange position for all axes, and the color for the indicator button is changed to green.

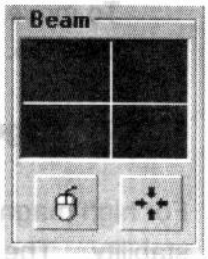
⚠ CAUTION

Start specimen exchange operation after the color of the indicator changes to green.

Specimen Exchange Positions

X	25.0 mm
Y	25.0 mm
R	0°
T	0°
Z	12.0 mm

3.5.6.9 Operation of Electrical Image Shift



The Electrical Image Shift function moves the scanning image electrically. It is useful at high magnifications where mechanical stage motion is not very accurate. The range of shift is limited to +34 um at a working distance of 25 mm, +/-15 um at a working distance of 15 mm, and +/-2.4 um at a working distance of 2.5 mm. While the mouse cursor in the Scanning Image

area is turned to the Beam-Hand cursor the electrical image shift can be driven in two ways as follows.

(1) Mouse Dragging
Place the mouse cursor at a start point on the scanning image. Move the mouse to an end point while holding down the left button of the mouse (a red line is drawn) and release it. The image at the start point moves to the end point.

(2) RISM Function
If the end point of the above operation is near the center of the image, the red line is changed to a yellow line and the end point is positioned at the center of the image. When the left button of the mouse is released, the image at the start point moves to the center of the viewing screen.

To turn the mouse cursor to the Beam-Hand mark click the button in the Beam area of the **Scanning Image** window or click the left mouse button in the center of the image (where the mouse cursor is turned to the Hand mark). When the cursor is the Beam-Hand mark, it changes to the Stage-Hand mark by double clicking the mouse. The stage mouse operation is available with the same operation as mentioned above. The Stage-Hand mark and Beam-Hand mark appear alternatively by double clicking the mouse. To cancel the Beam-Hand mark, click the icon in Beam area again or click the right button of the mouse. The present amount of electrical image shift is indicated in the Beam area. To reset the electrical image shift at the center of its shifting range, click the button in the Beam area.

NOTE: 1. The range of shift is limited to +34 um at a working distance of 25 mm, +15 um at a working distance of 15 mm, and +2.4 um at a working distance of 2.5 mm.
2. The electrical image shift may cause defocusing or increase astigmatism. In such a case, focus the image or correct astigmatism once again.

3.5.6.10 Limitation of Stage Movement Area (T and Z axes)

Safe operating range of T and Z axes depends on size of the specimen. The X and Y axes operating range also depends on tilting angle and size of the specimen. The computer calculates the safe operating range and limits the stage motion. When the size and height of the specimen and optional detectors in use are set correctly in the Stage Control dialog window, stage motion will be kept within its safe range.

X and Y axes limitation for various tilting angles is shown in the table below.
T and Z axes limitation for various specimen sizes is shown on the next two pages.

Tilt Angle	X-direction Restriction	Y-direction Restriction	Specimen Size
0 to 25°	None	None	0 to 6 inches dia., 5 inch mask holder
	None	5 to 45 mm	5 inch mask holder
25 to 40°	None	None	0 to 5 inches dia., 4 inch mask holder
	3 to 100 mm	None	6 inches dia.
25 to 30°	10 to 100 mm	5 to 45 mm	5 inch mask holder
40 to 60°	None	None	0 to 1 inch dia.
	None	2 to 50 mm	2 inches dia.
40 to 59°	None	2 to 50 mm	3 inches dia.
40 to 55°	None	2 to 50 mm	4 to 5 inches dia.
40 to 53°	3 to 90 mm	2 to 50 mm	6 inches dia.
	None	2 to 50 mm	4 inch mask holder
30 to 53°	10 to 49 mm	5 to 45 mm	5 inch mask holder

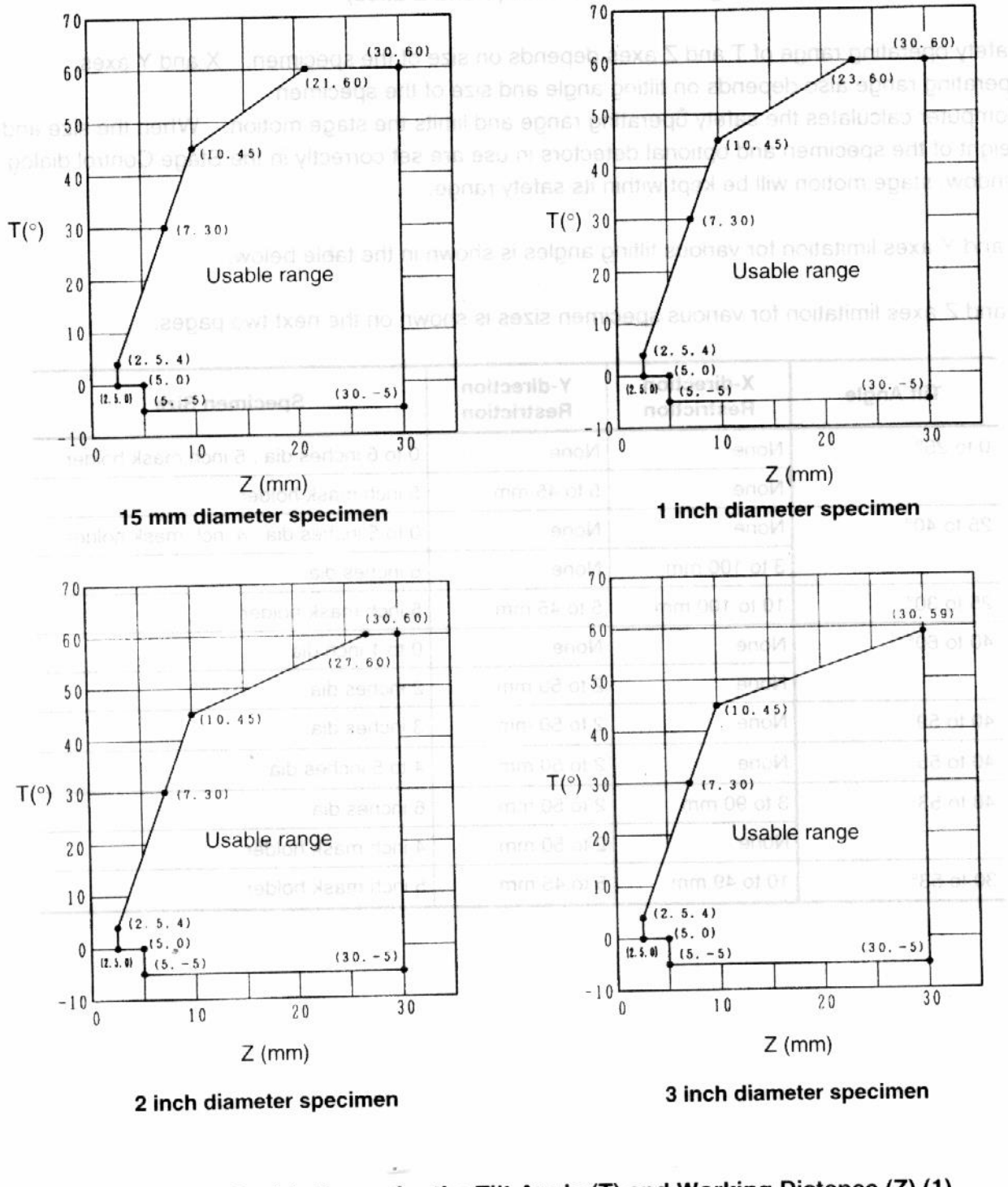
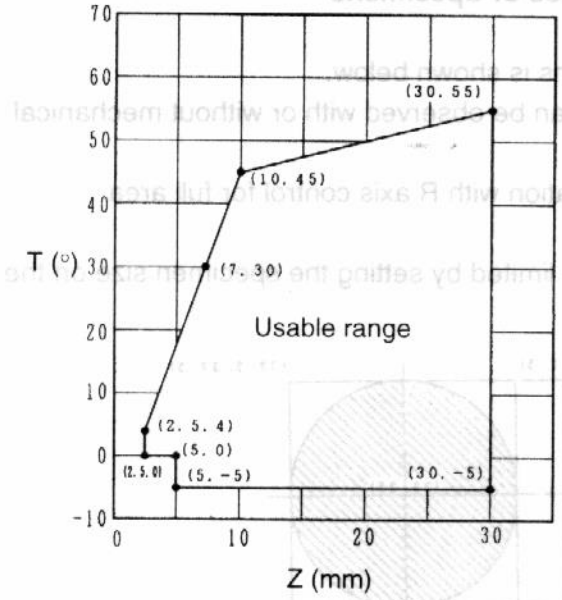
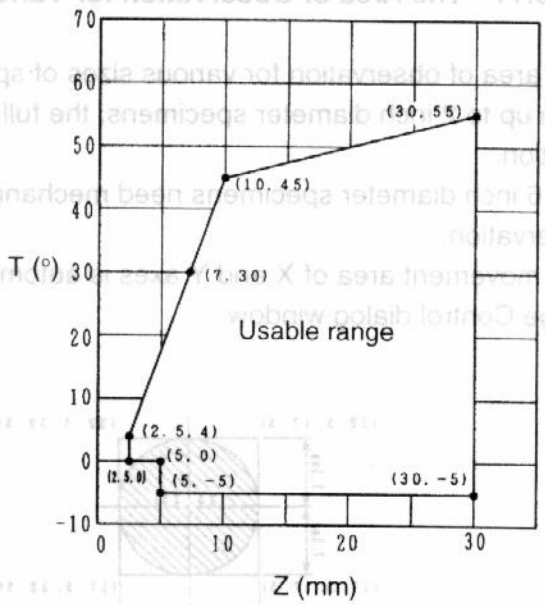


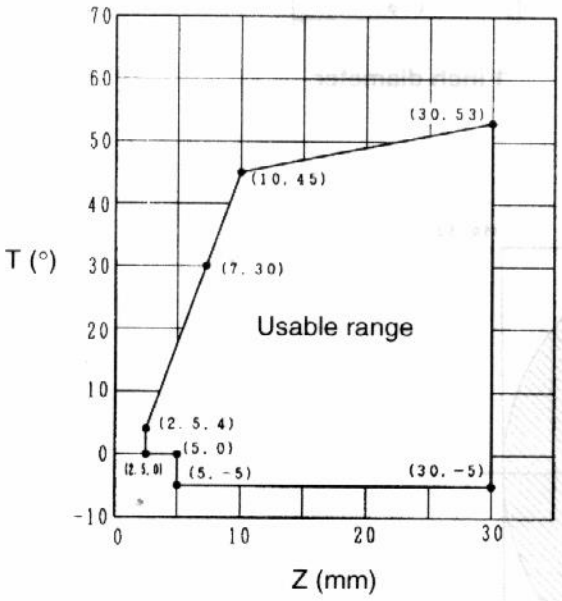
Fig. 3-1 Usable Range for the Tilt Angle (T) and Working Distance (Z) (1)



4 inch diameter specimen



5 inch diameter specimen



6 inch diameter specimen,
4 and 5 inch mask holder

Fig. 3-1 Usable Range for the Tilt Angle (T) and Working Distance (Z) (2)

3.5.6.11 The Area of Observation for Various Sizes of Specimens

The area of observation for various sizes of specimens is shown below. With up to 2 inch diameter specimens, the full area can be observed with or without mechanical rotation. 3 to 6 inch diameter specimens need mechanical rotation with R axis control for full area observation. The movement area of X and Y axes is automatically limited by setting the specimen size on the Stage Control dialog window.

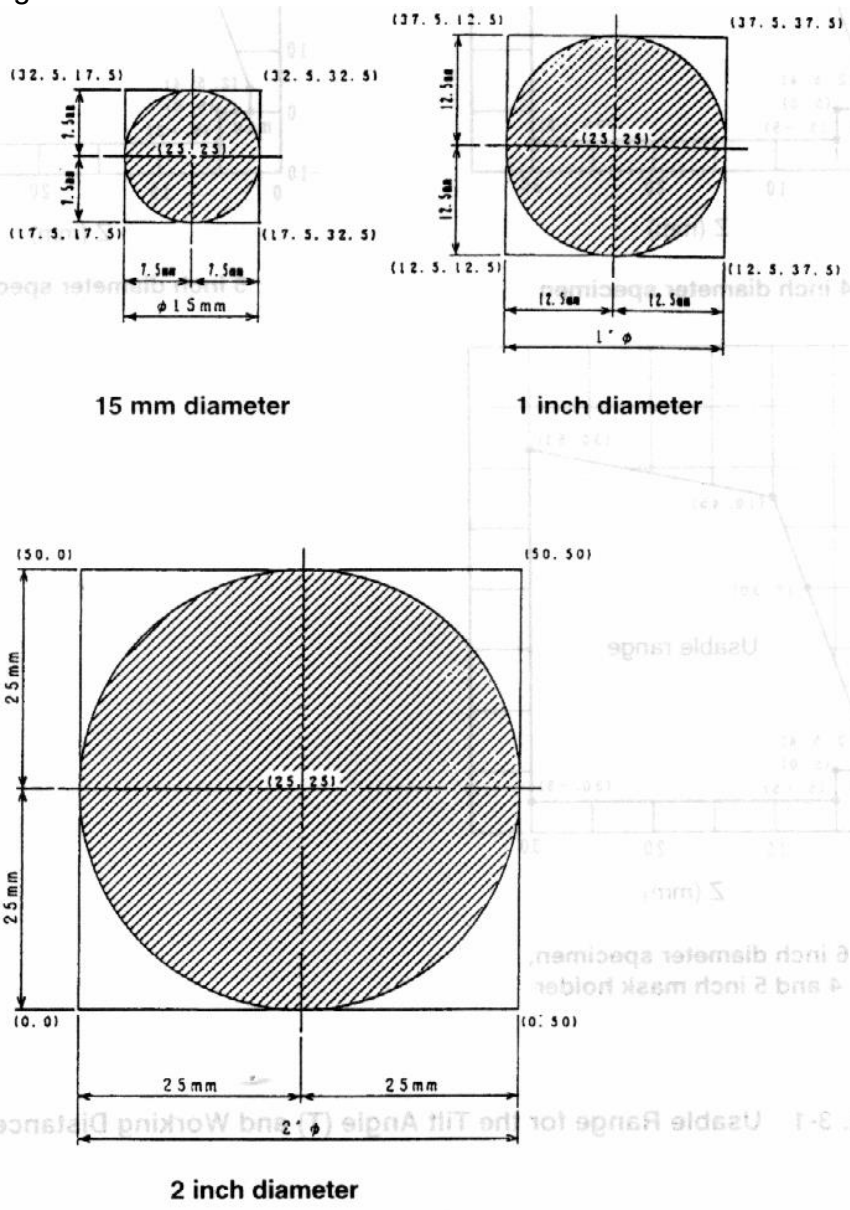


Fig. 3-2 Observation Area for 15 mm to 2 inch Diameter Specimen

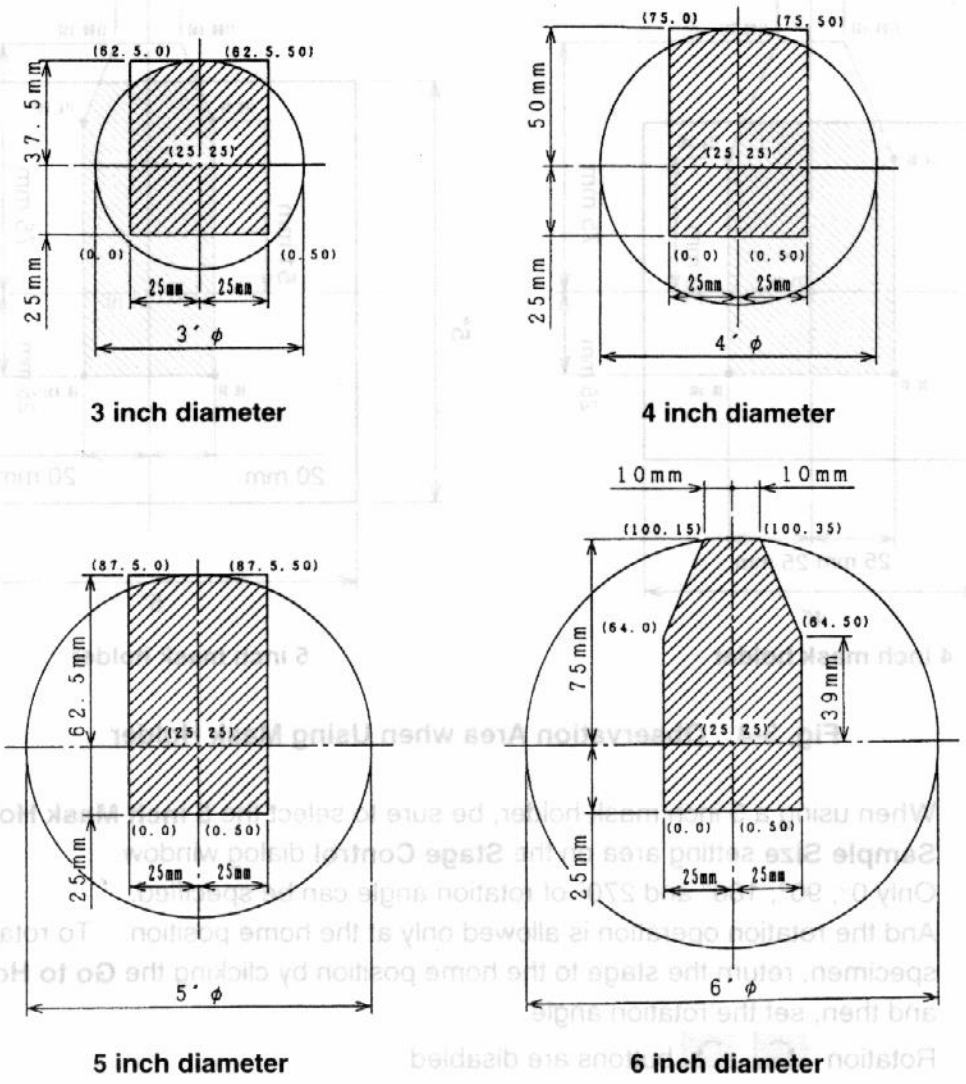


Fig. 3-3 Observation Area for 3 to 6 inch Diameter Specimen

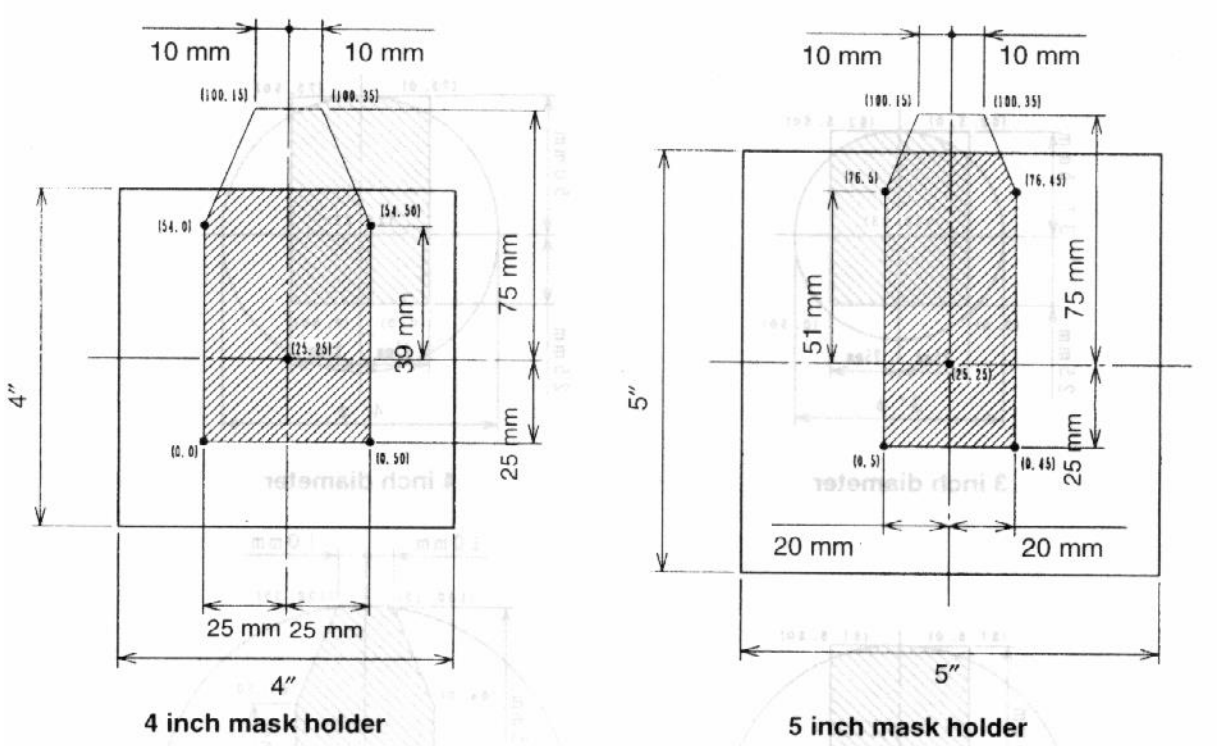


Fig. 3-4 Observation Area when Using Mask Holder

NOTE: When using a 5 inch mask holder, be sure to select the 5 **inch Mask Holder** in the **Sample Size** setting area on the **Stage Control** dialog window.
Only 0O, 90°, 180° and 270O of rotation angle can be specified. And the rotation operation is allowed only at the home position. To rotate a specimen, return the stage to the home position by clicking the **Go to Home** button and then, set the rotation angle.

Rotation  buttons are disabled.

⚠ CAUTION

When observing a 5 inch mask holder, do not operate X or Y axis while the R axis is moving.
If you operate X or Y axis before the R axis stops at the specified rotation angle, the specimen may strike the inner wall of the specimen chamber and be damaged.

⚠ CAUTION

When observing a 5 inch mask holder:
The stage can be stopped by **Stop** button on the **Stage Control** dialog window even while it is rotating.
If the rotation angle is not equal to 0°, 90°, 180° or 270°, make the following operation.

(1) When the Home Position indication on the **Stage Control** dialog window is green (X and Y axes are at home position):
   (a) Do not operate X or T axis.
   (b) Enter 0, 90, 180 or 270 in the Rotation indication box, and press the Enter key. The stage will start rotation and set at the specified rotation angle. Then, you may operate other stage axes.

(2) When X or Y axis is out of the home position (X, Y = 25.000 ± 0.050 mm):
   In this case, rotation movement is disabled. First you must move X and Y axes to the home position as follows.
   Move both axes towards the home position carefully.
   (a) Using Stage Step buttons in the **Scanning Image** window. Use lower magnification if faster speed is necessary.
   (b) Using mouse operation in the Specimen Monitor Area. You can select driving speed with the Speed slider on the **Stage Control** dialog window.
   (c) Using trackball. Use lower magnification if faster speed is necessary.

3.5.7 Use of Signal Control Function for Upper SE Detector as Backscatter Detector

Rather than a conventional dedicated backscatter detector, the S 4700 uses a software feature to bias an E x B filter located in the column so that the upper SE detector may be used as a backscatter detector. Bias is set up to prevent lower energy secondary electrons from reaching the detector while higher energy, backscattered electrons are accelerated, collected and converted to secondary electrons so that the detector can image them.

To realize this function, the upper detector of the main unit electron optics has been changed besides adding the function to the control program. The change of the upper detector plus the new program version has actualized the following functions.

(1) Upper detector allows detection of backscattered electrons.
(Especially effective for detecting backscattered electrons at low accelerating voltage.)

(2) Ratio of secondary and backscattered electrons detected by upper detector can be controlled.

Since the backscattered and secondary electrons have the features given in the table below, image contrast can be improved bycontrolling the detected signals in accordance with the application.

Features of SE Information	**Features of BSE Information**
• Provides excellent information on high-resolution surface structures	• Provides excellent compositional information
	• Internal information obtainable
• Voltage contrast obtainable	• Allows less influence of charging
	• Allows no edge contrast

NOTE: Since the detection efficiency of backscattered electrons with the upper detector drops considerably with a longer WD (distance between specimen and objective lens), the WD should be kept within 5 mm for acquiring SEM images mainly of backscattered electrons with this function.

3.5.7.1 Operating Procedure for Use of Backscatter Mode

(1) Click the Signal Control button at the bottom of the scanning image window, and the Signal Control window opens.

(2) Select SE on this window **to set the upper detector** signal to the usual SE signal. Upon selecting SE, both the SE and BSE signals are detected by the upper detector, but since the intensity of the SE signal is much greater than the BSE signal, the upper detector signal (SEM image contrast) is mostly the same condition as the secondary electrons.

(3) To acquire a SEM image in which BSE information is reflected even more, select SE/BSE on the Signal Control window and set the ratio of backscattered electrons as described in the procedure below

(4) To increase the ratio of backscattered electrons at the upper detector, operate the scroll bar on Signal Control window or else click the arrow button at the edge of the scroll bar to

increase the indicated negative value (0 to -150 V). A numeral of 0 to -150 can also be directly input into the numerical indicator on the window.

NOTE:

1. Since the detected amount of secondary electrons is reduced in order to increase the ratio of backscattered electrons at the upper detector, the absolute value of detected signal will decrease as the indication is increased in the numerical indicator on Signal Control window. If the absolute value of detected signal is insufficient upon increasing the ratio of backscattered electrons, select the UHR-A mode (see item 3 below) at Operation Mode on the Column SetUp window. The probe current will increase together with the detected signal amount.

2. In order to detect backscattered electrons at the upper detector, an electrode is added above the objective lens to convert the backscattered electrons emitted from the specimen into secondary electrons. Due to this electrode, part of the visual field (corner part) is cut off near the minimum magnification in both high mag and low mag modes. The magnification at which part of the field is cut off varies with the WD; for instance, in LM mode at a WD of 12 mm, the field may be partly cut off at a magnification around x60.

3. When the indication is changed in the numerical indicator on Signal Control window or SE and SE/BSE modes are changed, the axial conditions (aperture alignment) of the objective lens will change, and require adjustment. This is caused by a variation of the applied voltage at the signal control electrode due to the above operation.

3.6 Saving and Recording Images

3.6.1 Saving and Recording Images

A conventional camera is not available on UCLA's SEM. Images may be saved and stored on writable CDs or FTP'd over the Internet.

(1) Saving Images

Direct Saving, which saves an image from the Scanning Image display, and Captured Image Saving, which saves captured images are available. Refer to 3.6.5 Saving an Image Displayed in the Scanning Image Screen (Direct Save) and 3.6.6 Saving Captured Image.

(2) Printing Images

Printing is not available in the Nanolab.

(3) Copying Images to Other Application Software

The image displayed on the **Scanning Image** window can be copied to Windows-clipboard. You can use the image on application software by simply pasting it. When the PCI image database software is used, images are transferred directly to it without saving images. Refer to 3.1 0.12 Copy Image

(4) Image Information

Auto data display, and text and graphics written in the image using data entry function are recorded with the image. A text file including image information such as operating condition, date and others is created when the image is saved. It is saved in the same directory as of the image.

(5) Recording to CD.

A R/W CD is installed in the Hitachi computer bay and may be used to store images of up to many hundreds (depending on the resolution.)

a Open the left cabinet bay door (where the display power switch is lo-cated)and press the TDK drive open switch.

b Load the blank or partially blank CD onto the tray and close the drawer.

c After the image has been captured and saved to the appropriate directory, go to the Windows desktop and double click on the Nero short cut. This is the CD writer program.

d Select the CD Wizards panel and follow the directions. Always choose multisession so that you can add more data to the CD.

e A directory of 2 windows appears, the left window is the blank CD directory and the right window is the hard drive directory. Navigate to the image -containing directory in the right window and simply drag the desired images and files from the right window to the left window. Note that text files containing SEM picture conditions will also be stored in the picture directory and should be copied if this information is to be presented with the picture.

f Click on the burning CD icon in the top menu to initiate the burning. Unless there are many files, the copying should take only a minute or two.

g Acknowledge the copy complete pop-up panel and exit the program. The disk will automatically be ejected when the program is complete. (It is a good idea to verify that the files were copied intact by opening one of them from the CD.)

NOTE: Do not use the hard disk for long term storage. Images will be periodically removed from the hard drive.

3.6.2 Preparing Images for Recording

The image source to be recorded is a frozen image in the image memory except for direct photographing (not available).

(1) Freezing an Image

(a) Using Run/Freeze Button

Scanning image will be frozen. When scanning speed is slow, scanning continues to the end of frame and then image is frozen. Image size is 640 x 480 pixels in Standard or Dual Screen mode. It is 1024 x 768 pixels in Full Screen mode.

(b) Capturing an Image

An image is captured and frozen. Image size depends on the Capture Resolution setting in the Image Setup dialog window (640 x 480, 1280 x 960 or 2560 x 1920 pixels).

(c) Direct Photographing (Not available in the Nanolab)

(2) The Source of Image to be Recorded

When commands or buttons of the same function are placed on multiple areas, the image sources for the commands are as follows.

(a) When you use menu commands, buttons on the toolbar or buttons on the **Scanning Image** window, the image displayed on the **Scanning Image** window is used as the image source. Image size depends on the way of freezing, as mentioned above. In Dual Screen mode, the **Record A/B** button further selects A (left) or B (right) screen image as the image source.

(b) When you use buttons on the **Captured Image** window, the selected image on the window is used as the image source. Image size depends on the Capture Resolution setting in the **Image Setup** dialog window.

(3) Embedding Texts and Graphics Overlaid on the Image

(a) Auto Data Display

When the **Embed Into Image** box in the **Data Display dialog** window has been checked, the auto data display is embedded into the image data when the image is saved to disk. If it is not checked, only the image data is saved. This setting is also

applied for Print, Copy and PCI Transfer commands.
If the **For Photograph** box is checked, the position of the auto data display in the saved image is shifted slightly upward to ensure that it is properly framed in photographs. It is recommended to not check the box if the saved image data will be used on the computer only.

(b) Data Entry

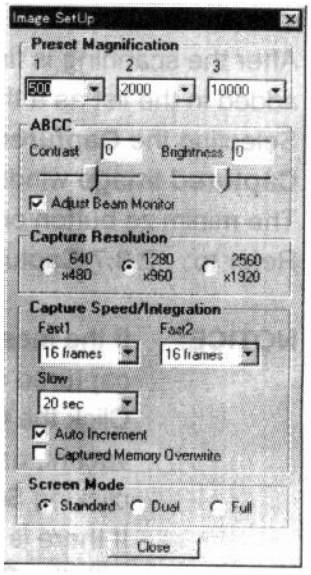
Overlaid graphics and texts are put on photographs or image files when photo recording, direct saving, printing, copying to the clipboard or PCI transfer is done while these are shown on the image.

Note that when above operations are done with buttons on the **Captured Image** window, graphics and texts are not applied on images. To put data on a captured image, copy a captured image to the **Scanning Image** window by clicking the  Display button and then make above operations. Refer to 3.10.8 Data Entry

3.6.3 Setting Conditions for Image Capturing

Image Capturing records an image using a specified scanning mode and a specified resolution. To select conditions for Image Capturing, open the **Image Setup** dialog window by clicking the icon  on the toolbar or selecting **Image** command in the **Setup** menu.

(1) Capture Resolution



Select one of three image resolutions for capturing.

- 640 x 480: Low resolution
  Advantageous for small image sizes and faster acquisition times.
- 1280 x 960: Medium resolution
  Adequate image quality with reasonable acquisition times. Recommended for usual operation.
- 2560 x 1920: High resolution Fine quality image.

The large image size results in a long acquisition, storage and processing time.

(2) Capture Speed/Integration

Select a number of frames to be integrated for Fast scan integration and a scanning time for Slow scan.

- Fast 1/Fast 2: 16 to 1024 frames integration
- Slow: 20 to 160 seconds scanning time

Fast scan integration is effective for specimens susceptible to charge. Slow scan is advantageous in order to obtain high-resolution images.

(3) Auto Increment checkbox
If this box is checked, the captured image number is incremented with each capture operation.

(4) Captured Memory Overwrite
If this box is checked, a memory area specified for capturing is overwritten without a warning message.

3.6.4 Image Capturing

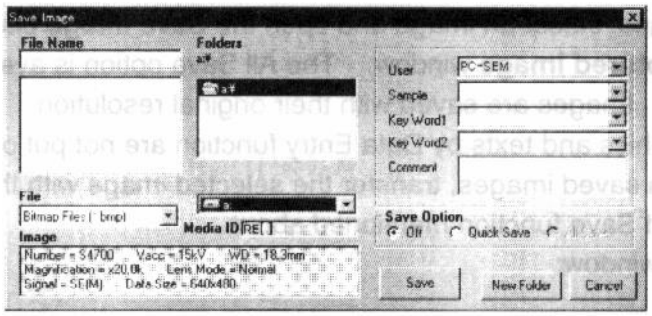
To start Image Capturing, click the Capture  button in the **Scanning Image** window, or select the **Capture** command in the **Scan** menu. When the scanning speed is set at FAST1 or FAST2, frame integration is performed. When the scanning speed is set at SLOW1 to SLOW4, a single frame Slow scan is performed. Image capturing can be started either in RUN or STOP status. After the scanning is finished, the **Captured Image** window opens and the captured image is added in the list as a thumbnail. Selecting the **Captured Image** command in the **Window** menu at any time can open the **Captured Image** window. The minimize button on the title bar iconizes the window and places it on the task bar.

NOTE: If the message window [Overwrite Memory Area No. ..] appears, a previously captured image exists in the area specified for the newly captured image. Click the OK button to overwrite it, or click the **Cancel** button and select another, or vacant, area in which to send new data. Clicking on an available thumbnail and clicking **Set Cap** does this. Then start Image Capturing again.
If there is no vacant or overwritable area, save these images and then delete areas with the **Clear** button.

3.6.5 Saving an Image Displayed in the Scanning Image Screen (Direct Save)

The image **displayed in the Scanning Image** window, simply frozen or captured, can be saved. Resolution of saved image is 640 x 480 when saved just after freezing the image (In the Full Screen Display mode, it is 1024 x 768). When saved after capturing or after recalling from the **Captured Image** window with the **Display** button, saved image files have capture resolution. Overlaid graphics and texts by Data Entry function and CD measurement function are put on saved images when saved while they are shown on the image. To save an image, open the **Save Image** dialog window by clicking Direct Save icon on the toolbar or select the **Direct Save** command from the **File** menu. When the image is just frozen, resolution of the saved image is 640 x 480 pixels. For the captured image or recalled image by the Display command in the **Captured Image** window, resolution of the saved image follows the capture resolution. In Save Image dialog window:

(1) Select the drive and a folder in the **Folders** listbox.



a : Floppy disk
c : Hard disk (used as system area)
d : Hard disk (reserved as user area)
f...: Other storage devices (If installed)

(2) Select an image format on **File Type** box.
bmp: Windows bitmap
tif : TIFF (Tagged Image File Format)
jpg: JPEG

(3) Input **File Name** (extension code is not necessary).

(4) Select user's name from the User listbox, or input a new name.

(5) Input or **select Sample** name and **Keyword** 1 and 2 on each listbox. Entry of these items is not necessary-but useful-for selection of files in the **SEM Data Manager** window.

(6) Input **Comment** when required.

(7) Set **Save Option** if necessary.
Off: Save one image only.
Quick Save: File name is automatically generated for successive saving operation.

Input of a file name is required once at first. Generated file names are {Input file name} + q + n (n = 1,2...).

NOTE: Note that for file names on Quick Save and All Save, only up to 251 characters is allowed .
Images of 1024 x 768 resolution saved in the Full Screen Display mode can not be photographed or transferred to the **Scanning Image** window. Images of that size present no problem when opened on the PC.

3.6.6 Saving Captured Image

Captured images can be saved using the Save  button in the **Captured Image** window. To save captured images, select an image and open the **Save Image** dialog window by clicking Save button in the Captured Image window. The All Save option is available in the **Save Image** dialog window. Images are saved with their original resolution. Note that overlaid graphics and texts by Data Entry function are not put on saved images. To put overlaid data on saved images, transfer the selected image with the Display  button and then use the Direct Save function mentioned above.
In **Save Image** dialog window:

(1) Select the drive and a folder in the **Folders** listbox.
a: Floppy dlsk
c : Hard disk (used as system area)
d : Hard disk (reserved as user area)
f..: Other storage devices (If installed)

(2) Select an image format on **File Type** box.
bmp: Windows bitmap
tif : TIFF (Tagged Image File Format)
jpg: JPEG

(3) Input **File Name** (extension code is not necessary).

(4) Select user's name from the User listbox, or input a new name.

(5) Input or select **Sample** name and **Keyword 1** and **2** on each listbox. Entry of these items is not necessary-but useful-for selection of files in the **SEM Data Manager window.**

(6) Input **Comment** when required.

(7) Set **Save Option if necessary.**

Off:	Save one image only.
Quick Save:	File name is automatically generated for successive saving operation. Input of a file name is required once at first. Generated file names are {Input file name} + q + n (n = 1,2...).

All Save: Saves all images in **Captured Image** window at a time.
File names {Input file name} + n (n: capture number) are automatically generated.

NOTE: Note that for file names on Quick Save and All Save, only up to 251 characters is allowed.

3.6.7 Taking Photographs (Option)

This option is not currently available in UCLA's NRF.

3.7 Using SEM Data Manager

SEM Data Manager is an image filing program with an easy-to-operate database function. A database table is established for each user, and acquired SEM images are registered to this table automatically when saving. The SEM Data Manager lists image files, finds images following a Select query, displays images, displays and enables image information editing, and allows image processing.

3.7.1 Precaution using SEM Data Manager

(1) The SEM Data Manager has been designed for S-4700 SEM image database control. Image formats available include 8-bit gray scale BMP, TIFF and JPEG. It is possible to register images of other color modes, which are converted into 8 bit gray scale images when image modifications (i.e. Data Entry, Image Processing etc.) have been performed.

(2) Use the Batch Process function to delete or move images to other directories, in order to keep information in the database of SEM Data Manager. Using Windows File Manager or Explorer functions for such operations will cause errors when you try to access these images from SEM Data Manager. When such errors occur, remove these images from the database using the **Batch Process-Remove List** function. If desired, images can be added to the database using the **Add From File** function.

(3) When an image is saved, a file {imagefilename}.txt is created automatically in the same directory as the saved image. It includes operating conditions of the SEM and other image acquisition information necessary for the database organization. Do not delete, move, or edit these files.

(4) Do not edit Image Database files {Username}.mdb as they are compatible with Microsoft Access database files. Unexpected modifications of database files may cause errors in the SEM Data Manager.

(5) The file UserList.txt includes a list of User names registered on SEM Data Manager. Do not delete, move or edit this file.

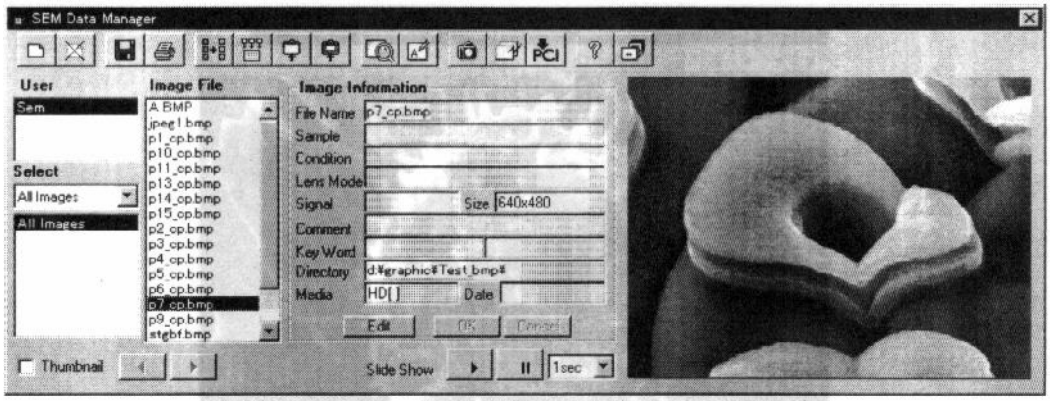
3.7.2 Registering Images on SEM Data Manager Database

When an image is saved, it is registered into the SEM Data Manager database automatically. The user name can be selected when saving an image. You can register image files already stored on disk using the **Add from File** command. When image data from other S-4700 SEMs are added to the SEM Data Manager, the corresponding text files ({ImageFileName.txt}) can be found in the same directory. SEM Data Manager uses these text files to input image information into the database.

3.7.3 Using SEM Data Manager

(1) Opening SEM Data Manager

Click SEM Data Manager icon on the toolbar of the Main window, or select the **Open SEM Data Manager** command from the **File** menu.



(2) Making or Selecting a User

Select a user from the **User** list. To make a new user database, click the Make New User button and input a new user name in the dialog box. You can also make a new user name on the Save Image dialog window when you save images.

(3) Selecting Images

Select a query item from the **Select** pull-down list. Further, select a sub item in the list. Files matching the selection search are listed in the **Image File** list. Click a file name to display an image in the display area. Or you can select an image by clicking the thumbnail image.

(4) Editing Image Information

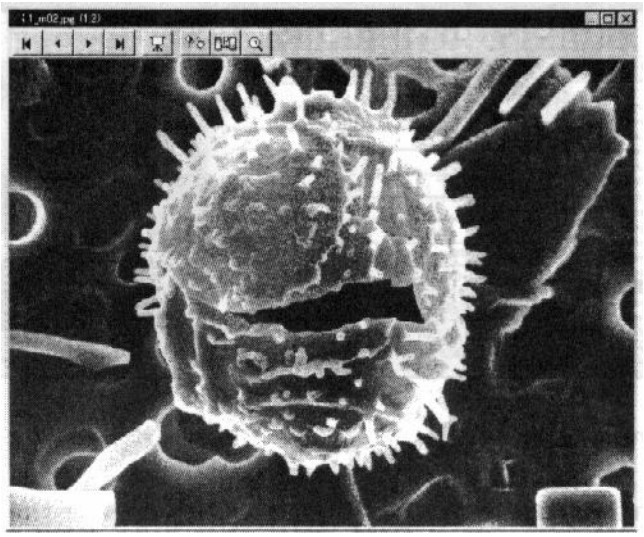
To change or edit image information, click the **Edit** button and input the necessary changes, then click the **OK** button. Items that can be edited include the sample, keywords and comment.

(5) Thumbnail Display

If the Thumbnail box is checked, thumbnails of images are displayed. You can then select an image by simply clicking on a thumbnail print. Selection of a thumbnail is linked with selection from the **Image File** list. If there are more than 40 images, click the **Page** button to scroll images to the next or previous page. If the number of listed images is more than 40, click Page button to scroll images for display to next or previous page.

(6) Viewer Display

To display an image in the **Viewer** window, click the Viewer icon  in the toolbar or double-click a thumbnail image. Zooming, image processing and contrast conversions are available in this window. Refer to: 3.8.1 Contrast Conversion and 3.8.2 Image Processing



(7) Data Entry

The Data Entry function is available for a saved image. Data Entry function is brought up by clicking the Data Entry  button. The selected image is displayed in the **Viewer** window together with the Data Entry tool box. The **Combine** button on the **Data Entry** tool box embeds overlaid data into image data.

(8) Saving Processed Image

To save the result of image processing and/or contrast conversion, close the Viewer window and click the **Image Save**  button in the SEM Data Manager window. A message dialog window, "The Image Name [...] Overwrite?" appears. Click the Yes button to overwrite the original image or click the No button and input a new file name in the **Save Image dialog** window to save as a new file.

(9) File Operation

Use the Batch Process function to delete or move images to other directories to keep image information intact and accessible by the database of the SEM Data Manager. To open **the Batch Process** dialog window, click the Batch Process  button in the toolbar.

(10) Adding Image **Files to Database**

Image files already stored on disk can be added to the database using the Add from File command  . When copying image data from other S-4700 SEMs to the SEM Data Manager, text files having the same name as the image files ImageFileName.txt will accompany it. SEM Data Manager uses these text files to register information of images into the database.

(11) Using Images on Some Other Application Programs

Images displayed in the image area can be copied to the Windows clipboard by clicking the Copy to Clipboard  button. The copied image can then be pasted into other application programs as bitmap data. Or use the Copy to Clipboard (640 x 480)  button to copy the image with fixed 640 x 480 pixels resolution.

(12) Slide Show

The slide show starts and stops by clicking the respective buttons. The display interval can be selected as well. If the **Viewer** window is open, the image will be scrolled through it as well.

(13) Transferring an Image to the **Scanning Image** Window

The Image Transfer button  transfers the image displayed in the image area to the **Scanning Image** window. It is then possible to carry out **CD Measurement** on this image. When the size of image is different from 640 x 480,1280 x 960 or 2560x1920, or the color of the image is not 8 bit gray scale, image transfer will be inhibited.

(14) Photographing Saved Images

This option is not available in UCLA's NRF

(15) Delete a User

The Delete User button  deletes the current User database. You must empty the User database using the **Remove List or Delete Image** command in the **Batch Process** dialog window before deleting the user.

(16) Transferring an Image to the Quartz PCI Window

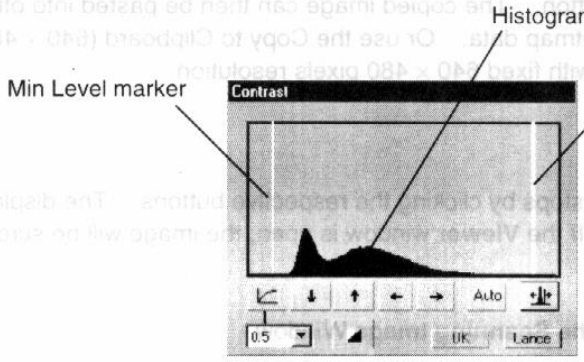
The PCI transfer button  transfers the image displayed in the image area to the Quartz PCI window together with the information text file.

3.8 Image Processing

Gray scale conversion and image processing can be performed. These processings are applied only to saved images.

3.8.1 Contrast Conversion

In the Viewer window, many gray scale conversions of the image are available. To apply conversions to the image in the Viewer window, open the **Contrast Conversion** dialog window by clicking the Contrast Conversion button  in the Viewer window. The result of this operation can be saved as a new file or can be overwritten as the same file.



.....Gamma button and Gamma Correction box:
Gamma Correction box selects a level of gamma correction. Gamma button applies gamma correction of the specified value.

.....Contrast Down button and Contrast Up button:
Down button decreases contrast by 10%. Up button increases contrast by 10%.

.....Brightness Down button and Brightness Up button:
Down button decreases brightness by 5%. Up button increases brightness by 5%.

.....Auto Contrast button:
Adjusts contrast automatically so that the histogram covers a full range of the gray scale.

.....Manual Conversion button:
Expands contrast so that the two levels specified by Min Level and Max Level markers cover a full range of the gray scale.

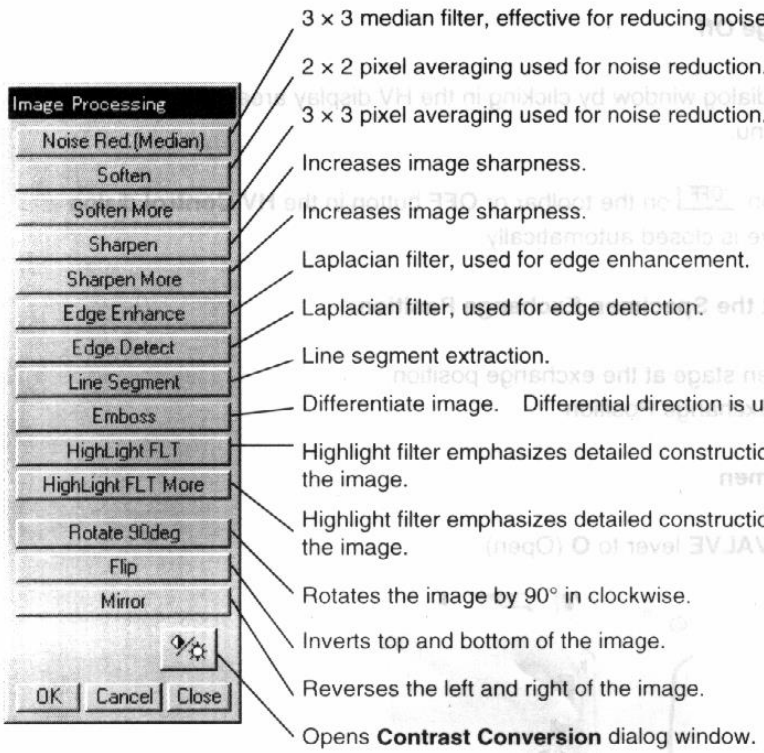
.....Invert button:
Inverts the gray scale settings of the image.

OK button applies conversion results to the original image and closes this dialog window.
Cancel button cancels the conversion results and closes this dialog window.

3.8.3 Saving Processed Image

To save the result of image processing and/or contrast conversion, close the **Viewer** window and click the Image Save  icon in the SEM **Data Manager** window. A message dialog window, "The Image Name [...] Overwrite?" appears. Click the Yes button to overwrite the original image or click the No button and input a new file name in the **Save Image** Dialog window to save as a new file.

3.8.2 Image Processing



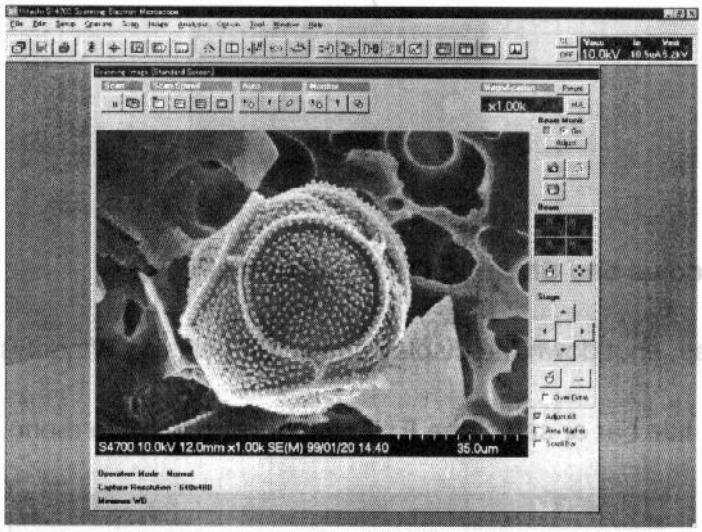
3.10 Using Other Functions

3.10.1 Screen Mode

(1) Standard Screen Display Mode

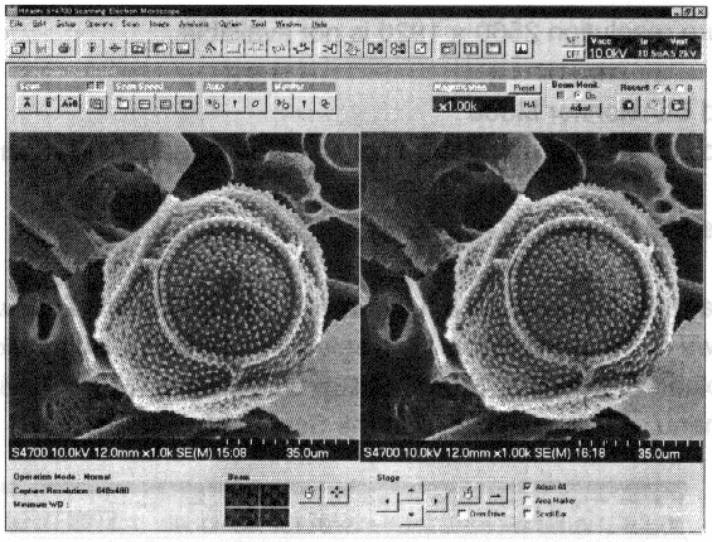
A scanning image is displayed as a 640 x 480 image. Use this mode for normal operation. All functions except for color mixing are available.

To select Standard Screen Display Mode, click the  icon on the toolbar or open the **Image Setup** dialog window by selecting **Image** command in the **Setup** menu. Then select Standard in the Screen Mode area. When the Standard Screen mode is chosen, it can be positioned at the center, the right or the left part of the screen alternately by toggling the  icon.



(2) Dual Screen Display Mode

The scanning image window has two 512 x 480 pixel image areas. These two images can be live or frozen independently, and can display different signals or the same signal. In this mode, color mixing is available, while line analysis and split screen modes are disengaged.



To select Dual Screen Display Mode, click the  icon on the toolbar, or open the **Image Setup** dialog window by selecting **Image** command in the **Setup** menu. Then select Dual in the Screen Mode area.

The following are functions having different operations from the Standard Screen mode.

(a) Signal Selection

You can observe two images with different signals on two image screens simultaneously. Use the **Signal Select** dialog window for setting signals for two images.

(b) Run/Freeze Operation

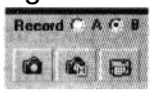
 and  buttons alter run and freeze status of scanning independently for A and B screen. To run or freeze two screens simultaneously, use  button.

The blue marks indicate that scanning is running or going to freeze.

(c) Capturing Images

The small indicators above the Capture  button shows which screen is to be captured. You can change the indication by clicking the indicators. Green color indicates corresponding screen will be captured by clicking the Capture button. When both indicators are set to green, both A and B screens are captured simultaneously.

(d) Image Source for Recording

The Record A/B buttons 

select which screen is to be recorded by direct or memory photographing, direct saving, copying to clipboard or transferring to PCI.

(e) Capture Resolution

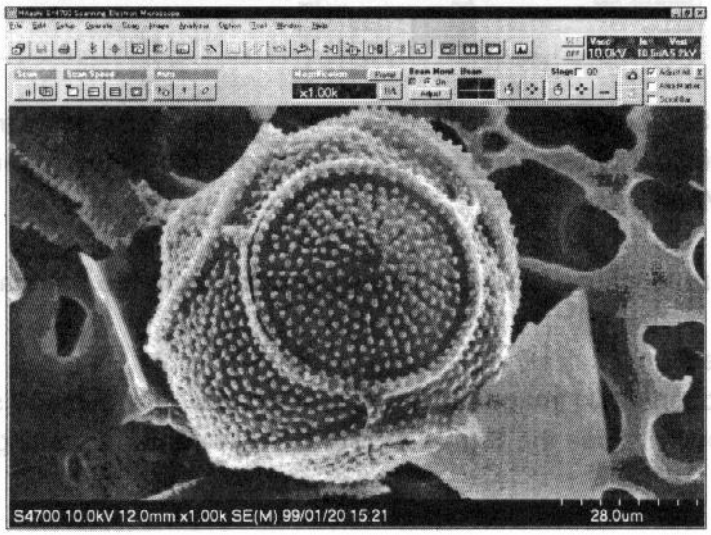
The capture resolution 2560 x 1920 is not available.

(f) ABCC and BC Monitor Mode

ABCC and BC monitor mode are applied to the signal of the A screen image.

(3) Full Screen Display Mode

A scanning image is displayed as a full frame in the SEM Main window. The large size of the image allows close observation. To select Full Screen Display Mode, click the icon on the toolbar, or open the **Image Setup** dialog window by selecting **Image** command in the **Setup** menu. Then select Full in the Screen Mode area.



(a) Extending Image Area

The image area can be extended.

When you click button, controls on the Scanning Image window are removed.

Instead, the **Show Control** Show Control button is placed at the upper-right corner of the window. Clicking the button shows controls.

Further, selecting the **Tool bar** command from **Window** menu hides or shows the toolbar.

When toolbar and/or controls are removed, the **Simple Operation** tool box may be a great help for operation.

(b) Direct Saving and Memory Photographing

The Direct Save command saves the viewing image with 1024 x 768 resolution when saved just after freezing image with the Run/Stop button. Note that images of this size can not be transferred to the Scanning Image screen or photographed by operations on the SEM Data Manager. On the other hand, direct saving after capturing saves the image with the specified capture resolution.

Memory photographing of the image frozen by the Run/Stop button results in slightly smaller size of photograph compared with the direct photographing.

(c) Other Limitations

Line analysis and split screen modes are disengaged in this mode.

The scanning speed in FAST scan is slower (about 1/4) than in other screen modes. The capture resolution of 640 x 480 pixels is not available.

3.10.2 Split Screen and Dual Mag Mode

Split Screen mode displays two images in the viewing area, and allows images of different signals or at different magnifications. This mode is available in standard display mode. To start Split Screen mode, click the  icon in the toolbar or select **Split DM Mode** command into the **Scan** menu. The **Split/Dual Mag** controller is brought up and the scanning image area is divided into two. The magnification ratio of two images is selected with **x1, x5, x10** buttons on the controller. In the case of **x5** or **x10**, a box cursor corresponding to the field on the right side is shown in the left image. You can select the particular field to be the magnified image by dragging this box cursor with the mouse.

To change signals of these images, open the **Signal Select** dialog window and select signals in the **Split Screen Mode** area.

To return to the Standard display mode, click the **Off** button, and to release Split Screen mode also click **Exit** button in the **Split/Dual Mag** controller.

3.10.3 Signal Selection and Color Mixing

The S-4700 allows accommodation of a couple of optional signal detectors, in addition to the standard secondary electron detector. When these detectors are installed, you can select a signal from among these detectors. Using Dual Image Display mode or Split Screen mode, you can display two images with two different signals simultaneously.

To select a signal;

(1) Standard Screen Display Mode and Full Screen Display Mode

Open the **Signal Select** dialog window by clicking the  icon on the toolbar or open the **Signal Select** command from the **Setup** menu. Select a signal of interest from the list in the **Normal Mode** area. The signal for line profile in the Line Analysis mode is selected independently of the signal for image in the **Line Profile** area.

(2) Split Screen Mode (available in standard screen display mode)

Open the **Signal Select** dialog window by clicking the  icon on the toolbar or selecting the Signal Select command from the Setup menu. Select signals for the Left and Right side images from the list in the **Split Screen Mode** area.

(3) Dual Screen Display Mode

Open the **Signal Select** dialog window by clicking the  icon on the toolbar or selecting the **Signal Select** command from the **Setup** menu. Select signals for both A (Left) and B (Right) side images from the list in the **Dual Screen Mode** area.

(4) RGB Color Mixing Mode (available in dual screen display mode)

The Color Mixing mode is a function that displays a color composite image. Each of three colors (Red, Green or Blue) is assigned for two images selected, A (Left) and B (Right) screens and displayed as a color composite image. This function is available only in the Dual Screen mode and the color composite image is displayed on the right screen. To display a color composite image, open the **Signal Select** dialog window. Assign A or B signal (or OFF) for the three colors by selecting the appropriate colors and checking **Color Mixing** box. If the A signal is SE and the B signal is BSE, and A is assigned Blue and B is assigned both Red and Green, then a color composite image of yellow BSE and Blue SE is displayed. To return to standard image display mode, uncheck the **Color Mixing** box. A color mixing image can be saved as a 24 bit color image file. Select B of the **Record A/B** buttons and then, save the image.

3.10.4 X-ray Analysis Mode

Scanning modes for analysis are available in the Standard Screen Display mode. To enable these scanning mode icons in **the Scanning Image** window, click the Analysis  icon on the toolbar or select **On** in the **Analysis** menu. To disengage these buttons, click the Analysis icon again or select **Off** in **the Analysis Mode** command in the **Analysis** menu. In Standard Screen mode, all Line Analysis, Spot Analysis and Area Analysis modes are available. In Dual and Full Screen mode, Spot Analysis and Area Analysis modes are available.

 Normal mode:
Normal image observation mode.

 Line Analysis mode: Displays a line profile of the signal intensity as a horizontal line in the observed image. The Line Analysis button  is used for two scanning modes as follows:

(a) Position Set mode for Line Analysis
Upon the first click of the button in other scanning modes or in Line Analysis mode, a horizontal dotted line cursor is shown on the image. This line cursor corresponds to a position of the scanned line in Line Analysis mode. To position the line cursor, locate the mouse icon near the line. When the mouse cursor is changed to an intersecting arrow mark  , drag the line cursor with the mouse, while holding down the left button.

(b) Line Analysis mode
When the Line Analysis button is clicked in Position Set mode, the scanning image is frozen and a waveform, which is a profile of the signal intensity of the line, is shown on the image. You can move the line cursor in this mode with the same operation as above, and you can change scanning speeds.
Use **Scanning Speed** buttons to select line scanning speed. Fast1/Fast2 scans

with fast speed, useful for SE or BSE signal profiling. Slow1 to Slow4 scans with slow speed, used for X-ray intensity profiling.
When the **Back Ground** in the **Signal Select** dialog window is checked, the line profile is overlaid on the image. When it is not checked, only the line profile is shown on the screen. The Run/Stop button changes operation by alternately clicking it. When scanning is stopped, a profile is shown clearly on the image.

Spot Analysis mode:
Stops the scanning and places the electron beam at a specified point on the image.

Used for X-ray analysis of a point on the specimen. The Spot Analysis button  is used for two scanning modes as follows.

(a) Position Set mode for Spot Analysis

Upon the first click of the button in other scanning modes or in Spot Analysis mode, a cross-hair cursor is overlaid on the image. The cross point of the cursor corresponds to a position where the electron beam is positioned in Spot Analysis mode. To select a position of the cursor, locate the mouse icon near the cross point. When the mouse cursor is changed to an intersecting arrow mark  , drag the cursor with the mouse while holding down the left button.

(b) Spot Analysis mode

When the Spot Analysis button is clicked in Position Set mode, the scanning image is frozen and the electron beam is positioned at the cross point of the cursor. You can make analysis at this point.
The cursor can also be moved in this mode with the same operation as above.
The Run/Stop button and Scanning Speed buttons are disabled in this mode.

Area Analysis mode:
Scans the electron beam in a selected frame in the image. Used for X-ray analysis of a specified area on the specimen. The Area Analysis button  is used for two scanning modes as follows.

(a) Position Set mode for Area Analysis

Upon the first click of the button in other scanning modes or in Area Analysis mode, a box cursor with dotted line is overlaid on the image. The box cursor corresponds to an area where the electron beam is scanned in Area Analysis mode.
To set a position and size of the cursor, locate the mouse icon near the line, corner or inside of the box. When the mouse cursor is changed to  (change the size in horizontal direction),  (change the size in vertical direction),  (change the size in both directions), or  (move the position), drag the cursor with the mouse while holding down the left button.

(b) Area Analysis mode

When the Area Analysis button is clicked in Position Set mode, the scanning image is frozen and the electron beam is scanned in the box area (the cursor is changed to a straight-line box). The cursor can be moved with the same operation as above.
The Run/Stop button and Scanning Speed buttons are disabled in this mode.

3.10.5 Signal Processing (Gamma Control, Differential Image)

Processing of the image signal, including gamma correction and differentiation is available on a live image. For signal processing, open the Signal Processing dialog window by clicking the Signal Processing icon  on the toolbar, or by selecting the **Signal Processing** command in the **Image** menu.
Select Gamma, Differential 1, Differential 2 or Off. These processing routines are effective only at slow scanning speeds.

(a) Gamma:

Gamma correction suppresses excessive contrast, maintaining the contrast of the average brightness of the image.

(b) Differential:

Differential 1 and 2 are high-pass filters for the image signal. When applied, the image is differentiated in a horizontal direction and details of the image are emphasized, while broad shades are suppressed. Results vary with scanning speeds because it applies time domain differentiation.

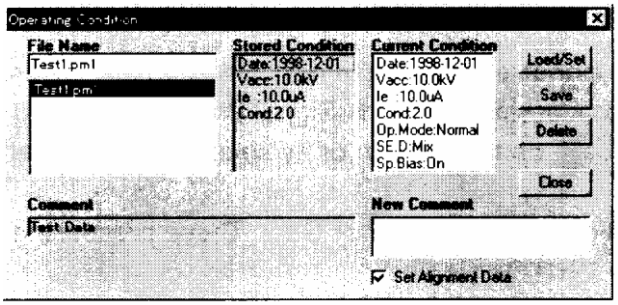
3.10.6 Condition Memory Function (Operating Condition)

This function is provided for saving and loading conditions of the electron optical column. If the column is aligned and a specimen is observed at a particular accelerating voltage, the same condition can be reproduced. Conditions can then be reloaded even after changing conditions for observation of other specimens. Saved, and listed, conditions include accelerating voltage, emission current, condenser lens 1, and beam alignment and aperture alignment. Operating mode and detector selection is saved as well.

NOTE: For each of High and Low magnification modes, condition data files have different extension, *.pm1 for High and ~.pm2 for Low Mag mode. These files are selected automatically according to present magnification mode.
While the **Operating Condition** dialog window is open, operation on other windows is disabled.

(1) Saving Present Operating Conditions
Use the following steps to save the present operating conditions.

(a) Open the **Operating Condition** dialog window by selecting the **Operating Condition** command from the File menu.



(b) Input **File Name**.
(c) Enter a comment in the New Comment box if you wish.
(d) To include alignment data, check the **Set Alignment Data** box.
(e) Click the **Save** button.

(2) Loading a Set of Operating Conditions
Use these steps to load a set of operating conditions.

(a) Open the **Operating Condition dialog** window by selecting the **Operating Condition** command from the File menu.
(b) If you wish to include alignment data, check the **Set Alignment Data** box.
(c) Select a **File Name** and confirm conditions shown on the **Stored Condition** area. Then, click the **Load/Set** button.

(3) Deleting an Operating Conditions File
Use these steps to delete a set of operating conditions from disk.
(a) Open the **Operating Condition** dialog window by selecting the **Operating Condition** command from the File menu.
(b) Select a **File Name** to be deleted, and click the **Delete** button.

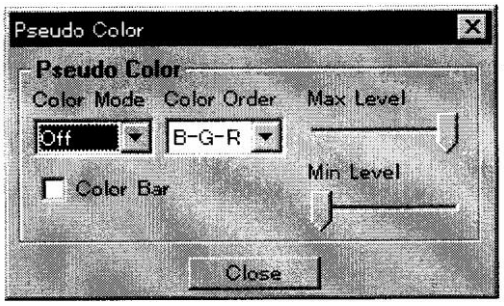
3.10.7 Pseudo Color Display

Scanning images are formed using intensities of the imaging signals. These images are presented in gray scale; however, they can be displayed in color by replacing brightness levels in an image with colors. Image saving with 640 x 480 resolution and 8 bit color, printer output

and video printer output of pseudo-color images are possible. Photo recording does not support color images.

Use these steps to display a pseudo-colored image.

(1) Open the **Pseudo Color** dialog window by clicking the Pseudo Color icon on the toolbar or select the **Pseudo Color** command from the **Image** menu.

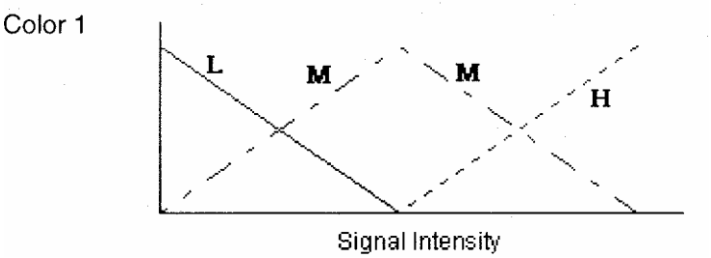


Set the following parameters:

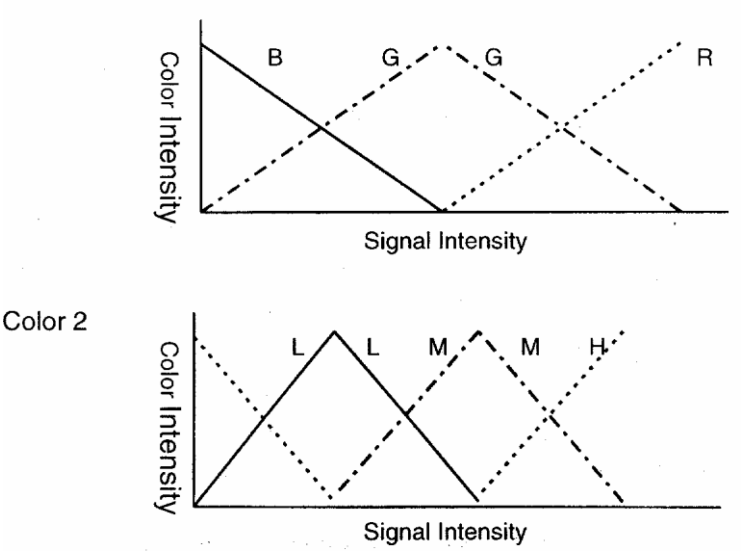
(a) Color Mode: Color mode selects a method of coloring.

1) Off: Cancels Pseudo Color and returns to the normal monochrome display.

2) Color 1, Color 2: The relation of signal intensity and intensity of each R, G and B color is as shown below, where L, M and H correspond to R, G and B color specified with Color Order.



For example when the B-G-R is selected for Color Order, intensity of each color is assigned to signal intensity as shown below. In this case, Blue color represents dark area and Red color bright area.



3) Slice
The signal intensity is assigned for 8 colors.

(b) Color Order:
Color 1 Order specifies the colors assigned for L, M and H in Color 1 a nd Color 2 mode.

(c) Level:
Level sets a range of signal intensity assigned for Pseudo Color images. When the intensity distribution of the image signal is only a small part of a full range, the contrast of Pseudo Color image can be adjusted by the following.

1) Max Level:
Set a maximum of the signal assigned for the color image.
Adjustable range is 75 to 100% of the full scale.

2) Min Level:
Set a minimum of the signal assigned for the color image.
Adjustable range is 0 to 25% of the full scale.

(d) Color Bar:
Displays color bar at the right side of image.

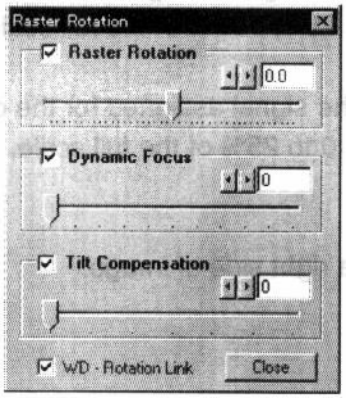
3.10.8 Data Entry Function

The Data Entry function is available both for a viewing image and a saved image. When the Data Entry function is brought up in the Main window, te xts and graphics are applied to the image on **Scanning Image** window. When it is brought up in the SEM **Data Manager** window, it is applied on a saved image in the SEM **Data Manager** window. Overlaid data can be

embedded in image files, so when an image file is opened using any application software, applied texts and shapes will exist in the image. To open the **Data Entry** toolbox for overlaying data on an image **in the Scanning image** window, click the icon on the toolbar, or select the **Data Entry** command from the **Image** menu. To open it for overlaying data on a saved image, click the icon on the toolbar in the SEM **Data Manager** window.

3.10.9 Raster Rotation, Dynamic Focus and Tilt Compensation

To use Raster Rotation, Dynamic Focus and Tilt Compensation functions, open the **Raster Rotation** dialog window by clicking the icon on the toolbar or by selecting the **Raster Rotation** command from the **Operate** menu.



(1) Raster Rotation

The scanning of the electron beam can be rotated within a range of -200O to +200O, using the slider. This allows observation of an image at the best orientation. To operate the Raster Rotation function, check the **Raster Rotation** box. To select a rotation angle, move the slider, click the arrow buttons, or input an angle into the angle indication box.

NOTE: Image rotation caused by the objective lens magnetic field is compensated automatically even when the above rotation angle is set at 0 or the **Raster Rotation** box is not checked. The scanning direction is kept to coincide with the direction of stage movement by this function. If it is necessary to disable the automatic compensation, set the **WD-Rotation Link** in the **Environment** tab of the **Environment Setting** dialog window at **Controllable,** and uncheck the WD **Rotation Link** box in the **Raster Rotation** dialog window.
For normal operation, it is strongly recommended to enable the automatic compensation function.

(2) Dynamic Focus

Dynamic Focus scans the focal length linked with the scanning positions. When a specimen is tilted, the field of view that can be focused is small (particularly at low magnifications and at a short WD). Dynamic Focus function allows you to focus the beam for the entire field of view.

Use the following steps to focus the entire field.

(a) Set the Raster Rotation angle at 0. In this condition, direction of the scanning beam coincides with the specimen tilting direction.

(b) Check the **Dynamic Focus** box and focus the image so that the center of the image is focused. Adjust the **Dynamic Focus slider** so the whole image is in focus.

(c) Alternatively, use the Reduce 2 scanning speed. After focusing the center part of the image, set the scanning speed at Reduce 2 and move the scanning area to the top of the screen. Adjust **Dynamic Focus** slider for the best focus.

NOTE: If magnification, WD, or accelerating voltage is changed, the Dynamic Focus slider needs to be re-adjusted.
When the specimen tilting angle is high and magnification is lower than 1000x, the image may have some distortion.
At SLOW1 or faster scanning speed, unexpected defocusing may appear in the image. It is caused by a slow response of the magnetic field of the objective lens.

(3) Tilt Compensation

When a specimen is tilted, magnification along the tilting direction is [cos (tilting angle)] lower than that of a non-tilting direction. As a result, the image appears to be contracted in the tilting direction. The image can be corrected at the magnification in all directions by using Tilt Compensation function.

Use the following steps for Tilt Compensation.

(a) Set the Raster Rotation angle at 0. In this condition, direction of the compensation coincides with the tilting direction.
(b) Use Dynamic Focus, if necessary.
(c) Check the **Tilt Compensation** box, and set the angle to the specimen tilting angle (move the slider or input angle into the angle indication box).

NOTE: Tilt Compensation may result in an unnatural image when a specimen has three dimensional structure.

3.10.12 Copy Image

The **Copy Image** command copies the image from the **Scanning Image** window to the Windows clipboard with pixels of 640 x 480. The copied image can be used in any application software such as a word processor or image processor by pasting it from Windows clipboard. To copy an image to the Windows clipboard, select the **Copy Image** command from the **Edit** menu or click the Copy Image button  on the toolbar.

3.10.13 Copy Attribute

The **Copy Attribute** command copies information (magnification, accelerating voltage, etc.) of the data display in the **Scanning Image** window to the Windows clipboard as a text file. The copied text can be used in any application software such as a word processor or image processor by pasting it from Windows clipboard. To copy image attributes to the Windows clipboard, select the **Copy Attribute** command from the Edit menu or click the Copy Attribute button  on the toolbar.

3.10.14 Oblique Image

An oblique (or bird's-eye-view) image is displayed. To open the **Oblique** dialog window, select the **Oblique** command from the **Analysis menu or** click the Oblique button  on the toolbar.

3.10.15 Environment Setting

Operation environments are set in the Environment Setting dialog window. To open the **Environment Setting** dialog window, select the **Environment Setting** command from the **Option** menu.

The Environment Setting dialog window is used to:
(a) Select the controls for mouse operation on the scanning image
(b) Set the data transfer to and from the PCI software
(c) Set the automatic rotation correction linked with working distance
(d) Select the type and size of the font used in the Data Entry and CD Measurement functions
(e) Set functions of motorized stage
(f) Set stage driving direction by X or Y axis stage operation
(g) Set stage driving speed by using the trackball or joy-stick

(h) Set the sensitivity of mouse operation (focus, stigma, brightness and contrast adjustment) in the scanning image
(i) Set the directory where the thumbnail data is located
(j) Set the size of images placed on a page using the Layout command of DTP applications such as Page Maker

(k) Set horizontal scanning speed

3.10.16 Toolbar Setting

You can select tool buttons placed on the toolbar.
To open this **Toolbar Setting** dialog window, select the **Toolbar Setting** command from the **Option** menu.

It is not possible to place all provided tool butto ns on the toolbar. Choose only the important buttons so they will not drop out to the right hand side of the toolbar. The button arrangement is refreshed each time you change check/uncheck of boxes. The button arrangement is saved independently for each login name. You can use your own toolbar when logged in with your unique login name.

NOTE: Some buttons for optional functions may not be selected when the options are not installed.

3.11 Image Quality

The following are references for getting better image quality.

3.11.1 Accelerating Voltage and Image Quality

There is a multitude of accelerating voltages to choose from. Resolution, image quality, charging and other effects are greatly determined by the selected accelerating voltage. Below is a guideline for selecting an accelerating voltage with which to image various specimens.

(1) Resolution:
The electron beam size is smaller with a higher excitation value of Cond Lens 1. However, image resolution also depends on the S/N ratio of the image a nd on the ease of focusing and astigmatism correction.

(2) S/N ratio:
The signal to noise ratio is better with lower excitation values of Cond Lens 1.
(3) Charging:
Charging of insulator specimens is greater at smaller excitation values of Cond Lens 1.
(4) Signal source:
Generally the backscattered electron imaging needs higher probe current than the secondary electron imaging. X-ray analysis needs much higher probe current.

3.11.2 Condenser Lens Setting and Image Quality

Probe current is adjusted by changing the Cond Lens 1 value. To increase probe current, select a lower Cond Lens 1 value (larger spot size). Information necessary for setting of Cond Lens 1 is as follows.

(1) Resolution:
The electron beam size is smaller with a higher excitation value of Cond Lens 1. However, image resolution also depends on the S/N ratio of the image and on the ease of focusing and astigmatism correction.

(2) S/N ratio:
The signal to noise ratio is better with lower excitation values of Cond Lens 1.

(3) Charging:
Charging of insulator specimens is greater at smaller excitation values of Cond Lens 1.

(4) Signal source:
Generally the backscattered electron imaging needs higher probe current than the secondary electron imaging. X-ray analysis needs much higher probe current.

3.11.3 Objective Lens Aperture Size and Image Quality

The objective lens aperture has four openings: 100, 50, 50 and 30 micrometers (numbered 1, 2, 3 and 4). For normal operation, use number 2 or 3 (50 micrometers). The electron optical column of S-4700 is designed to achieve highest resolution with a 50 micrometer aperture. When a larger probe current is required, for example for X-ray analysis, use number 1 (100 micrometers). Resolution may degrade with this large aperture. Use number 4 (30 micrometers) to reduce probe current, for example to reduce charging. Resolution is not improved with the smallest aperture, but the depth of focus is better. Refer to: 3.12.5 Alignment of the Objective Lens Aperture

APPENDIX

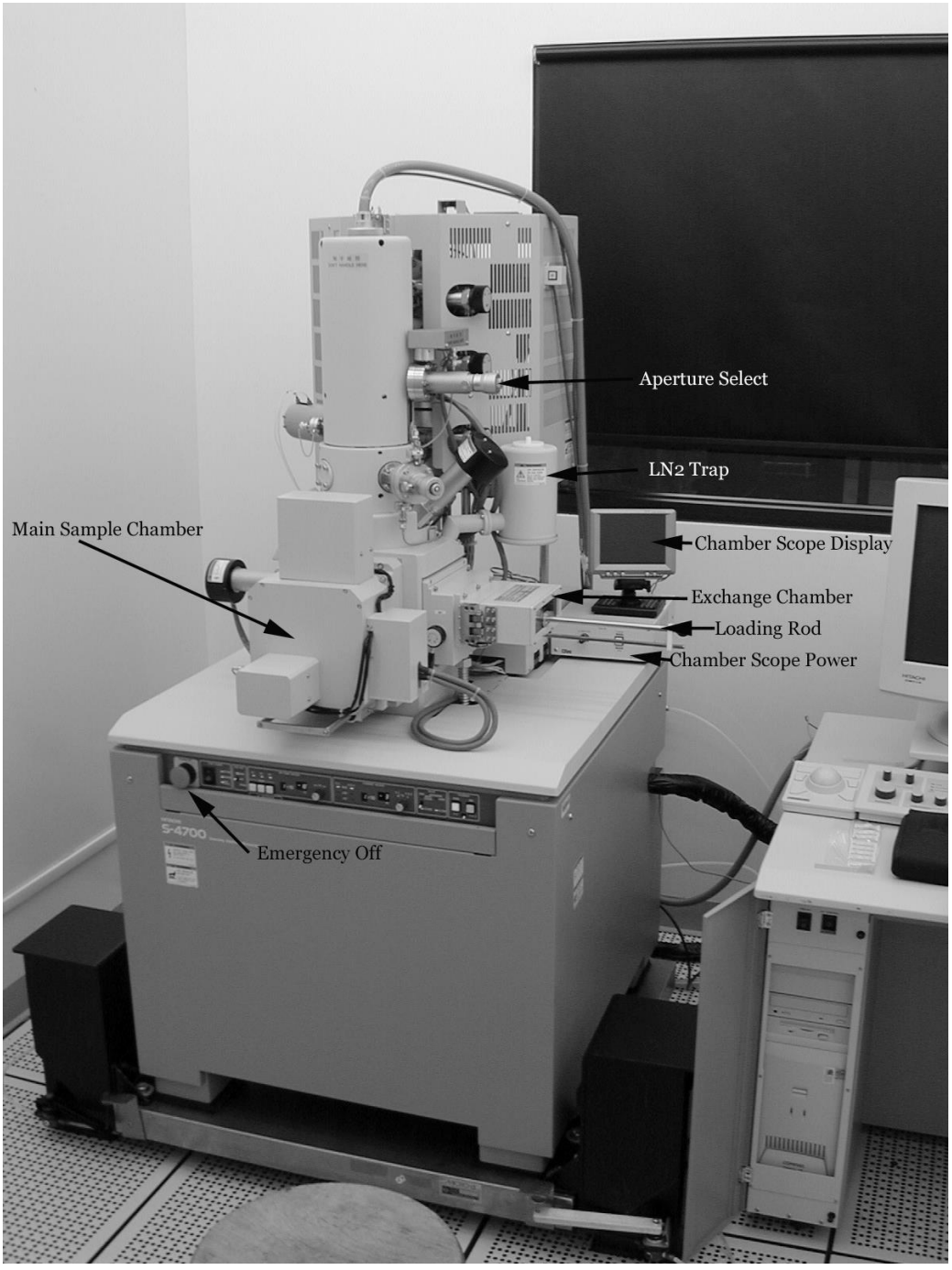


Fig 1-Hitachi S4700 SEM Column

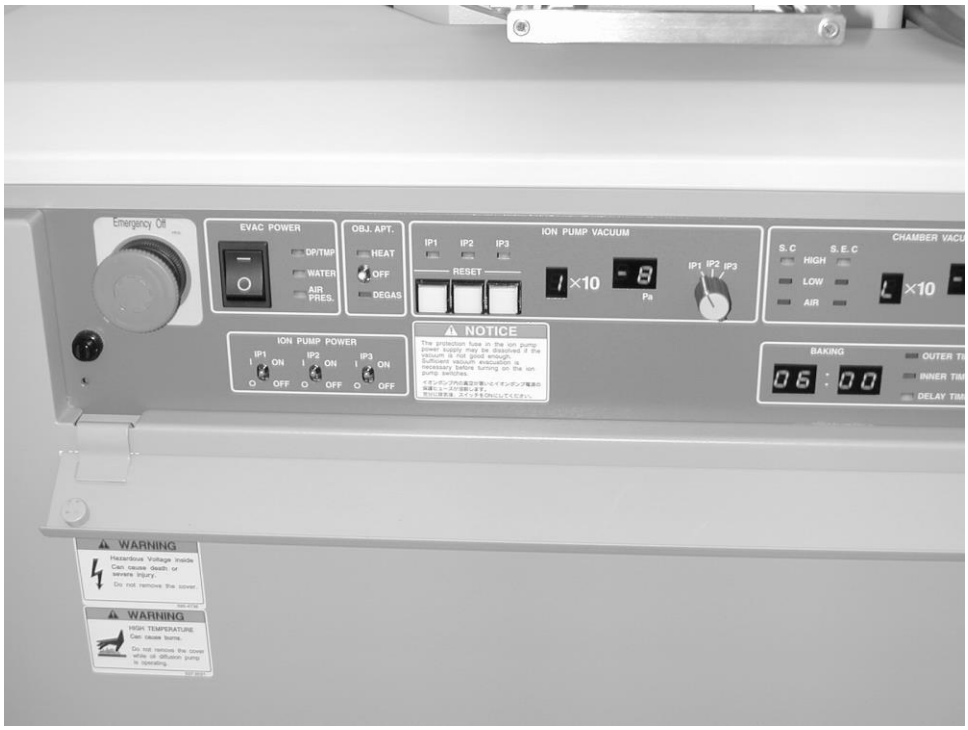


Fig 2. SEM Vacuum Control Panel (Left Side)

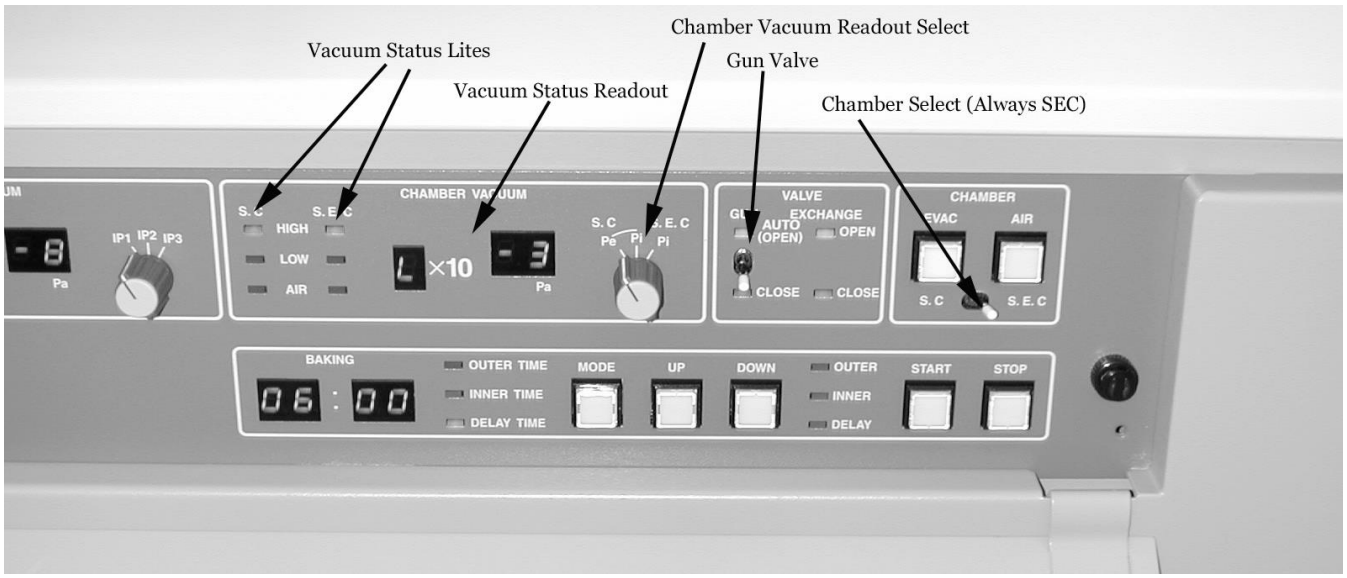


Fig 3. SEM Vacuum Control Panel (Right Side)

Fig 4. SEM Computer

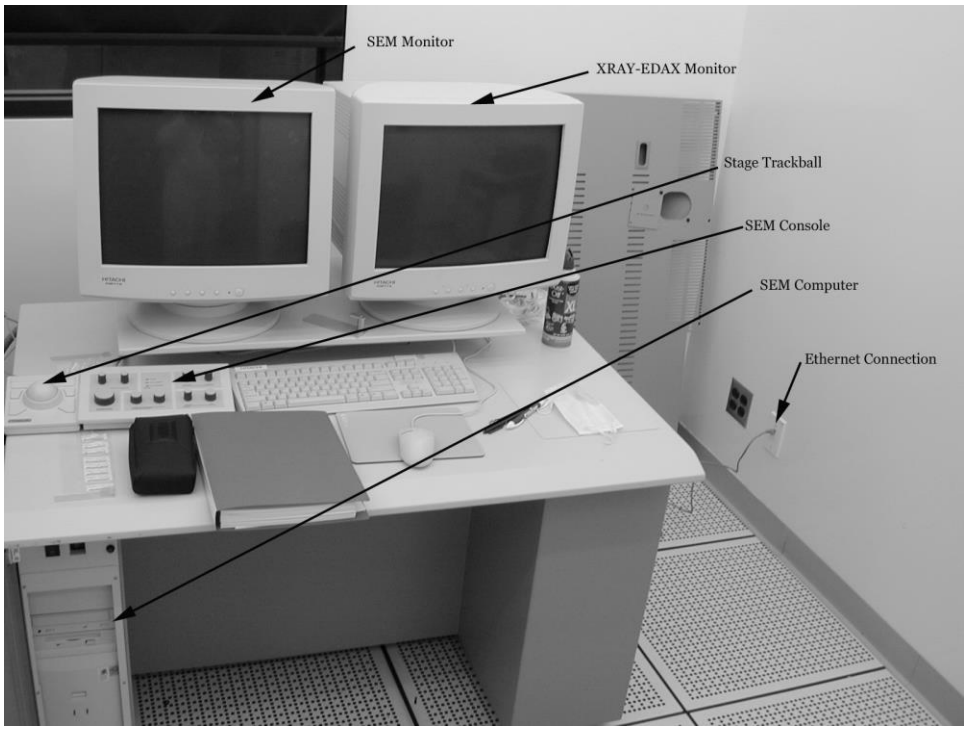


Fig 5. SEM monitors, consoles and computers