JEM-2100

Electron Microscope

JEOL

Serving Advanced Technology

Next-Generation TEM with Excellent Operability and Expandability

The transmission electron microscope (TEM) is an essential tool in all fields of scientific research including semiconductor development, biology and materials science. The JEM-2100 has further advanced the industry-standard JEM-2010, which showed excellent performance in image quality and analytical capabilities among 200 kV high-resolution TEMs. A next-generation TEM, the JEM-2100 is designed for improvements in operability and mechanical stability of the instrument.
The JEM-2100 achieves instrument control by a Windows PC. In addition, it has increased its expandability. Various optional attachments, such as a STEM image observation device and an energy dispersive X-ray spectrometer (EDS), can be easily added to the microscope.

High-brightness electron gun
A Lab_6 electron gun, which has high brightness and high emission stability, is very effective for high-sensitivity analysis of a microarea down to several nanometers, as well as for high-resolution imaging. When you observe materials susceptible to radiation damage by a highly accelerated electron beam, such as carbon nanotubes and polymer materials, you can easily select the optimum accelerating voltage according to materials.

Established electron optical system
The JEM-2100 incorporates a established electron optical system, providing a variety of objective-lens configurations (ultrahigh resolution, high resolution, high specimen tilt, cryo, high contrast).
This established electron optical system also includes a rotation- and distortion-free imaging system and an α selector function for the variation of the electron-beam illumination angles.

Digital STEM image observation device (option)
The optical conditions of the JEM-2100, such as probe diameter and camera length, are optimized for observations using the scanning modes (STEM-BF/DF/HAADF, BEI, SEI) and analyses (EDS, EELS). These optimized conditions are immediately retrieved through a GUI. In addition, connecting various analytical attachments to the JEM-2100 enables you to efficiently obtain STEM images and perform element analysis.

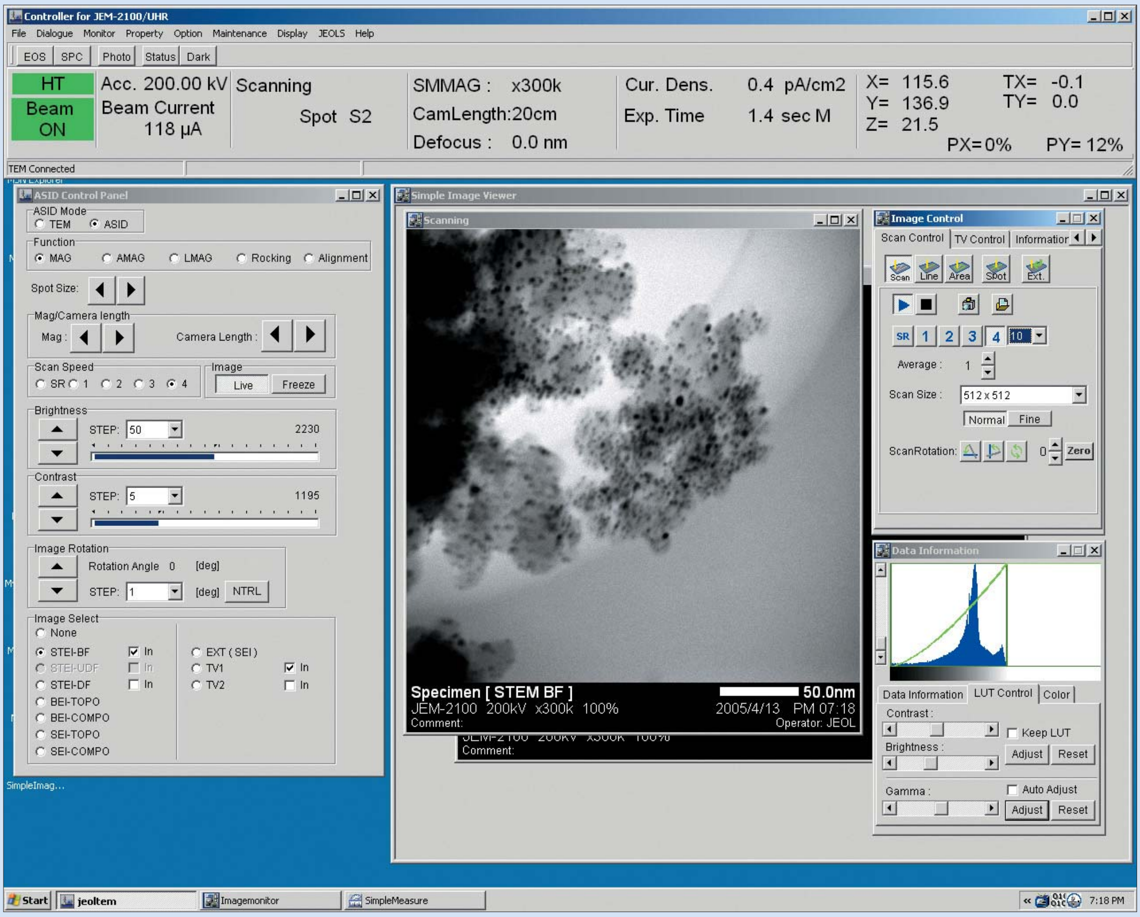
Piezo-controlled goniometer
A new goniometer stage that incorporates a piezo device offers smooth operation for selecting fields of view at the atomic level.

Newly designed base frame
The JEM-2100 uses a new base frame and a passive air mount, greatly improving the vibration-proof performance.

This photograph shows the JEM-2100 provided with optional attachments.

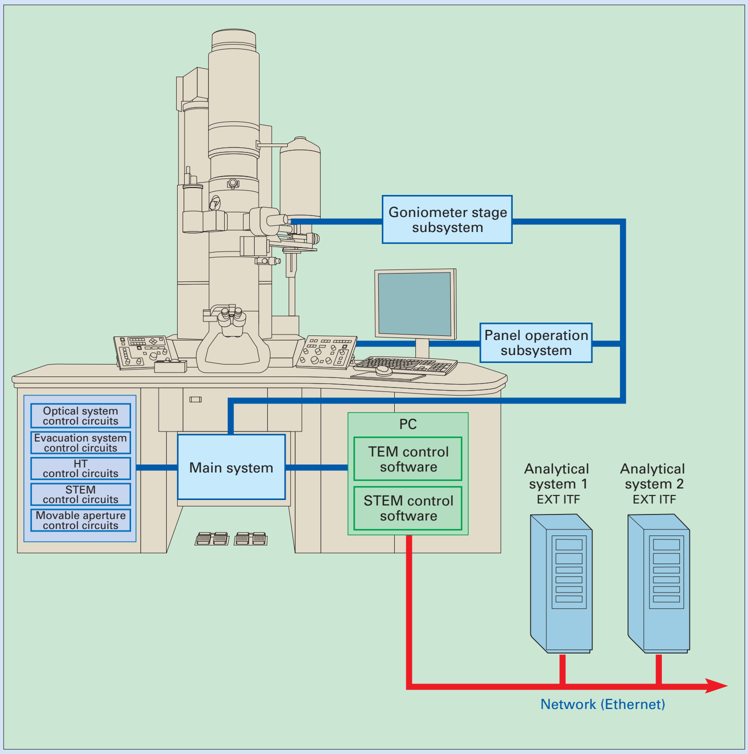
User-friendly operation tools

All operations can be performed using a control panel and a GUI on the monitor. The control panel functionally positions buttons and knobs for common tasks, such as adjusting focus and brightness and changing magnification.
GUI incorporates a wealth of functions, ranging from memory of observation conditions, saving and reproducing special observation conditions to recording through-focus images. Thus, you can easily retrieve them according to needs.



Multi-functional PC control

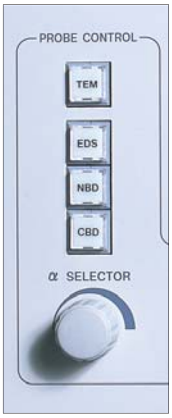
The control system of the JEM-2100 consists of the main system and two subsystems. The main system controls basic functions such as the electron optical system and evacuation system. The subsystems control the goniometer stage and panel operation. You can operate these systems through a built-in host PC designed to manage data.
Also, using the networking capabilities of a PC, you can easily connect various analytical equipment and imaging devices to the instrument.
The control technology of the JEM-2100 integrates a wide range of systems, and is a keystone for expanding TEM application fields.

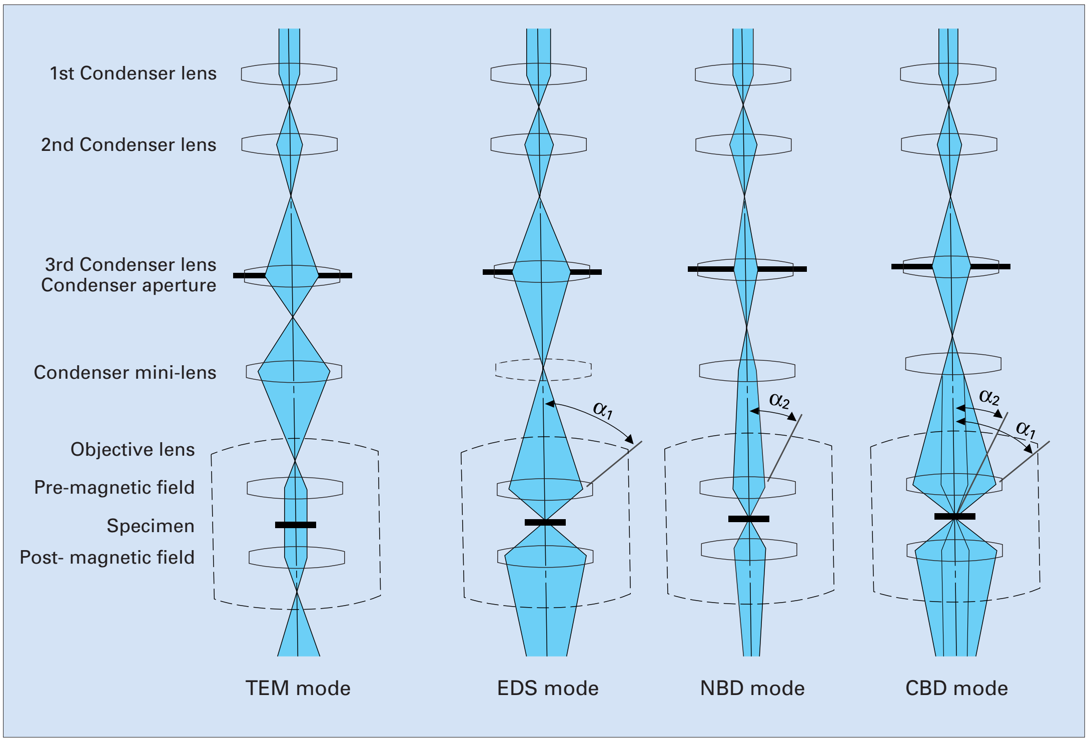


Multi-Functional Electron Optical System

Quick beam select system

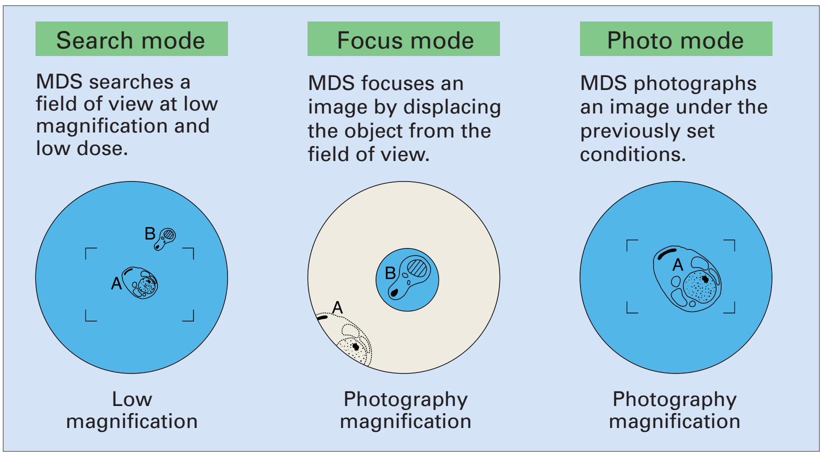
The Quick Beam Select System is provided for the following four illumination conditions: TEM image observation (TEM), EDS analysis (EDS), nano-beam diffraction (NBD) and convergent-beam diffraction (CBD). You can select the optimum condition from these four modes with one touch operation. This system enables you to easily perform high precision, nanoarea analysis and CBD.



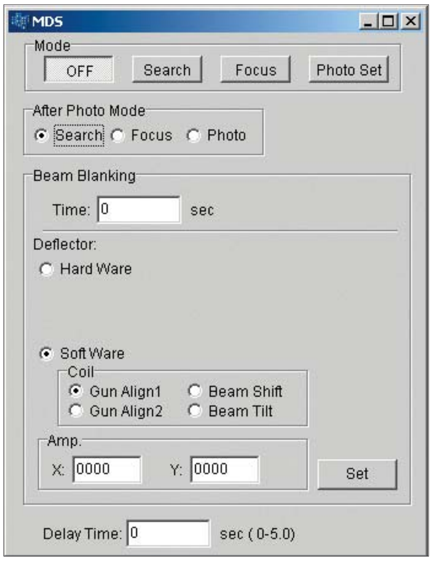


Minimum dose system (MDS)

A MDS is included as the standard function in the JEM-2100. Using this system, you can easily switch each mode - field search (Search), focusing (Focus) and photography (Photo) - through a GUI, and can minimize an electron-beam dose for observation. This system is effective for specimens susceptible to electron-beam radiation damage, such as frozen specimens, organic materials and negatively-stained specimens.



A: Photography field
B: Field of view for focusing

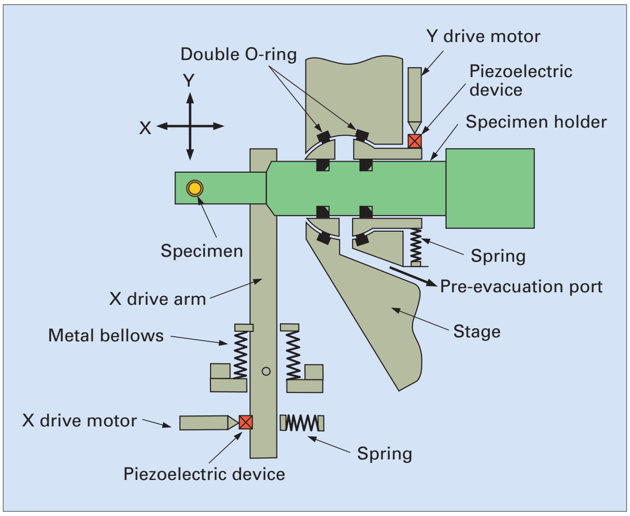


Latest Technologies for Mechanical Configuration

New goniometer stage

The newly developed goniometer stage achieves precise specimen movement and stable specimen holding. In particular, the specimen moves with the highest accuracy in a wide range of magnifications: from low magnification to the maximum magnification for nano-area imaging.
This new stage comes with a piezoelectric device, allowing fine specimen movement at high magnifications and specimen-drift correction*.
Also, the stage incorporates a touch-sensor safety mechanism (JEOL patent), making it possible to tilt the specimen up to the maximum angles.

*The Piezo Device Movement Power Supply is optionally provided.

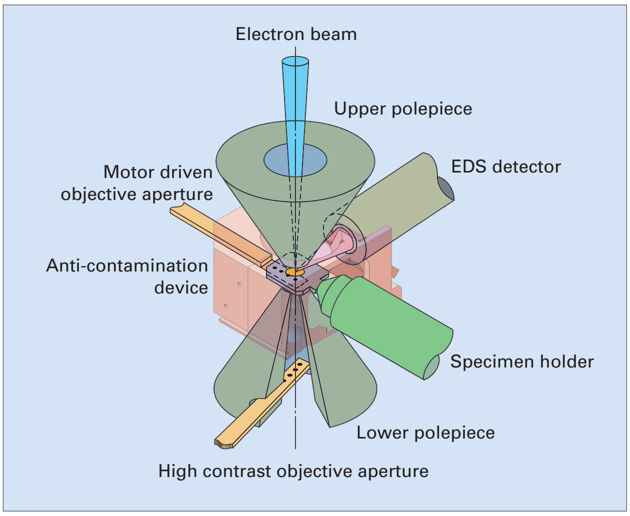


Large solid angle EDS (option)

For high-sensitivity analysis, the JEM-2100 incorporates an EDS detector with a detection area of 50 mm^2, achieving a solid angle of 0.28 sr for X-ray acquisition.
This EDS detector provides sensitivity more than twice that offered by an EDS detector with a detection area of 30 mm^2, under the same X-ray acquisition conditions.

JED-2300T

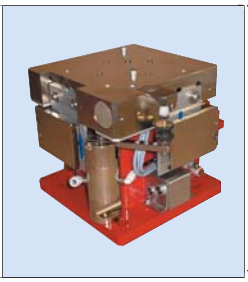
Detector:	50 mm^2
Solid angle:	0.28 sr (with HRP)
Take-off angle:	24.1° (with HRP)

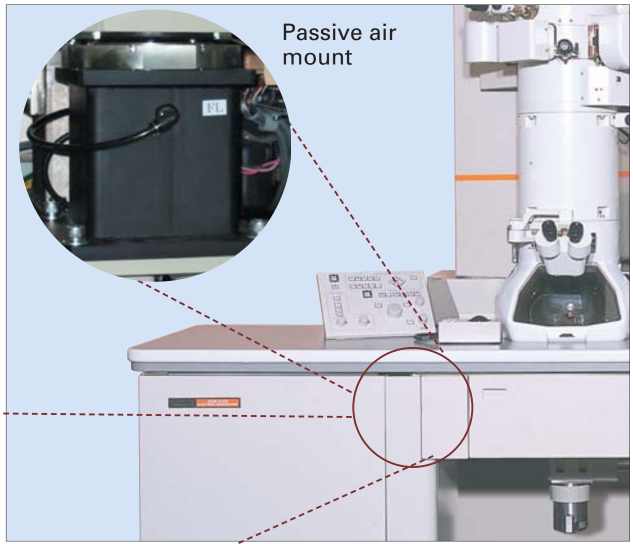


Vibration-proof instrument structure

For nanometer-scale imaging and various analyses, measures to prevent vibration are important factors. The JEM-2100 adopts a new base frame and a passive air mount, greatly improving the vibration-proof performance.
In addition, the JEM-2100 is fitted with an optional active air mount. The use of this mount has enabled the JEM-2100 to operate even in an environment with some vibration, in which it was conventionally difficult to install a TEM.

Active air mount (option)





Variations of Accelerating Voltages for Observation Purposes

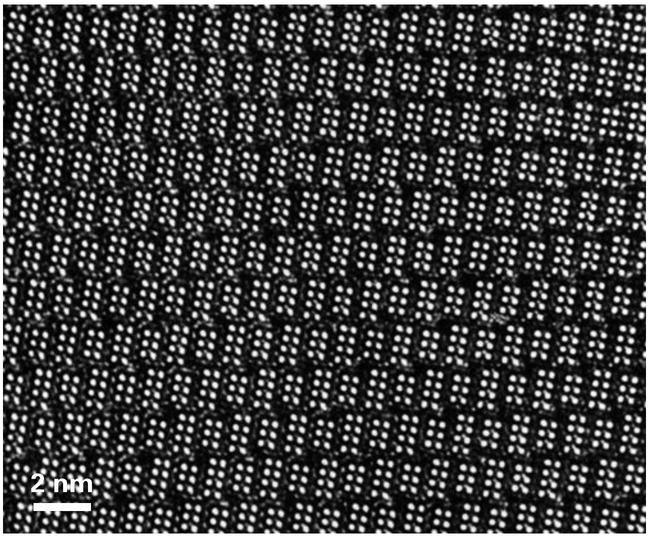
The optimum accelerating voltage can be easily selected according to specimens and observation purposes.

For high-resolution observation

The resolution of a TEM image depends on the wavelength of electrons (λ) and the spherical aberration coefficient (Cs) of the objective lens. If the Cs is the same, by increasing the accelerating voltage (using short wavelength electrons), a higher resolution is obtained.
The highest accelerating voltage of 200 kV is effective for observing materials and semiconductors.

Observation conditions
Accelerating voltage: 200kV
Specimen: Nb_2O_5

[200kV]

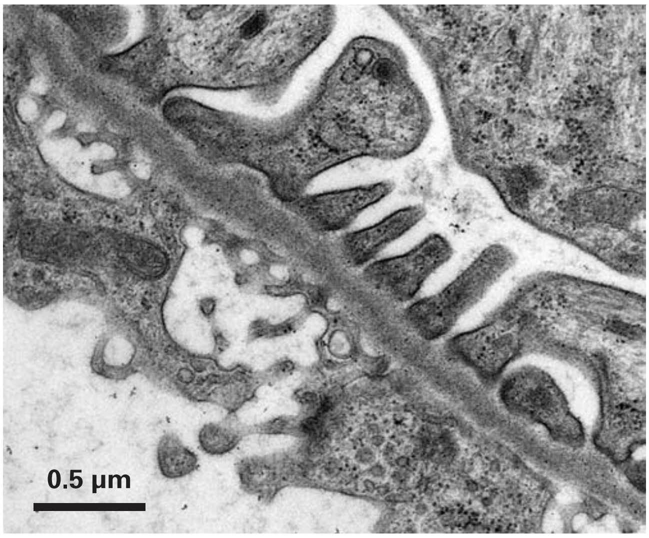


For high-contrast observation

Scattering-absorption contrast is formed by cutting part of electrons scattered by the specimen, using an objective aperture inserted into the electron path. As the accelerating voltage is low, the scattering probability increases, enhancing the scattering-absorption contrast.
High-contrast observation at around 120 kV is effective for a thin section of stained biological specimen.

Observation conditions
Accelerating voltage: 120 kV
Specimen: Glomerulus of mouse kidney

[120kV]

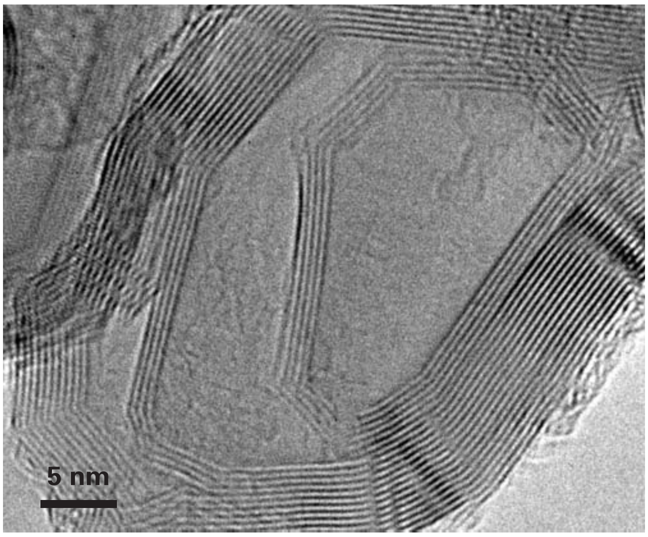


For reducing damage to specimen

When you observe specimens susceptible to damage by the 200 kV electron-beam irradiation, such as carbon nanotubes and carbon graphite, selecting a low accelerating voltage of 100 kV or 80 kV can reduce the beam-damage to the specimen.

Observation conditions
Accelerating voltage: 100 kV
Specimen: Carbon graphite

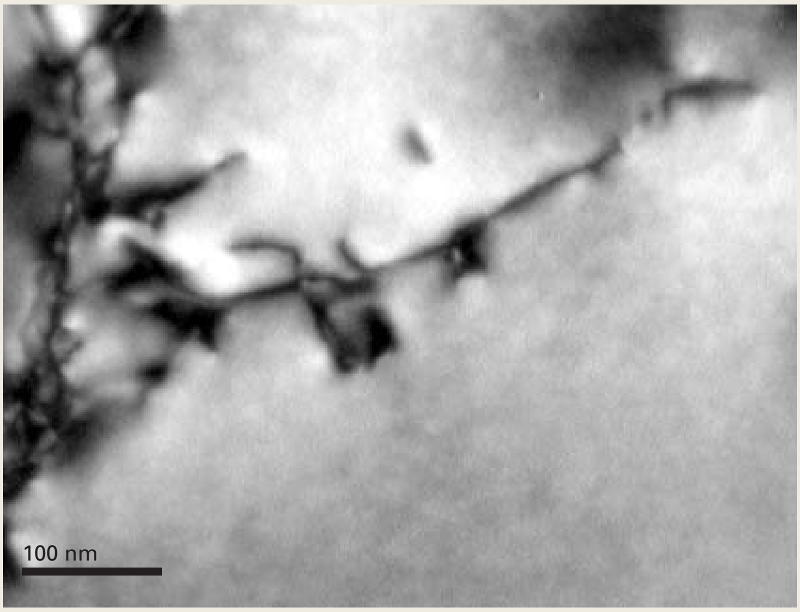
[100kV]



Bright- and Dark-Field Images of Dislocations

Figures below show a bright-field image (BF image) of Al wire and a dark-field image (DF image) of it obtained by the weak-beam method. The use of the weak-beam method resolves dislocation structures more clearly than the BF image does. In Al wire, various crystal defects (dislocations, etc.) are present caused by the fabrication process of the wire. To observe these defects, a function that can easily switch the BF image and DF image modes is very effective.

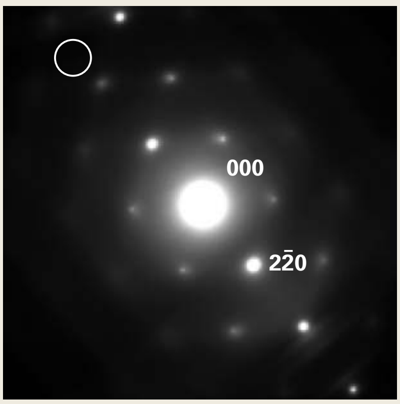
Bright-field image ([110] zone-axis incidence)



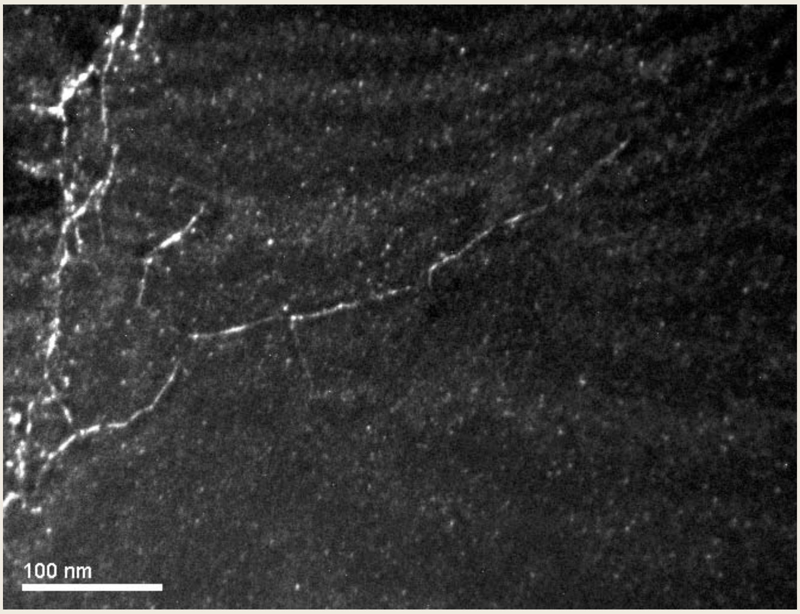
The BF image under the zone-axis incidence enables you to easily observe dislocations.

Specimen: Al wire

Dark-field image (using weak-beam method)



Electron-diffraction pattern
The diffracted beam limited by an objective aperture (white circle) is used for imaging the DF image (right).

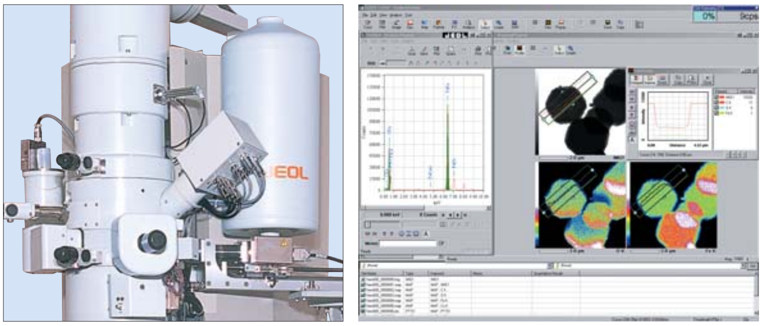


The DF image using the weak-beam method visualizes the dislocations with higher resolution.

EDS Analysis

Highly efficient EDS analysis

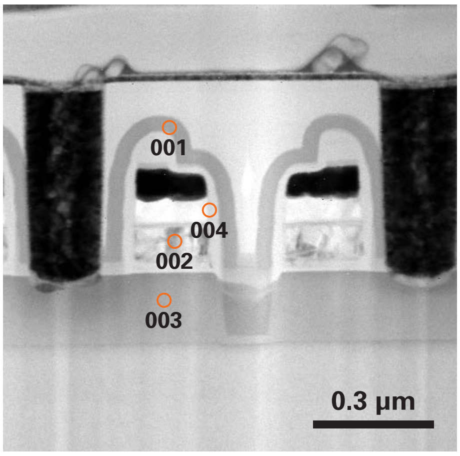
The JEM-2100 can integrate the JED-2300T energy dispersive X-ray spectrometer and a STEM image observation device into the instrument. This configuration enables you to precisely analyze the target positions while observing a STEM image. In addition, by specifying multiple analysis points, measurement of each point and storage of measured data can be performed automatically. Optionally, the JED-2300T can be equipped with a detector having a wide detection area of 50 mm², effective for high-sensitivity analysis.

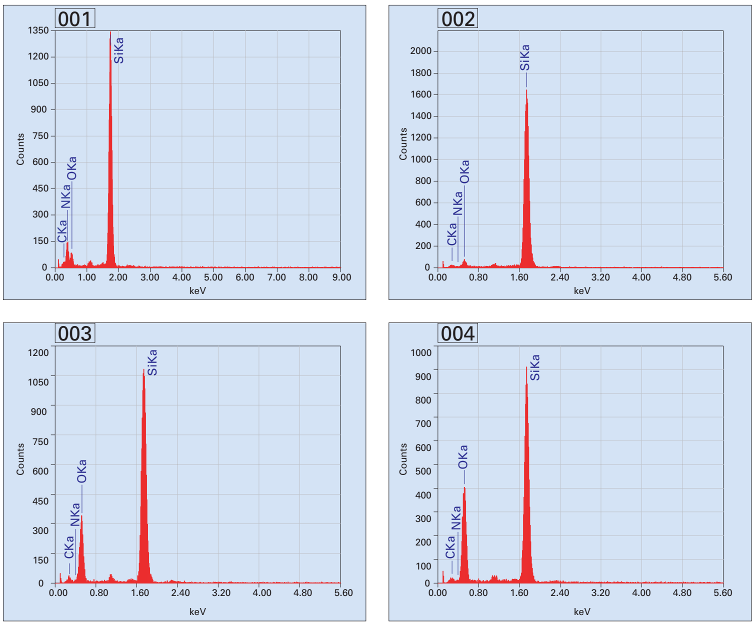


External view of the JEM-2100 with the JED-2300T and GUI for EDS analysis.

Point analysis

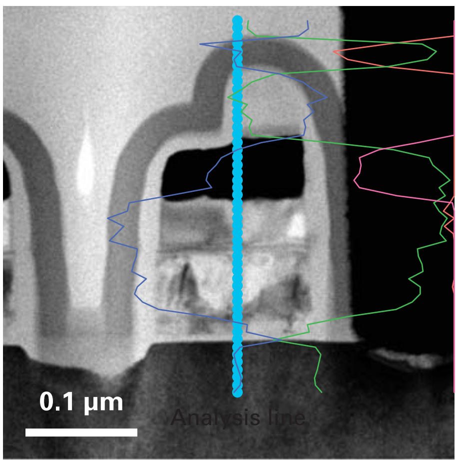
Figures shown below and at right are examples of point analysis of a semiconductor device. Multiple points (001 to 004) specified on a STEM image can be analyzed automatically.

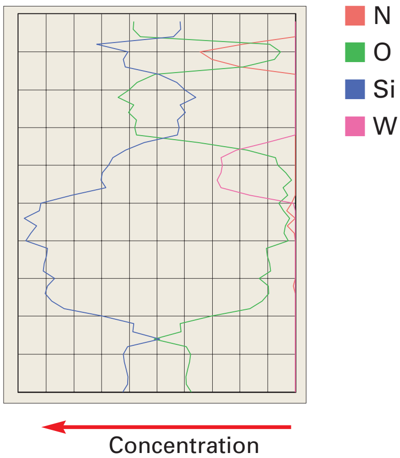




Line analysis

Figures below show examples of line analysis of a semiconductor device. The analysis result is displayed as the distributions of concentrations of the constituent elements (graph).



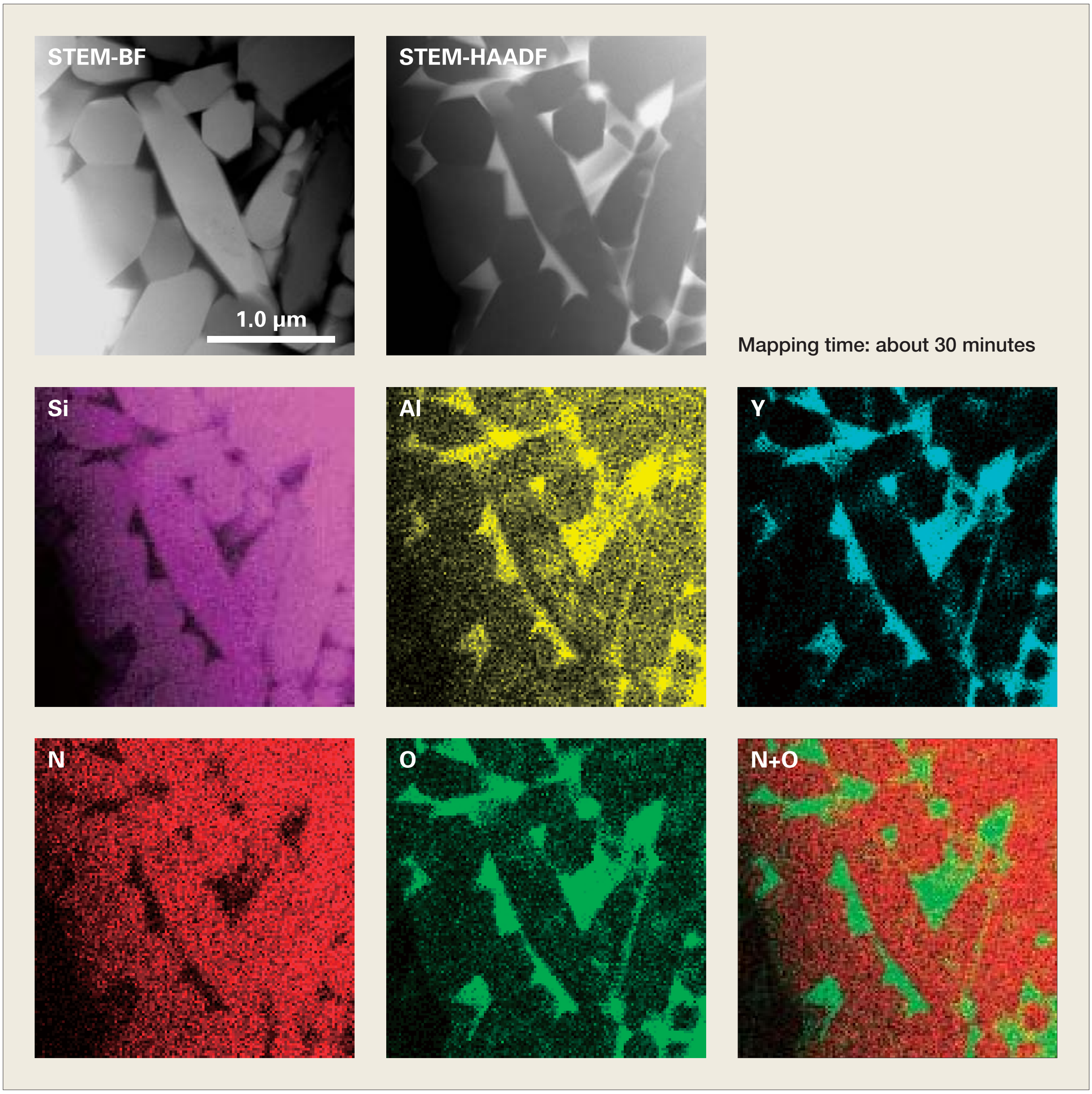


EDS Mapping

By combining a STEM-BF image or a STEM-HAADF image with EDS maps, detailed information on elemental-distribution can be obtained. In EDS mapping, the use of the probe-tracking (drift-correction) function enables you to acquire data that are not affected by specimen drift even in a long-time measurement.

Example of analysis of sintered ceramic material

Figures shown below are STEM images and EDS maps obtained from a sintered ceramic material, called SIALON.
The HAADF image shows a bright contrast on the grain boundaries, indicating that heavy elements are distributed on the boundaries [1]. EDS mapping reveals the existence of Y (yttrium) on the boundaries. Since the JEM-2100 uses an EDS detector having a high detection sensitivity for light elements, it can map N (nitrogen) and O (oxygen) rapidly, which were conventionally analyzed by EELS [2].



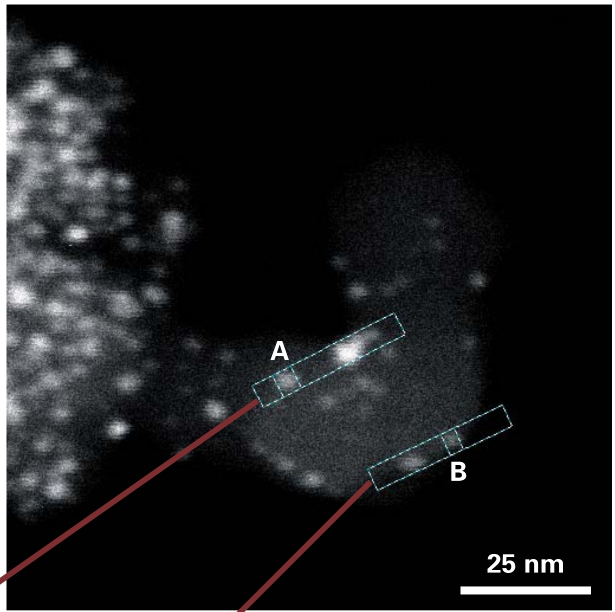
Mapping time: about 30 minutes

[1] The HAADF image is called the Z contrast image. Since the image intensity is proportional to the square of the atomic number (Z), the portions of heavy elements appear bright in the image.
[2] Generally, EELS has an advantage over EDS in light-element mapping, since its detection efficiency for light elements is higher than EDS.

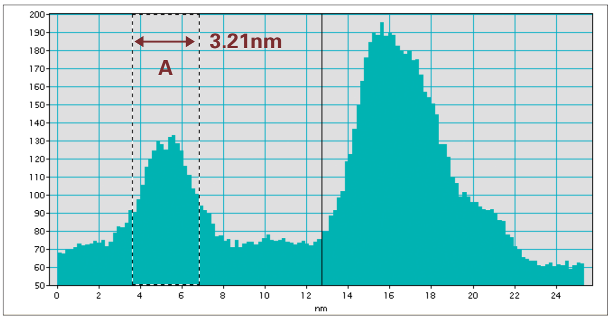
Nanoparticle Analysis

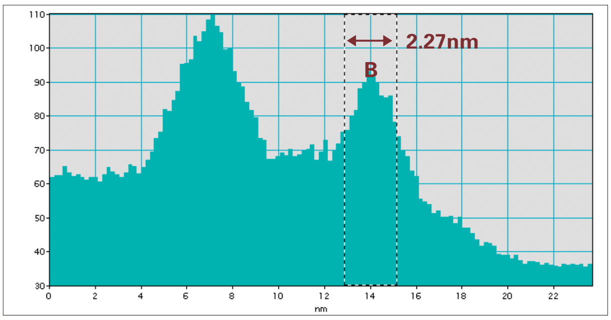
Application of EDS mapping to catalyst particles (10% Pt-C)

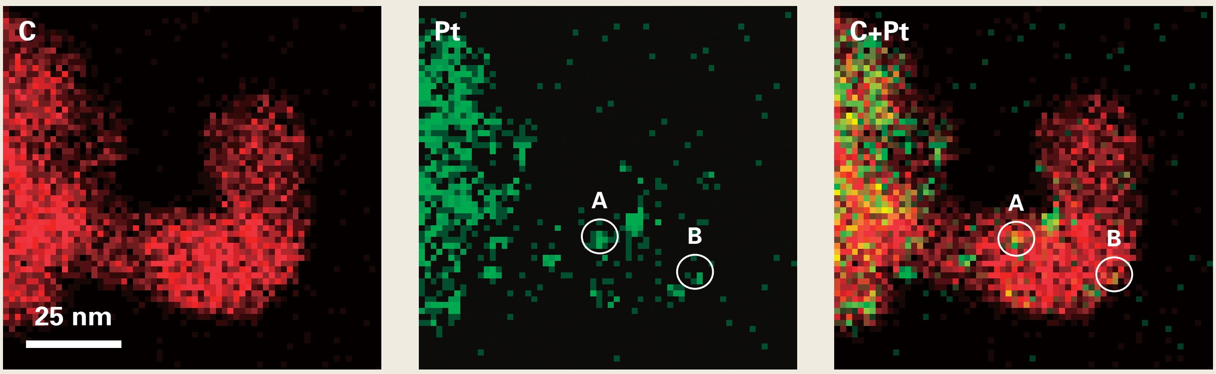
Even with a LaB_6 electron gun, focusing an electron beam to produce a narrow probe allows observation of nanoparticles by a STEM-HAADF image.
In addition, the use of an EDS detector with high detection efficiency (detection area: 50 mm^2) enables you to acquire the element distributions of particles down to 2 to 3 nm in size.
STEM-HAADF image at right reveals that Pt nanoparticles with an average diameter of about 3 nm are distributed on a C support. EDS maps at the bottom indicate that a Pt distribution image agrees very well with the STEM-HAADF image, demonstrating a high spatial resolution provided by EDS.



Particle-diameter measurement using HAADF image







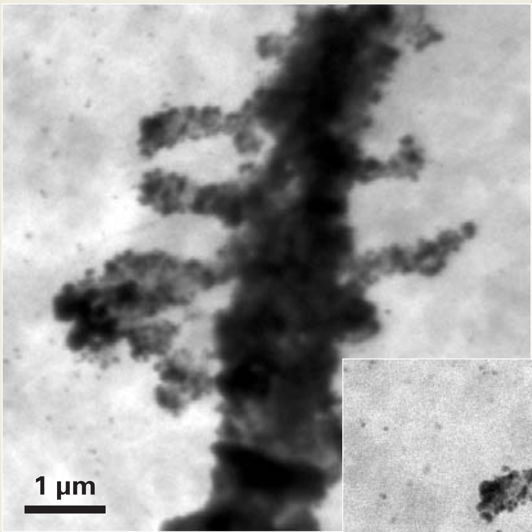
Acquisition conditions
Number of pixels: 64×64 pixel
Acquisition time: about 60 minutes

New Application Possibility of STEM

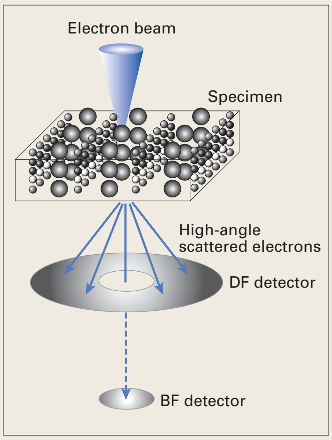
Application of STEM to biological specimen (dendritic spines of pyramidal cells of rat hippocampus)

STEM is a powerful observation method for not only materials science but also biological field.
Golgi staining (silver impregnation) is used to examine an external cell form by selectively staining nerve cells in brain tissues.
Specimens having microstructures down to 1 µm, for example, dendritic spines, are difficult to analyze using an optical microscope. Furthermore, since specimen thickness for TEM is limited within around 100 nm, the entire form of dendritic protrusions and dendritic spines are difficult to obtain from a TEM image. However, STEM allows acquisition of clear images even from relatively thick sections.
Figures shown below are TEM and STEM images obtained from a section having a very high thickness of 4 µm. Compared to the TEM image, the STEM-BF image reveals the structures of the specimen more clearly. In addition, the STEM-DF image shows a high contrast originating from silver. This demonstrates that STEM is also useful for observing biological specimens and polymer materials.

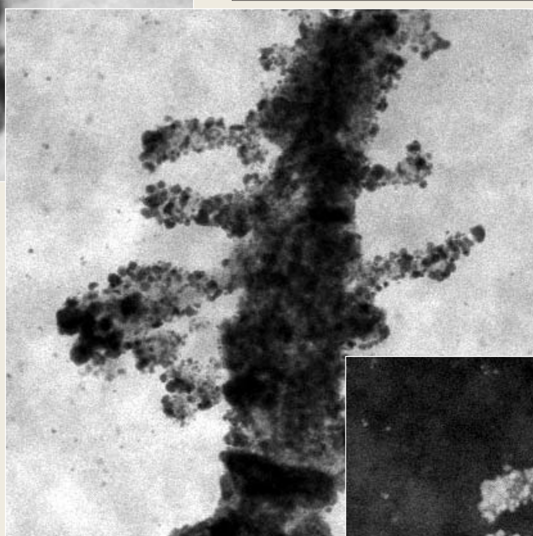
TEM



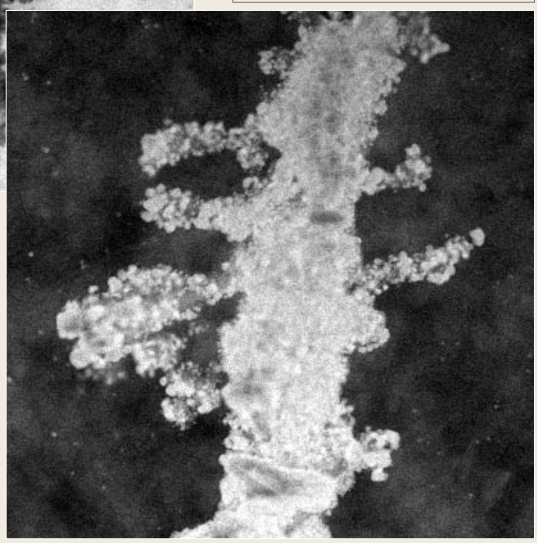
STEM-BF/DF detectors



STEM-BF



STEM-DF



Specimen: Dendritic spines of piramidal cell of rat hippocampus
Specimen preparation method: Golgi staining (silver impregnation)
Specimen thickness: 4 µm

High-Quality 3D Reconstruction

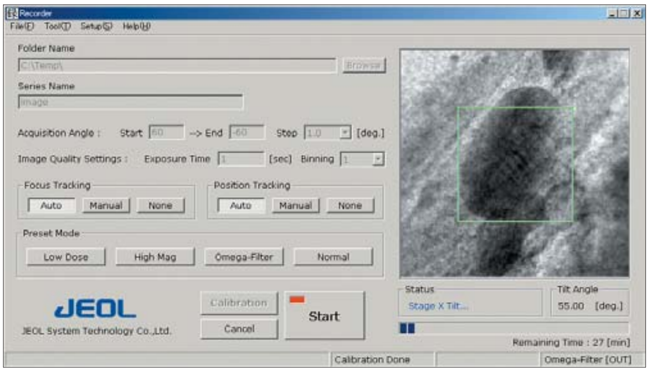
TEM Tomograph System (option)

The JEM-2100 can be equipped with an optional TEM Tomograph System that automates electron tomography.
The TEM Tomograph System automates the tomography process ranging from acquisition of a series of specimen-tilt images to 3D reconstruction of images.
The TEM Tomograph System adopts three programs (*Recorder*, *Composer* and *Visualizer*) that incorporate a unique algorithm for automating various adjustments specific to electron tomography.

Recorder

This program automatically acquires a series of specimen-tilt images necessary for tomography.
To increase the precision of 3D reconstruction, it is necessary to acquire images as many as possible while tilting the specimen in certain steps. The *Recorder* automatically performs tilting of the specimen in steps, correction of the shift of field caused by specimen tilt, adjustment of focus and acquisition of images in a short time.

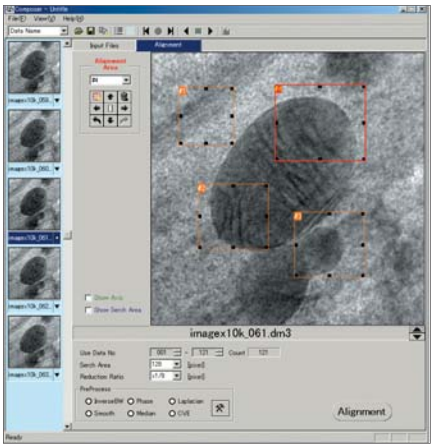
Recorder operation screen



Composer

This program carries out 3D reconstruction from a series of tilt images acquired.
The *Composer* achieves precise alignment of the image data by calculating 3D positions on the tilt axis and analyzing the angular information with high accuracy. Thus, it is possible to rapidly perform highly accurate 3D reconstruction with easy operation.

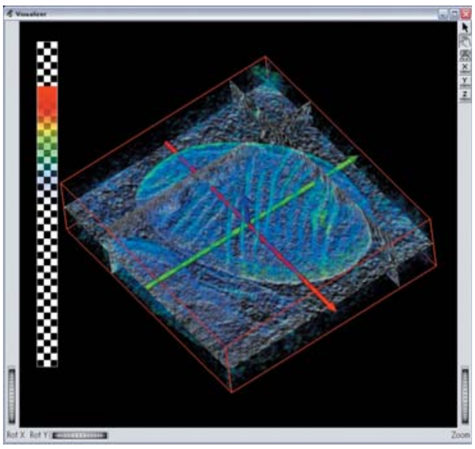
Composer operation screen



Visualizer

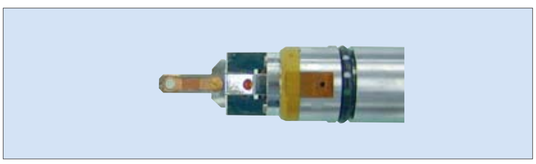
This program displays 3D data in various ways such as volume rendering and surface rendering, and also enables you to manipulate the data for flexible observation.
Using a mouse, you can freely move and display 3D images. The *Visualizer* also has a measurement function.

Visualizer operation screen



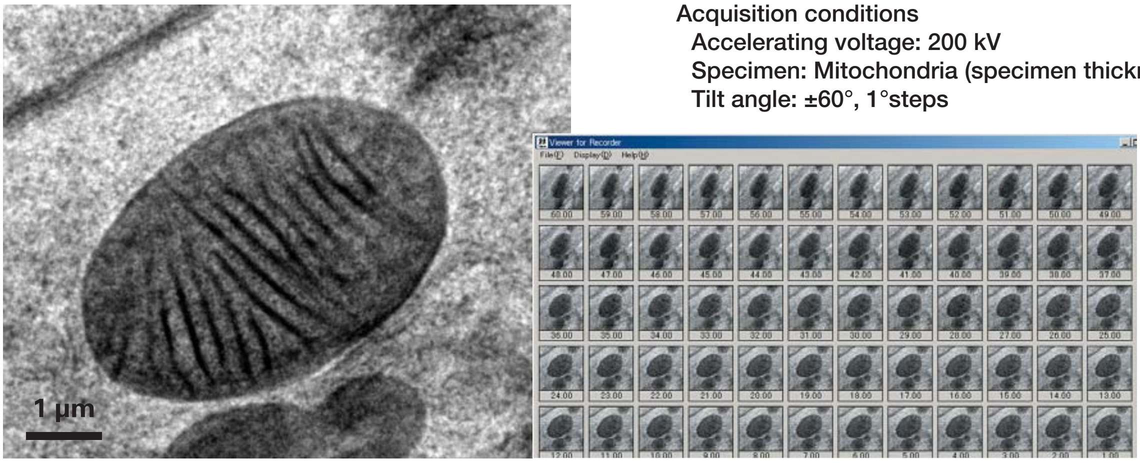
High Tilt Specimen Retainer (option)

The High Tilt Specimen Retainer is effective for acquiring images at high tilt angles.



Applications of 3D reconstruction

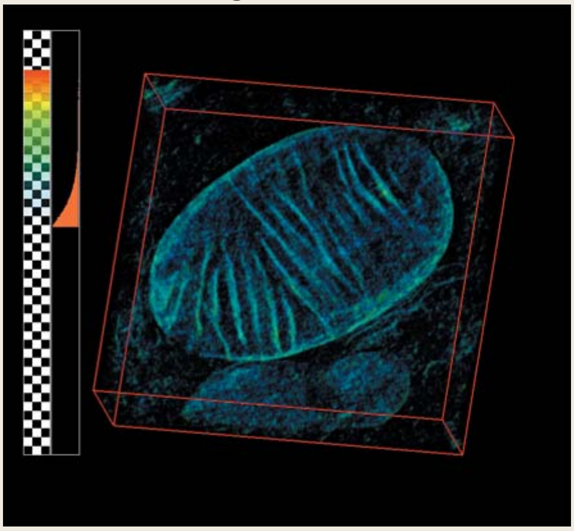
Recording a series of specimen-tilt images



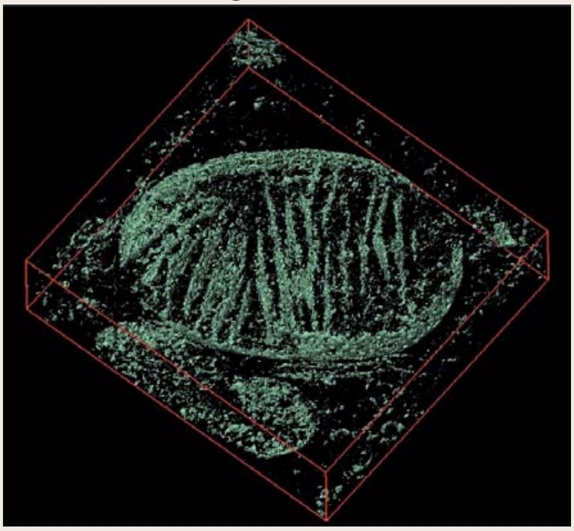
Acquisition conditions
Accelerating voltage: 200 kV
Specimen: Mitochondria (specimen thickness: 500 nm)
Tilt angle: ±60°, 1°steps

Displaying with various reconstructed image

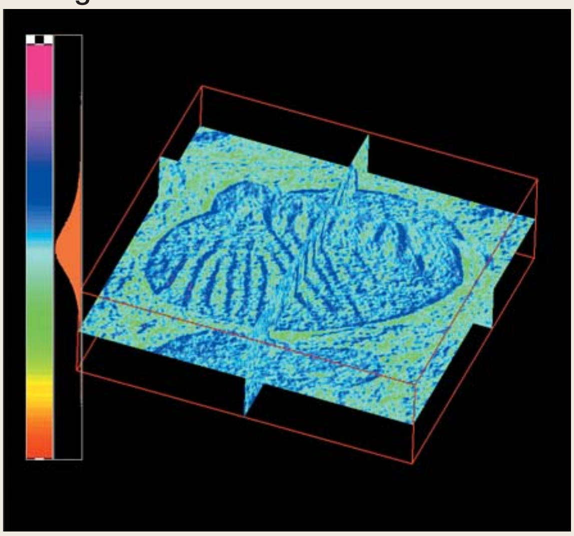
Volume rendering



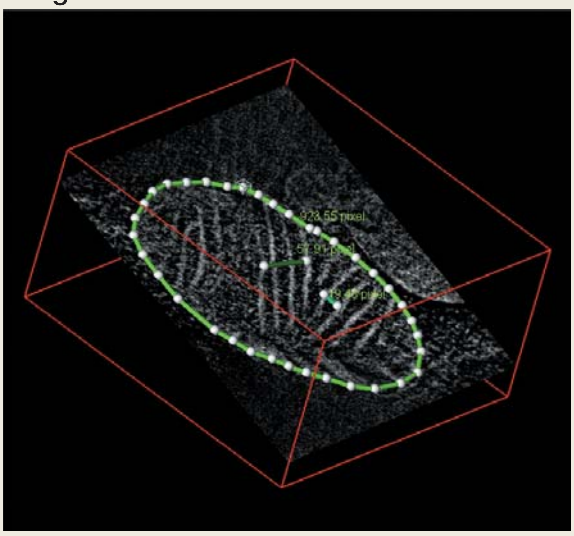
Surface rendering



Slicing



Length measurement



Main Specifications

Configuration[1]		Ultrahigh resolution	High resolution	High specimen tilt	Cryo	High contrat
Polepiece		URP	HRP	HTP	CRP	HCP
Resolution	Point	0.19 nm	0.23 nm	0.25 nm	0.27 nm	0.31 nm
	Lattice	0.14 nm				
Acc. Voltage		80, 100, 120, 160, 200 kV				
	Min. step	50 V				
Stability	Acc. Voltage	2×10^{-6}/min				
	OL Current	1×10^{-6}/min				
Objective Lens	Focal length	1.9 mm	2.3 mm	2.7 mm	2.8 mm	3.9 mm
	Spherical aber.	0.5 mm	1.0 mm	1.4 mm	2.0 mm	3.3 mm
	Chromatic aber.	1.1 mm	1.4 mm	1.8 mm	2.1 mm	3.0 mm
	Min. step	1.0 nm	1.5 nm	1.8 nm	2.0 nm	5.2 nm
Spot Size (diameter)	TEM mode	20 to 200 nm				1 to 5 μm
	EDS mode	0.5 to 25 nm α-selector	1.0 to 25 nm α-selector	1.5 to 35 nm α-selector	2.0 to 45 nm α-selector	10 to 500 nm
	NBD mode					—
	CBD mode					—
CB Diffraction	Convergent angle (2α)	1.5 to 20 mrad or mored				—
	Acceptance angle	±10°				—
Magnification	MAG mode	×2,000 to 1,500,000		×,500 to 1,200,000	×1,200 to 1,000,000	×1,000 to 800,000
	LOW MAG mode	×50 to 6,000				×50 to 2,000
	SA MAG mode	×8,000 to 800,000		×6,000 to 600,000	×5,000 to 600,000	×5,000 to 400,000
Camera length	SA diff.	80 to 2,000 mm		100 to 2,500 mm		150 to 3,000 mm
	HD diff.	4 to 80 m				
	HR diff.[2]	333 mm				
Specimen chamber	X/Y	2 mm (±1.0 mm)				
	Z	0.2 mm(±0.1 mm)	0.4 mm (±0.2 mm)			
Specimen tilting X, Y		±25°/±25°[3]	±35°/±30°[3]	±42°/±30°[3]	±60°/—[4]	±38°/±30°[3]
EDS[5] (30mm²/50mm²)	Solid angle	0.13/0.24 sr.	0.13/0.28 sr.	0.13/0.23 sr.	[6]	0.09 sr./—
	Take-off angle	25°/22.3°	25/24.1°	25/25°	[6]	20°/—

1) Specify a configuration (UHR, HR, HT, CR or HC) when ordering the JEM-2100.
2) An optional high-resolution electron diffraction stage is required.
3) When using the specimen tilting holder (EM-31630: option).
4) When using the high-tilt specimen holder (EM-21310).
5) An optional EDS is required.
6) EDS installation not possible.

Installation Requirements & Optional Attachments

Installation requirements

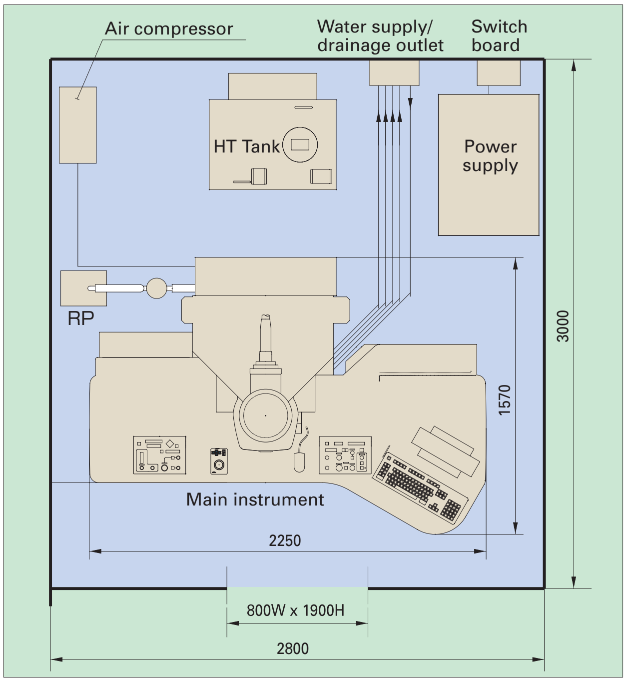
Temperature:	20 ± 5°C Fluctuation should be 1°C/h or less
Humidity:	60% or less
Power:	Single phase 240/220/200 V, 7 kVA
Grounding terminal:	100 Ω or less
Cooling Water:	Flow rate: 7.5 L/min Pressure: 0.2 to 0.3 MPa Temperature: 15 to 20°C Temperature fluctuation: 0.1°C/h or less

Dry nitrogen gas

Inlet pressure:	0.01 to 0.02 MPa gauge
Hose joint:	ISO 7/1 Rc 1/4

Dry N_2 gas should be provided by customer.

Installation room example



Dimensions of installation room

Floor space:	2,800 (W) × 3,000 (D) mm or more
Ceiling height:	2,800 mm or more
Entrance:	800 (W) × 1,900 (H) mm or more

Scanning image observation device

Full digital control

The BFI and DFI-HAADF detectors for STEM images and the image acquisition unit are provided.

- Scanning image observation device
- Image acquisition unit
- Dark field image observation device

Dry pump system

This system is an evacuation system that uses a turbo-molecular pump (TMP) having high evacuation rate.

- TMP vacuum pump unit

Energy dispersive X-ray spectrometer

JED-2300T

This spectrometer, used with a TEM, qualitatively and quantitatively analyze constituent elements with high sensitivity and high energy resolution. In addition, a combined use with STEM image observation device provides element maps.

Motor drive aperture

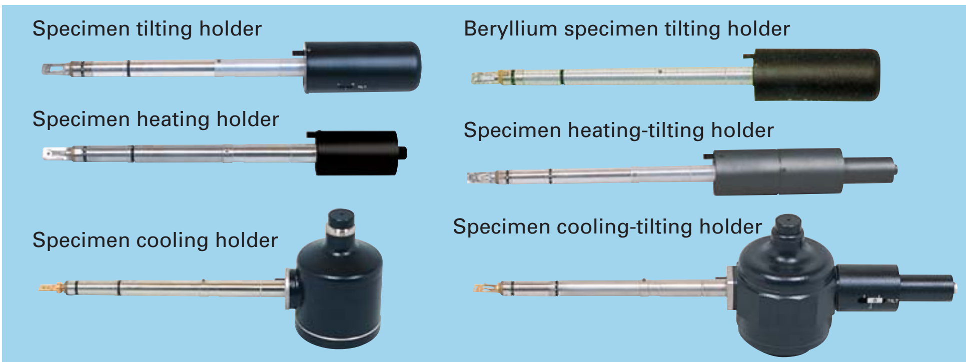
Remote control

- Motor drive CL aperture
- Motor drive OL aperture
- Motor drive OL high contrast aperture
- Motor drive IL aperture
- Motor drive aperture control printed circuit board

Extensive specimen holders

The quick specimen retainer, provided as standard, enables you to quickly exchange the specimen only by switching the tip of the holder. Also, extensive specimen holders are available, including the specimen tilting holder, the beryllium specimen tilting holder, the specimen heating holder, and the specimen cooling holder.

- Beryllium specimen retainer: EM-21150
- Specimen tilting holder: EM-31630
- Beryllium specimen tilting holder: EM-31640
- Specimen heating holder: EM-21130H
- Specimen heating-tilting holder: EM-31670SHTH
- Specimen cooling holder: EM-21090
- Specimen cooling-tilting holder: EM-31660
- High tilt specimen retainer: EM-21310



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