High Power Optics

JSM-7001F/JSM-7001FA

Thermal FE SEM

JEOL

Serving Advanced Technology

JSM-7001F/JSM-7001FA

Thermal Field Emission Scanning Electron Microscope

High Performance SEM for Nanoscience

Observation of nanomaterials

- Stable high-magnification observation by the highly stable specimen stage.
- STEM* (Scanning Transmission Electron Microscope) observation of thin-film specimens.

Large specimen chamber for a variety of applications

- 5-axis computer controlled specimen stage.

Newly developed operation monitor for accommodating many functions

- Simultaneous display and acquisition of four live images.
- User login automatically sets the conditions you used last time.
- Eco design reduces the power consumption down to 2 kVA during operation.

* : Option

JSM-7001F Basic system

High Power Optics

Analysis of nano structures

- Analysis volume down to a few tens of nm with high probe current at low voltages achieved by the aperture angle optimizing lens.
- EDS**(Energy Dispersive X-ray Spectrometer) high-speed elemental analysis with high probe current.
- WDS*(Wavelength Dispersive X-ray Spectrometer) trace elemental analysis with a large probe current of 200 nA.
- LV SEM* (Low vacuum SEM) for analysis of non-conductive specimens.

General-purpose objective lens with no leakage of a magnetic field around the specimen

- Any specimen, such as magnetic materials, can be observed.
- EBSD*(Electron Back Scatter Diffraction) characterization with high accuracy.

High performance maintained for a long time

- Clean specimen environment maintained by the specimen exchange airlock chamber.
- Long-life electron gun for reduced maintenance works.

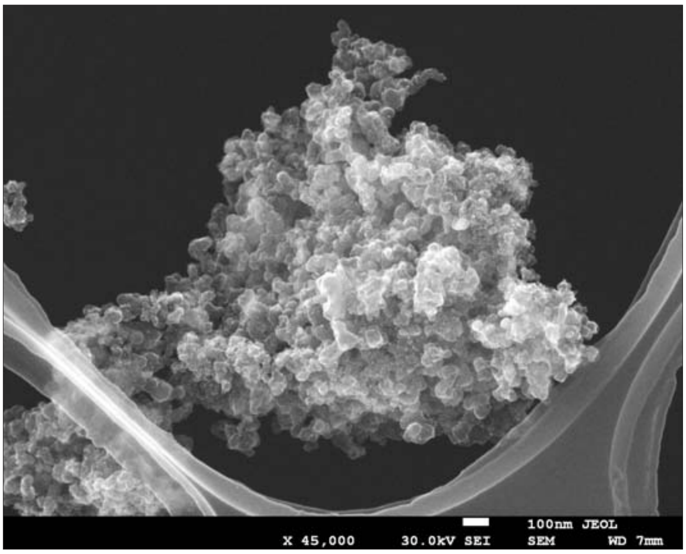
** : Built into the JSM-7001FA

JSM-7001FA EDS embeded system

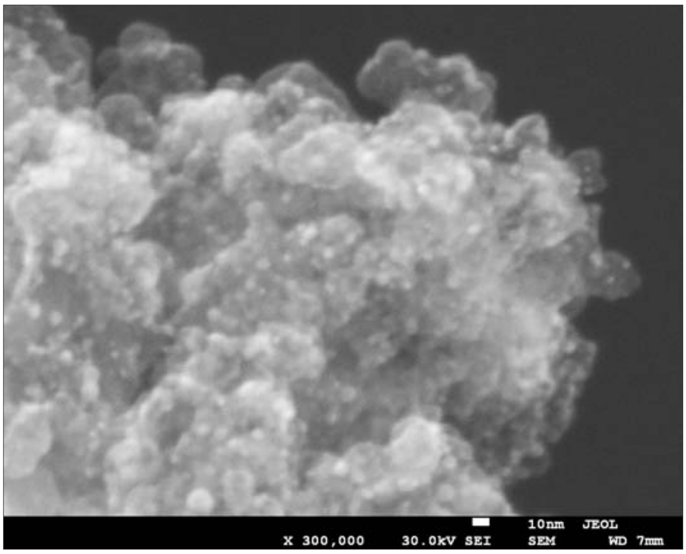
Observation of Nanomaterials

The High Power Optics developed for nanostructure characterization provides the guaranteed resolution of 1.2 nm, making routine observation at magnifications higher than ×100,000 possible. Low electron beam energy can be used for observation of fine surface structures. The optimum probe current is continuously variable. The optimum probe current can be set for non-conductive specimens or specimens susceptible to heat, making it possible to obtain high quality images.

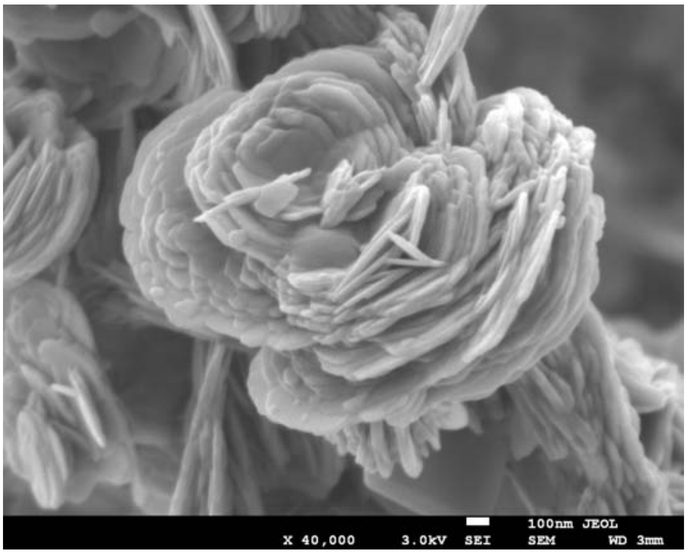
Observation of surface structures by secondary electron (SE) images



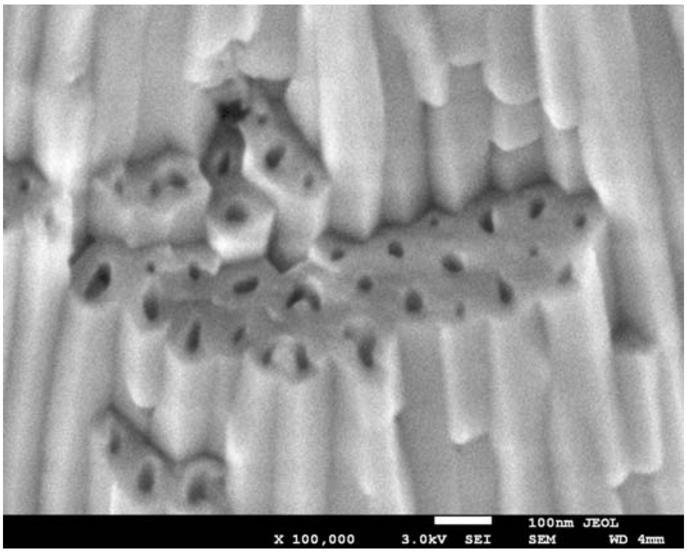
Catalyst SE image



Catalyst SE image



VPO catalyst SE image



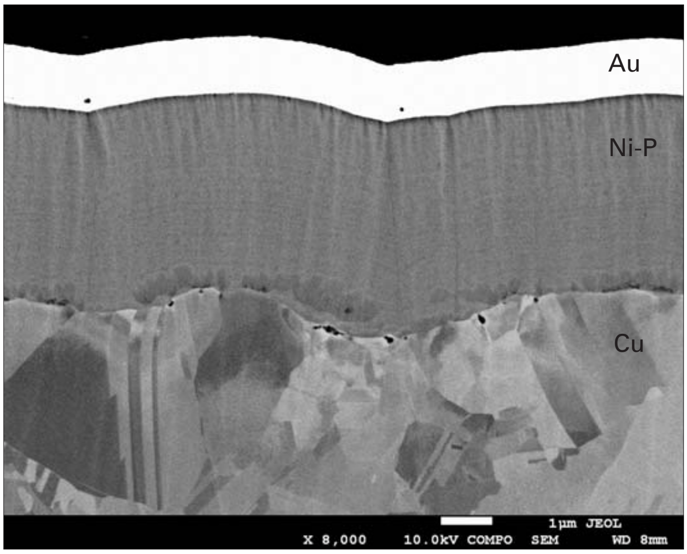
Anodized aluminum (no coating) SE image

Observation of compositional distribution by backscattered electron (BE) images

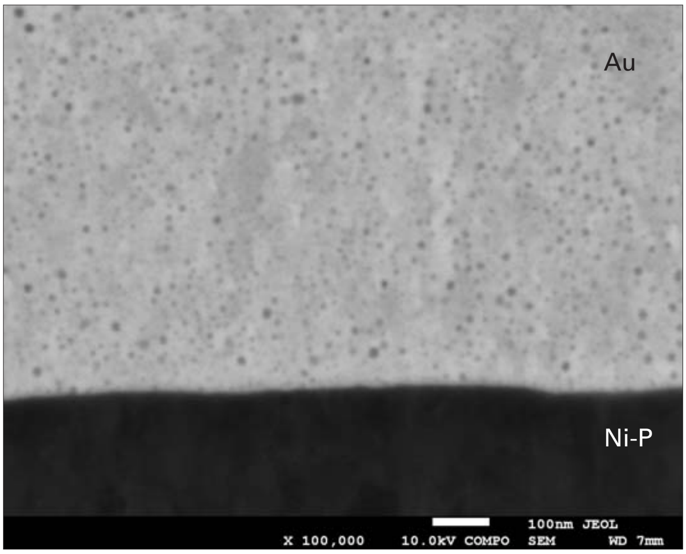
The backscattered electron detector* is used for surface observation by separating compositional contrast and topographic contrast. This detector is highly sensitive even at low electron energies and enables you to observe compositional images with a resolution similar to secondary electron images. Compositional images are useful for determining analysis points at elemental analysis, thus indispensable for nanostructure characterization. The Gentle Beam enables you to observe compositional distribution (BE image*) at the nanometer level.

The retractable BE detector is in.

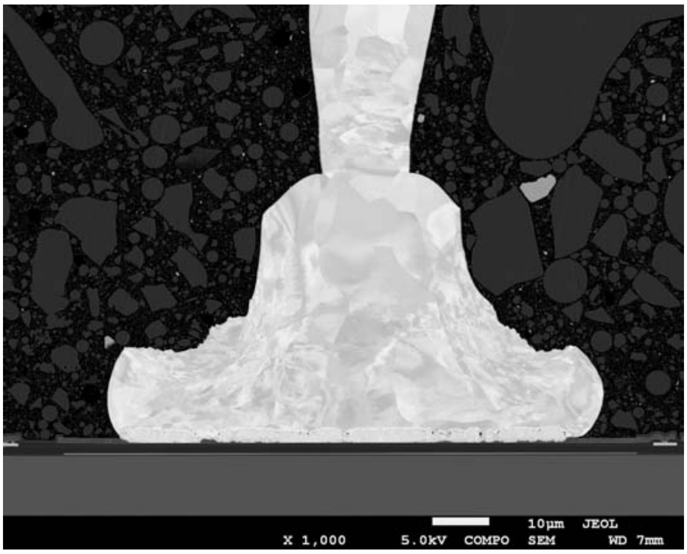
The semiconductor backscattered electron detector is inserted below the objective lens when it is used. To insert or retract the detector, click the RBEI on the SEM monitor. The safety mechanism for the stage movement is linked to the detector.



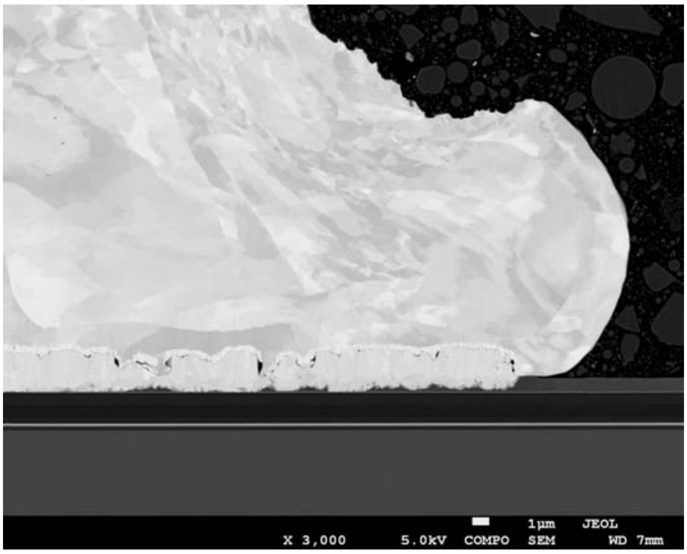
Cross section of card edge connector. BE image



Cross section of card edge connector, showing the distribution of nanodiamond grains in gold plating. BE image



Cross section of wire bonding (CP cross section). BE image



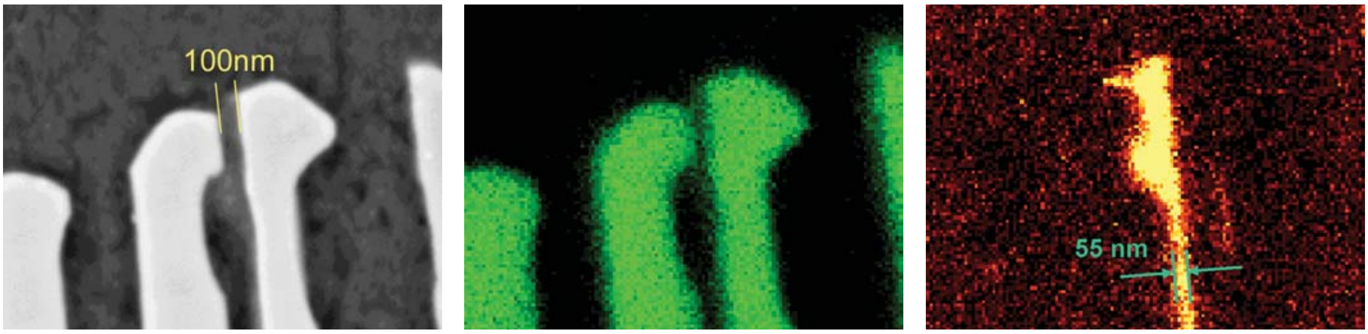
Cross section of wire bonding (CP cross section). BE image

Analysis of Nanomaterials

Nanovolume elemental analysis by EDS

The analysis volume for EDS is determined not only by the diameter of the incident electron probe but also by the electron scattering range inside a specimen. The lower the electron energy, the smaller the scattering range. The High Power Optics on JSM-7001F produces a small electron probe for characterization of nanostructures even at low electron energies. This design makes it possible to analyze a volume as small as a few tens of nm.

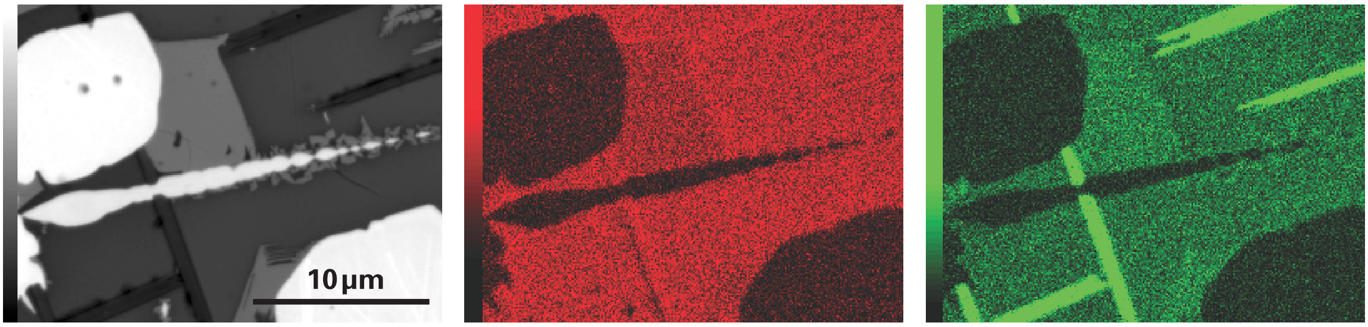
The JEOL EDS is built into the JSM-7001FA.
An EDS is optional for the JSM-7001F



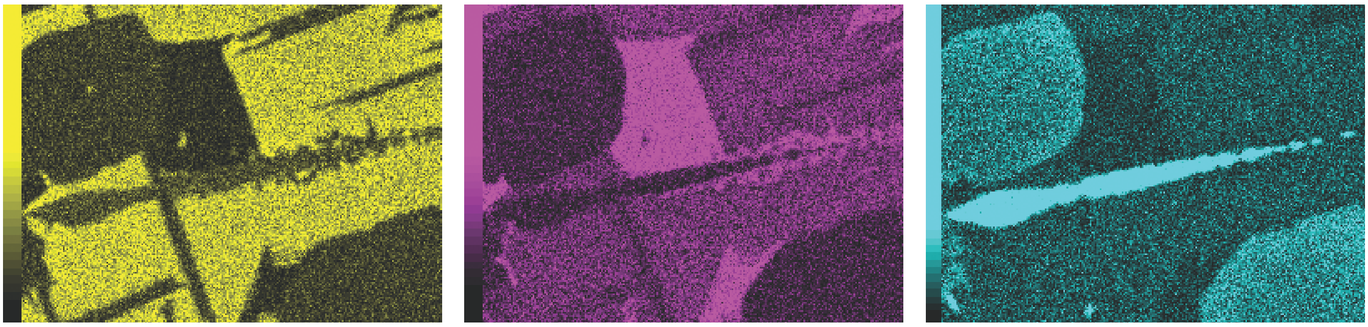
Backscattered electron image Al-alloy Cu mapping Si mapping

A 50nm volume can be analyzed with EDS by using low electron energies. 5kV, 2.5nA, original magnification ×50,000

The JSM-7001F can produce large probe current while maintaining a small diameter probe. The high count rate of the advanced EDS detector makes it possible to rapidly acquire elemental maps. For example, X-ray mapping with a large probe current of 100 nA provides high-quality data only in 1 minutes, with its quality equivalent to that obtained by spending 30 minutes to 1 hour with a conventional FE SEM.



Backscattered electron image O-Kα Al-Kα

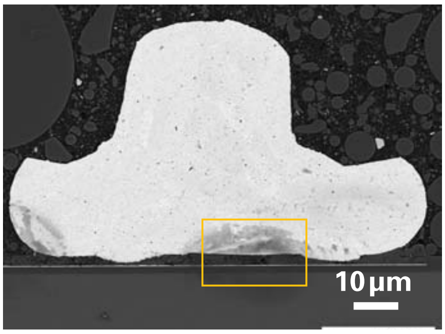


Si-Kα Fe-Lα Zi-Lα

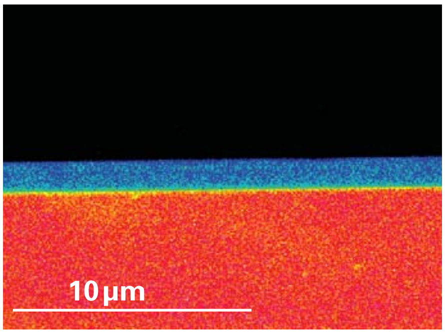
High speed elemental maps acquired with the Mini Cup Detector. Specimen : Crucible
Accelerating voltage : 5kV, Probe current :100nA, Acquisition : Live 50 seconds

Nanovolume elemental analysis by WDS*

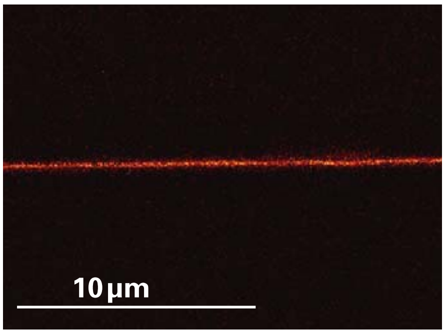
The wavelength dispersive X-ray spectrometer (WDS) can analyze trace elements. With its higher energy resolution, WDS can also separate peaks of elements close to each other, which is difficult by EDS. Furthermore, the High Power Optics of the JSM-7001F makes it possible to perform WDS analysis for a volume as small as 100 nm, which was not achieved by a conventional EPMA.



Cross section of gold wire bonding.



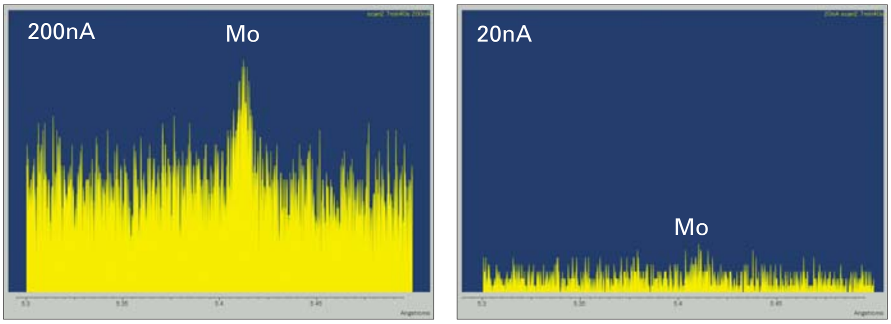
Si-Kα map obtained with WDS.



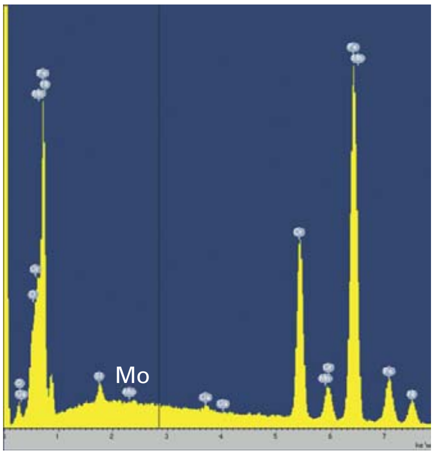
W-Mα obtained with WDS (barrier metal layer)

Trace element analysis by WDS*

For trace element analysis by WDS, a probe current larger than 100 nA is required. With 20 nA probe current, the detection sensitivity of WDS is degraded to that of EDS. Thus, to exploit the advantage of WDS, the High Power Optics of the JSM-7001F is essential.



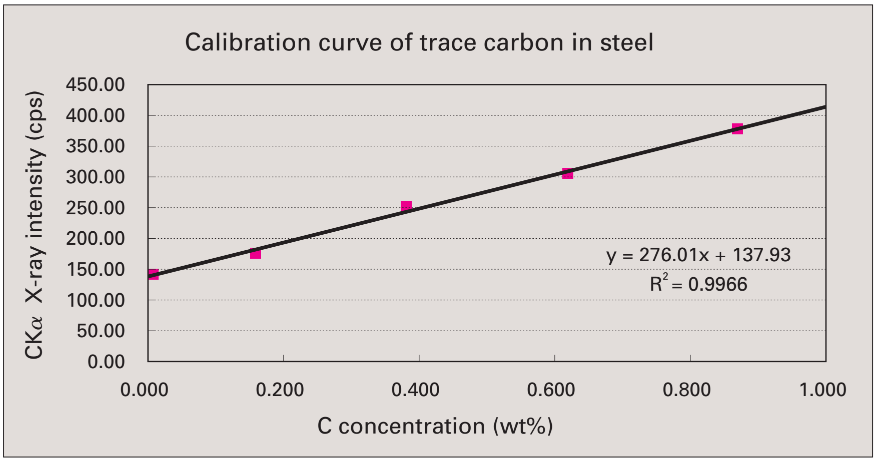
Comparison of WDS spectra obtained with 200 nA and 20 nA at 15 kV.
Specimen: 0.2% molybdenum in stainless steel, Acquisition time : 7 min per spectrum.



EDS spectrum.

Carbon analysis in steel by WDS*

The figure at the right shows an example of analysis of carbon steel by WDS. Quantitative analysis can be performed using a calibration curve.

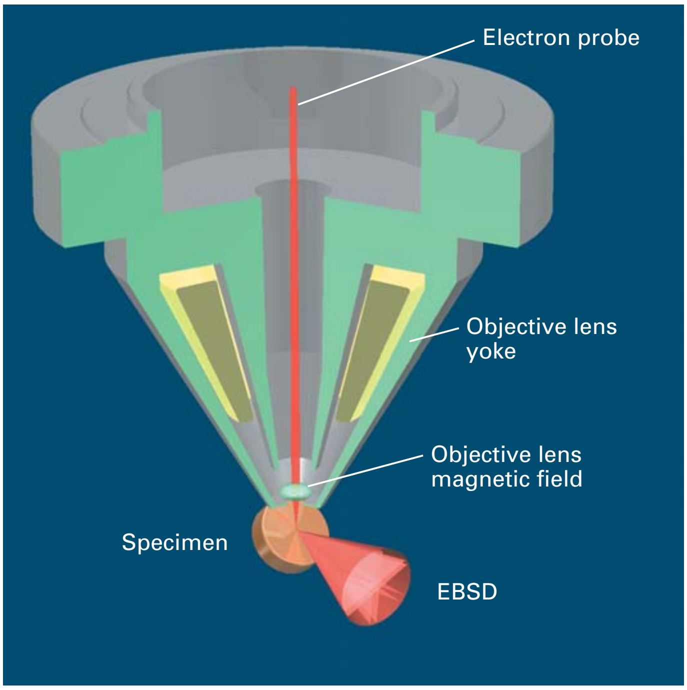


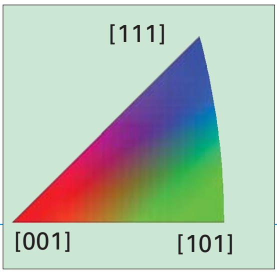
Calibration curve of carbon steel.

Characterization of Nanomaterials

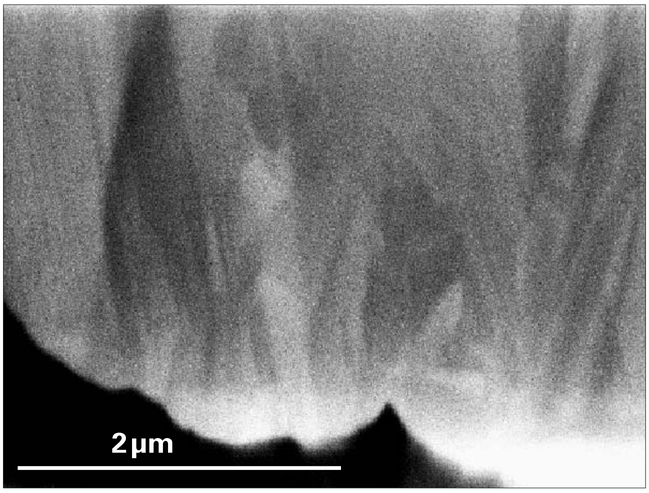
Analysis of nanomaterials by EBSD

The in-lens thermal FEG (field emission electron gun) produces a stable probe current over a long period of time. The general-purpose objective lens of the JSM-7001F does not leak magnetic fields around the specimen, making it possible to detect distortion-free EBSD patterns. The high electron probe current at a small probe enables one to perform EBSD analysis with a spatial resolution down to a few tens of nm. The High Power Optics provides high-speed, high-accuracy EBSD characterization.

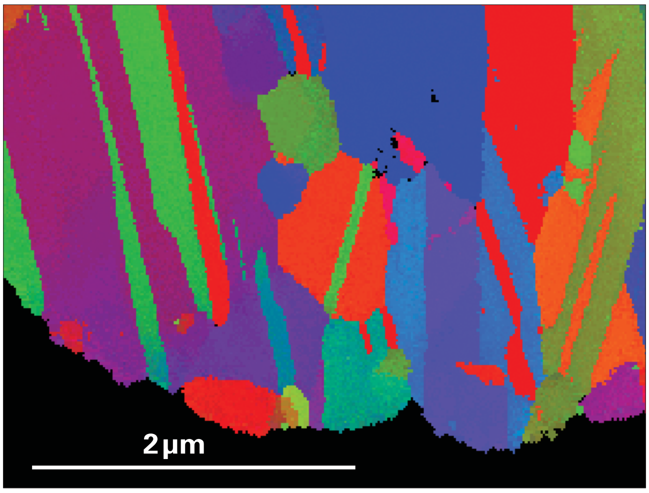




Specimen : Copper plating on
card edge connector
Accelerating voltage : 25kV
Probe current : 1.5nA
Original magnification : 20,000



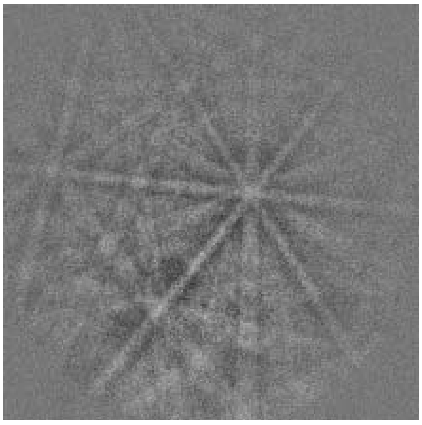
Backscattered electron image.



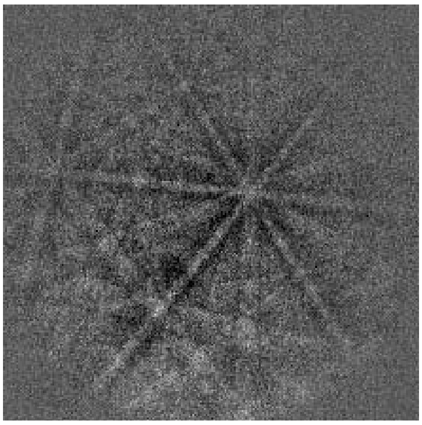
EBSD orientation map.

Is 1 nA sufficient for EBSD characterization?

A larger probe current improves the signal-to-noise ratio (S/N) of EBSD patterns. In order to shorten the acquisition time, it is important to obtain a good S/N on each analysis point by increasing the probe current. The High Power Optics of the JSM-7001F, which produces a large probe current even with a small probe, allows efficient EBSD characterization of nanostructures of the specimen.



5ms, 20nA

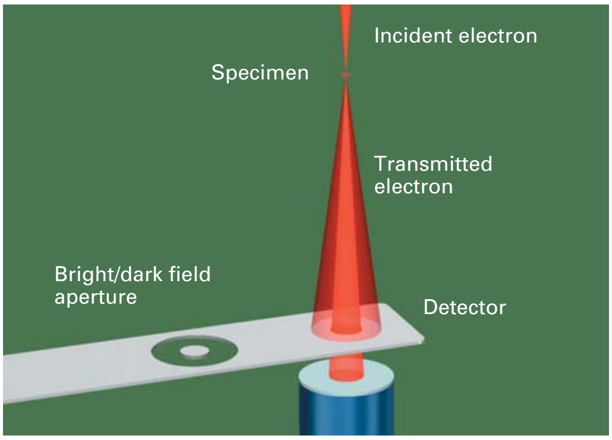


50ms, 1.3nA

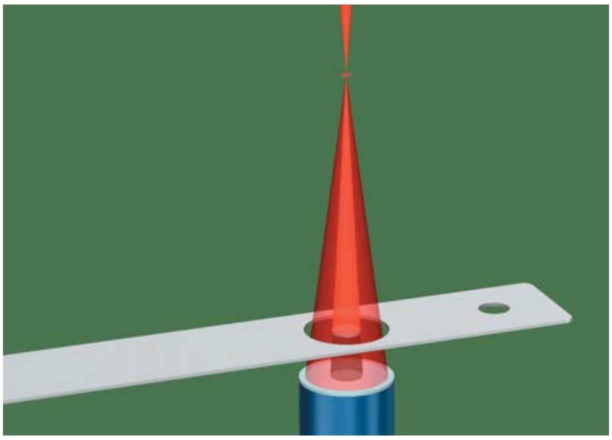
Observation and Analysis of Thin-Film Specimens by STEM

Scanning transmission electron detector (STEM)*

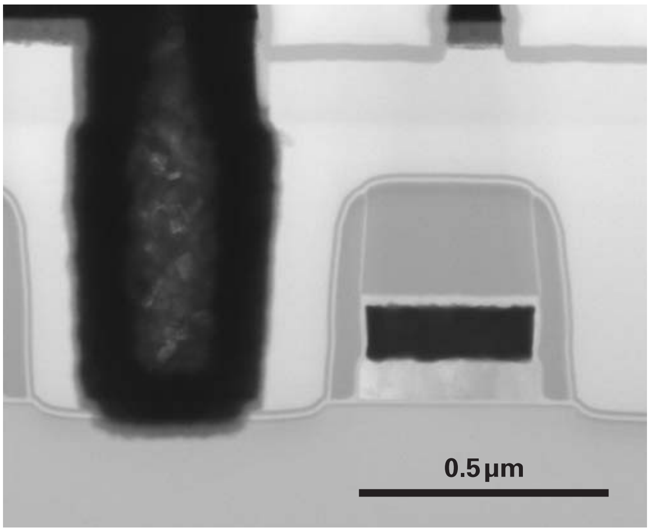
The STEM forms a scanning transmission image of a thin-film specimen. A STEM image is similar to one obtained with a TEM. This technique is useful for observation and analysis of thin-film specimens or ultra-fine particles. By placing a shutter between the specimen and the STEM detector, you can switch between a bright field image and dark field image.



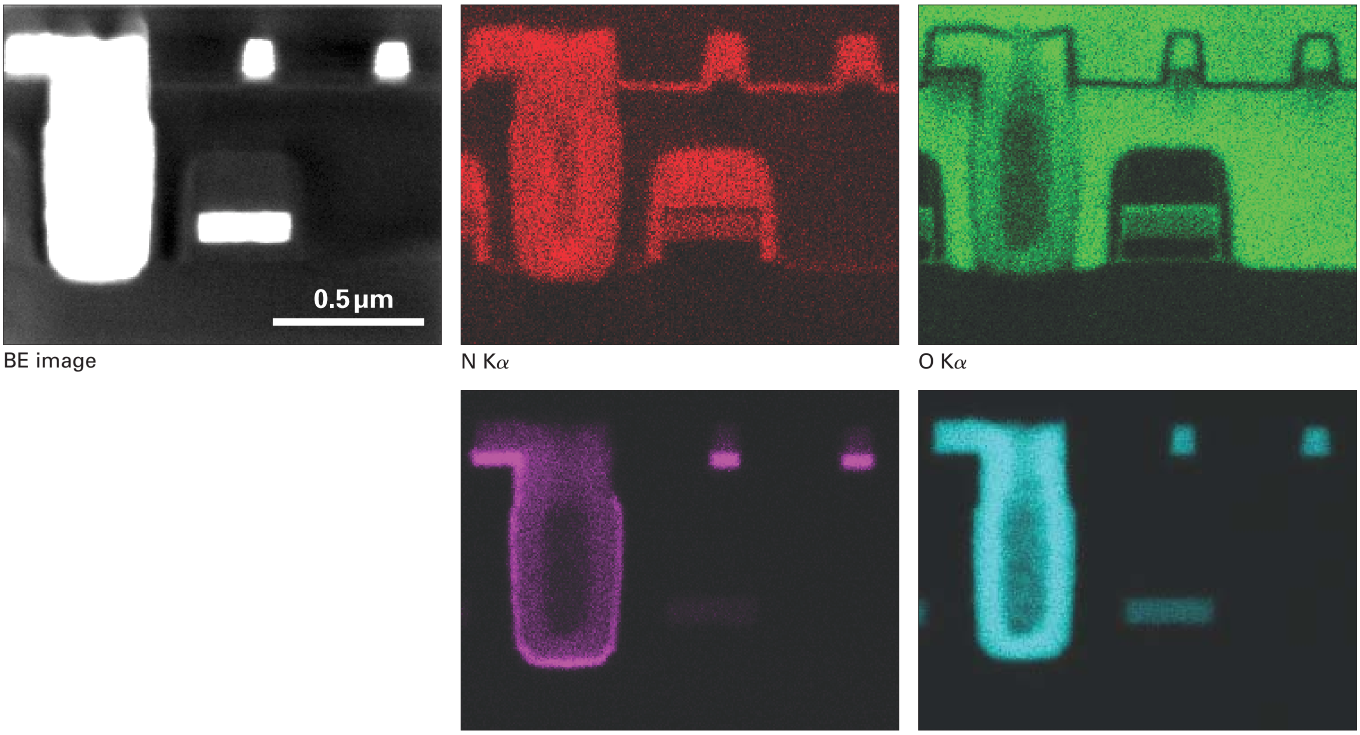
Bright field



Dark field



IC (bright field image)



BE image

N $K\alpha$

O $K\alpha$

Ti $K\alpha$

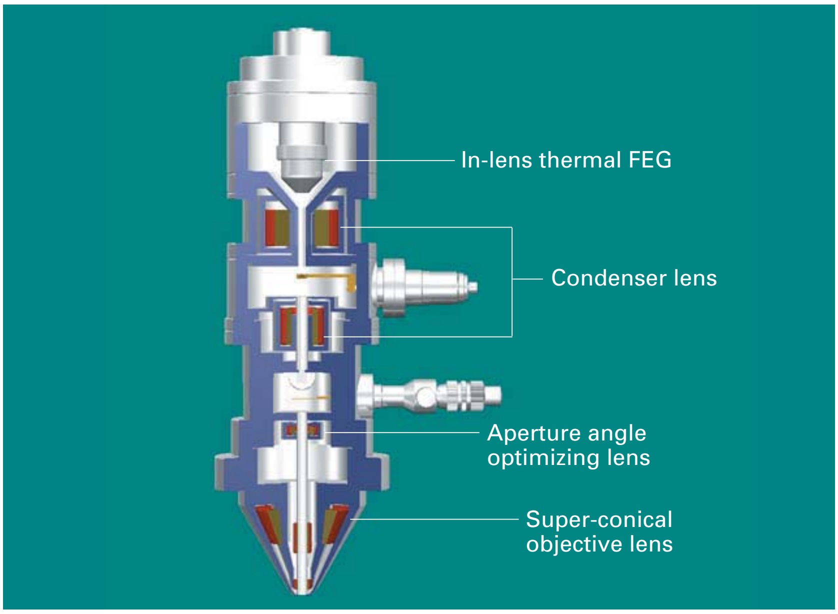
W $L\alpha$

DRAM (prepared by JEOL Ion Slicer).

30kV, 8nA

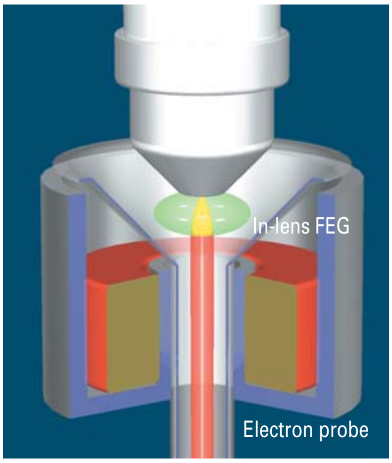
High Power Optics

The High Power Optics achieves both observation and analysis at high magnifications. This innovative optical system combines the in-lens thermal FEG (JEOL patent) capable of producing a probe current 10 times larger than conventional FE gun and the aperture angle optimizing lens that maintains a small probe diameter even at large probe current (JEOL patent). This breakthrough offers a probe current higher than 200 nA. The High Power Optics is suitable for a wide range of applications from high-magnification observation to EDS and EBSD characterization, with the smallest objective lens aperture for high resolution imaging. You do not need to switch the aperture.

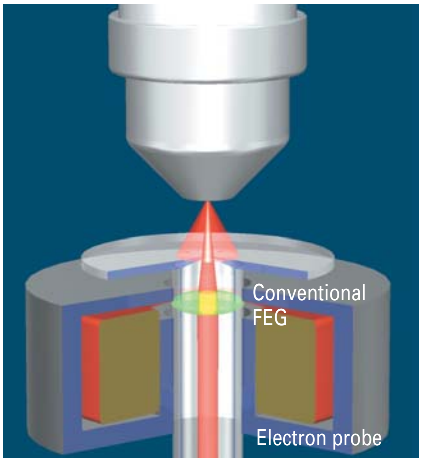


In-lens thermal FEG

The JSM-7001F with the new in-lens Thermal FEG can produce a probe current higher than 200nA at 15kV. This is ten times larger than that obtained with a conventional thermal FEG. The in-lens thermal FEG is a combination of a Schottky FEG and the first condenser lens and is designed to collect the electrons from the gun efficiently. A conventional FEG design utilizes only a small portion of electrons generated from an electron gun.



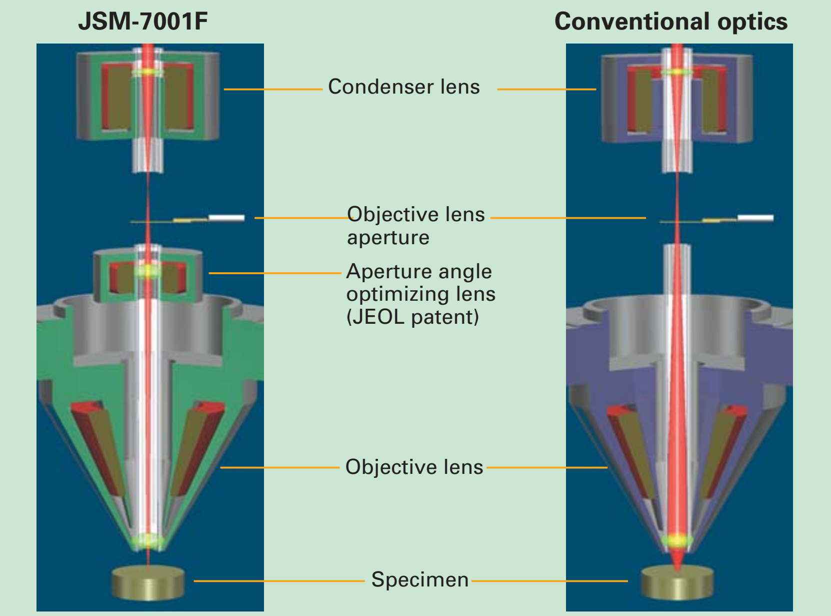
Unique in-lens thermal FEG on JSM-7001F.



Conventional FEG and condenser lens design.

Aperture angle optimizing lens

The aperture angle optimizing lens is placed above the objective lens and automatically optimizes the aperture angle of the objective lens for the entire range of probe current. With the help of this fully automated lens, the probe diameter stays small even at very large probe current.

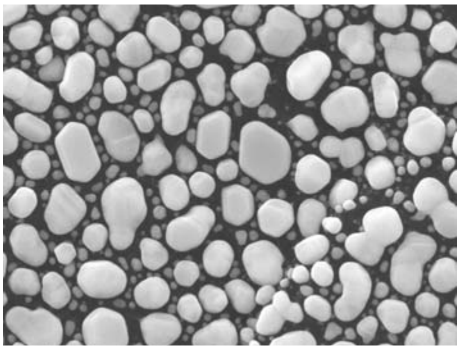


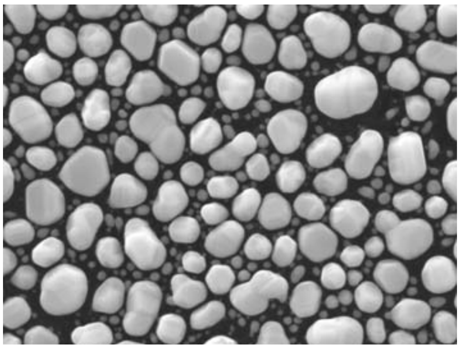
Large probe current with a small probe size obtained with the aperture angle optimizing lens.

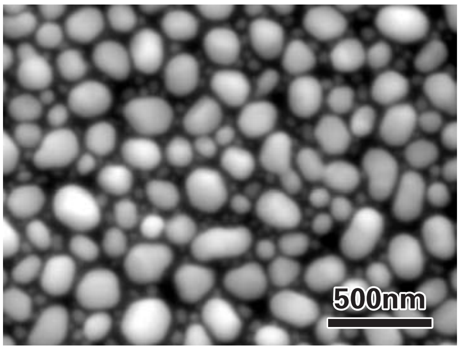
Without an aperture angle optimizing lens, the probe size becomes larger with large probe current.

Small probe diameter even at large probe current

The JSM-7001F with the in-lens thermal FEG can produce a probe current larger than 200 nA at 15 kV. This is 10 times larger than that obtained with a conventional design. The in-lens thermal FEG is a combination of a Schottky FEG and the low-aberration condenser lens, and is designed to collect electrons from the gun efficiently.


Probe current : 50pA


Probe current : 500pA



Probe current : 200nA

Improved resolution at high probe current

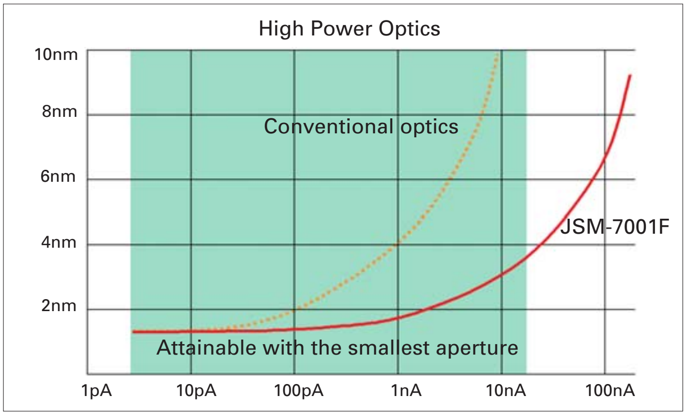
You can reduce the charging effect on a non-conductive specimen by using a small probe current. A small probe current is also required for a specimen susceptible to heat. Alternatively, a large probe current is essential for rapid elemental or EBSD analysis. In quantitative analysis, it is important to use the same large probe current anytime. The JSM-7001F enables you to continuously control the probe current by the condenser lens. Furthermore, you do not have to change the objective lens aperture except during applications such as WDS, which require high probe current. The High Power Optics minimizes user adjustments to ensure consistent high quality imaging and analysis of nanostructures.

High stability for a long period of time

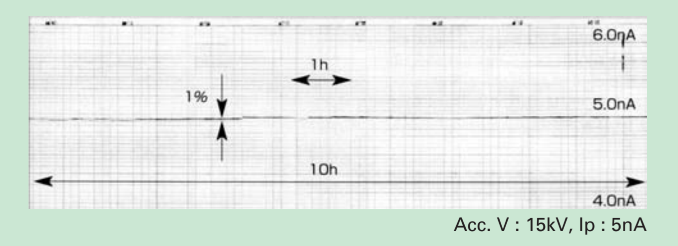
It is indispensable to have a stable electron probe and a stable specimen stage for acquisition of reliable analysis data. The JSM-7001F produces stable probe current over a long period of time. The specimen exchange airlock chamber minimizes diffusion of gas molecules into the gun chamber, making it possible to produce a stable electron probe in a short time after a specimen exchange.

Probe current detector*

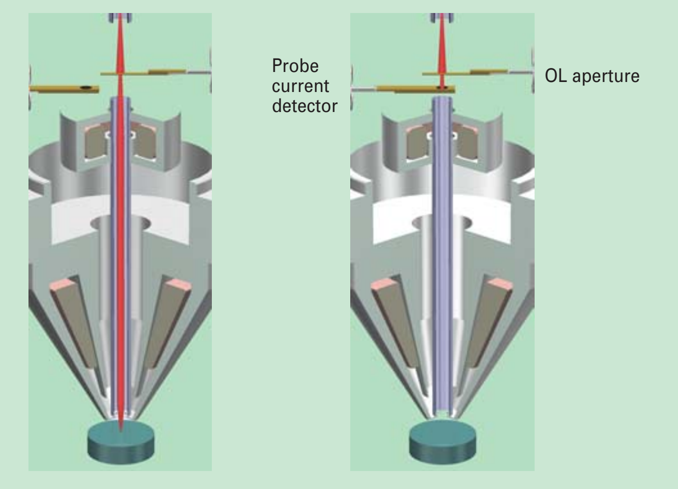
The probe current detector is inserted into the electron path just below the objective lens aperture to monitor the probe current anytime during analysis.



Resolution vs. probe current
(Up to 20nA is obtained with the smallest aperture)



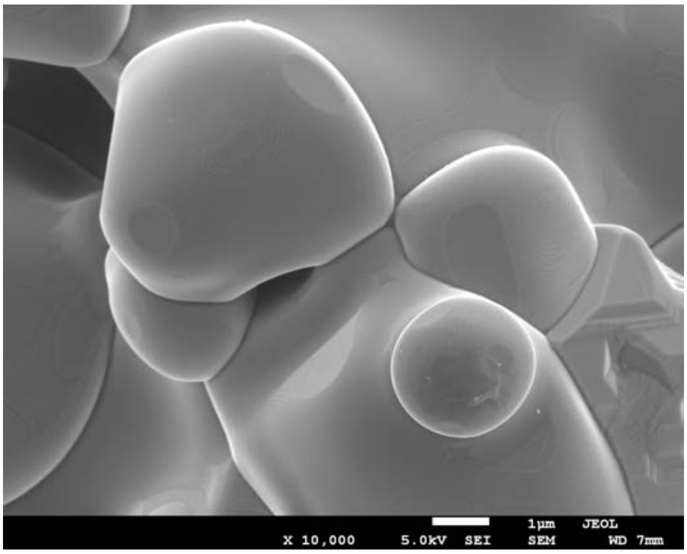
Probe current stability.



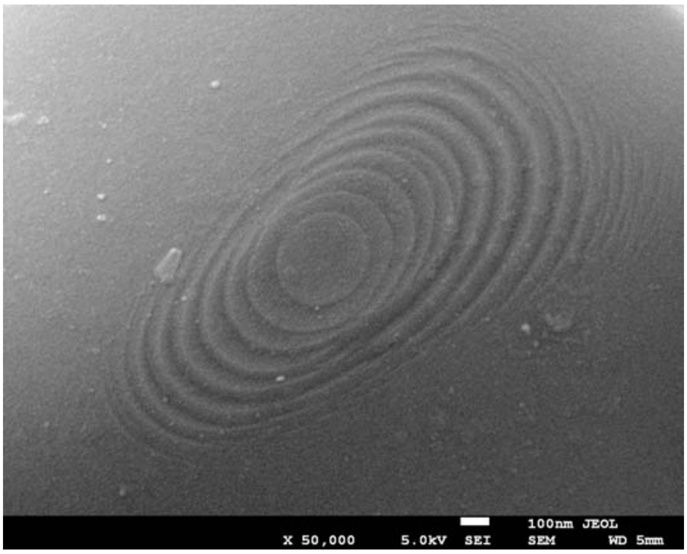
Left : During observation of image.
Right : During measurement of probe current.

Objective lens

The super conical objective lens provides high resolution: 1.2 nm at 30 kV and 3.0 nm at 1 kV. This lens is also suitable for a wide range of analytical applications while not degrading a high resolution. 3 nm at 15 kV is guaranteed with a probe current of 5 nA, which is large enough to efficiently perform analysis. The magnetic field of the lens is confined within the lens yoke so that it does not interfere with EBSD analysis or observation of large magnetic specimens.



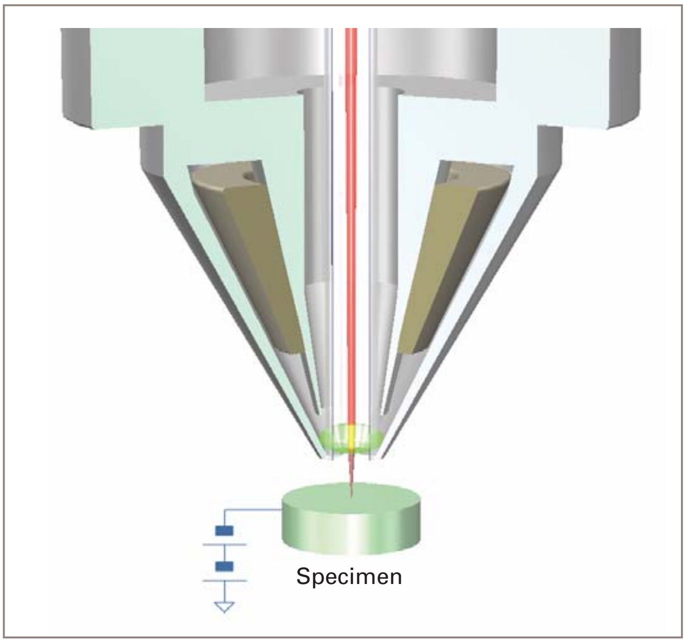
Ferrite SE image

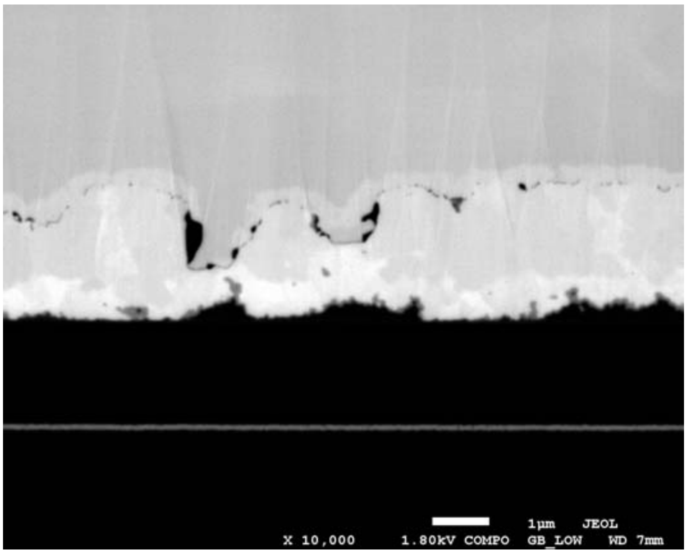


Ferrite SE image

Gentle Beam

The Gentle Beam (GB) decelerates incident electrons just before they hit a specimen to reduce the charging of non-conductive specimens, and to enhance image quality of backscattered electrons at low electron beam energies.

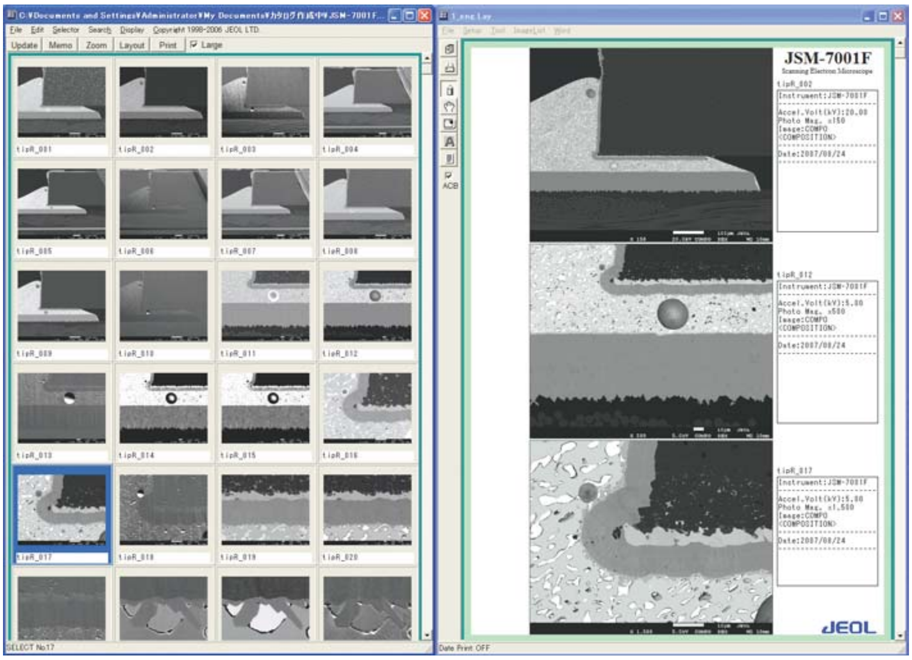




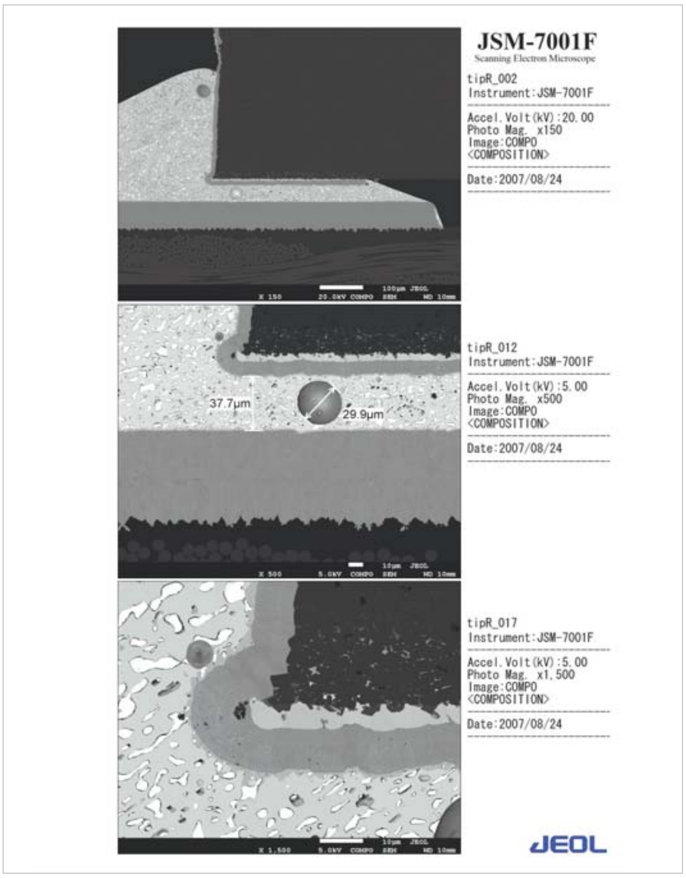
Gold wire bonded interface BE image

Report Editing

The JSM-7001F is provided with Smile View that is a report creation software program developed to make data presentation more versatile. A report can be created by simply pasting stored images on the report layout sheet built into this software. The software allows for flexible layout. The size and the pasted position of images are automatically adjusted. The micron bar on the image is automatically calibrated so that it is displayed with the appropriate size on the image. In addition, the indicated magnification, and the brightness and the contrast of the images are optimized automatically.



Smile View.



JSM-7001F
Scanning Electron Microscope

tipR_002
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Photo Mag. x150
Image:COMPO
<COMPOSITION>
Date:2007/08/24

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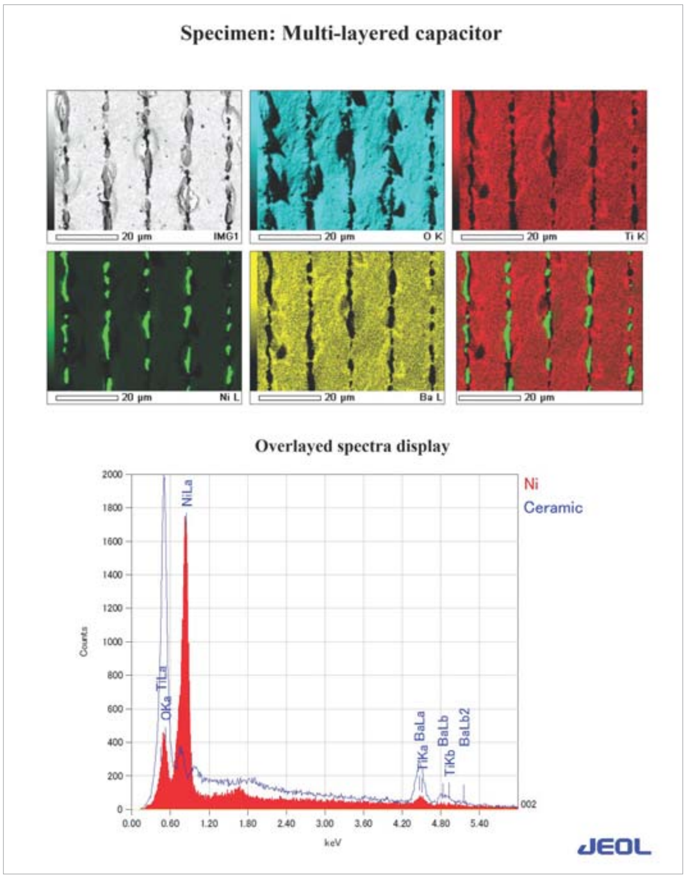
Date:2007/08/24

Smile View layout with measurement.



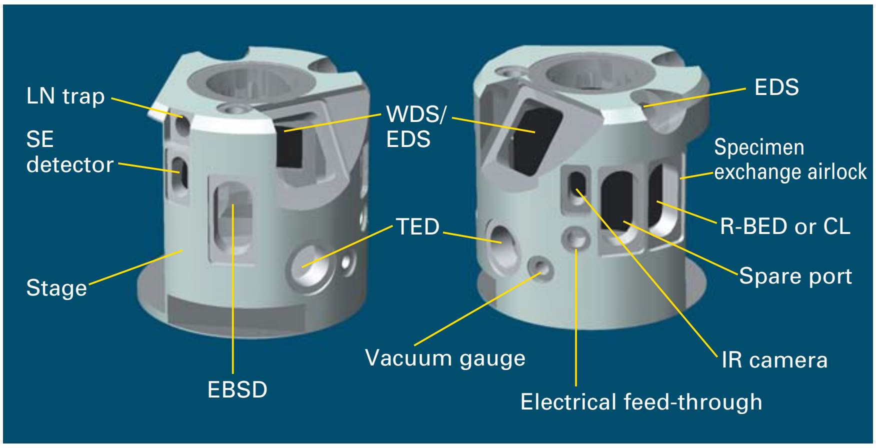
Specimen: Multi-layered capacitor

Overlayed spectra display

Smile View layout of EDS analysis results.

Specimen Chamber Optimized for Analysis

The specimen chamber is optimized for a large variety of detectors including the secondary electron detector, backscattered electron detector, EDS, WDS, EBSD, cathodoluminescence detector, and an IR camera. The secondary electron detector, EDS, and EBSD are all mounted on the same side of the specimen chamber. Stage tilt is perpendicular to the EBSD detector for simultaneous imaging and analysis on a tilted specimen surface.
The specimen chamber is always kept at high vacuum, minimizing specimen contamination.



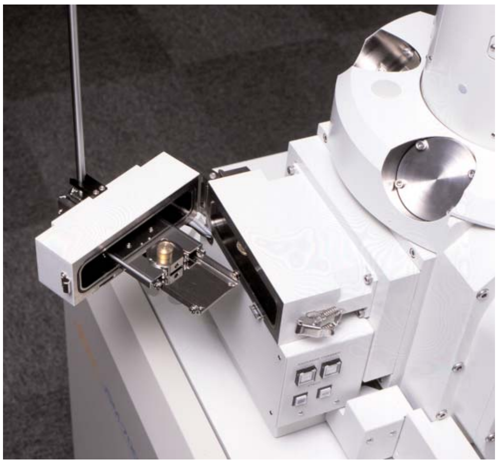
Versatile multi-purpose specimen chamber.

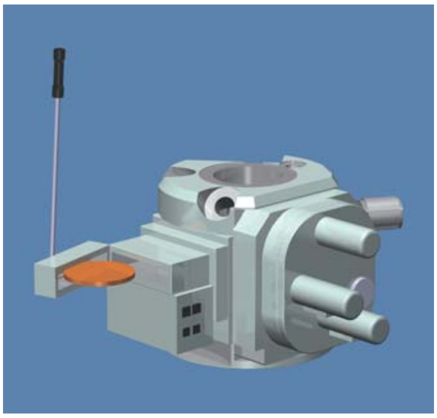
One-action specimen exchange chamber

The specimen chamber, electron optics, and electron gun chamber are kept at clean, high vacuum, even during specimen exchange. A specimen is introduced into the specimen chamber through an airlock chamber. Thus, specimen contamination is reduced, and high performance is maintained for a long period of time. The emission current from the FEG is quickly stabilized after a specimen exchange.

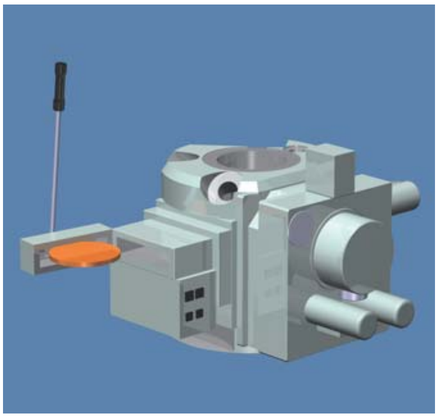
Stage Exchange	Type I stage X=70mm, Y=50mm	Type II stage X=110mm, Y=80mm	Type III stage X=140mm, Y=80mm
Type I airlock Max. 150mm	86mmφ coverage	150mmφ coverage	–
Type II airlock Max. 100mm × 40mmH	86mmφ coverage	100mmφ coverage	–
Auto airlock Max. 200mm	86mmφ coverage	150mmφ coverage	200mmφ coverage

Coverage indicated above is achieved with X-Y and rotation.

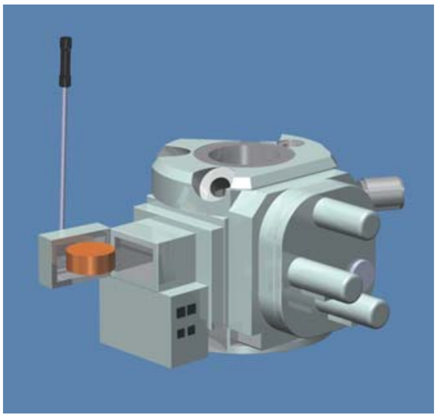




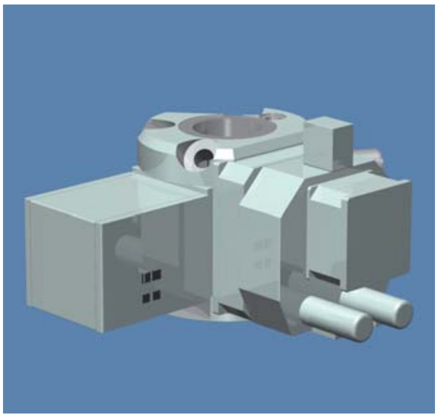
Type I stage and type I airlock



Type II stage and type I airlock



Type I stage and type II airlock



Type III stage and auto airlock

Computer Controlled Large Eucentric Specimen Stage

The JSM-7001F is equipped with a large eucentric specimen stage that has minimum focus change during X and Y movements, tilting and rotation of the specimen. A variety of software is provided for enhancing the efficiency of operation, which is useful for observation and analysis.

Computer control

The eucentric specimen stage is motor-driven and computer controlled for all five axes. The observation point is displayed on the stage map in real time.

Stage map

Stage map graphically displays the specimen position. The specimen can be moved by clicking or dragging the mouse on the graphic display.

Track ball

The track ball can move the specimen in the X and Y directions.

Click center

A click on a live image moves the clicked point to the center of the image.

Mouse drag

The field of view at high magnifications can be adjusted by dragging the mouse on a live image.

Navigator

Navigator is used to specify the location where to move the specimen stage and to move the stage.

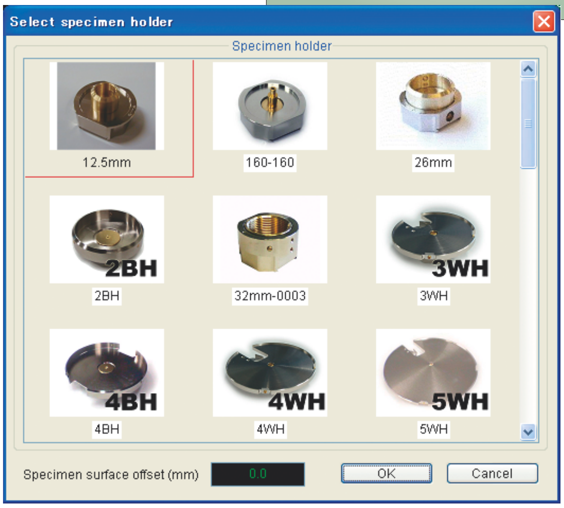
Step control

The specimen stage is moved at an interval which is specified by a user.

Eucentric rotation

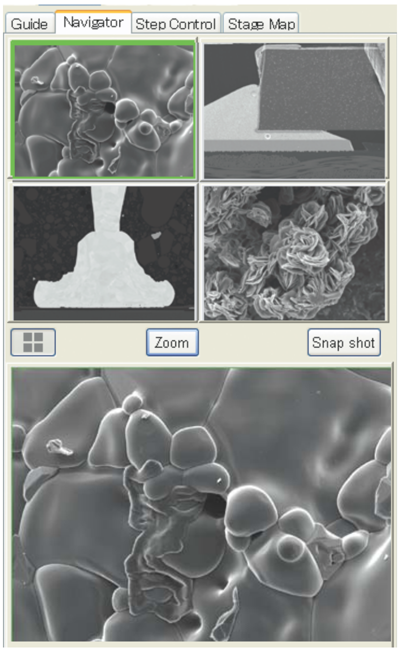
The specimen stage can be rotated around a presently observed area.

Stage movement buttons and track ball.

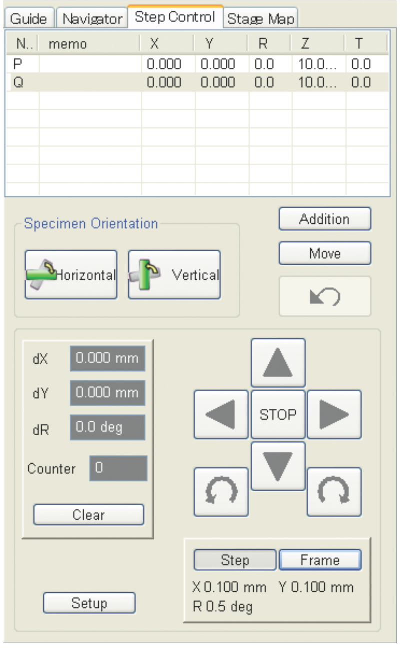


Specimen surface offset (mm) 0.0

The holder selecting window.



Navigator

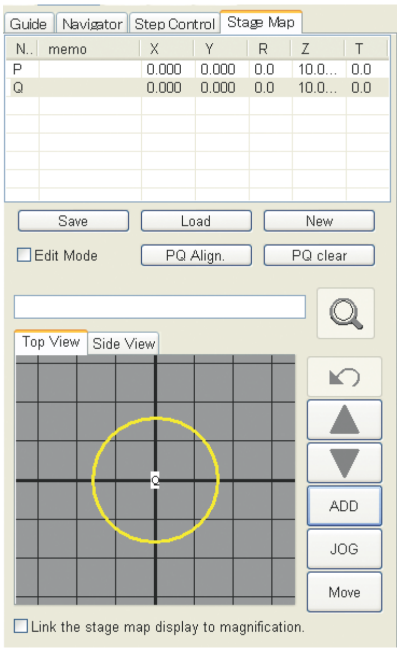


N..	memo	X	Y	R	Z	T
P		0.000	0.000	0.0	10.0...	0.0
Q		0.000	0.000	0.0	10.0...	0.0

dX 0.000 mm
dY 0.000 mm
dR 0.0 deg
Counter 0

X 0.100 mm Y 0.100 mm
R 0.5 deg

Step control



N..	memo	X	Y	R	Z	T
P		0.000	0.000	0.0	10.0...	0.0
Q		0.000	0.000	0.0	10.0...	0.0

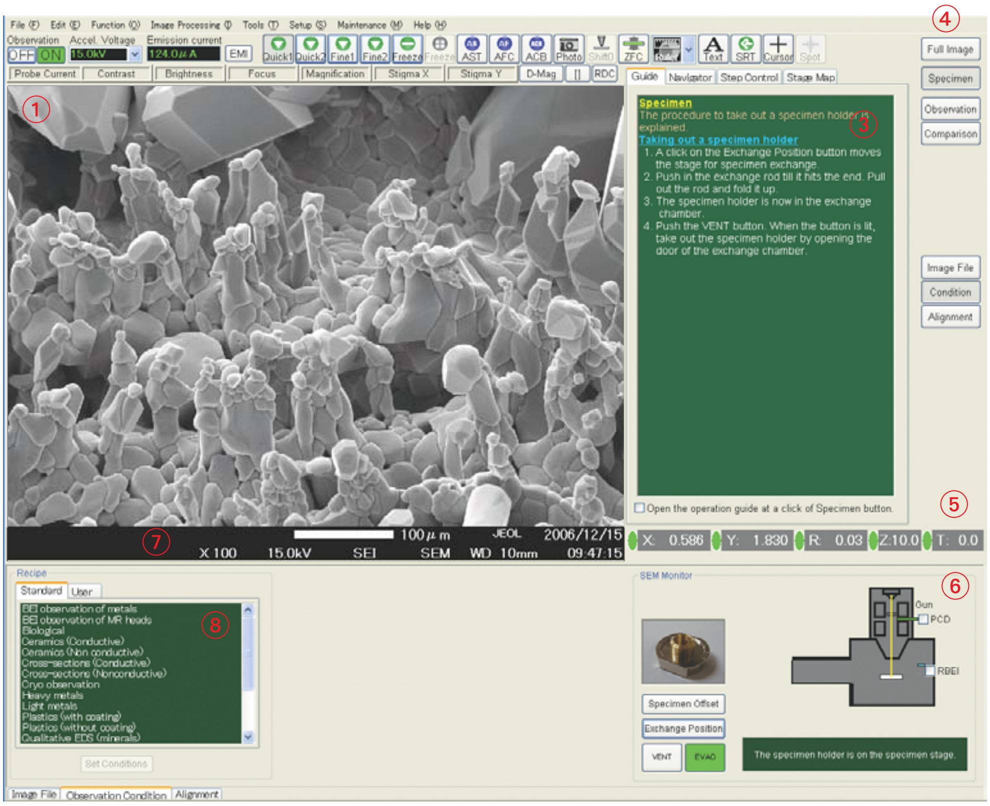
☐ Edit Mode

☐ Link the stage map display to magnification.

Stage map

Operation Menu to Facilitate Versatile Functio

To facilitate the versatile functions from observation to analysis, the function switching buttons are provided. By fixing the size and position of the default window, you can easily operate all of the functions.



Specimen

The procedure to take out a specimen holder is explained.

Taking out a specimen holder

1. A click on the Exchange Position button moves the stage for specimen exchange.
2. Push in the exchange rod till it hits the end. Pull out the rod and fold it up.
3. The specimen holder is now in the exchange chamber.
4. Push the VENT button. When the button is lit, take out the specimen holder by opening the door of the exchange chamber.

☐ Open the operation guide at a click of Specimen button.

BEI observation of metals
BEI observation of MR heads
Biological
Ceramics (Conductive)
Ceramics (Non conductive)
Cross-sections (Conductive)
Cross-sections (Nonconductive)
Cryo observation
Heavy metals
Light metals
Plastics (with coating)
Plastics (without coating)
Qualitative EDS (minerals)

The specimen holder is on the specimen stage.

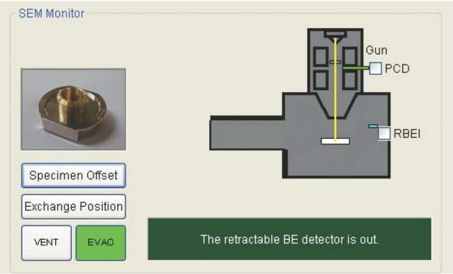
① Live image
② Manual operation
③ Operation guide and specimen stage operation
④ Function switching
⑤ Specimen stage coordinate
⑥ SEM Monitor (displays the specimen holder to use, and the status of specimen insertion and electron-probe illumination.)
⑦ Observation conditions
⑧ Observation condition recipe

SEM monitor

SEM Monitor displays the operation status of the specimen, electron probe, and detector. This monitor enables you to evacuate the specimen exchange airlock chamber and select the specimen holder to use.

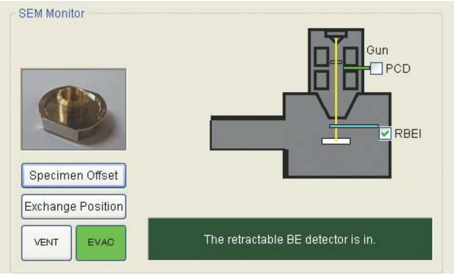
The retractable BE detector is out.

Specimen inserted.



The retractable BE detector is out.

Electron probe ON.



The retractable BE detector is in.

BE detector inserted.

Observation condition recipe

The standard observation condition recipe file is provided for typical specimens, making it easier to initially set the observation or analysis conditions of a new specimen. This recipe enables you to save and repeatedly use the customized operation conditions optimized for various specimens. You can quickly switch between the observation and analysis conditions.

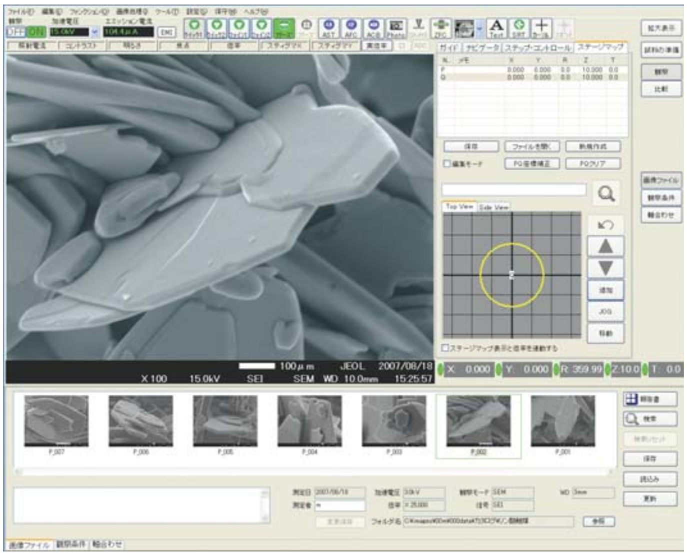
Operation panel

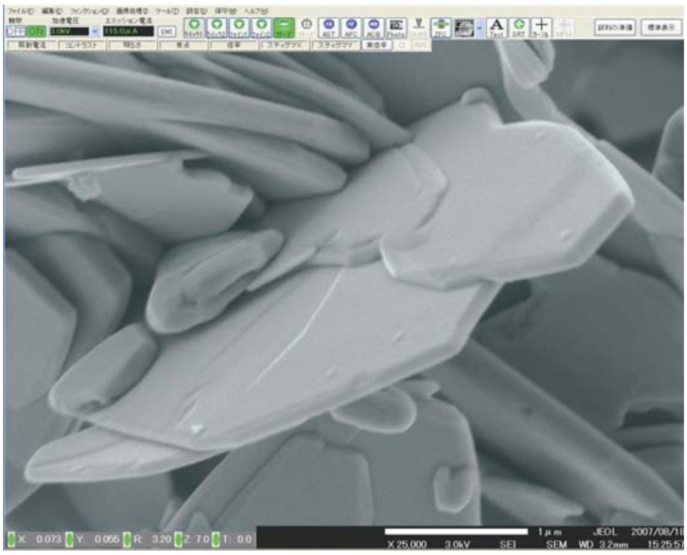
You can operate all operations of the JSM-7001F with a mouse. The operation panel is also provided with knobs for certain operations. The operation knobs are suitable for users who want analog operation, for example, magnification adjustment and focusing. The combined use of the mouse and knobs is also available.

ns

Observation mode

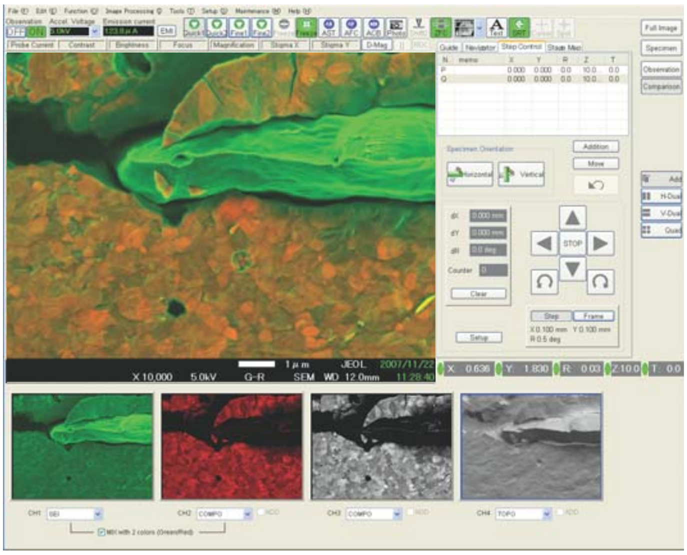
Live and saved images are displayed. You can select a saved image and move the specimen stage to the location of the image. Clicking the Report button enables you to paste saved images on the layout sheet and to create a report in a short time.

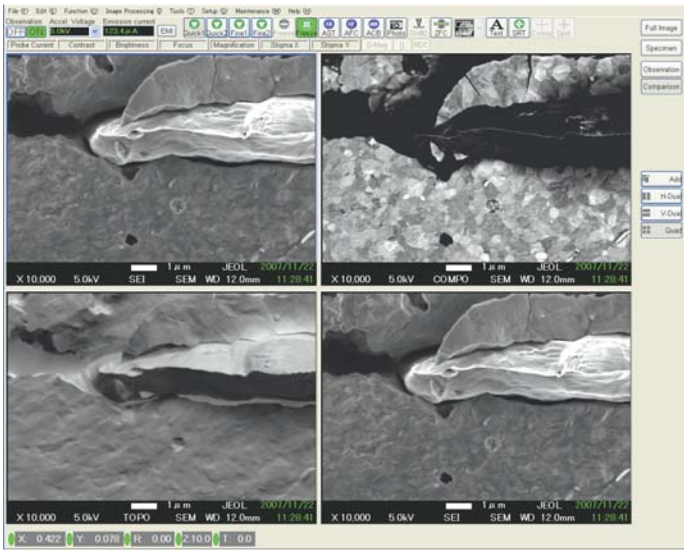

Observation.


Enlarged live image display.

Comparison mode

Up to four live images can be displayed simultaneously for comparative observation. Up to four images can be added and displayed as live images. In addition, two kinds of images, for example, SE and BE images, can be mixed with a coloring of blue and red and displayed as a live image. Multiple images can be recorded with one scan.

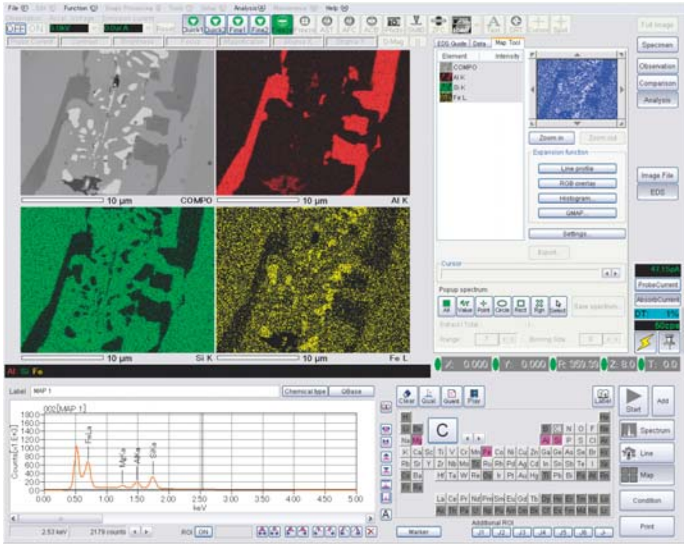

Setting of adding images


Simultaneous display of four images

Widening the Application Fields

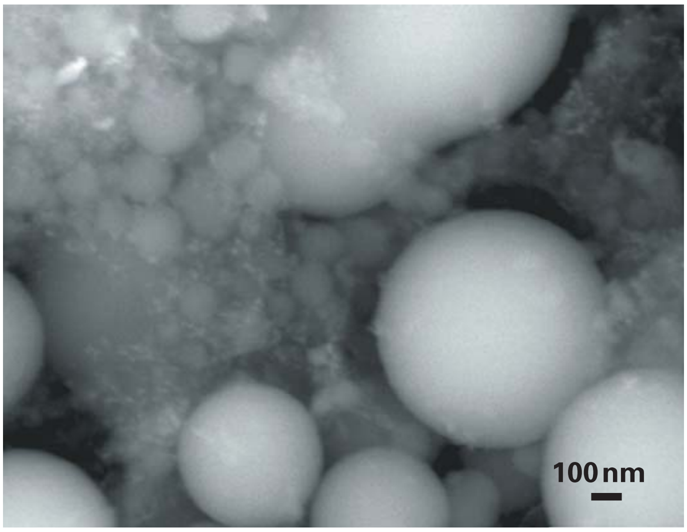
Elemental analysis mode

An EDS developed by JEOL is built into the JSM-7001F. Selecting the elemental analysis mode simultaneously displays the SEM image and EDS analysis menu. Selecting an area of interest on the SEM image starts acquisition of qualitative and quantitative analyses of this area. The results of these analyses are saved with the SEM images of the analysis areas, and the indication of "Analysis" is added to the thumbnail display of the corresponding saved images. The JSM-7001F can be combined with various EDS analyzers.



LV SEM for observation and analysis of non-conductive specimens

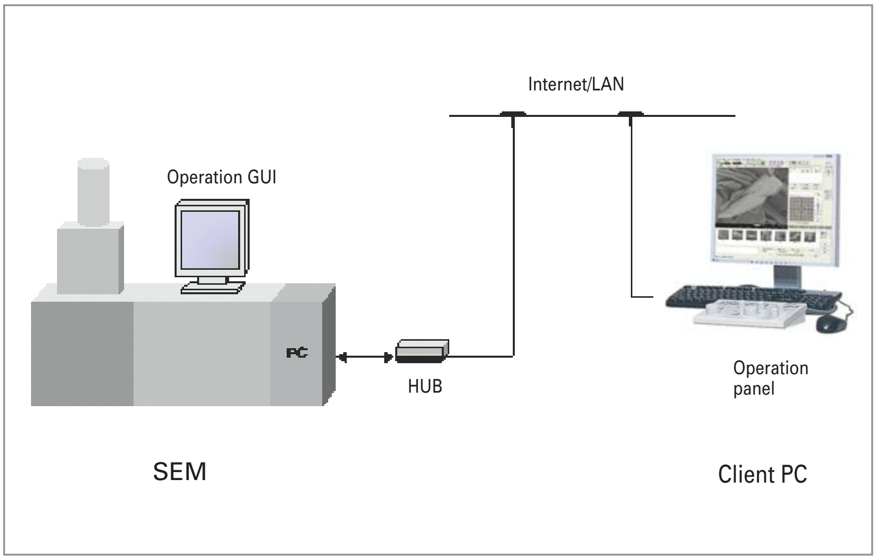
The LV SEM enables you to observe non-conductive specimens at high electron energies required for elemental analysis. Although incident electrons are slightly scattered due to the low vacuum, EDS elemental analysis can be performed without conductive coating. To minimize the contamination inside the lens caused by the low vacuum, dry nitrogen gas is introduced into the specimen chamber.



Spherical particles in mold resin (no coating) observed in LV mode. 15kV

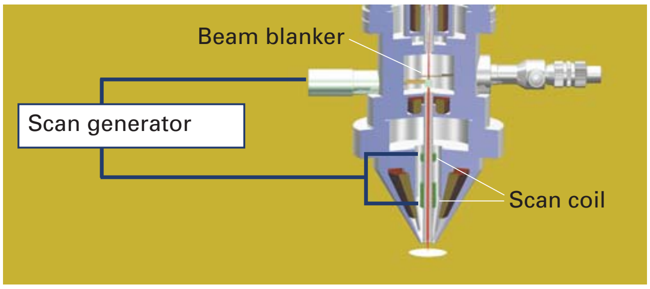
Remote control of SEM*

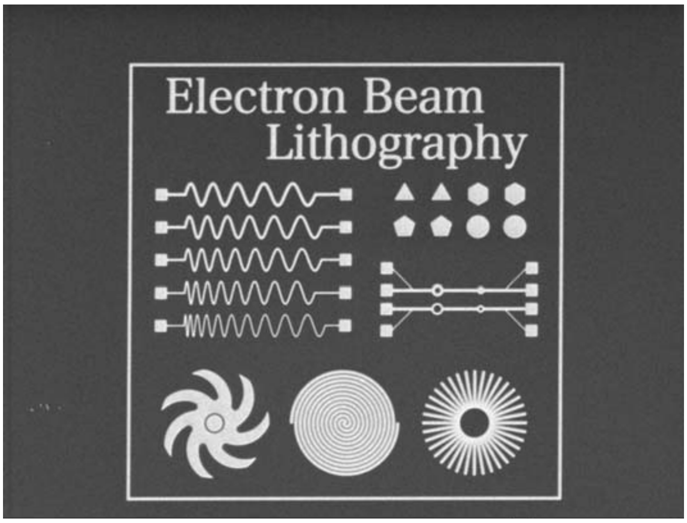
You can operate JSM-7001F from a remote PC through the internet or LAN. You use a mouse on the JSM-7001F operation menu displayed on a remote Windows PC. The specimen stage is controlled by a mouse click on the SEM image as well as the stage control functions, that is, navigator, step control, and stage map.



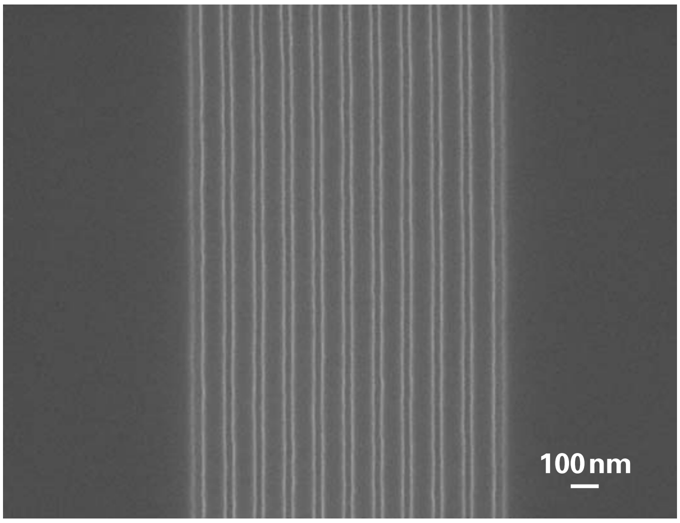
Electron beam lithography*

The JSM-7001F has a unique electron optics, which maintains a small probe diameter even with a large probe current. This is desirable for electron beam lithography. JSM-7001F is capable of drawing a very fine pattern with the addition of an electron beam blanking device* and a pattern generator*. Electron dosage (electron probe current) can be controlled continuously with the condenser lens, thus, an optimum exposure condition can be selected.





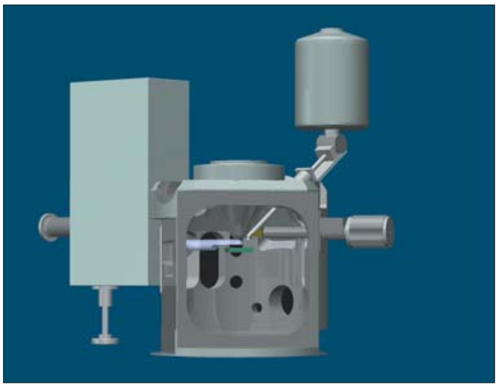
Test patterns



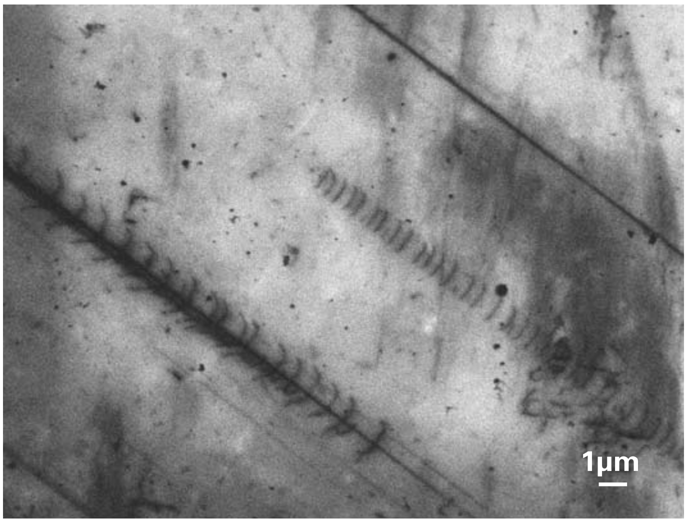
Line and space

Cathodoluminescence (CL)*

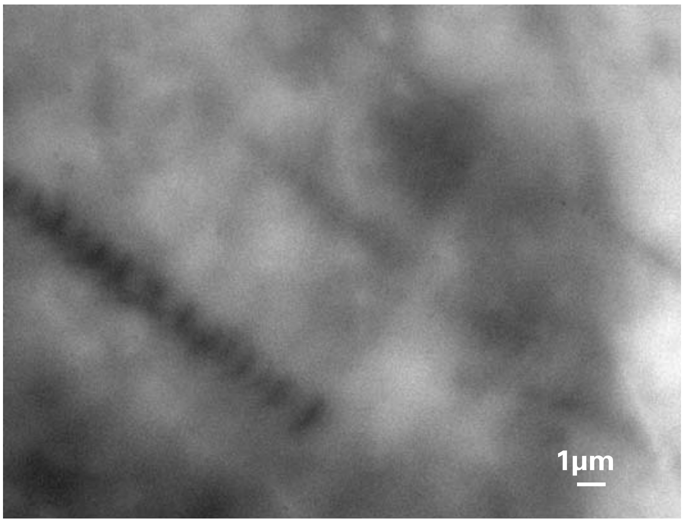
CL analysis determines the local condition of electrons, which is not attainable with a secondary electron image. A lower accelerating voltage improves spatial resolution of the CL image.



GATAN CL unit



Diamond (CL image) 2kV



Diamond (CL image) 10kV

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