HITACHI
Inspire the Next

Ion Milling System

IM4000 Series

IM4000
IM4000 PLUS

Ion Milling System

IM4000 Series

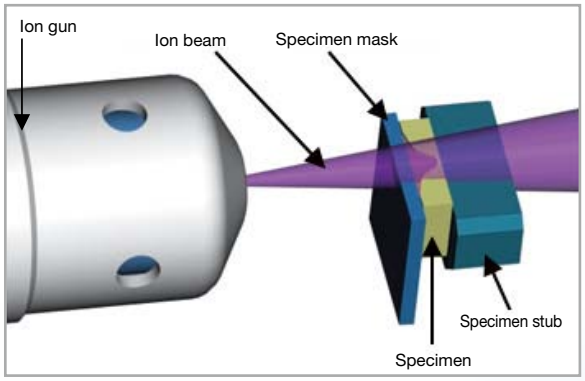
Hybrid Model: Dual Milling Configuration Available

This ion milling system is equipped for both cross-section milling and flat milling.
By switching the milling holder, it can be utilized for applications according to a wide range of purposes.

Cross-section Milling

High quality preparation of structures below the sample surface for SEM observation is commonly reserved for focused ion beam systems.
Other alternatives for preparing cross-sections rely on mechanical or cleaving methods, which often distort internal structures or induce damage.
The Hitachi Ion Milling System utilizes a broad, low-energy Ar+ ion beam to produce wider, undistorted, cross-sections without applying mechanical stress to the sample.

Processing Principle



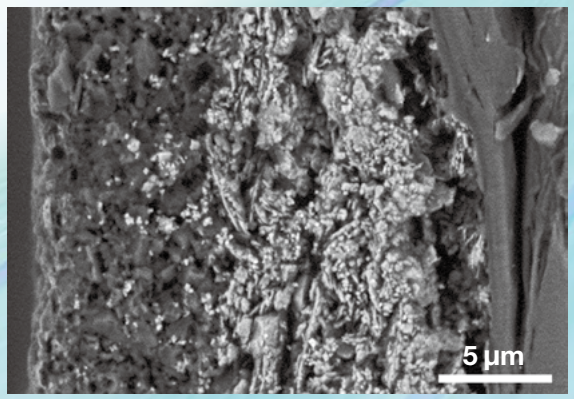
Schematic diagram for processing during Cross-section milling

A mask is placed directly on top of the sample and is not only used for protecting the top surface, but also provides a sharp edge to create a flat, damage-less, cross-section face by sputtering away material that is exposed beyond the masked edge.

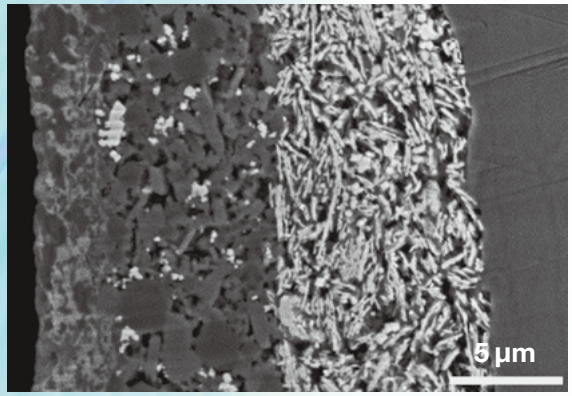
Features and Applications

- **High quality damage-less cross-sections for the analysis of structures below the surface**
- **Sample examples: Electronic components such as IC chips, PCB, LED (analysis of layers, interconnects, cracks, voids), metals (EBSD grain structure, EDS elemental analysis, coatings), polymers, papers, ceramics and glasses, powders, etc.**
- **Removable sample stage unit enables bench top optical alignment of the sample and for site specific ion milling (see explanation)**
- **Samples with maximum dimensions of 20 mm wide x 12 mm long x 7 mm thick can be milled**
- **Sample stub compatibility eliminates the need to change mounts between mechanical polishing, ion milling, and SEM observation (Hitachi models)**

Specimen:
Thermal Paper



Cross-section by razor



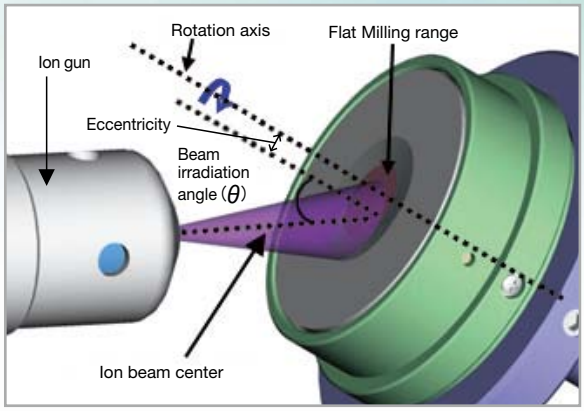
Cross-section by ion milling

The Next Generation Ion Milling System

Flat Milling

SEM observation of metallographic microstructures or defects of various materials requires special sample preparation. Traditional mechanical sample preparation via grinding and polishing can result in deformation, flaws, and artifacts that obscure the true structure of the material. Hitachi offers an ion milling system that can eliminate mechanical stress induced in the sample. The IM4000 can quickly and effectively provide a damage-less flat milling method to enhance mechanically prepared materials.

Processing Principle



Schematic diagram for processing during Flat milling

The ion beam exhibits a Gaussian shaped current-density profile. When the ion beam center coincides with the sample rotation center, the center of the sample material is removed at a higher rate than the surrounding area. As the sample rotation and swing center are varied with respect to the ion beam center, a wide-area can be sputtered with increased uniformity.

Features and Applications

Approximately 5 mm in diameter can be ion-milled uniformly

Eliminate flaws and artifacts generated from traditional mechanical grinding and polishing techniques

Diverse range of materials can be processed by flat ion milling

Observation of crystal grain boundaries and multi-layer films:

Relief ion milling by sputtering perpendicular to the sample surface can enhance topography of composite materials or crystal orientations for observation.

Interface observation, X-ray analysis, EBSD* analysis:

Flat ion milling at an oblique angle minimizes the dependence between sputtering rate and crystal orientation, yielding reduced surface topography and a flatter sample surface.

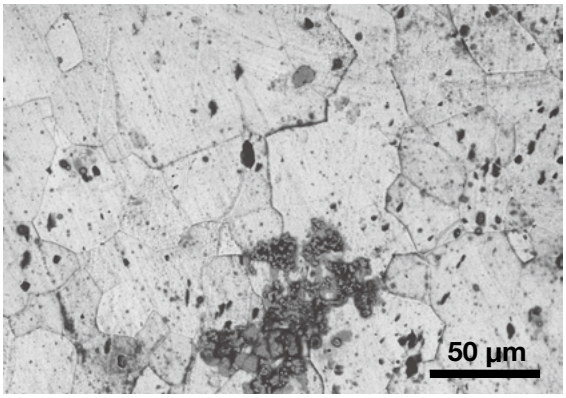
Allowable sample size up to 50 mm diameter x 25 mm height

Multi-function stage:

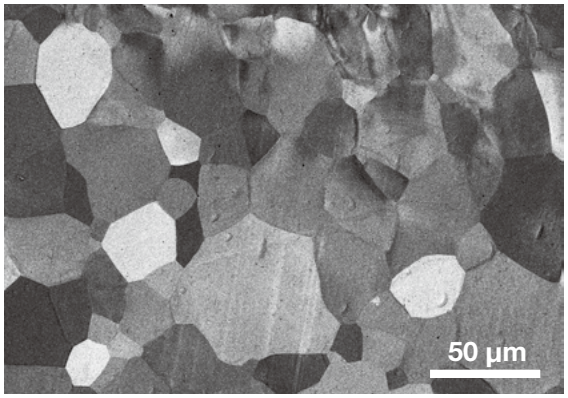
Multiple rotation speeds and stage oscillation modes provide even greater control to reduce artifacts and sputter flatter surfaces in difficult materials.

* EBSD: Electron Back-Scattered Diffraction

Specimen:
Steel



After Mechanical Polishing



After Flat Milling

Function

Higher Milling Rate IM4000PLUS Available

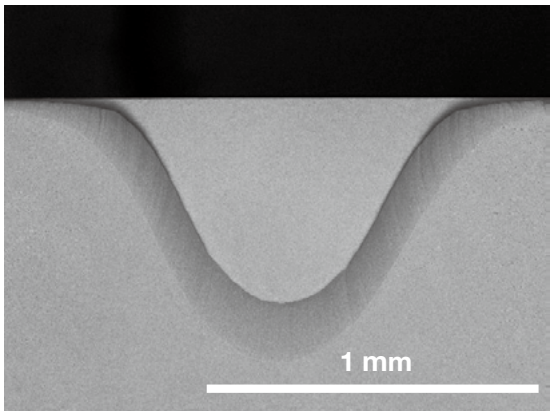
Milling rate enhanced by higher ion beam current is now available in IM4000 series.

(Milling rate: 500 µm/hr , 50%*1 greater than that of IM4000 @ Acc. Voltage 6 kV, Si sample)

*1 Overhang from the mask 100 µm, Accelerating voltage: 6 kV

IM4000PLUS

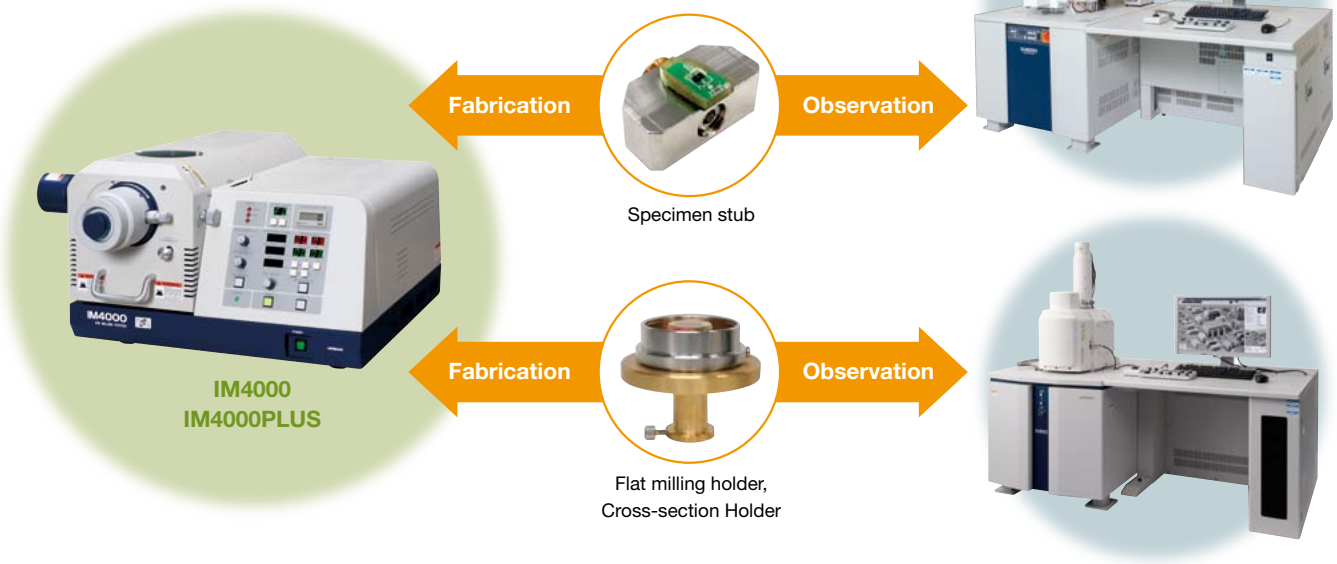
Specimen: Si Wafer



IM4000PLUS fabrication result

Specimen Linkage with a Hitachi SEM

- **A specimen can be transferred from the IM4000/IM4000PLUS to a Hitachi SEM without removing it from the specimen stub.**
- **Either the Flat Milling Holder or the Cross-section Holder can be fully mounted on a Hitachi SEM which has a draw-out specimen chamber.**
- **Additional milling can be done after SEM observation.**
- **The mask for Cross-section Milling can be fine tuned with a micrometer.**

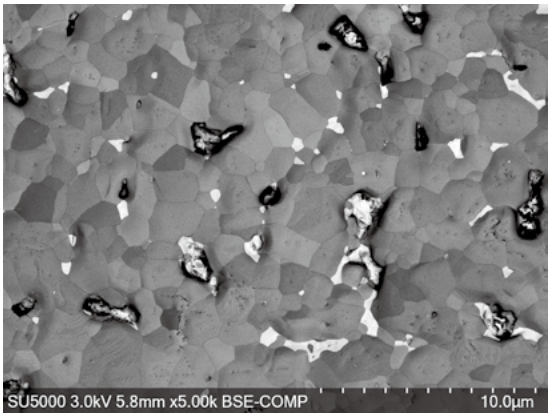


* Screen shows simulated image

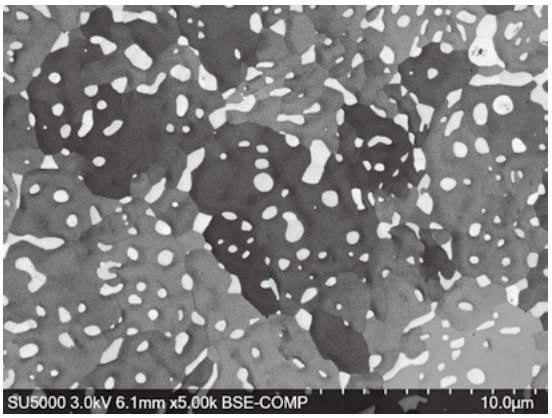
Ion Beam Intermittent Irradiation to Reduce Thermal Damage

Ion beam irradiation can be automatically switched on & off in order to minimize unnecessary specimen heating.

Specimen: Lead-contained Solder



Continuous ion beam irradiation



Intermittent ion beam irradiation

BSE Image
SEM: SU5000

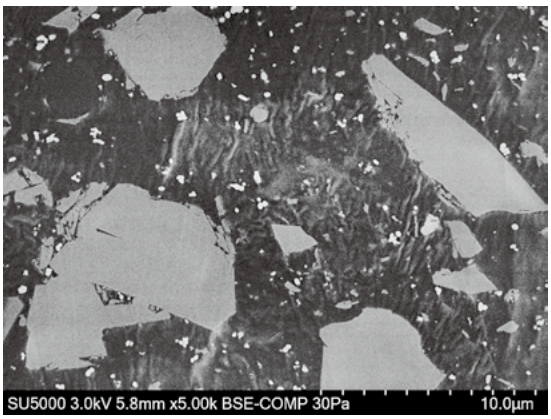
Cooling Temperature Control Function*2

IM4000PLUS with Cooling Temperature Control Function

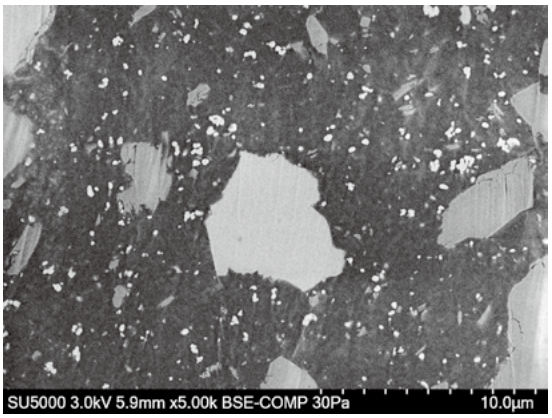
Ion milling with indirect LN_2 cooling near the processing area of the specimen.
This function is effective for temperature sensitive or beam-distorted materials.
There is a temperature controller to prevent a specimen from cracking due to excessive cooling.

*2 Not standard function of IM4000/IM4000PLUS, and available as optional accessory

Specimen: Silicone Rubber



Without cooling



With cooling

BSE Image
SEM: SU5000

Optional

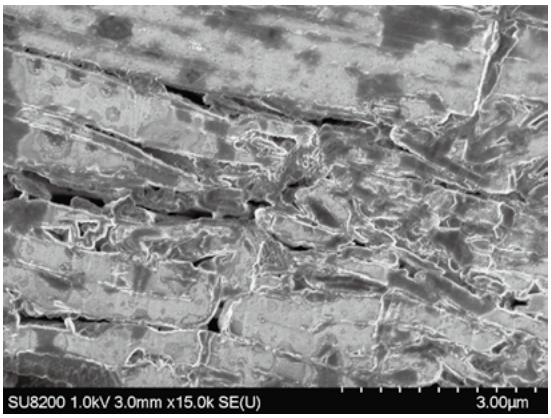
Air Protection Holder

Air Protection Holder is used to keep a specimen isolated from the atmospheric environment.

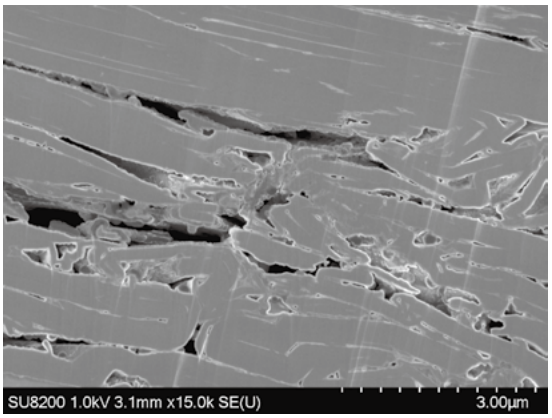
A specimen enclosed in the sealed cap can be transferred to another instrument where it can be released in an evacuated chamber. Thus, a specimen fabricated using the IM4000/IM4000PLUS can be loaded into a SEM*1, FIB*1, and/or SPM*2 without exposing it to the atmospheric environment.

*1 To be applied for Hitachi FE-SEM or FIB equipped with the specimen exchange chamber for Air Protection Holder .
*2 Hitachi SPM equipped with the vacuum specimen chamber.

Specimen:
Li ion battery negative electrode (after charged)

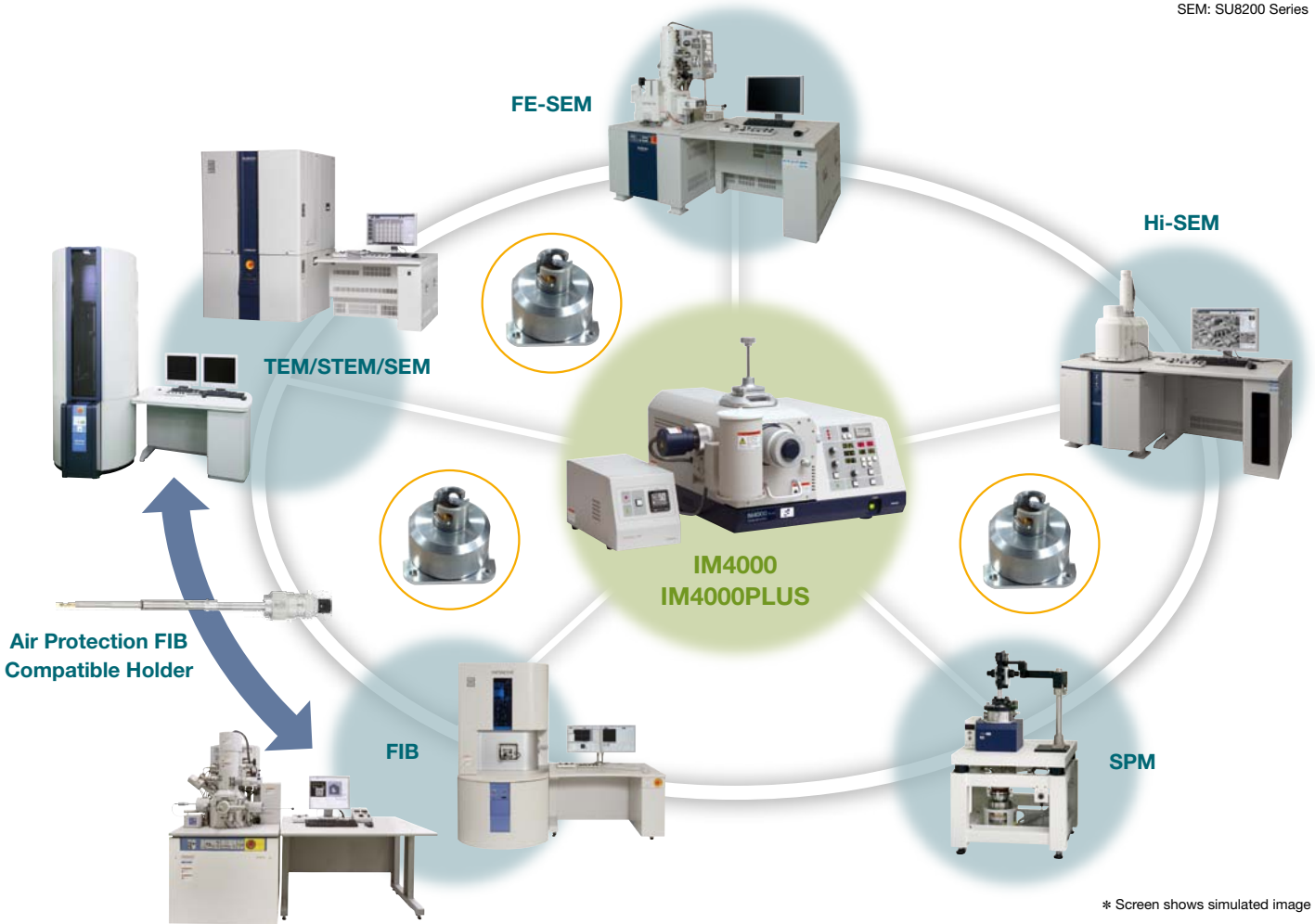


Without Air Protection Holder



With Air Protection Holder

SE Image
SEM: SU8200 Series



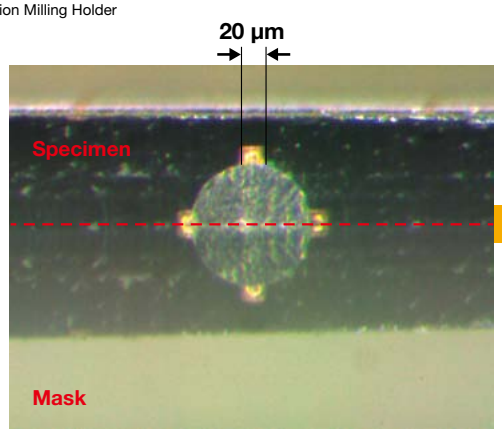
* Screen shows simulated image

Cross-section Milling Holder Fine Pitch Tuning

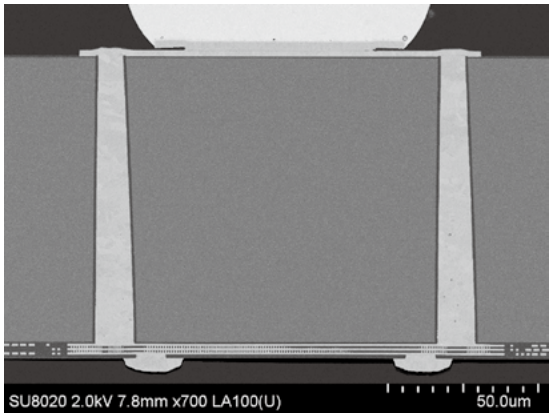
Improved Fine Pitch Tuning Function is added on Cross-section Milling Holder for precise mask positioning.*3
The mask will be positioned very precisely to the region of interest by using the Fine Pitch micrometer.
The following shows the result generated when the mask is placed to the aimed position (the center of 20 µm pad) for TSV milling.

*3 1/5 pitch against the current Cross-section Milling Holder

Specimen:
TSV (Through Si Via)



Optical Microscope image after fine pitch tuned



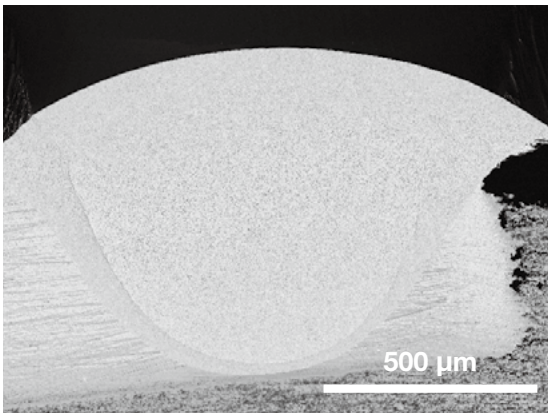
After Cross-section milling

BSE Image
SEM: SU8020

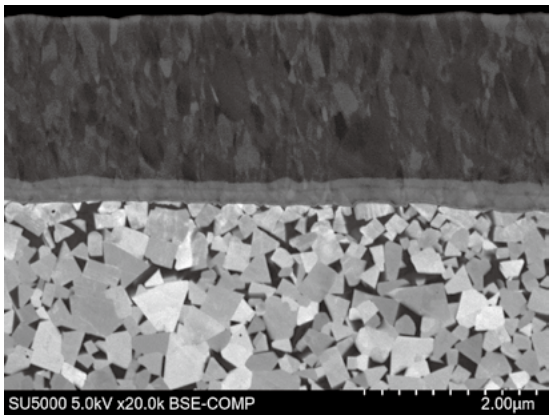
Higher Beam Tolerance Mask

It has been developed to correspond with the higher milling rate Ion gun; it is twice as hard as the standard mask, thus enabling longer milling times for hard materials.

Specimen:
Cemented carbide drill,
Milling time: 4 hours



Cross-section whole view image



Enlarged of the left image

BSE Image
SEM: SU5000

In-situ Optical Zoom Microscope

Optical Zoom Microscope enables observation of the specimen during milling with magnifications of 15 to 100X.
A trinocular type enables monitoring through CCD Camera (Optional)*4.

*4 CCD Camera and the monitor will be prepared locally

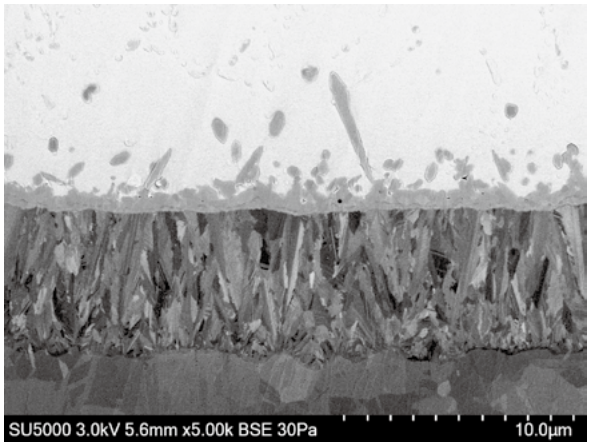
Trinocular type

Binocular type

Application

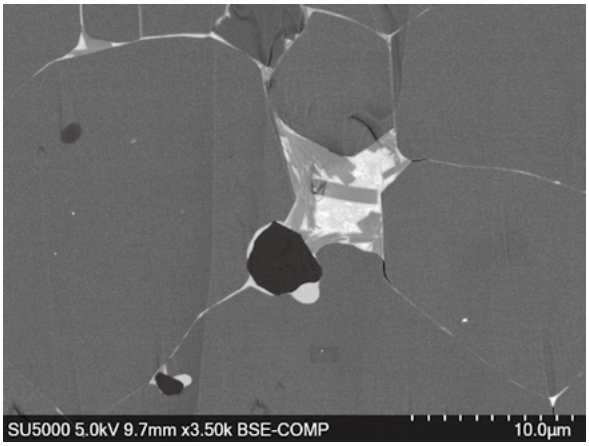
Cross-section Milling

Specimen: Lead-free Solder



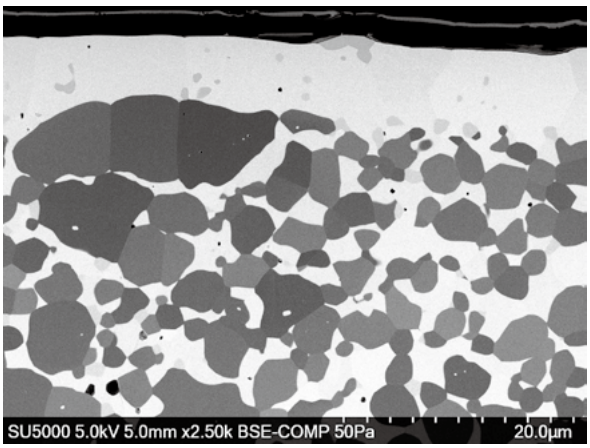
BSE Image
SEM: SU5000

Specimen: Neodymium Magnet



BSE Image
SEM: SU5000

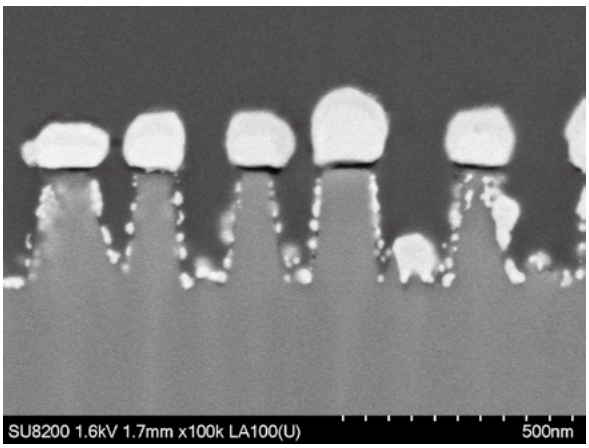
Specimen: Lanthanum-doped Ceria



Specimen Courtesy: Prof. Katsunori Hanamura,
Tokyo Institute of Technology

BSE Image
SEM: SU5000

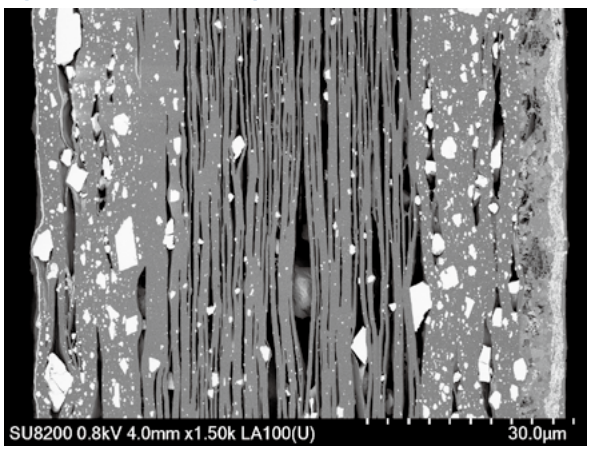
Specimen: Nano Pillar



Specimen Courtesy: Prof. Masahiko Yoshino,
Tokyo Institute of Technology

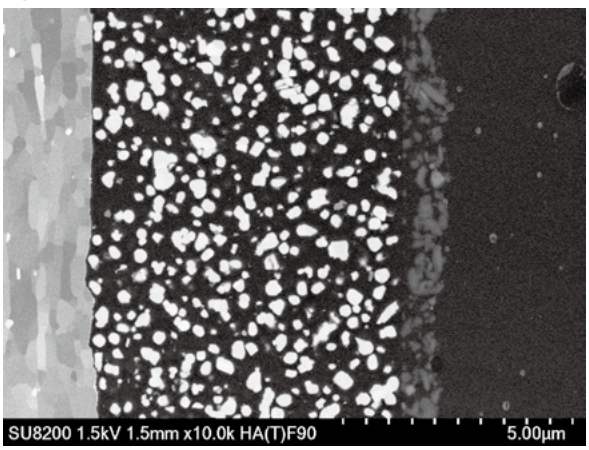
BSE Image
SEM: SU8200 Series

Specimen: Thermal Paper



BSE Image
SEM: SU8200 Series

Specimen: Painted Film

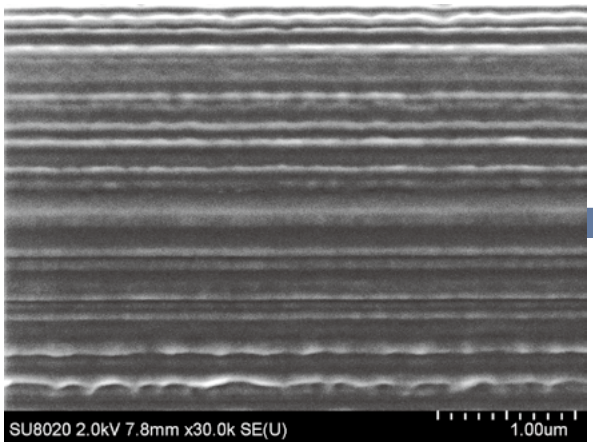


BSE Image
SEM: SU8200 Series

Flat Milling

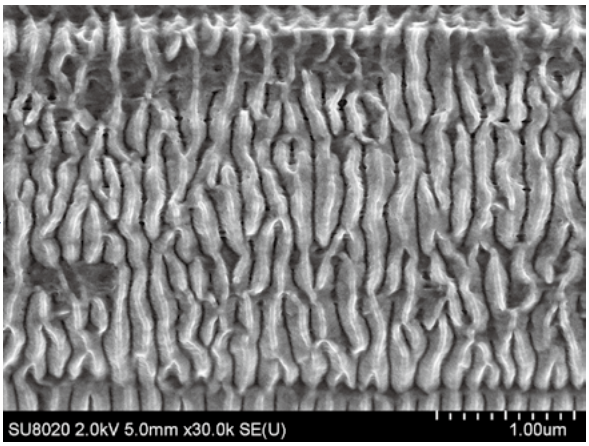
Flat milling on the surface of carbon fiber unveiled the buckling structure expected from spinning.

Specimen: PAN (Polyacrylonitrile) Carbon Fiber



Before ion milling

SE Image
SEM: SU8020

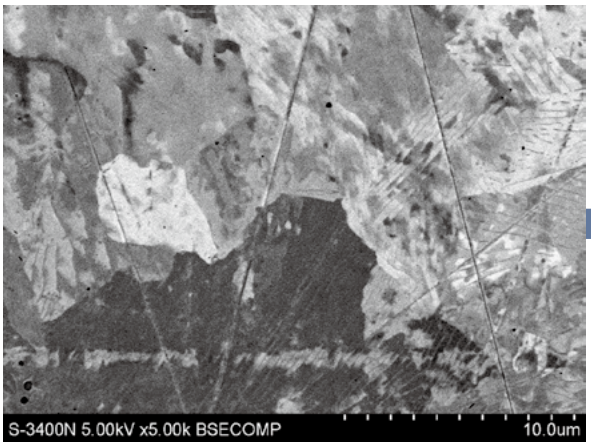


After ion milling

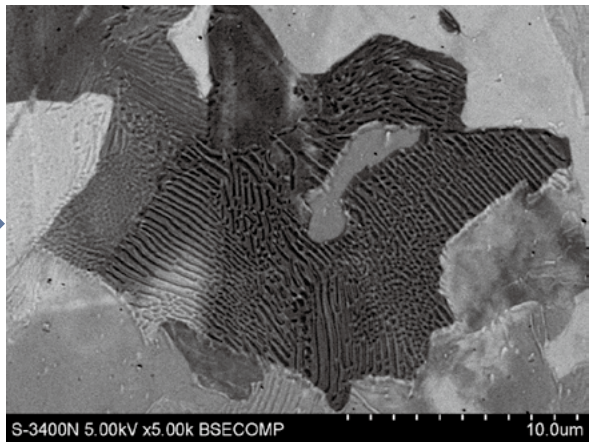
SE Image
SEM: SU8020

Metal microstructures are typically distorted when only mechanical grinding is performed; after ion milling it can be observed.

Specimen: Chrome-molybdenum Steel



Before ion milling
(Mechanical polishing surface)

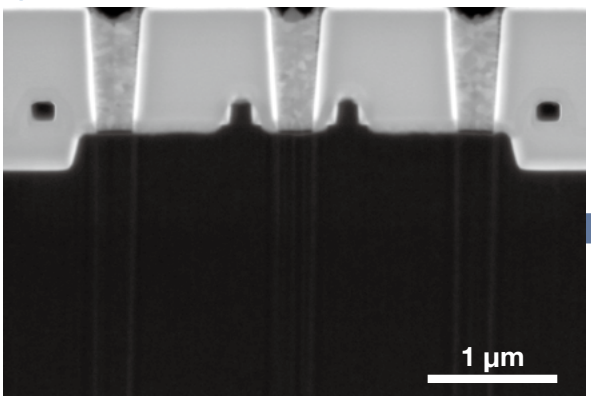


After ion milling

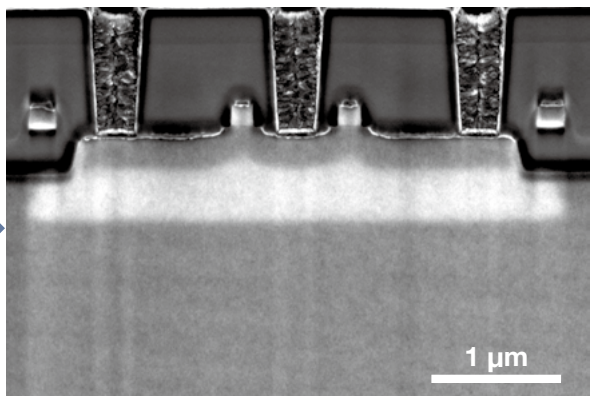
BSE Image
SEM: S-3400N

The dopant layer which can not be observed if only FIB fabricated, will be revealed after flat milling at the accelerating voltage of 0.5 kV.

Specimen: SRAM



Before ion milling
(FIB fabricated surface)



FIB fabricated & Ion milling

SE Image
SEM: SU8200 Series

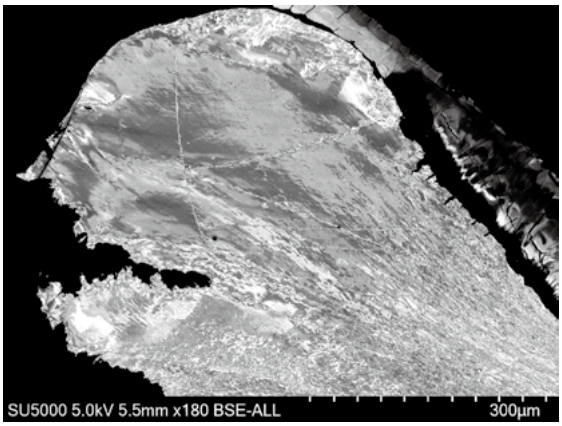
Application

Application for EBSD & SPM

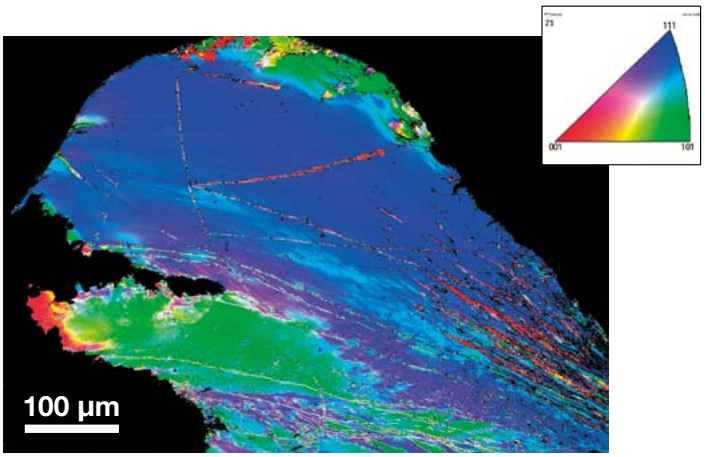
EBSD

Structural observation by BSE Imaging and crystal orientation information by EBSD are combined for the analysis.

Specimen: Meteoric Iron, (Cross-section milling)



BSE Image
SEM: SU5000



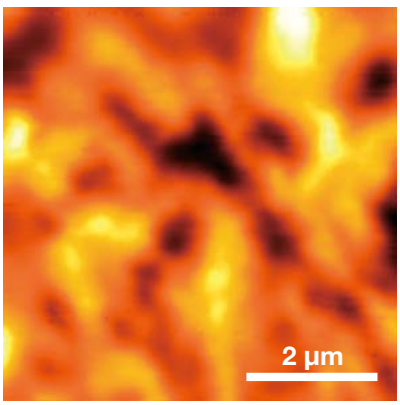
IPF*1 Map (Z)

*1 IPF: Inverse Pole Figure

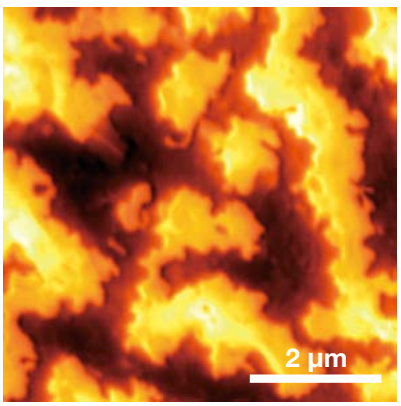
SPM

Flat milling a poorly mechanically polished sample can enable significantly clearer magnetic domain observation.

Specimen:
Hot Worked Neodymium Magnet, (Flat milling)



Before ion milling
(Mechanical polished)



After ion milling

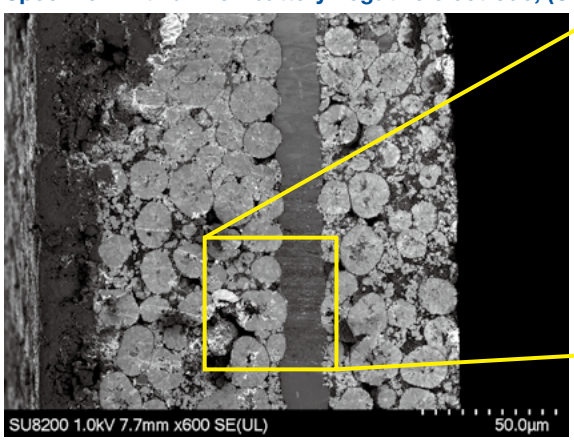
Specimen Courtesy:
Daido Steel Co., Ltd.

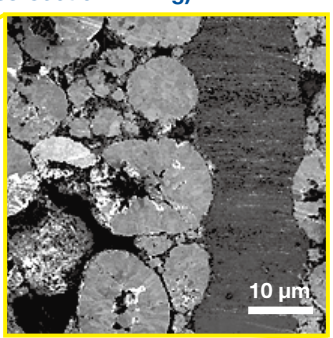
MFM*2 Image
SPM: AFM5300E

*2 MFM: Magnetic Force Microscopy

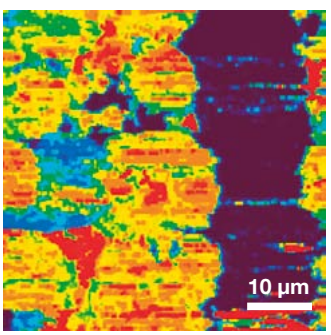
The abnormal contrast indicated by the SEM images can be identified as a low resistance area by SSRM*3 Image.

Specimen: Lithium ion battery negative electrode, (Cross-section milling)





SE Image
SEM: SU8200 Series



SSRM Image
SPM: AFM5300E

*3 SSRM: Scanning Spread Resistance Microscopy

Major specification

Item	Description			
	IM4000	IM4000PLUS	IM4000	IM4000PLUS
	Cross-section Milling		Flat Milling	
Gas used	Ar (argon) gas			
Accelerating voltage	0 to 6 kV			
Maximum milling rate (Material: Si)	≧ 300 μm/hr*4	≧ 500 μm/hr*4	–	
Maximum sample size	20 (W) × 12 (D) × 7 (H) mm		Φ50 × 25 (H) mm	
Sample moving range	X±7 mm, Y 0 to +3 mm		X 0 to +5 mm	
Ion beam intermittent irradiation	Standard function			
Rotation speed	–		1 r/m, 25 r/m	
Swing angle	±15°, ±30°, ±40° *5		±60°, ±90°	
Tilt	–		0 to 90°	
Gas flow rate control system	Mass flow controller			
Evacuation system	Turbo-molecular pump (33 L/S) + Rotary Pump (135 L/min at 50 Hz, 162 L/min at 60 Hz)			
Dimension	616 (W) × 705 (D) × 312 (H) mm			
Weight	Main unit 48 kg + Rotary pump 28 kg			
IM4000 / IM4000PLUS with cooling temperature control unit				
Cooling temperature control function	Indirectly cooling by LN_2, Range of set temperature : 0 to −100°C			
Options				
Air protection specimen holder	Only cross-section milling		–	
Cross-section milling holder (FP)	100 μm/rotate*6		–	
Zoom stereo microscope unit	Binocular type, Tri-eye (for CCD)			

∗4 Si protrudes 100 μm from the mask edge.
∗5 Swing angle at cooling is ±15°and ±30°.
∗6 Movement pitch of the mask, 1/5 pitch against the current Cross-section Milling Holder.

Installation Requirements

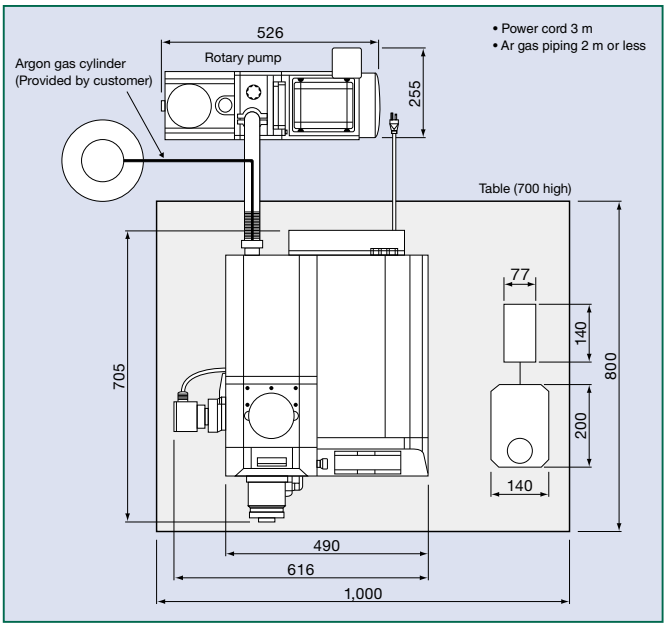
Item	Description
Room Temperature	15 to 30°C
Humidity	45 to 85% without moisture condensation
Power supply*7	AC100 V (±10%) , 50/60 Hz, 1.25 kVA
Grounding	100 Ω or less

Products prepared by customer

Item	Description
Ar gas	99.99% purity
Ar gas pressure	0.03 to 0.05 MPa
Ar gas tubing*8	1/8 inch SUS piping (1/8 Swagelock-compatible), Pressure regulator
Oxygen content meter*9	19% oxygen concentration
Recommended table	1000 (W) x 800 (D) x 700 (H) mm or more, Min. weight tolerance : 70 kg (Minimum strength when installing only IM4000 on the desk)

∗7 IM4000 and IM4000PLUS are equipped with a power cord with 3-Pin plug or with M6 crimp contact terminal.
∗8 Tubing connects Ar gas supply (Ar gas cylinder) to the equipment. Pressure gauge regulator required.
∗9 Adequate ventilation and air quality measurements are required.

System layout (unit: mm)



Science Ring

This logo symbolizes Scientific and Analytical instruments of Hitachi High-Tech Group. It is composed with an “S”, standing for “Science”, our technology core competency, and with a ring that represents close connection we make with our customers.
This “Science Ring” shows how we are committed to create new values by strengthening ties between Science and Society.

NOTICE: For correct operation, follow the instruction manual when using the instrument.

Specifications in this catalog are subject to change with or without notice, as Hitachi High-Technologies Corporation continues to develop the latest technologies and products for our customers.

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