SCANNING ELECTRON MICROSCOPE

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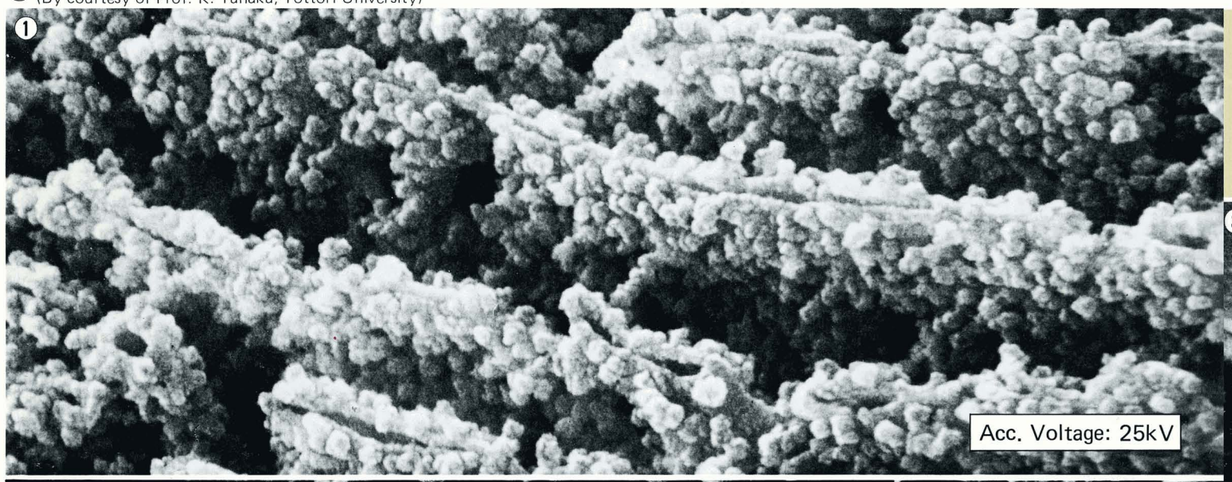
Enhanced imaging capability for high technology applications — from biology to materials research & development

Hitachi, Ltd. has been developing a cold field emission electron source for over 15 years under the guidance of Professor Albert V. Crewe of the University of Chicago. The field emission electron source features an epoch-making high resolution for scanning electron microscopy. It has an inherent source brightness which is greater than the normal tungsten filament by 1,000 times. It is a key to breaking through the conventional resolution limit. Hitachi, Ltd. introduced the first field emission ultra high resolution scanning electron microscope HFS-2 in 1972. Since that time, Hitachi, Ltd. has already built and delivered more than 250 sets of similar instruments throughout the world, though most are located in Japan.
The S-800 is a new computer controlled ultra high resolution scanning electron microscope with a cold field emission electron source.

① Specimen: Rough surfaced endoplasmic reticulum of rat lacrimal gland Magnification: 100,000X
(By courtesy of Prof. K. Tanaka, Tottori University)

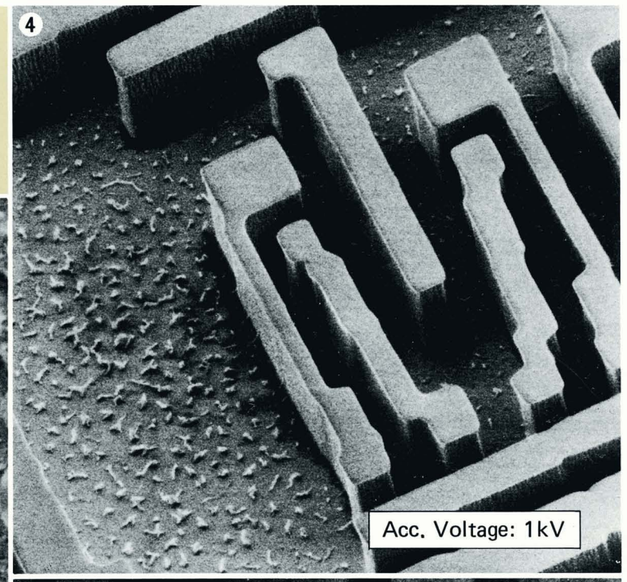
② Specimen: Intracellular structures of rat lacrimal gland Magnification: 70,000X
(By courtesy of Prof. K. Tanaka, Tottori University)

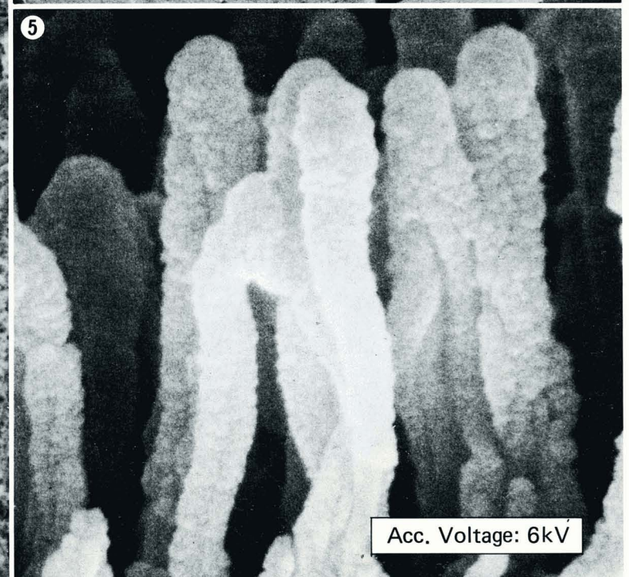


③ Specimen: Yeast cell (candida trapicalis)
(By courtesy of Prof. M. Osumi, Japan Womans University)

④ Specimen: VLSI patterns produced by SIEL method
(By courtesy of NTT Electrical Communications Laboratories)

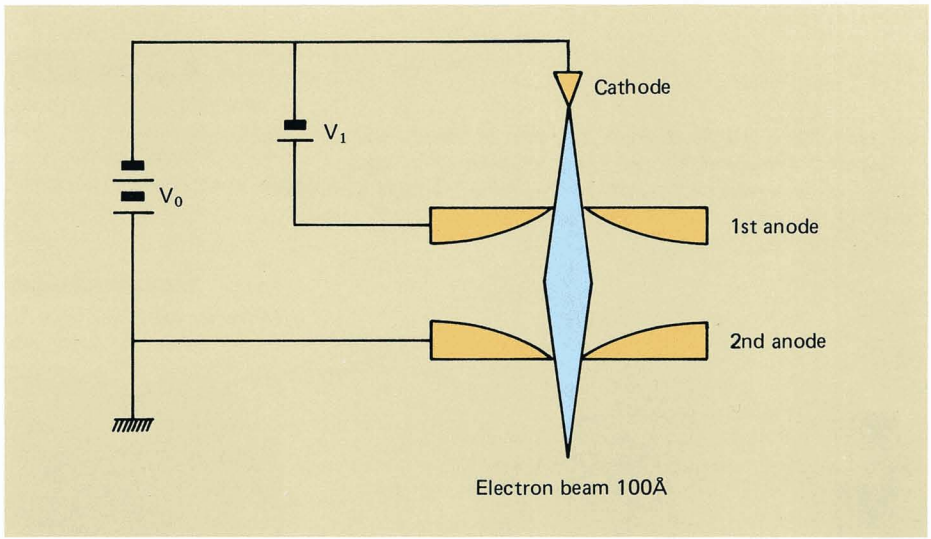
⑤ Specimen: Amorphous ultrafine particles
(By courtesy of Mr. S. Ohnuma, Research Development Corporation of Japan)

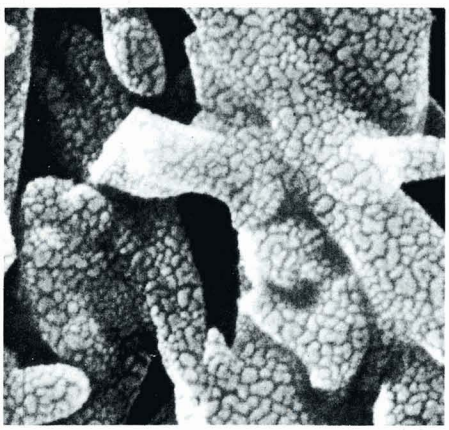




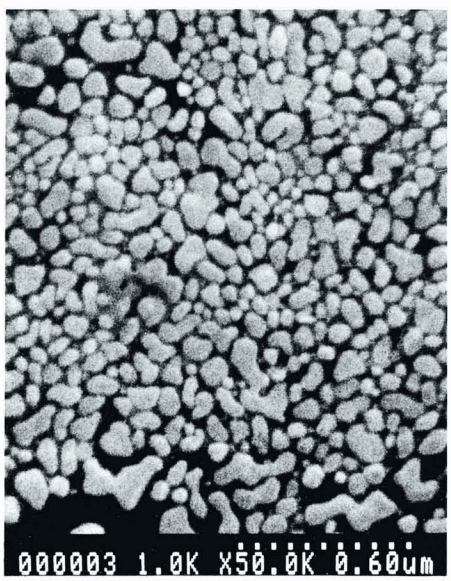
Ultra high resolution by field emission electron source

The field emission electron source consists of a pointed cathode and two anodes. The cathode is made of a single crystal tungsten tip polished to 1,000Å in radius of curvature. The emission intensity is on the order of 10^5 A/cm^2 which is surprisingly high when compared with 10 A/cm^2 of conventional thermionic sources such as a tungsten hairpin type filament. Because of the great emission intensity in the field emission, there is a sufficient current available that allows excellent resolution with good signal to noise ratio.

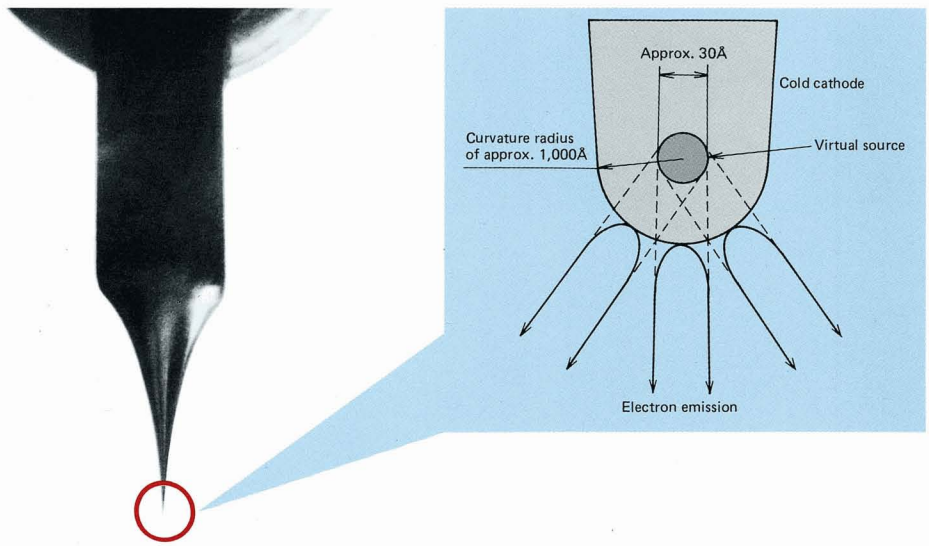




Au-Coated mag. tape 25 kV 100,000X



Evaporated 1.0 kV 35,000X



Comparison of Electron Sources

	Field emission (Cold cathode)	LaB_6	Tungsten Filament
Brightness (A/cm^2·sr)	10^9	10^7	10^6
Virtual source (Å)	$<10^2$	10^5	$>10^5$
Energy spread (eV)	0.2	1.0	1.0
Service life (h)	≧2,000	1,000	40
Operating vacuum (Pa)	10^{-7}	10^{-5}	10^{-3}

The table above is a comparison of various electron sources available for scanning electron microscopes. It is obvious to note that the field emission (cold cathode) is the most promising electron source for ultra high resolution microscopy, specifically in terms of source brightness, source size, emission current, energy spread and service life. It excels any other source without question.

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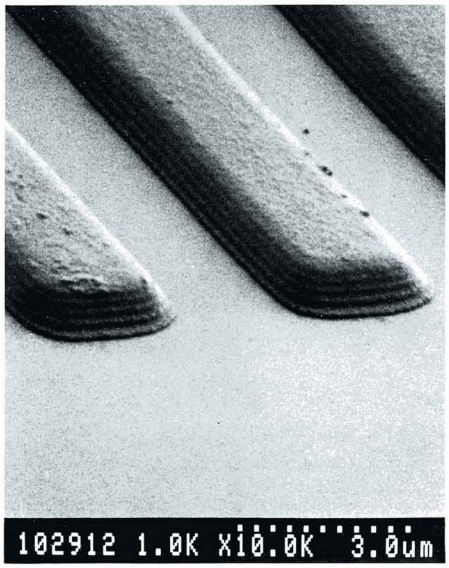
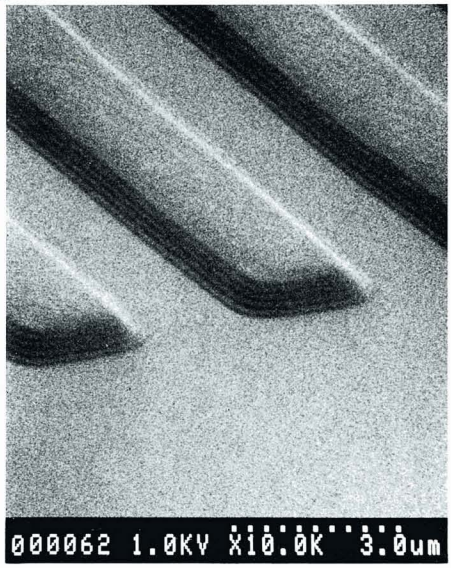
High resolution low voltage operation by field emission electron source

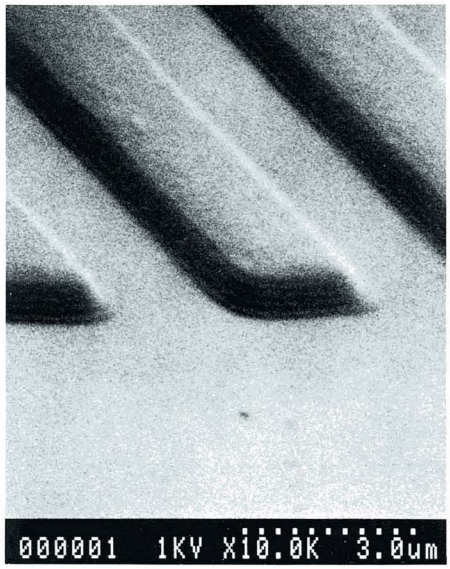
Difference of image quality by each electron gun.



Cold FE

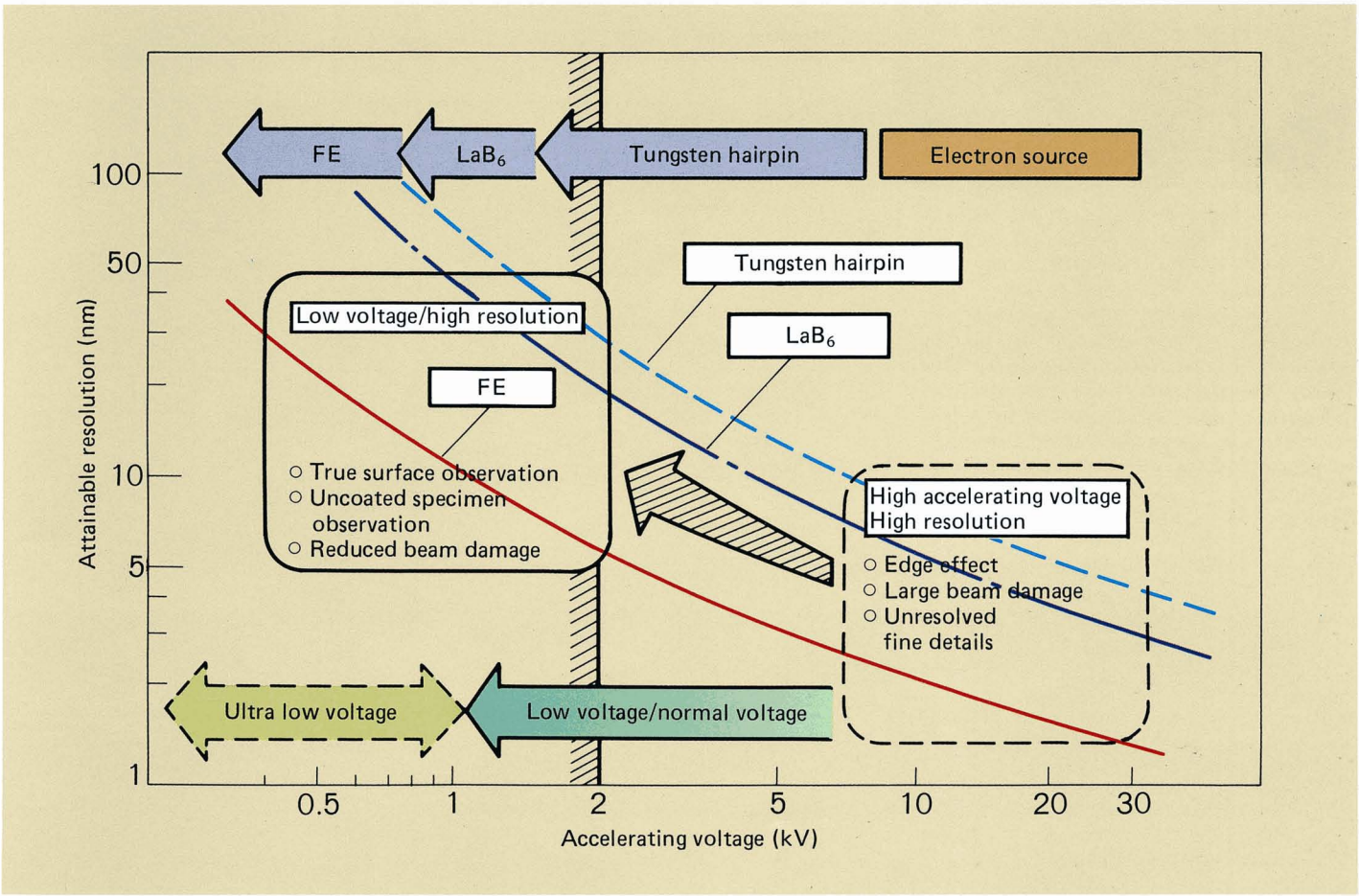


LaB_6



Tungsten hairpin

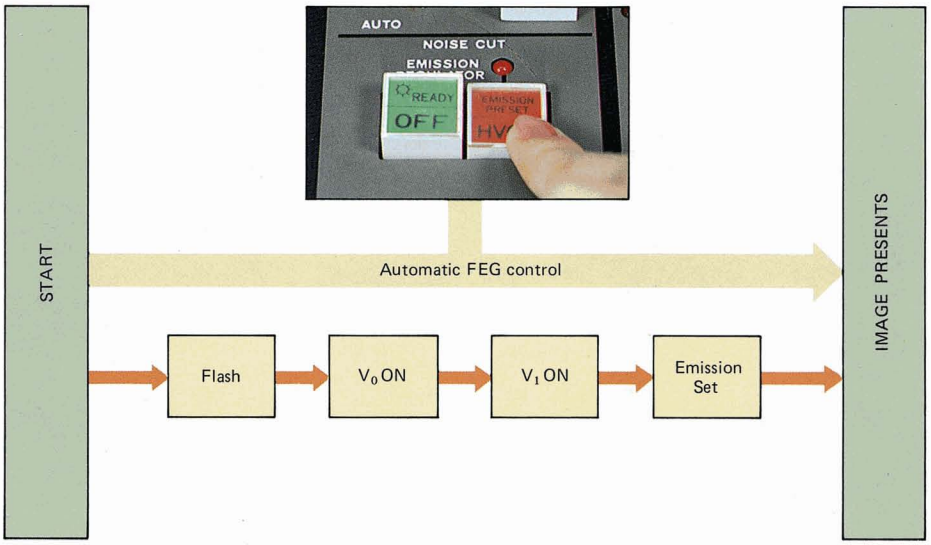
Attainable resolution at various operating voltages and with various electron sources



Optimum and Reliable Field Emission Gun Controlled by CPU System

Automatic FE Gun Control

The S-800 field emission electron source is controlled by CPU system in its entirety. Operation of the gun is started by pressing the button. The CPU system processes a series of operation required to optimize the field emission gun as illustrated at right. Following the start switch operation, image is presented on the CRT screen automatically. Unlike any conventional SEM that utilizes a thermionic electron gun, there is no need for operator to properly regulate filament excitation current for saturation point. The S-800 field emission electron gun is the first and the only one in the world that assures optimum and reliable operation for anyone.

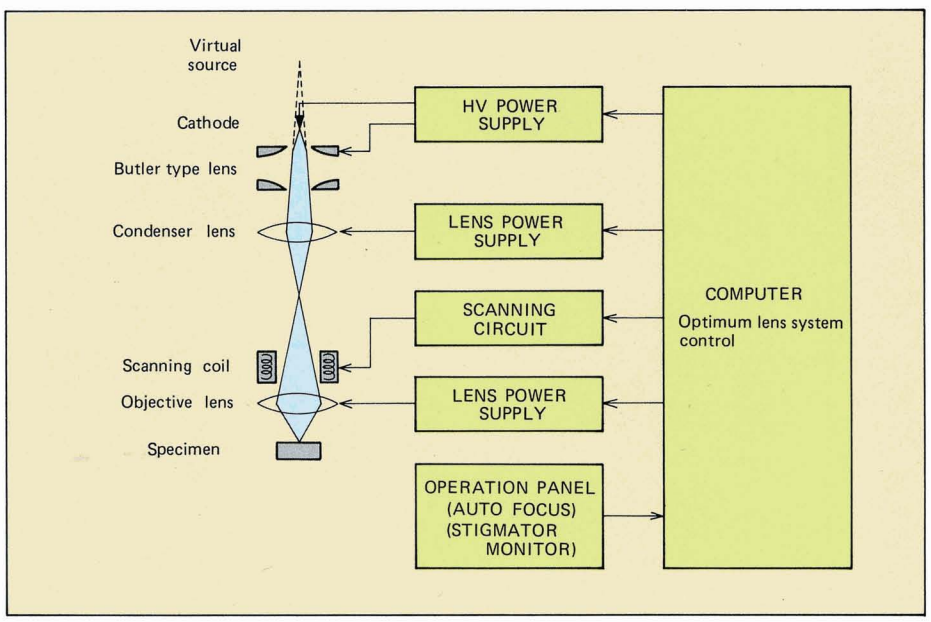


Optimum Lens System Control

The S-800 field emission electron source utilizes Butler type electro-static lens as well as electro-magnetic condenser and objective lenses. In the field emission electron source, a change of either 1st anode voltage (V_1) or 2nd anode voltage (V_0) results in the positional change of virtual source as illustrated at right. This phenomenon usually requires operator to compensate for the condenser and objective lens excitation conditions. In the S-800, the computer takes care of this complicated and critical operation automatically and keeps both condenser and objective lens conditions optimum for SEM work.

Separate super autofocus and dynamic stigmonitor permit enhanced image presentation at a touch of buttons.

The S-800 allows high resolution scanning electron microscopy in a simplest and easiest manner for anyone.



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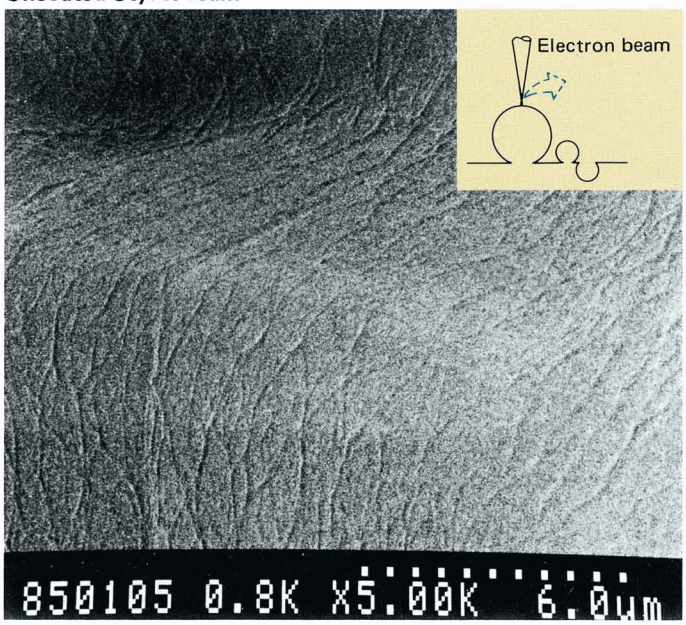
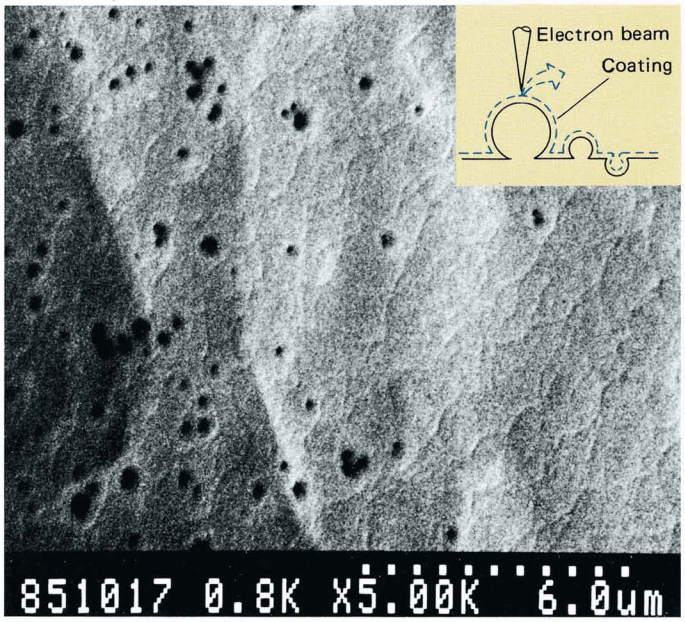
Quality image recording at low voltage operation without specimen coating

Uncoated Styrol foam

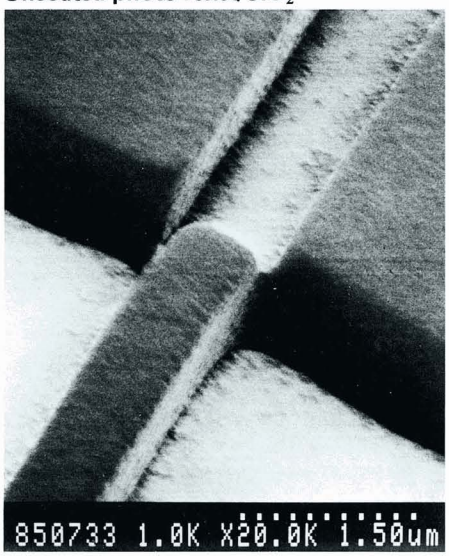


Coated Styrol foam

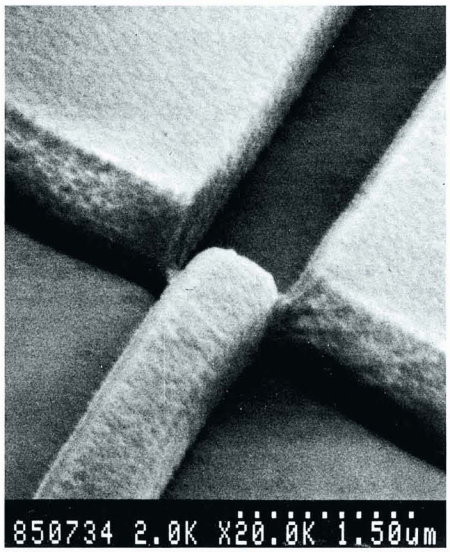


Specimen: Styrol foam

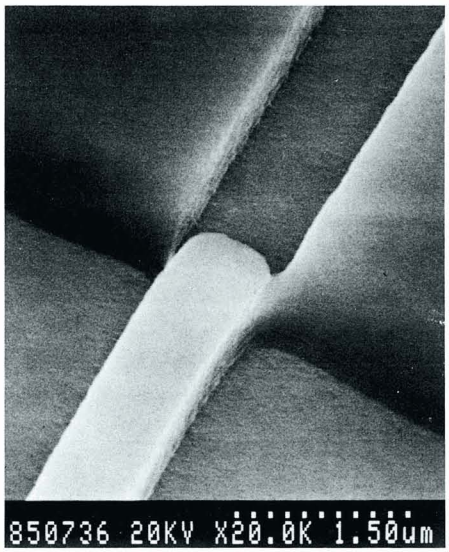
Uncoated photo resist/SiO_2



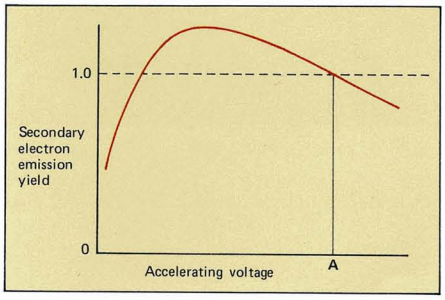
1kV



2kV



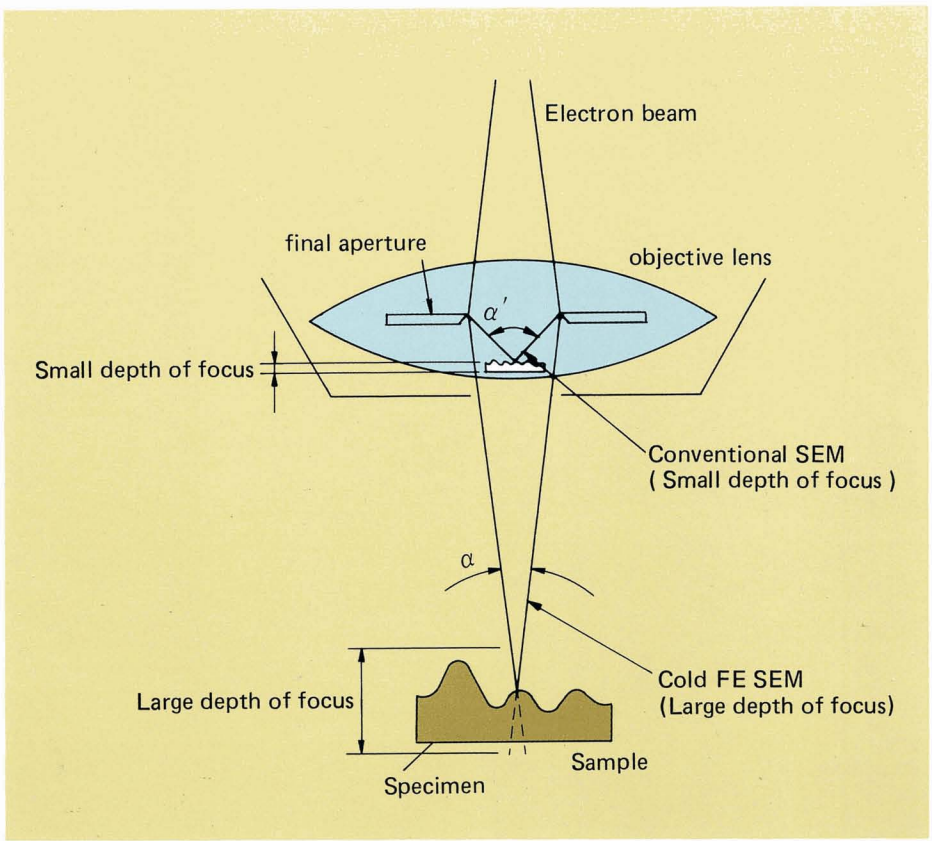
20kV



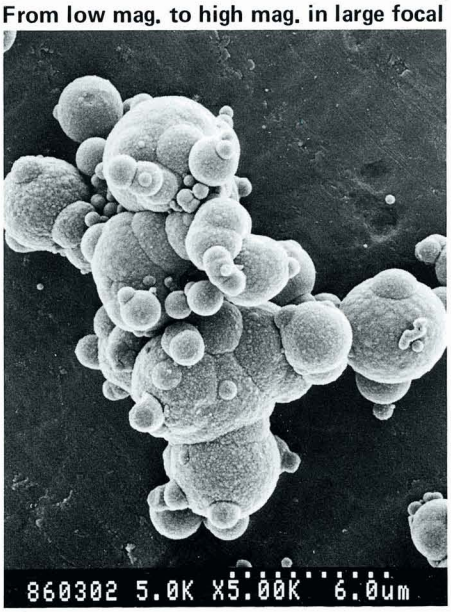
This graph shows a general secondary electron emission yield at various accelerating voltages. Although secondary electron emission yield varies depending on material and incident beam angle (or specimen tilt angle), the point (A), i.e., yield 1.0 is obtainable at accelerating voltages of 1 kV ~ 10 kV.

Large Depth of Focus

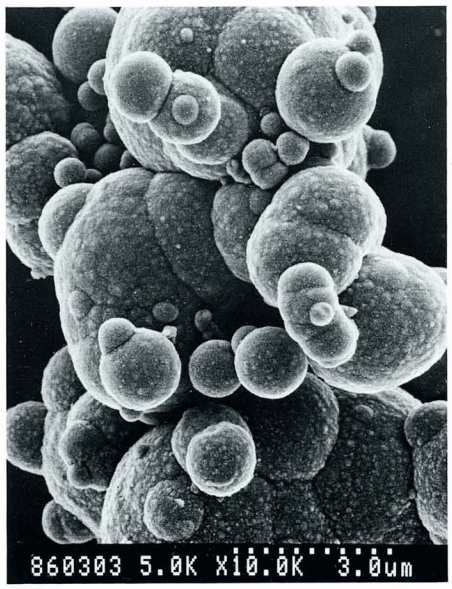
The depth of focus is a function of incident beam angle that scans across the specimen. Typically use of a small final aperture and a large working distance permits a small incident beam angle and allows a large depth of focus.
The field emission source permits conventional normal geometry in which the specimen is placed outside the final lens allowing a large working distance, a large sample accommodation, small magnetic interference of the final lens, versatile sample handling and exchange capability. Due to its inherent source brightness (1,000 times greater than thermionic source) and small source size (1/10,000 of thermionic source), the field emission gun permits ultra high resolution with a large depth of focus.



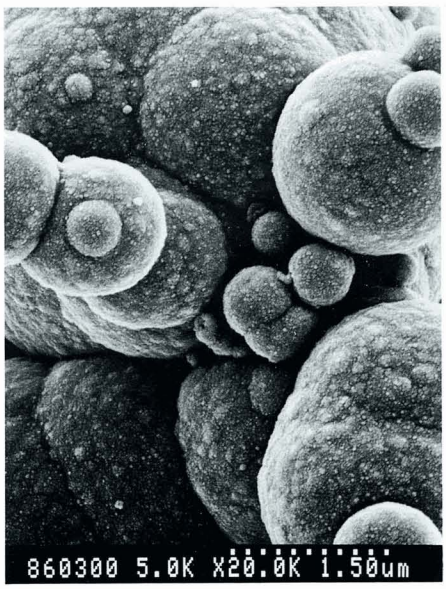
From low mag. to high mag. in large focal depth



Low mag.



Middle mag.



High mag.

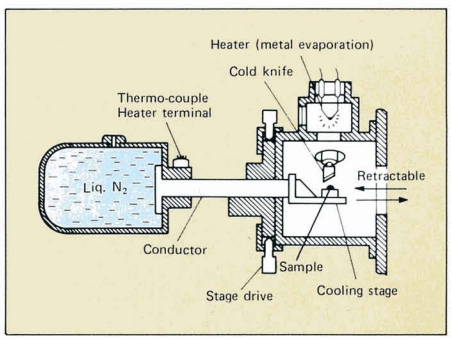
Cryogenic/BSE (RE) Imaging

Cryogenic System (option)

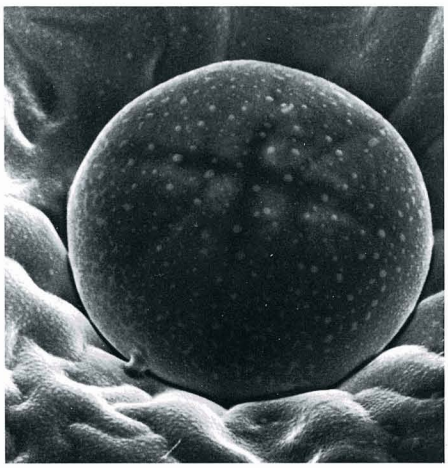
The cryogenic technique was originally developed for biological specimens but it has been found useful for polymer materials or many other water-containing/emulsion materials. The cryogenic technique employs liquid nitrogen in which specimens are quickly frozen and observed on an SEM. It eliminates artefacts caused by complicated chemical processing and drain-out of original chemical components. The S-800 design allows this unique technique as demonstrated below.

The photo shows a cryogenic system mounted on the S-800 and the sectional diagram the inner construction. There are a cold knife for specimen fracturing and a mini-coater for specimen coating. The specimen stage is directly connected to a liquid nitrogen dewar to ensure good cooling efficiency and operation. The specimen temperature is regulated $-120^{\circ}C$ through ambient temperature via controller which permits sublimation control of the specimen.

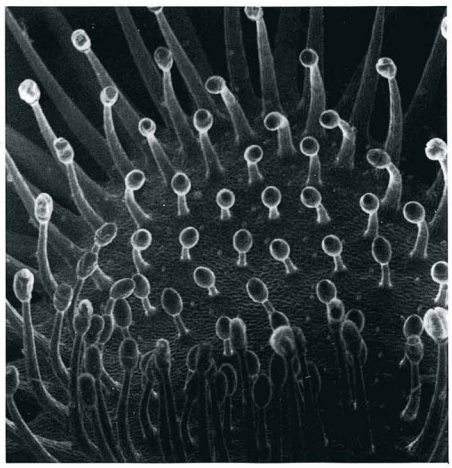
Cryogenic system mounted on the S-800



Sectional diagram of the cryo-system
(Cold stage is retractable in and out from the specimen chamber)



Specimen: Beefsteak plant
Magnification: 800X
(By courtesy of Prof. Matsushima, Saitama University)

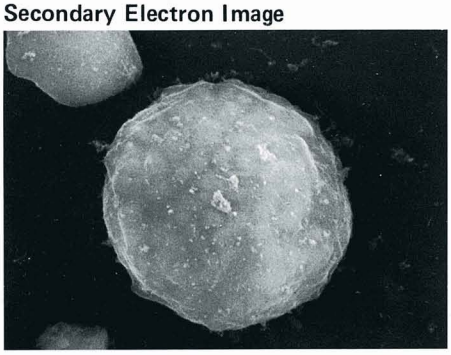


Specimen: Leaf of moorgrass
Magnification: 20X

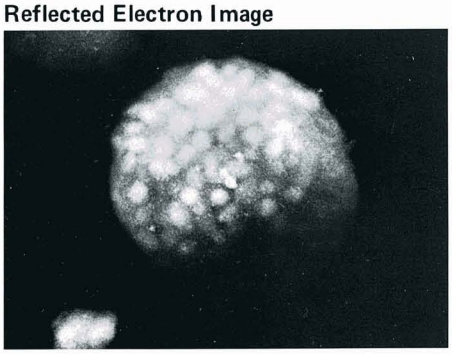
Back scattered Electron Imaging (option)

The backscattered electron image is generally related to atomic number of elements composing the specimen. This is generally called an atomic number contrast and provides elemental information. There is another advantage in the use of backscattered electron image. It is less sensitive to the specimen charging artefact than normal secondary electron imaging. The S-800 allows use of Hitachi's Hi-pass type high sensitivity reflected electron detector which utilizes a scintillator/photomultiplier combination. Due to its excellent sensitivity and rapid response time, it can be used in many application fields.

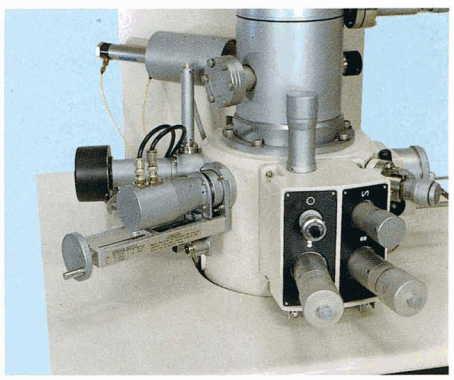
Secondary Electron Image



Reflected Electron Image

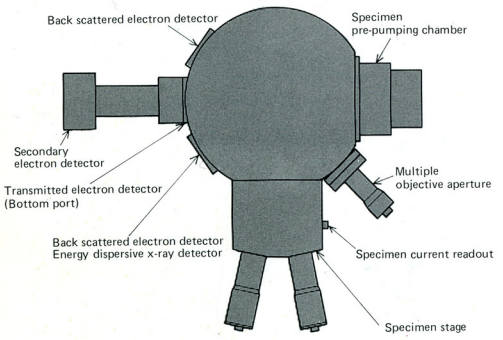


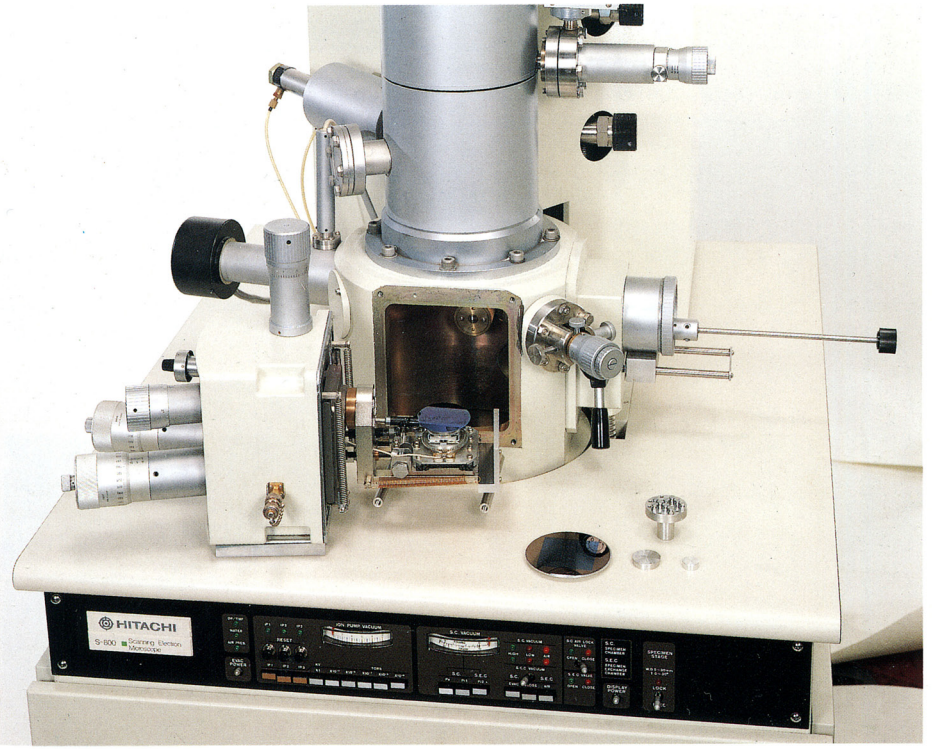
Specimen : Rabbit acidothil leucocyte Magnification: 8,000X
(By courtesy of Prof. K. Tanaka, Tottori University)

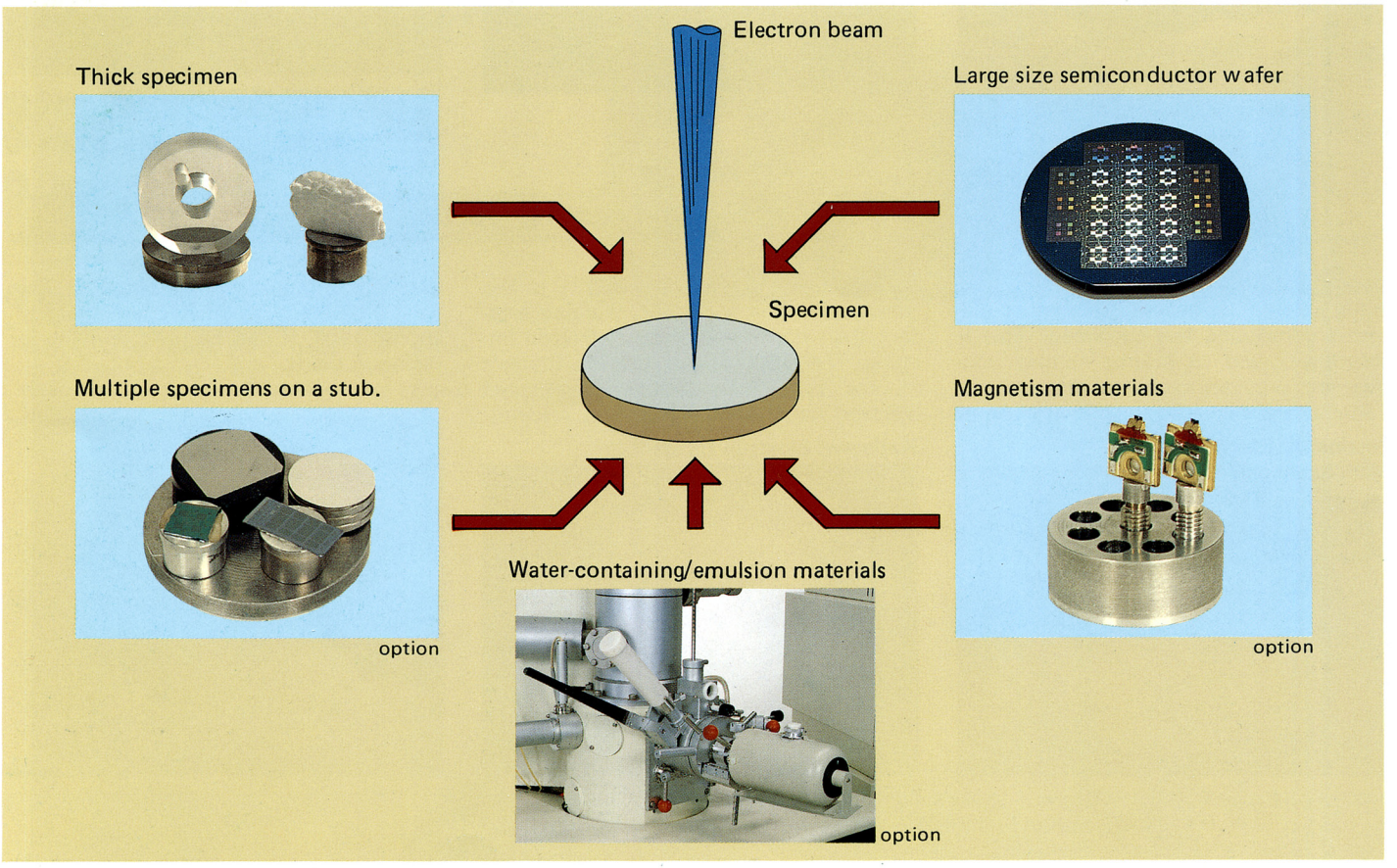


Versatile Sample Handling Capability

The S-800 specimen chamber is spacious and versatile. It allows an EDX spectrometer, back scattered electron detector and transmitted electron detector positioned simultaneously in addition to the standard secondary electron detector and multiple objective aperture in place.
The specimen stage accommodates 2" diameter sample (maximum) through the standard pre-pumping/airlock chamber or 4" diameter sample through direct front door stage mounting. The stage allows a full 25 mm traverse along X, Y and Z axes.

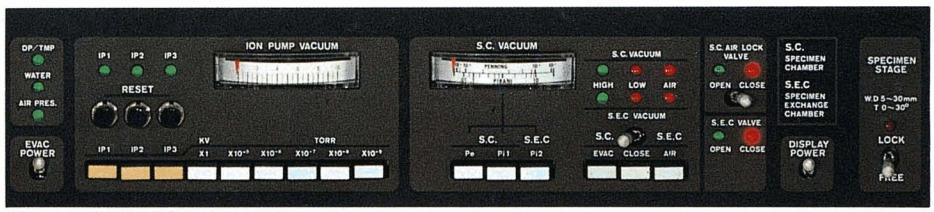




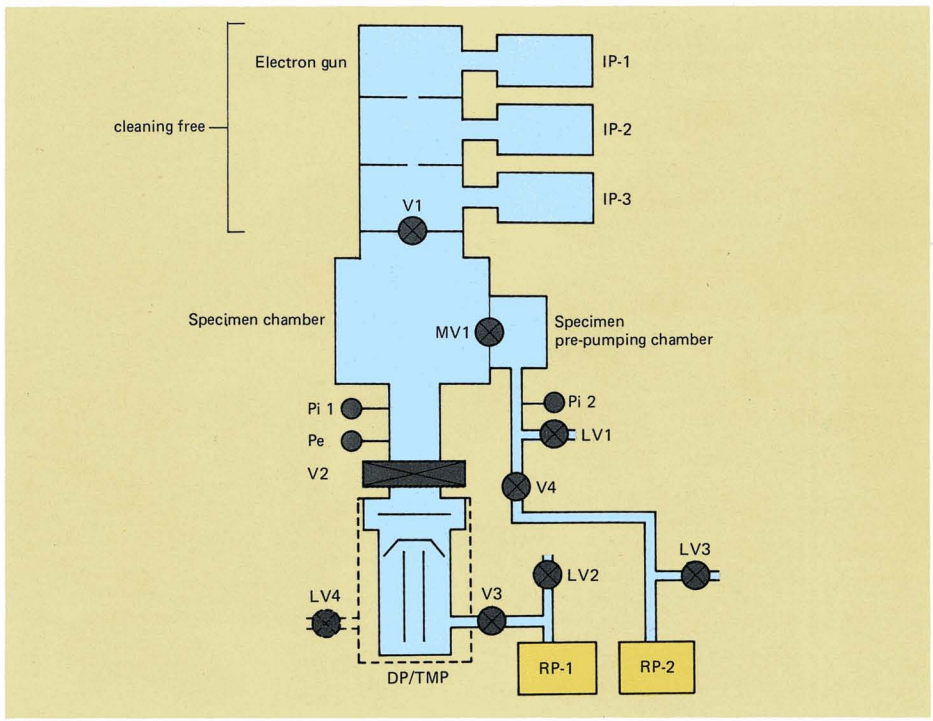


Clean Vacuum System

The S-800 has four (4) separate pumping systems. The first system consists of ion pump IP-1 and pumps out a gun exclusively. There are two intermediate chambers between the gun and specimen chamber. They are evacuated by the 2nd and 3rd systems (IP-2 and IP-3). These intermediate chambers allow efficient differential pumping operation so that both the gun and the specimen chamber may operate with minimal vacuum interaction. The 4th system consists of a liquid nitrogen trap, diffusion pump and rotary pump combination. It evacuates the specimen chamber exclusively. This system may be replaced with a turbo molecular pumping system at option. The entire pumping sequence is automatically controlled and ensures reliable/simple operation.



Vacuum Control Panel



S-800 Vacuum System

Maintenance (cleaning)

Maintenance service is much easier than with the conventional SEM because of S-800's clean and high vacuum system.

	Cold FE-SEM	Thermal electron source	
		LaB_6	W
Wehnelt	–	○	○
Anode	–	○	○
Filament exchange	–	○	○
Aperture for c. lens	–	○	○
Aperture for obj. lens	○	○	○

○: need cleaning

Unique Computer Controlled Display

❶ Functionally grouped parameter display
- Operating parameters such as emission current, accelerating voltage, magnification and working distance are displayed on a single panel right next to the viewing CRT screen.
- Straight-forward digital display of magnification and accelerating voltage.
- Clear color-bar display for image brightness and contrast level reading/setting.

❷ Two large viewing CRTs
- Two large viewing CRTs (150 x 135 mm screen) are standard and are convenient for simultaneous display of two images either of different signals or at different magnifications. Either one of the two images may be recorded at a flick of a switch.

❸ Ultra high resolution photo CRT
- Recording exposure is activated at a touch of PHOTO switch. The ultra high resolution CRT with a dynamic grey scale range turns out quality photographs on every exposure. The system returns to a normal viewing mode automatically when the recording exposure is finished.

❹ High voltage control
- Accelerating voltage 1 ~ 30 kV at 1 kV step.
- FE control is by CPU system.

❺ Automatic brightness and contrast
- Optimum image brightness and contrast setting is done at a touch of this button. This is a standard feature.

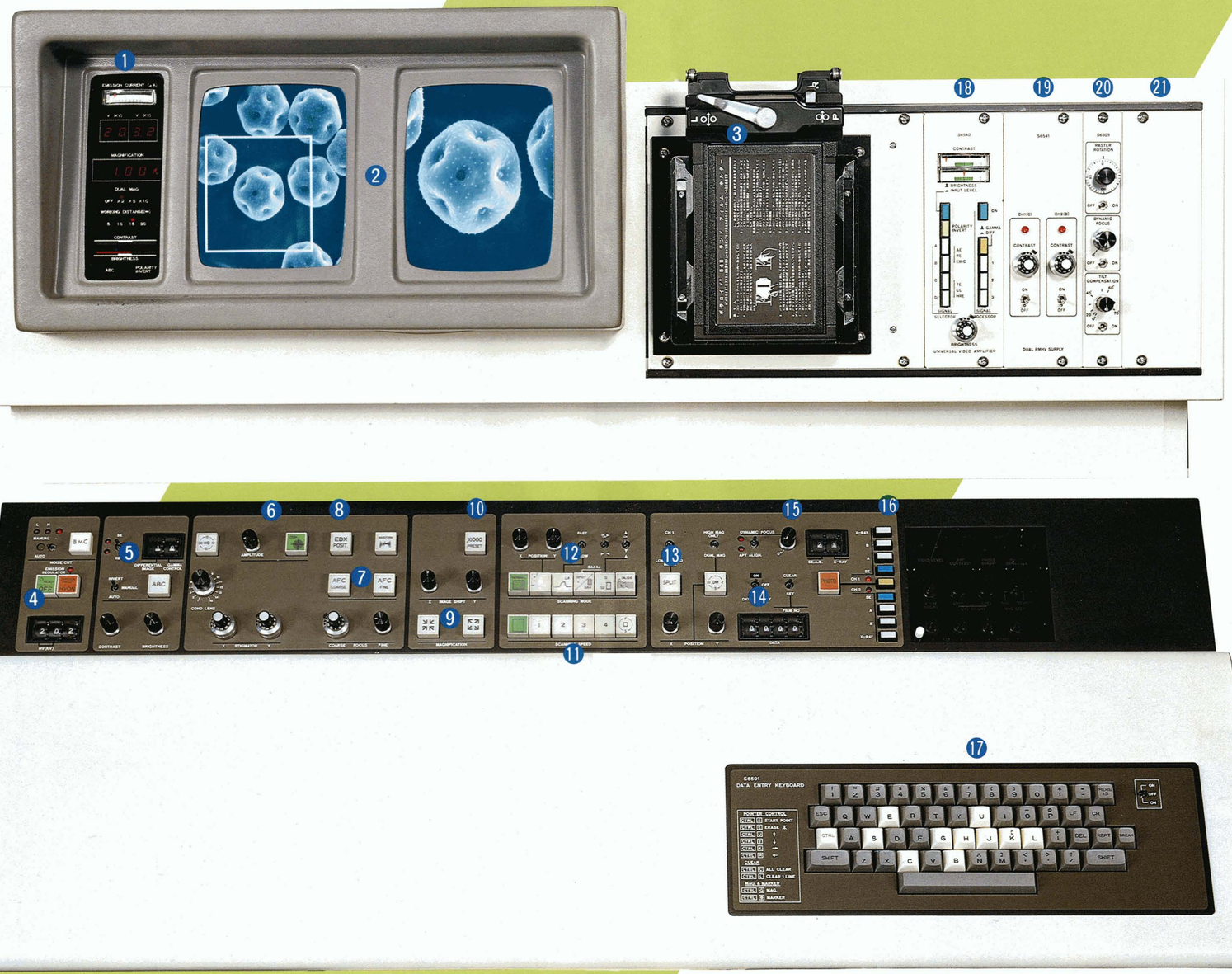
❻ Dynamic stigmator monitor – See page 14
- Astigmatism correction is simple by locating a good focused area at the center of the CRT screen.

❼ Super autofocus mode – See page 14

❽ EDX position mode – See page 17

❾ Finger-tip magnification control – See page 14
Magnification change is simple by operating a twin-key (UP and DOWN buttons).

❿ Quick-look low magnification mode
- A fixed 1,000x is available at a touch of a button. It is useful for a quick look general survey purpose. A touch of the same button returns you to a normal viewing mode immediately.



⓫ Scanning speed
- Seven (7) speed selections are available at a touch of buttons.
- Full frame rapid scan mode permits a flicker-free quality image which is convenient and useful for field selection.
- Reduced area rapid scan mode allows high and low speed selection. The high speed may be useful for field selection and the low speed for fine focus and astigmatism correction.

⓬ Scanning mode
Six (6) modes such as raster scan, line set/analysis, and point set/analysis are available via push button controls.

⓭ Split screen/dual mag image display
- Simultaneous display of the same image at two different magnifications or of two different types of images may be done on the two large CRT screens. (Hitachi patent)
- Two images may be presented on a single CRT simultaneously by splitting the screen.
- This mode is not only convenient for dynamic observation of specimen but also useful for maintaining the corelation of the recorded data.

⓮ Automatic data display – See page 15

⓯ Dynamic focus
- This mode assures a sharp edge-to-edge focus for specimens tilted at large angles, particularly at low magnifications.

⓰ Signal selector
- It allows selection of any two separate imaging signals.

⓱ Keyboard data entry (option) – See page 15

⓲ Video signal amplifier (option)

⓳ Dual photomultiplier power supply / control (option)

⓴ Raster rotation/Dynamic focus/Tilt compensation unit (option)

㉑ Accessory room

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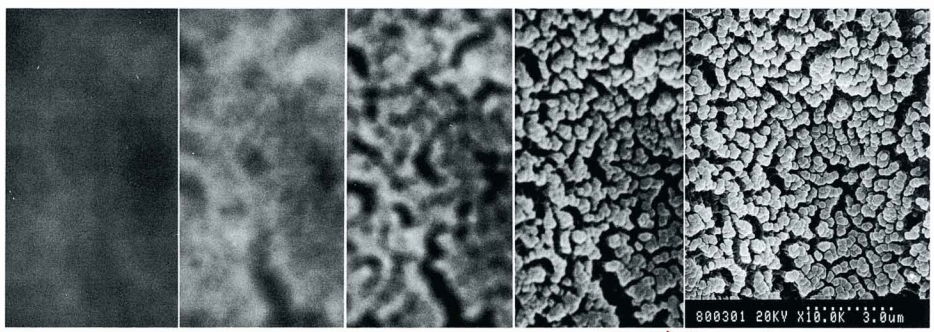
Automated and Convenient Routine Microscopy

The S-800 permits routine microscopy with its most advanced automatic functions. Operating vacuum is achieved by an automatic pumping system. After the vacuum is ready, a touch of "HV ON" button activates a display system. Selected accelerating voltage is applied in an automatically controlled way (soft start). It triggers the scanning system and specimen image is automatically presented on CRT screen (at 1,000x). Automatic image brightness and contrast and Super Auto-Focus system, both of which are activated by pushbuttons, optimize the image. The operator is only required to select the field and set the magnification. The Super Auto-Focus system is not restricted by the specimen position nor accelerating beam voltage. The computer searches all possible conditions for the best focused images throughout. It is quick and precise. It covers most of the routine microscopy with satisfactory results. The Super Auto-Focus utilizes differentiated video signal to monitor the focus conditions and regulate objective lens current for the best focus condition. The computer takes care of these operations most efficiently.

For ultra high resolution microscopy, manual overrides may be best utilized. Manual focusing control is also computer controlled. It is linked with magnification and permits focusing control at the same condition throughout the magnification range. In the low magnifications, focus control current requirement is large but it is small in the high magnifications. The magnification linked focus control system assures easy and comfortable manual control. In addition, the focus control (coarse) is an endless type which permits continuous endless turn and better maneuverability.

The automatic data entry allows correct

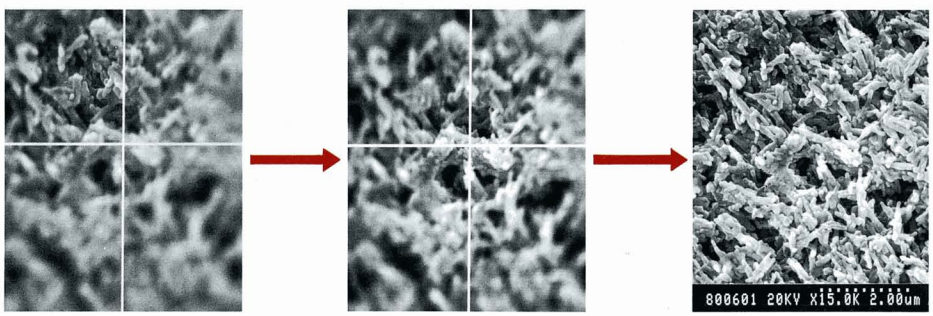
Super Auto-Focus Operation



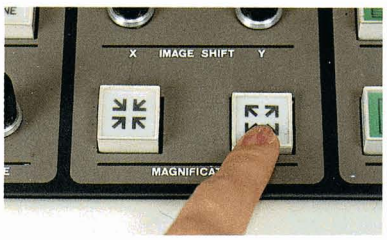
Specimen : Pollen of azalea

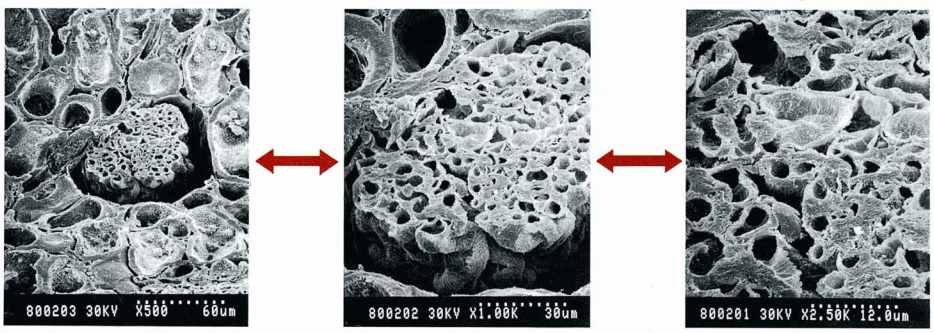
2 seconds or sooner

Dynamic Stigmator Monitor



Finger-Tip Magnification





Specimen : Kidney

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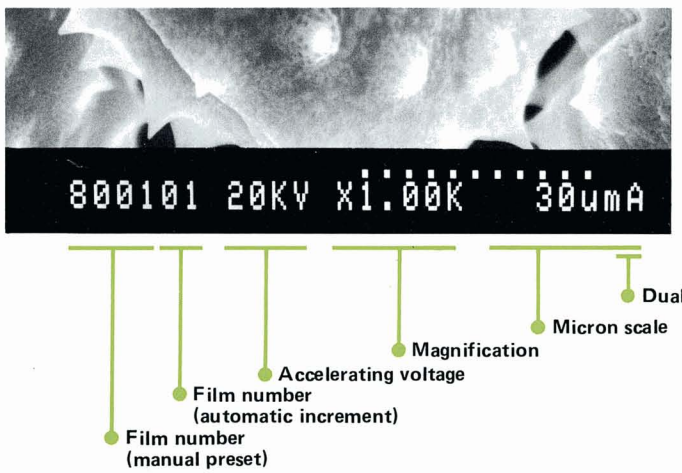
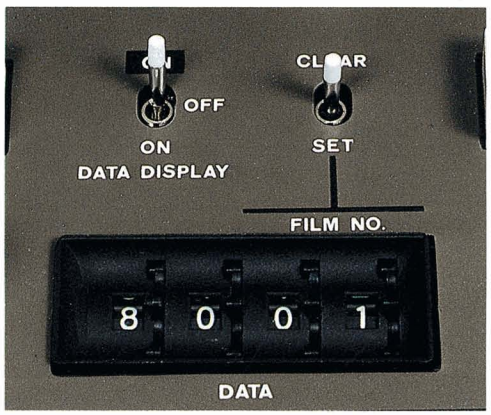
and permanent recording of operating parameters together with a corresponding image. It permits recording of film number, accelerating voltage, magnification and micron scale. This data recording is available at the operator's choice either with or without a dark background stripe at the bottom of the micrograph.
The keyboard data entry permits display and recording of any additional information utilizing an alpha-numeric and other symbolic character generator system which is convenient and useful for making notes of specimen, operating conditions or giving elemental information.
The recording position is selected by a teletype key operation throughout the CRT screen.
Photographic recording is activated at a touch of "PHOTO" button. When the recording exposure is finished, the system turns on an electronic chime to let the operator know of it and at the same time returns the system back to its normal viewing mode automatically.
The S-800 includes a host of other features that are designed to facilitate microscopy. Some of these features are:

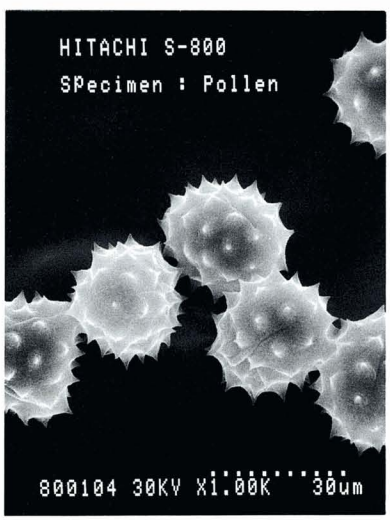
a) Dual scanning speeds for reduced area rapid scan mode which are convenient and useful for high resolution microscopy, specifically for fine focus and astigmatism correction.
b) Dynamic stigmator to help the operator with astigmatism correction.
c) Dynamic aperture alignment mode for precise final aperture positioning. The wobbling amplitude of objective lens is linked with magnification so that this mode may be operated in the same wobbling condition at all magnifications.
d) Y-modulation (Oblique) mode permits selection of optimum scanning lines/frame for optimized image presentation and recording.

Automatic Data Display/Recording



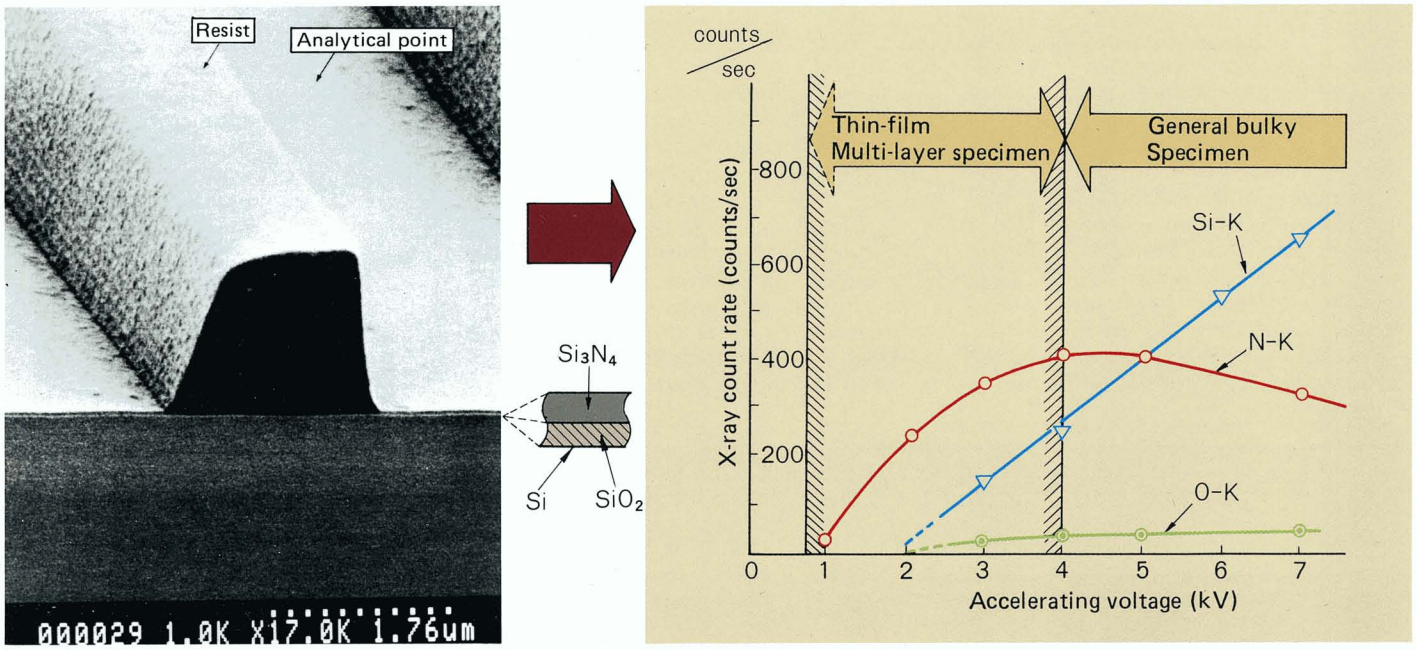


Keyboard Data Entry/Recording (option)



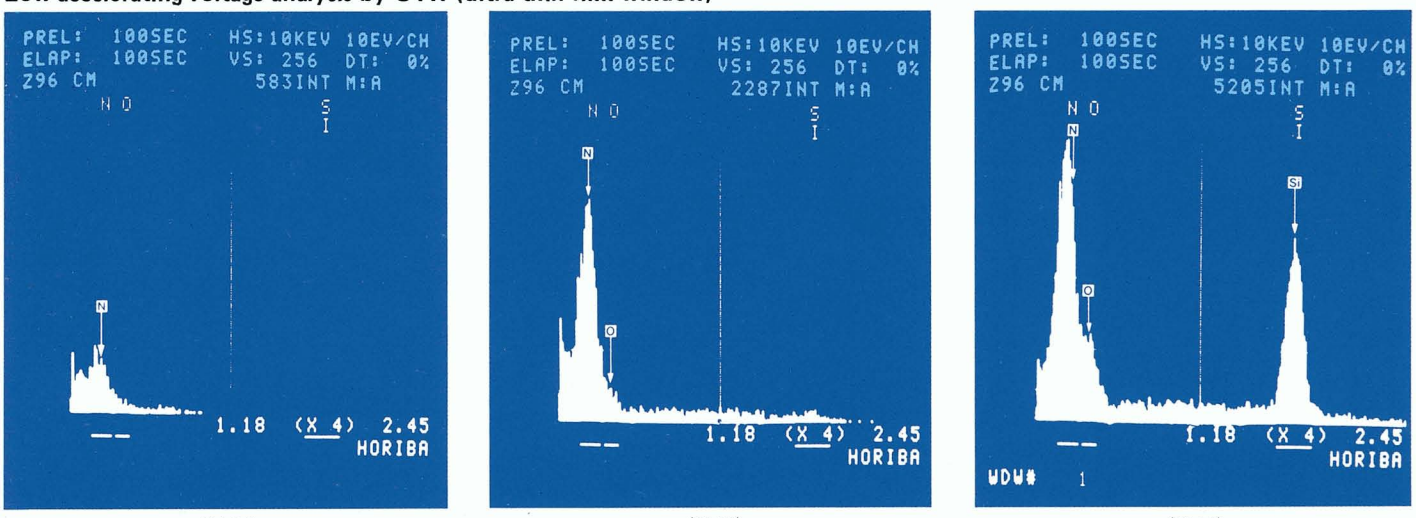
Operating keyboard

At low voltage operation, light element analysis of multi-layers.

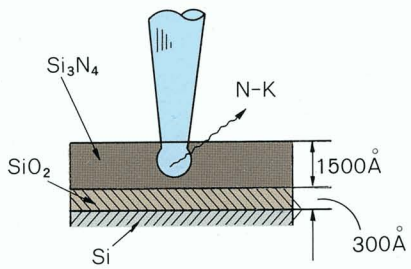


Secondary Electron Image
Acc, Voltage: 1 kV
Sample: Resist Pattern

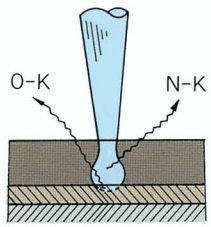
Low accelerating voltage analysis by UTW (ultra thin film window)



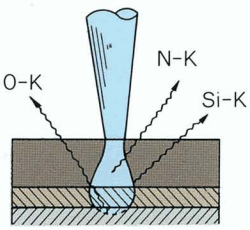
(1kV)



(2kV)



(3kV)



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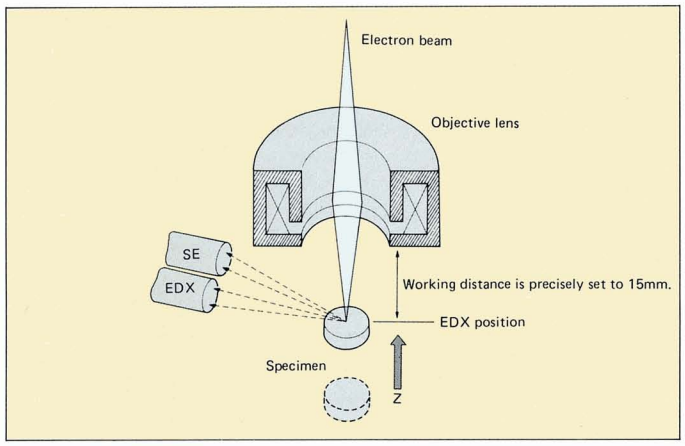
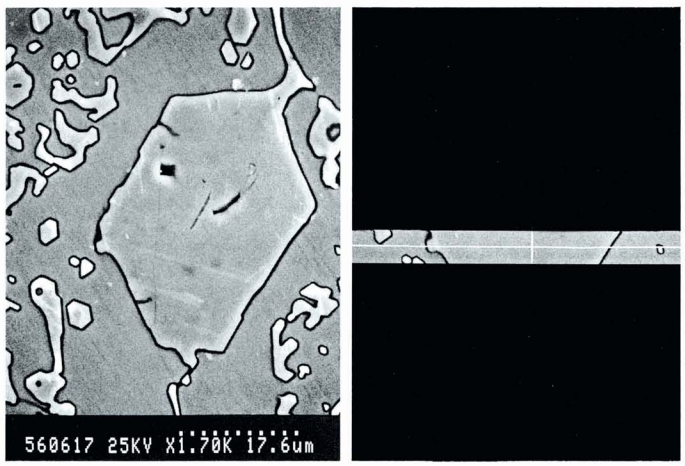
EDX Position Mode

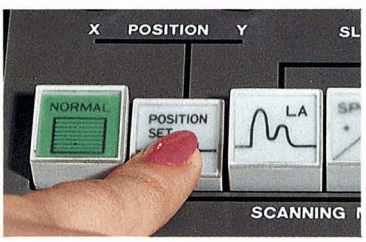


Specimen Z-positioning for elemental analysis using EDX spectrometer is efficiently and accurately done in this mode. It provides optimum solid angle of the detector with respect to the specimen and allows quality elemental analysis.

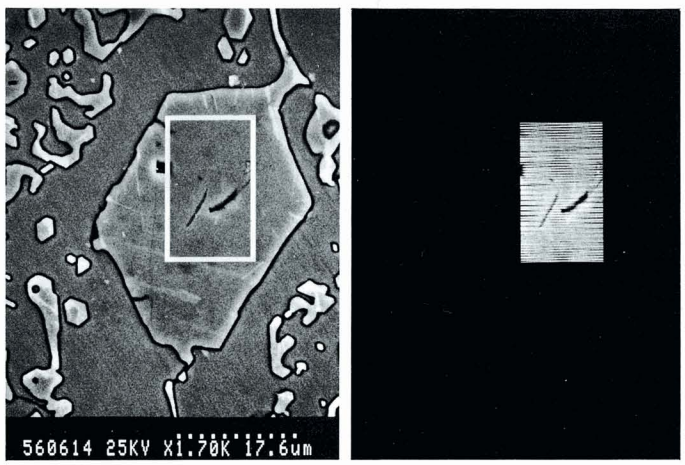
Real Time Image for Spot/Line Positioning



Analytical spot/line set may be done using a real time image on the CRT screen. Conventional setting was possible only with after-glow image on the CRT screen which fades out in seconds. The real time image is presented in a form of vertically reduced area so as to facilitate the analytical area selection.



Analysis Area Finder (Patent pending)



This mode is useful for elemental analysis of a localized area which is greater than that covered by a fixed beam or a point analysis mode. This mode is particularly useful for analyzing mean element concentration of any selected area. Instead of a large probe diameter, this mode utilizes a fine focused probe scanned on a selected area of specimen. It is possible to change the scanning area and position within the presented image on the CRT screen.

Specifications

- Resolution: 20Å guaranteed
- Magnification: 20x ~ 300,000x
- Electron Optics
  - Electron gun: Field emission electron source
  - Accelerating voltage (V_0): 1 ~ 30 kV (1 kV/step)
    [0.5 ~ 5 kV (100 V/step) / 5 ~ 25 kV (1 kV/step)] (option)
  - Lens system: 2-stage electro-magnetic lens
  - Stigmator: 8-pole electromagnetic type (X, Y)
  - Beam deflector: 2-stage electro-magnetic type
  - Objective lens aperture: Click stop type 4 openings, externally selectable and alignable
- Specimen stage
  - Traverse X: 0 ~ 25 mm
    Y: 0 ~ 25 mm
    Z: 5 ~ 30 mm (continuously variable)
    Tilt: −5° ~ +45° (continuously variable)
    Rotation: 360° (continuously variable)
  - Specimen size: 50 mm dia. x 20 mm high (maximum) through specimen airlock device
  - Specimen stubs: 36 mm dia., 25 mm dia., 15 mm dia.
  - Specimen exchange: Airlock/prepumping system
- Display system
  - Viewing CRT: 9" (Effective field 150 x 135 mm) x 2 sets
  - Recording CRT: Ultra high resolution type (Effective field 120 x 90 mm) x 1 set
  - Scanning speed: 0.04, 0.5, 1.5, 10(9), 40(35) sec/frame for viewing
    40(35)*, 80(100)*, 200, 400 sec/frame for photo recording
  - Scanning mode: Full frame rapid* scan, reduced area rapid scan, slow scan, photo scan, line set, line analysis, spot position, analytical area finder, dual mag/split screen, dynamic focus, waveform monitor, oblique
  - Signal processing/mode: Automatic image brightness & contrast, gamma control, polarity reverse/invert, dynamic stigmator monitor, super autofocus, automatic data display
  - Electrical image shift: ±20 μm (at V_0 = 30 kV, WD = 30 mm)
  - Data recording: Film number, accelerating voltage, micron bar with scale and magnification
  - Image presentation: Secondary electron, x-ray* and back scattered* electron (via POST HV off) images
- Vacuum system
  - Vacuum sequence: Full automatic with pneumatic valving system
  - Ultimate vacuum: 1×10^{-7} Pa (electron gun), $2 \times 10^{-6} \sim 7 \times 10^{-5}$ Pa (1st and 2nd intermediate chamber), 7×10^{-4} Pa or better (specimen chamber)
  - Vacuum pumps: DP (570 l/sec) x 1, RP (140(168)* l/min) x 2, IP x 3
    *at 60 Hz
  - Air compressor: 1 set
  - Pumping time for specimen exchange: About 3 minutes
- Safety device
  Instrument is protected for power, water and vacuum failures
- Dimensions & weight:
  - Column: 740 (width) x 880 (depth) x 1,500 (height) mm, 295 kg
  - Display: 1,100 x 900 x 1,180 mm, 235 kg
  - Ion pump power supply: 600 x 550 x 400 mm, 75 kg
- Standard components

Column	1
Display	1
Ion pump power supply	1
Rotary pump	2
Air compressor	1
Auto transformer	1
Standard tool	1
Spare/expendables	1
Instruction manual	1

Optional Accessories

1. Specimen stages	Cryogenic system Specimen tensile stage IC stage
2. Signal detectors	Hi-pass back scattered electron detector Transmitted electron detector
3. Display modules	Data entry keyboard Raster rotation/Dynamic focus/ Tilt compensation unit Video signal amplifier TV scan unit Dual photomultiplier power supply
4. Others	Turbo molecular pump system Vacuum evaporator with gimbal system Critical point dryer Image processor

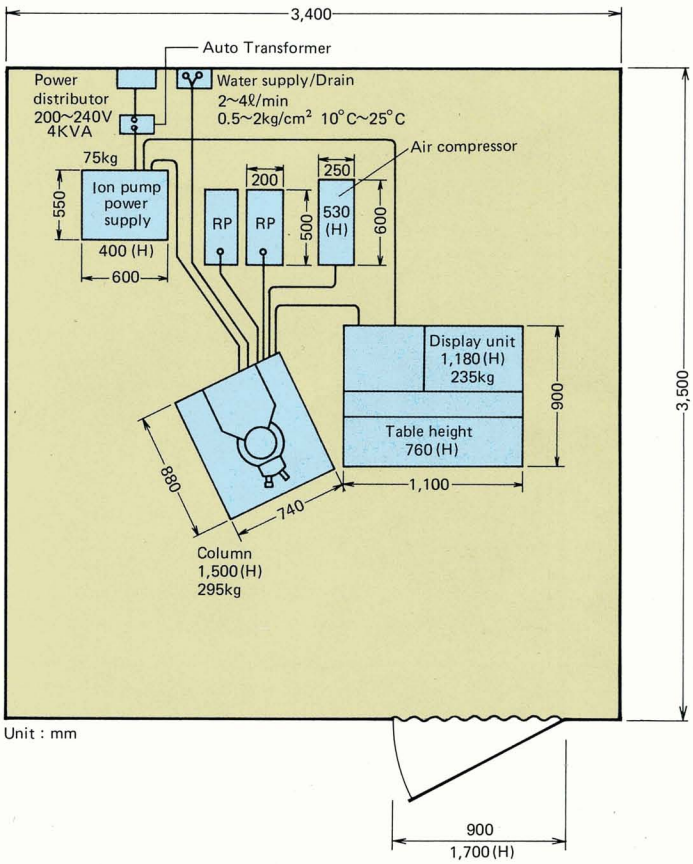
Installation

Ambient conditions:
- Temperature: 15°~25°C (59°~77°F)
- Humidity: 60% or less RH

Power: 200~240V (4 kVA)
*Continuous pumping down is required for Ion Pump

Ground terminal: Less than 100Ω x 1
(100 ohms or less) x 1

Cooling water:
- Flow: 1~1.5l/min
- Pressure: 0.5~1 kg/cm²
- Temperature: 10~20°C
- Quality: Normal city water
  (Use filter if too much deposit included)
- Tap: Water facucet 10 mm dia.
- Drain: Natural drain on the floor level



Unit : mm

[Example]
Expanded SEM system

EDX S-800 Image processor

Hitachi, Ltd. Tokyo Japan

For further information, please contact your nearest sales representative.

(Alteration reserved.)

Catalog No. EX-E591Q Printed in Japan YN-TH(H)