

Scanning Electron μ scopy

ver. 0.0.0.-2 β

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1 Introduction

SEM is a great thing. First: Max Knoll in 1935-ben. You can buy SEM since the 60's.

The electron-matter interaction can produce:

- Forward Scattered e^- (Transmitted e^-): fig. 1
- Energy-lost e^- : fig. 1
- High Angle Scattered e^- : fig. 1
- Secondary e^- : @Wiki Click here!
- Backscattered e^- : Click here!
- Auger e^- : @Wiki
- X-ray photon ("Röntgen-photon"): Click here!

The SEM sample is thick \Rightarrow the forward products are irrelevant.

2 SEMatics of SEM

- e^- source
 - Thermionic emitters eg. W or LaB_6
 - Field Emission source
- Objective lens: Lorentz-effect / Lorentz-force at cca 1° like optical lens. The focus can be set by changing the current in the coils.

Figure 1:

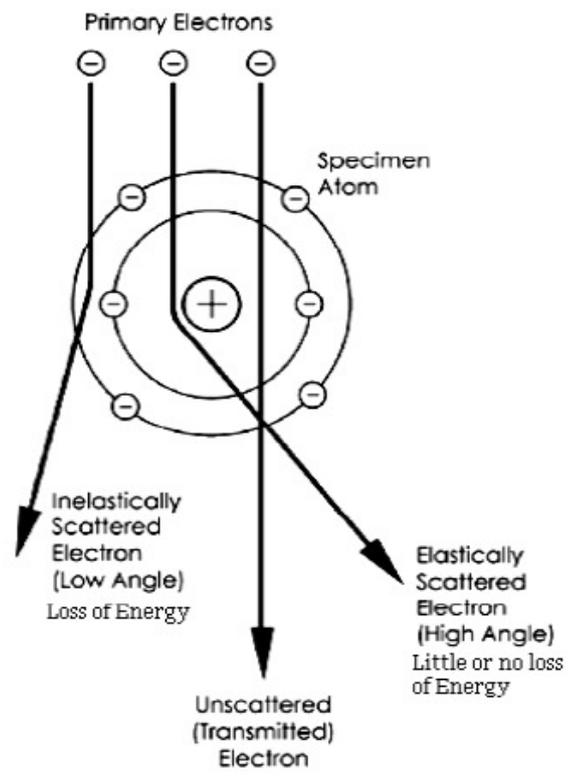
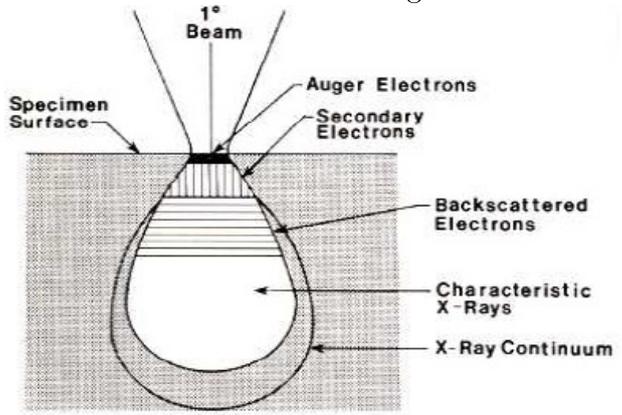


Figure 2: Penetration



- Correction lenses: \approx correct the astigmatism of the beam.
- Scanning coils
- ETD detector
- Sample holder stage

Due to the scanning coils, the electron beam scans the sample's surface and induces "products" (secondary electrons, backscattered electrons, (Auger electrons, X-rays)) what will be collected by the corresponding detectors. The computer notes the signal value of the detector and the position of the point of the sample which was excited. Then, draws an image.

Figure 3: Thermonic emitter and field emission source/gun

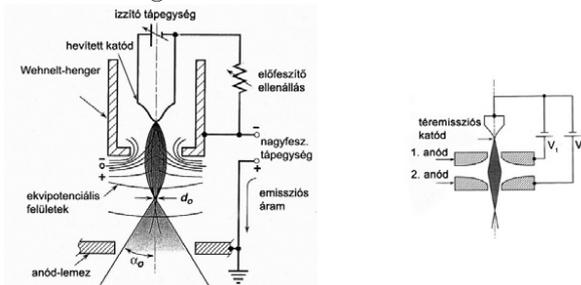
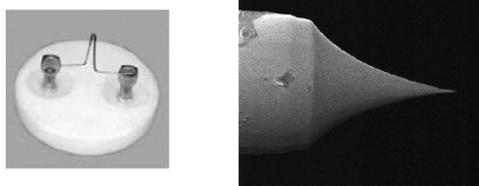


Figure 4: Thermonic emitter and field emission source/gun



Accelerating voltage: 0-30 kV

3 Sample preparing

1. We need electrically conductive sample.
2. Sample has to tolerate high vacuum.

3. Vacuum has to tolerate the sample.
4. Sample has to endure the electron irradiation (eg. heat load).
5. Clean sample.

4 Parameters of SEM

Most important parameter is the point resolution. PR depends on the beam diameter (on the sample surface) and the beam-sample interaction volume (the “pear” (fig. 1)).

Magnification is also important.

Depth of field is also important. DOF is inverse proportional to the magnification.

5 Specifics of the detected signals

5.1 Secondary e^-

Emitted by the outer electron shells; low energy ($E < 50eV$) \Rightarrow low depths (1-10 nm). Contains information about the surface morphology.

5.2 Backscattered e^-

Rutherford scattering; high energy $E_{BSE} \approx E_{beam}$. Contrast depends on the atomic number (Z).

6 JSM-25S

During the excercise we will use a JEOL JSM-25S-II device, similar to the JSM-IC25S in Washington. Vacuum is produced by a diffusion vacuum pump and a rotation vacuum pump.

7 Usage the JSM-25S

... will be shown during the lab.

JEOL JSM-IC25S Scanning Electron Microscope
STANDARD OPERATING PROCEDURE

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1. SUMMARY

Equipment	JEOL JSM-IC25S Scanning Electron Microscope		
Picture			
Specification	Load locked sample chamber that accepts standard microscopy pucks or special wafer carriers. Will handle up to a 4-inch diameter wafer. Full X, Y, Z, theta, phi goniometer movement. Has optical spotting microscope for coarse sample positioning.		
Materials	Only conductive or conductive coated inorganic substrates or samples.		
Location	EE/CSE B029, EE MicroFabrication Laboratory (EE-MFL), UoW		
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2. INTRODUCTION

This Standard Operating Procedure (SOP) provides information on the operation of the JEOL JSM-IC25S scanning electron microscope (SEM). This equipment has undergone several modifications, which have rendered inoperable several auto-setup features and functions provided in the original design. The available user's manual for this equipment discusses, in detail, a number of issues involved in scanning electron microscopy and is very useful as a primary reference. The user's manual also covers the basic principles of operation, equipment design, technical information about its key components, as well as control-panel settings. It is suggested that the user become familiar with both documents. However, this standard operating procedure (SOP) should be used as the primary source for the steps involved in operating the scanning electron microscope (SEM) under its current modifications. In addition, this SOP also discusses use of the "SEMICAPS-1000" image capture and processing system and (*.tif format) image-file storage.

The operation of a scanning electron microscope (SEM) is based on scanning (or rastering) an electron beam across the sample and detecting electrons ejected from the surface. The incident electrons are back scattered from an atomic surface-species, or are scatter-diffused into the sample material. Due to the excitation of the atomic surface-species, x-rays, auger and secondary electrons are ejected from the sample surface. Since in the SEM the electron-detectors are positioned on the same side of the sample as the incident beam, only the back scattered and surface-emitted electrons are imaged. (In transmission electron microscopy-TEM, electrons transmitted through the sample are detected). In fact, the JEOL JSM-IC25S SEM has two Faraday Cup-like detectors—a back scattered electron (BEI) and a secondary electron (SEI) detector. The detectors are optimized to differentiate between the electrons back scattered from the surface-atomic species and the electrons emitted from the sample surface following absorption-emission transitions, also called secondary electrons. The secondary electrons undergo an interaction that involves excitation of a surface atom (by electron absorption) followed by electron emission from material surface. The JEOL SEM allows selection between both types of imaging detection. The back scattered electron (BEI) detector is very useful for higher degrees of magnification while the secondary electron (SEI) detector is more versatile. In both cases, the image contrast is obtained from the difference in electron counts from different planes, depths, edges and material interfaces. Imaging depth contours, surface planes and edges allows topographical and stereoscopic characterization of materials or devices. It should be noted that the SEM technique is somewhat invasive. Although most samples will be unaltered, charge flow (current) through the sample and strong excitation of the surface atomic layer, may affect some devices.

The JOEL JSM-IC25S is a scanning electron microscope. Its use is intended primarily for characterization of electrically conducting or semi-conducting materials, surfaces, and devices under a high degree of magnification (up to 32,000x, or approximately 1000Å resolution). Insulating materials or combined conductive/insulating structures can be imaged with varied success. In the SEM, insulating materials will accumulate the incident electronic charge, which will interfere with consequent electron-beam scanning. These charging effects can adversely effect the contrast across the image, and may dramatically deteriorate image quality. If applicable, deposition of a metal layer (such as by sputtering or evaporation) can in numerous cases dramatically improve imaging of insulating materials. This is not possible in situations where device function will be lost following metal deposition. In most cases, however, for

microelectronic device imaging, little sample preparation is needed. The main concern is providing a conductive path between the imaged material-surface and the sample holder (which is internally electrically grounded) to avoid the effects of sample charging. This will provide a drainage path for the excess absorbed electrons. Sample mounting is discussed later in section 7.

The SEM is used mainly for topographical characterization of material surfaces or micro device/circuit layouts. The sample can be displaced in the x-y plane and can also be tilted (up to 60°) and rotated. The tilt angle allows stereoscopic imaging for investigation of trench and side-wall profiles. SEM imaging is based on detection of back-scattered or secondary electrons from the imaged material surface; secondary and back-scattered electron intensities, as well as their respective SEM contrasts, for a variety of materials, are given in the manufacturer's manual (yellow binder).

3. LOCATION OF EQUIPMENT, ACCESSORIES, TOOLS, AND SUPPLIES

The JEOL JSM-IC25S scanning electron microscope is located in room B029 of the EE MicroFabrication Laboratory (EE-MFL) in the Electrical Engineering/Computer Science and Engineering (EE/CSE) building at University of Washington. It is located against the West wall between the laboratory counters and a laminar flow wet-bench. A "PowerPro" 486/25 MHz personal computer with "SEMICAPS-1000" image capture and processing system is interfaced and is located on the end of the lab counters.

There are three main parts of the JEOL JSM-IC25S SEM system: the electron beam gun, sample chamber, and vacuum components (two roughing pumps, one turbo-molecular pump-TMP, TMP water chiller, pneumatic and cam valves, and nitrogen tank). The user interface components are a CRT display, vacuum gauge, optical microscope and light source (for rough sample positioning), and control panels. The accessories include a Polaroid camera (operational status unknown) and a PC for image capture, as well as varied sample holders (one 4" wafer sample-holder, several raised and a few angled sample-holder pads), and carbon tape. These smaller components and accessories can be found in the cabinets above the PC. (The Ted Pella Corporation is an excellent source for SEM parts and components). In addition, the user's manual is found in a large yellow binder labeled "JEOL MANUAL". A SEM use logbook is also present near the main control panel. All users of the SEM must log in their usage in the logbook, which must include the date, the time, the person operating the SEM, the materials that were imaged, and any anomalies in the operation of the instrument. Recording all suspicious or unusual behavior as it happens greatly assists in troubleshooting and maintenance of the instrument.

4. PERSONAL SAFETY EQUIPMENT

No personal protective equipment is needed for the routine operation of this instrument. Powder free latex or PVC gloves are required for handling the sample holders and internal parts of the load lock to keep finger print oils off of the internal surfaces.

5. MATERIAL COMPATIBILITIES

In general, material compatibility issues for the SEM are not very complex. Most conductive or semiconductive microstructures will yield very satisfying images. The JEOL JSM-IC25S SEM is intended for characterization of microelectronic devices and materials, which may be very

sensitive to particulate contamination. *No biological matter is to be imaged using this system.* Since the SEM involves a vacuum system (approx. 10^{-5} torr), contamination of the chamber and load lock should be avoided. Always use powder-free gloves when handling any samples or parts, which will be placed into the SEM. Devices or circuits that may be sensitive to large currents from the electron beam should not be imaged using SEM. The JEOL JSM-IC25S SEM is designed to accept a limited range of sample sizes. Only the samples that will safely fit onto a sample holder and into the chamber should be imaged; round wafers should be no larger than the 4" wafer holder. The movable sample stage will allow positioning the sample to image the area of a 5" square sample.

6. PRIMARY HAZARDS AND WARNINGS

In general, no hazardous situations should arise from typical operation of this equipment. Hence, this section is intended to remind the user of important steps to ensure proper operation of the equipment. This is a list of scanning electron microscopy do's and don'ts—general guidelines:

1. Do not introduce unnecessary contaminants into the SEM chamber. Always wear latex rubber powder-free gloves when handling any parts which will be placed inside the SEM chamber or load lock.
2. When adjusting the filament knob, follow carefully the instructions in section 7, so not to burn out the filament.
3. Exhibit care when mounting the sample holder pad onto the loading lever. The screw threads can be damaged easily.
4. Devices with high current sensitivity should not be imaged using the SEM.
5. It is important that the turbo molecular pump (TMP) and the roughing pump (RP) should never simultaneously pump on the same chamber.
6. The nitrogen gas, used for venting the load lock, can cause asphyxiation in a poorly ventilated area if a significant leak is left undetected over a period of time.
7. The gas bottle is under pressure and should be firmly secured to a large immovable object. Mishandling of a pressurized gas bottle can cause severe damage and/or injury.

Few hazardous situations should arise using this equipment. Some possible issues and suggestions, if long-term use is expected, are presented in section 9. Other guidelines and operating procedures are outlined in detail in the following sections.

7. OPERATIONAL PROCEDURE CHECKLISTS

The operation of the scanning electron microscopy equipment is described in detail in the JEOL JSM-IC25S user's manual found in a yellow binder. However, several modifications made by previous users warrant special caution, since the equipment operation differs slightly from its original design. Some commands, functions and options included in the user's manual may not be available to the user at the present time. Additional hardware may have been installed and

incorporated in the operation of the SEM, therefore this paper (Standard Operating Procedure–SOP), and especially this chapter, give the most up-to-date detailed operation steps. It is best if the user becomes familiar with both the manufacturer’s manual (in the yellow binder) and this standard operating procedure paper prior to operating the SEM. This chapter is organized into three sections, which discuss the SEM operation steps (power-up and shutdown, vacuum system, and sample loading). It is important that the user is familiar with the location of the equipment and all of its key components.

Procedure 1. Power Up and Chamber Evacuation

1. Initialization:

The sample can be successfully loaded only if the sample positioning stage is in the correct initial position. Check that the sample stage is at the starting parameters:

stage rotation	= 0°
tilt angle	= 0°
x position	= 500
y position	= 500

The SEM will only be calibrated if the working distance (WD-distance between sample and electron beam gun) is either at 10 or 48 (mm). WD can be adjusted using the big knob above the x-y stage-position knobs.

Check that: WD = 48

Generally, there is no need to do any aperture adjustment and filament centering. The SEM should be in calibration and aperture and filament adjustments should only be performed by those who fully understand this procedure.

The pneumatic valve switches should all be closed (as pictured in Figure 1.). Check that all the valve switches are in the desired positions. Note that the system should be in valve lock (not auto.) mode.

The load lock valve (big CAM valve on top of chamber) should be closed—pushed in entirely, and the chamber CAM valve (smaller CAM valve between the electron source and chamber) should be open—pulled out. The CAM valves are operated by turning _ turn (counter-clock wise) to free, pushing or pulling to close or open (respectively) and again turning _ turn (clock wise) to lock the valve. Note that opening or closing the CAM valves may require some force.

2. Power-up Supplemental Equipment:

- * Turn on water re-circulation/chiller (two switches) for the turbo molecular pump (TMP).
- * Crack open the (very pure) nitrogen bottle (the pressure regulator should be set to 40 psi). This bottle is used to vent the load lock.
- * Turn on vacuum gauge to monitor the chamber pressure. This is a black box next to the SEM display CRT.

3. SEM Power-up:

- * On the vacuum pneumatic-valve panel (Figure 1.) turn the power switch on. This activates the pneumatic valve switches.
- * Turn the main panel power switch on. This switch has a safety, it must first be pulled and then switched. Push the momentary start button. The CRT display and valve check (light panel) should turn on.

4. Pump-down:

On the following page (in Figure 1.) is a vacuum line diagram, which can be found on the vacuum control panel. It is intended to aid the user in the SEM pump-down. In the diagram, observe the vacuum connections between the two roughing pumps (RP1, RP2), the turbo molecular pump (TMP)—which has replaced the diffusion pump (DP) on the diagram—and the SEM chamber and load lock. (Note: the DP switch is inoperable since the DP has been replaced). The vacuum lines are intercepted with a number of pneumatic valves (controlled by the indicated toggle switches) which allow manipulations of the vacuum. The step by step pump-down procedure follows.

- * Turn on roughing pumps—toggle switch “RP” on the valve control panel. The roughing pumps should noticeably turn on. Check the valve status light indicators on the right of the CRT. They should indicate which valves are ON or OFF. Wait one minute following RP power-up.
- * Open valves labeled: “V2”, “V1”, and “V4” (in that order). This applies RP into imaging chamber. Wait one minute following this step.
- * Turn the turbo molecular pump (TMP) on; this is done by pressing the “power” switch on the HP power supply. If this switch is already on, do not turn it off (this will shut down the entire system)! If the TMP is on prior to this step leave it on, it will slowly start to accelerate when the RP1 is applied on the backing line (switch “V2”). Check that the TMP has accelerated (the rotation indicator gauge on the HP TMP power supply).

Open valve labeled “LV2”. This brings the load lock to atmospheric pressure and allows opening of the sample chamber (in approx. 15 seconds). Once the sample chamber is open, the valve “LV2” should be closed (this stops the flow of nitrogen gas).

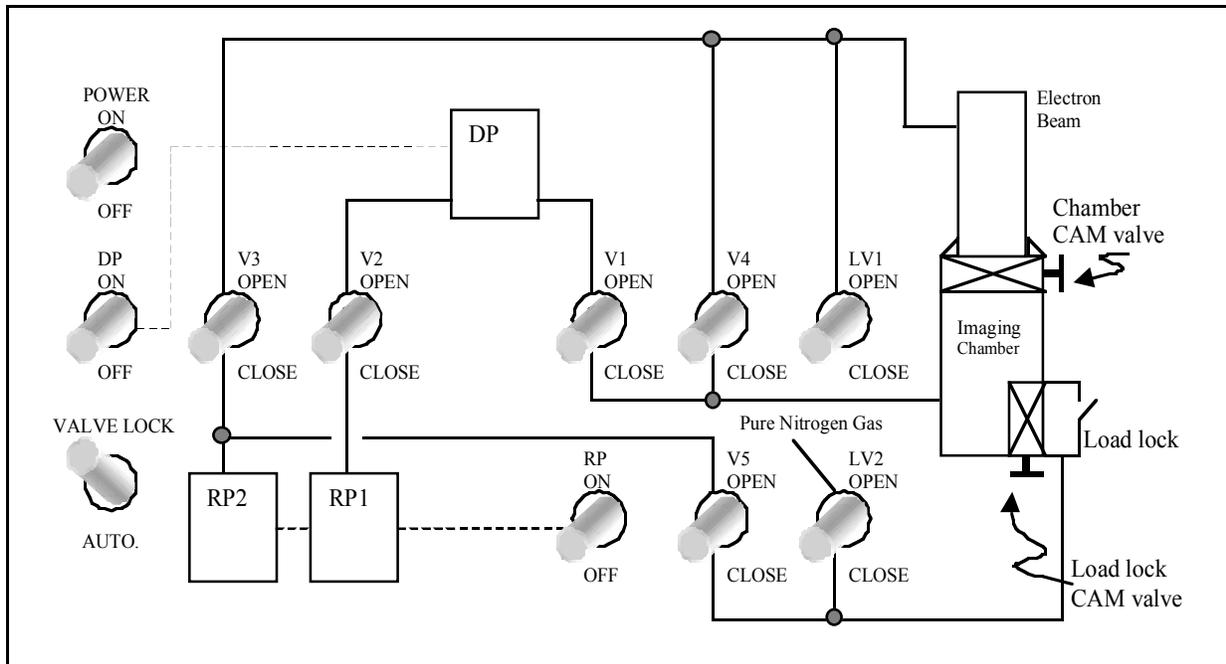


Figure 1. Vacuum Valve Panel

Procedure 2. Sample Loading, Sample Exchange

1. Sample Loading:

At this point the sample chamber (load lock) should be open and it can be pulled out to access the sample holder and mounting lever. Please use caution and be gentle to these parts. Use powder-free latex gloves for handling the sample holder and samples. The sample holder can be unscrewed from the mounting lever (long loading arm) and can be taken out to ease sample mounting. Two stainless steel flat-surfaced cylindrical plates should be found in the holder. The sample can be mounted onto these plates using double-sided carbon tape, which is electrically conductive. This tape will serve as an adhesive and will also provide a drainage path for the scanning electron current. If a packaged micro electronic device needs to be imaged, the grounding pin should be in conductive contact with the sample holder. Several hand-made cylinders are available allowing mounting of the sample at a non-normal angle. It is very convenient if several samples can be loaded simultaneously to avoid repeated timely sample exchange procedures. Alternatively, an entire round wafer of size up to 4" in diameter may be placed in the 4" wafer holder.

Carefully screw the sample holder onto loading lever/arm in the load lock and close door. (It is important to be gentle on the loading arm threads).

Keep the load lock door closed and open valve labeled "V5"; this engages the roughing pump (RP2) on the load lock.

Close valve "V5" when the load lock is evacuated and is tightly shut (will take less than 30 seconds).

Next, load the sample into the SEM imaging chamber. Open the load lock CAM valve. The CAM valve is opened by twisting the knob $\frac{1}{2}$ turn (ccw) and pulling it out. This may require some force. It is locked in place by turning $\frac{1}{2}$ turn (cw).

Once this valve is open one can see into the chamber through the view port. The loading lever/arm should be gently pushed in (following its path through the view port) and secured to fit snugly onto the receiving dovetail piece. (It is very important that the sample stage is in the initialization positions as described in section III.I.1.). Once this connection is made, the loading lever/arm can be unscrewed to release the sample into the SEM chamber. The loading lever/arm can then be retracted completely outside the SEM imaging chamber (use the view port).

When the loading arm is pulled out, the load lock CAM valve should be closed ($\frac{1}{2}$ turn ccw, push valve in, then $\frac{1}{2}$ turn cw to lock).

Set the working distance $WD = 10$ (mm). Check that the light indicator “WD10” on the main control panel turns on. This will ensure that the SEM images are calibrated.

Skip to procedure 3, “Control Panel Setup and SEM Imaging”.

2. Sample Exchange:

This part discusses the vacuum procedure to exchange a sample in the SEM imaging chamber. This is a very common procedure when multiple samples need to be imaged one after another. This section assumes that the previous sample has been loaded according to procedure in the sections above.

Go to LSP mode. Turn down the filament knob. Turn off SEI/BEI detectors (switch in middle position). Turn the electron acceleration voltage off. Set $WD = 48$.

Return the sample stage to initial settings as given in procedure 3.

Open load lock CAM valve. Insert loading lever/arm and screw the arm into sample holder. Pull sample holder away from receiving dovetail piece and completely out into load lock.

Close load lock CAM valve. Open leak valve labeled “LV2” to flow pure nitrogen gas into load lock. This will bring the load lock to atmospheric pressure after which the door will be able to be opened the sample withdrawn.

Procedure 3. Control Panel Setup and SEM Imaging

Once the sample is positioned into the SEM chamber the stage position can be adjusted and the optical microscope used to roughly position the sample. The optical microscope is engaged by turning the knob, which lowers an optical prism to image the sample. The working distance *must* be at 48 in order to engage the optical microscope! Also the light output for the optical microscope should be increased. It is found near the SEM chamber vacuum gauge. Unfortunately, the optical microscope can often be difficult to focus and sometimes of little use.

Check the vacuum gauge; the SEM chamber pressure should be approx. 10^{-5} mbar.

Set up the initial settings on the main control panel according to Figure 2 (taken from section 5.2.1 on page 5-6 of the user's manual—in the yellow binder):

<i>(Section 5-2-1 Initial Control Setting; Page 5-6 in "JEOL MANUAL")</i>	
Set the panel controls as follows:	
_ Control Panel	
- FILAMENT knob	Fully counterclockwise _
- ACCEL VOLTAGE: OFF button	Press
- SEI/BEI switch	Center position
- CONDENSER knob	12 o'clock position
- AUTO FOCUS: AFD button	Release
- BRIGHTNESS knob	3 o'clock position
- CONTRAST knob	7.0
- MAGNIFICATION: 45X switch	Up
- DYNAMIC FOCUS: DFC button	Release
- FOCUS: COARSE knob	5.0
- IMAGE SHIFT (__, __) knobs	12 o'clock position
- SCAN: SPEED H/L switch	H
- SCAN MODE: LSP button	Press "LSP"
- SCAN MODE: REDUCE button	Release
- POSITION (__, __) knobs	12 o'clock position

Figure 2. Initial Control Settings (from user's manual)

When all the above control settings on the main panel are set as given in Figure 2, proceed with the following steps:

Push the acceleration voltage 25kV button.

Select SEI or BEI detector. For the majority of imaging situations, use the SEI detector; the BEI detector is available for high magnification (resolution) microscopy.

Turn magnification to 100. This will make the next step easier.

Slowly turn up the filament knob. Be careful not to increase it to high, this will burn out the filament; use the following procedure:

Make sure that the SEM is in LSP mode. A horizontal line should be visible across the CRT display. Slowly increase the filament knob until a portion of the line begins to deflect vertically. The filament light indicator—next to the knob—should be on at this time. Stop at

the maximum vertical line deflection. For more information, this procedure is described in detail on page 5-16 of the “JEOL MANUAL” in the yellow binder.

Press the “picture” SCAN MODE button on the main panel.

On the CRT monitor, adjust (increase) the brightness and contrast knobs, as well as the brightness knob on the main panel. An SEM image should be visible, the following step gives suggestions to improve the contrast quality.

Adjust focus coarse and fine. The brightness and contrast knob as well as the condenser knobs can significantly improve the image quality. The magnification knob allows selection of this parameter, and the sample can be positioned using the sample stage positioners (x-y, rotation and tilt angle). For a discussion of the function of each setting on the main control panel please refer to the “JEOL MANUAL”.

Follow the steps in procedure 2 “Sample Exchange” for loading a different sample.

Procedure 4. Shut-down

The following steps give the shut-down procedure. It is very important to follow this procedure precisely for proper system venting and allowing ease of start up for the future use.

Return the sample stage to initialization position:

stage rotation = 0°
tilt angle = 0°
x position = 500
y position = 500

Return to working distance WD = 48 (mm) position.

Go to LSP SCAN MODE and return the magnification to 45.

Turn the detector off; SEI/BEI switch to middle position.

Turn the filament knob down and acceleration voltage OFF.

Open load lock CAM valve, insert the loading lever/arm into chamber and carefully screw into sample holder. Follow this procedure through the view port. Once the sample holder is secured withdraw the loading lever/arm completely. Close the load lock CAM valve.

Open leak valve “LV2” to vent the load lock with nitrogen gas. Close “LV2” when the door to the load lock can be easily opened.

Remove the sample carefully from the sample holder. Please use powder free latex/rubber gloves. After replacing the sample holder, close the load lock door.

Keep the load lock door closed and open valve “V5”. Wait one minute for the load lock to be evacuated.

Close valves “V4”, “V1”, “V2”, and “V5” in that order. The light display panel should illuminate the valves that are open.

Shut off the roughing pumps (RP switch OFF). This will automatically shut off the turbo molecular pump (TMP). Turn the TMP power switch on the HP power supply OFF.

On the HP power supply you should see the TMP blade speed rapidly decrease to zero. Turn vacuum gauge off.

Shut of water cooling system off (two switches) and close the nitrogen gas bottle.

Turn off power on the main control panel (this switch must be first pulled out and then switched off). Turn power off on the vacuum switch control panel. With this step the SEM should be powered down. Check that there is no power to the screen or other controls. If possible, return all settings on the main panel to initial settings given in Figure 2.

Log SEM use in logbook found next to the equipment.

Procedure 5. SEM Image Capture

The SEMICAPS image-capturing module allows capturing, averaging, image processing, measurement, and file storage of a video output screen of the JEOL JSM-IC25S scanning electron microscope (SEM). The “PowerPro” 486/25 MHz personal computer (PC) is interfaced with the video output of the SEM and has a copy of the “semicaps” software installed. The PC starts up in MS-DOS mode and the following commands will call up the program:

```
> cd semicaps      <enter>
> sem              <enter>
```

A previous SEM image may be displayed when the program is first started up. In the main menu, on the right side of the screen, several program sub-modules will be available (SEM, Camera, Measure, Process, Edit, System, and Exit). For example, the “Camera” sub-module allows image capture from video (PAL, or NTSC standard formats), the “Measure” menu allows the addition of scaled feature measurements on the captured image. “System” provides file utilities, and “Exit” quits the program and returns to MS-DOS. The “Read” and “Write” commands allow recalling a file from disk or saving a file from the workspace. (Note that “Write” will produce an image readable only in “semicaps”). The following two sections discuss the basic highlights of the software package—image capture and image export to the TIF-tagged image file format.

In the main menu of the “semicaps” software, click on the “SEM” button. This button will be in the top right corner of the screen. Note that when this button is depressed, the image on the SEM CRT monitor will no longer be displayed. It is therefore important to do majority of the image adjustment on the scanning microscope while not in “semicaps-SEM” mode and that a satisfactory image is obtained.

The following four options will be available in the “SEM” sub-program: “select area” (image size—big, small, tiny), “continuos” (continuos scan with averaging), “snap” (single image capture with averaging), and “final” (single image capture \w avg.).

To obtain the image from the SEM CRT monitor, click on “continuous” and set number of averages to 1. Since the brightness on the SEM and the image capturing system is not the same it will be necessary to decrease the brightness knob on the SEM main control panel. The “continuous” mode will draw an image across the screen updating each time the previous rendering is complete. This allows room for fine adjustments on the SEM to improve the image quality. Increasing the number of averages will improve the image granularity but will significantly reduce the rendering time. Once a satisfactory resolution has been obtained, click on the “quit” button, which will return the user to the “SEM” menu. Selecting “Snap” will do a single image rendering at the selected number of averages. Once the image is *snapped*, the user will be prompted to enter the SEM magnification. Automatically, this command will save a copy of the image to the hard drive. Note even though the file name extension is *.tif, this is not the standard tagged image file format. The procedure to export the image file to an MS-Word readable *.tif file is discussed in the next section.

Once an image is captured on the desktop, the user can use the “Process” image processing, “Measure”, or “Edit” utilities. The image processing allows adjustments of the contrast, brightness, and other image parameters and even allows the introduction of pseudo-color to the acquired image. The “measure” sub-program allows scaled measurement of distances and angles on imaged features of interest.

The “Edit” utility allows incorporating text with the image. It must be pointed out that after exporting the file, the image information under the additional measurements and text will be lost. It can only be recovered in “semicaps” if the original file is recalled.

Procedure 6. File Storage (*.tif format)

Once a satisfactory image is obtained (or read in from disk), the file can be exported to a MS-Word readable *.tif (tagged image file format) file. This is done the following way:

In the main menu of the “semicaps” software, go to “System” and click on “Export Image”.

Select:

Micron data	ON or OFF	
Symbol	ON or OFF	
Measurement	ON or OFF	and click on “OK”.

These options write to the *.tif file (or omit writing) the applied magnification data, edited text, and measurement, as previewed on the screen.

Select the file name and directory to which the file should be written and click on the “Write” button.

The file utilities, in the “System” menu allow preview of any images captured by “semicaps” as well as the typical file utility options.

8. HELPFUL HINTS, COMMON QUIRKS, AND TROUBLESHOOTING

The best source for detailed coverage of SEM procedures and components is the user’s manual (“JEOL MANUAL”) in the yellow binder. The manual has a large section on image contrast, depth of focus, and use of astigmatism control, which can yield significant improvements in

image quality. This SEM has had numerous years of use and does have its own quirks. Research faculty, graduate students and other staff, which have experience using this equipment, will likely be a great troubleshooting resource.

9. ENVIRONMENTAL HEALTH AND SAFETY ISSUES

There are no significant known environmental health and safety issues associated with the operation and use of this equipment. Although x-ray generation is expected from the incident electron-atom interactions the dose is predicted to be small. If continuous use of the SEM equipment is expected, thoroughly familiarize yourself with the equipment and safety issues.

Common sense can prevent most hazardous situations. The following are potential hazards, associated with pressurized gas bottles, which may cause health and safety issues:

- The nitrogen or helium gases, used for venting the load lock, can cause asphyxiation in a poorly ventilated area if a significant leak is left undetected over a period of time.
- The gas bottle is under pressure and should be firmly secured to a large immovable object. Mishandling of a pressurized gas bottle can cause severe damage.