ArBlade 5000

■ General

Items	Descriptions
Gas used	Ar (argon) gas
Ar gas flow control system	Mass flow controller
Accelerating voltage	0.0 to 8.0 kV
Evacuation system	Turbo-molecular pump (67 L/S) + Rotary pump (135 L/min (50 Hz), 162 L/min (60 Hz))
Size	619(W)×736(D)×312(H) mm
Mass	Main unit : 53 kg + Rotary pump : 30 kg

■ Cross section milling

Maximum milling rate (Material : Si)	1 mm/h*1 or more
Maximum specimen size	20(W)×12(D)×7(H) mm
specimen moving range	×±7 mm, Y 0 to +3 mm
Ion-beam intermittent irradiation	ON/OFF setting range 1sec to 59 min 59 sec
Swing angle	±15°, ±30°, ±40°
Wide-area cross section milling*2	Standard function, Maximum processing width : 8 mm

■ Flat-milling

Maximum milling area	ϕ32 mm
Maximum specimen size	Φ50×25 (H) mm
specimen moving range	×0 to +5 mm
Ion-beam intermittent irradiation	ON/OFF setting range 1sec to 59 min 59 sec
Rotation speed	1 rpm, 25 rpm
Swing angle	±60°, ± 90°
Ion-beam irradiation angle	0 to 90°

*1: The maximum milling depth in one hour for Si protruding 100 μm from the maskedge.
*2: Specimen moving range of X is ±5 mm. Other specifications are the same as the cross section milling holder.

■ Optional

Items	Descriptions
Cooling temperature control*3	Indirect cooling by LN_2, Range of set temperature: 0 to -100 ℃
Higher beam tolerance mask	2× beam tolerance as compared to the standard mask (Cobalt-free)
Stereo microscope unit for monitoring the process	15× to 100×, Binocular type, Trinocular type (correspond to CCD camera)

*3: Option to deliver with the main unit. Some functions may be restricted during the use of cooling temperature control.

■ Installation conditions

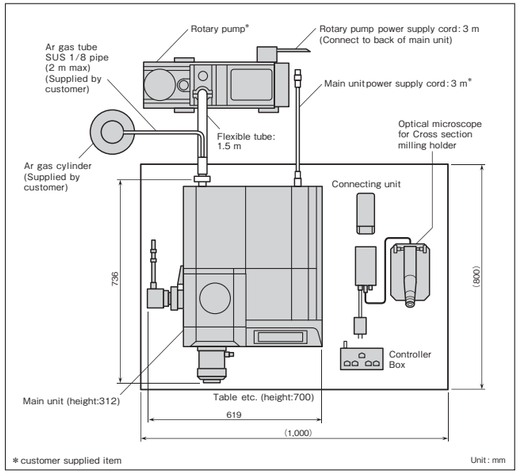
Items	Descriptions
Room temperature	15 to 30 ℃
Humidity	Below 70 % RH Condensation should be avoided
Power source	AC 100 to 240 V (Min 90 V, Max 250 V), 50/60 Hz, 1.5 kVA, 3P high tension cord
Grounding	Type D (below 100 Ω)

■ Products prepared by customer

Items	Descriptions
Ar gas	99.99 % purity
A gas pressure	0.03 to 0.05 MPa
Ar gas tubing*4	1/8 inch SUS pipe (correspond to 1/8 Swagelock), Pressure regulator
Oxygen content meter*5	Oxygen level of 19 % or more should be measurable
Recommended table	1,000(W)×800(D)×700(H) mm or larger The strength of the table should withstand the mass of the ArBlade 5000

*4: Piping to connect Ar gas supply (Ar gas cylinder) and the milling unit. Pressure regulator for supply equipment (Ar gas cylinder) should be purchased together.
*5: An oxygen meter and adequate ventilation are required in the operation area to avoid danger of suffocation by Ar gas.

■ Example of installation layout



Science for a better tomorrow

* This logo is the trademark of Hitachi High-Tech Corporation throughout the world.

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-Tech Corporation continues to develop the latest technologies and products for our customers.

Hitachi High-Tech Corporation
Tokyo, Japan
www.hitachi-hightech.com/global/science/

HTD-E288 2022.9

Ion Milling System
IM4000Ⅱ
ArBlade 5000

HITACHI
Inspire the Next

Ion Milling System
IM4000Ⅱ

Ion Milling System
ArBlade 5000

Science for
a better tomorrow

Base Model Hitachi Ion Milling System

Ion Milling System

IM4000II

＊Options are included in the image of exterior view.
＊The image on the LCD screen is example of the GUI.

Advanced Model Hitachi Ion Milling System

Ion Milling System

ArBlade 5000

＊Options are included in the image of exterior view.
＊The image on the LCD screen is example of the GUI.

Features of Hitachi Ion Milling System

1 Hybrid Milling

- All-in-one cross section milling and flat-milling capabilities.
- Efficient cryo-cooling for beam-sensitive specimens[*1].
- Air protection options to keep specimens free from atmosphere[*1].

2 High Milling Rate

- Improved cross section milling rates though advanced ion-gun design. (Milling rates may differ between IM4000II and ArBlade 5000.)

3 Wide-area Cross section Milling[*2]

- Customizable width (up to 8mm) can be processed.

4 Easy to Operate

- Simplified and user-friendly operation with LCD touch screen.
- Multi-milling and stand-by functions increase operational efficiency.
- Recipe creation and email notifications after processing using Advanced Control Software.[*1*2]

＊1 Option ＊2 Only compatible with ArBlade 5000

Cross section Milling

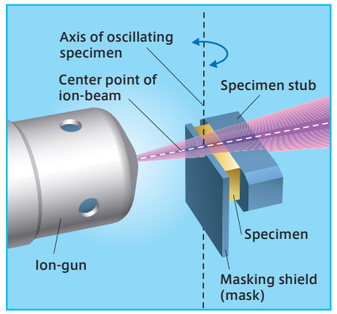


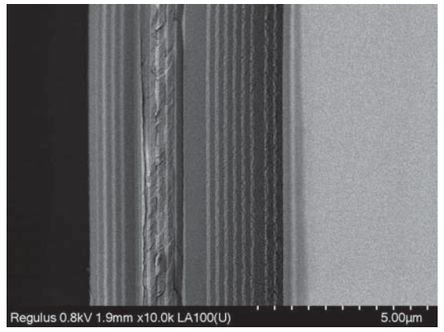
Diagram of Cross section Milling

A pristine surface can be achieved by sputtering (milling) protruding parts of the specimen that extend beyond the maskedge. By irradiating the ion-beam parallel to the processed surface of the specimen, flat and smooth milling is possible even with complex materials of different compositions.

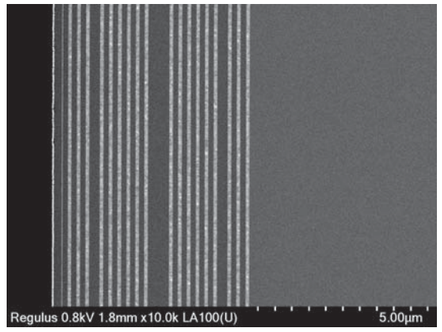
Main uses

- Prepare a cross section specimen in a localized region of interest (ROI)
- Prepare a cross section specimen that is difficult to polish by other methods (composite materials, multi-layer interface, papers/films, etc.)
- Preprocess specimens for EBSD analysis (electron backscatter diffraction)

After cleaving



After cross section milling



Specimen : Infrared filter

Flat-milling

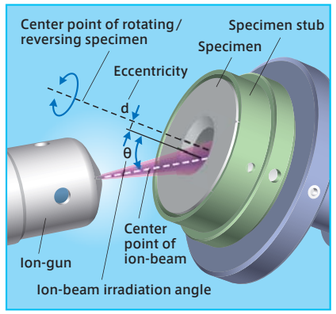


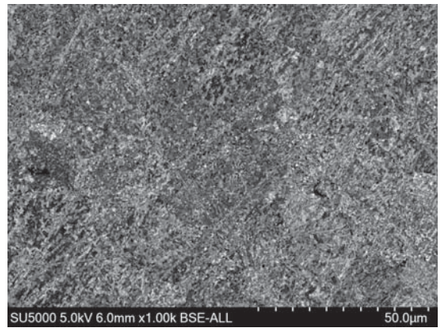
Diagram of Flat-milling

In flat-milling, a wider area can be processed than in cross section milling via eccentricity of the ion-beam and rotating specimen center points. It is also possible to emphasize or reduce irregularities by changing the irradiation angle of the ion-beam in order to reveal crystal orientation and/or subtle compositional differences.

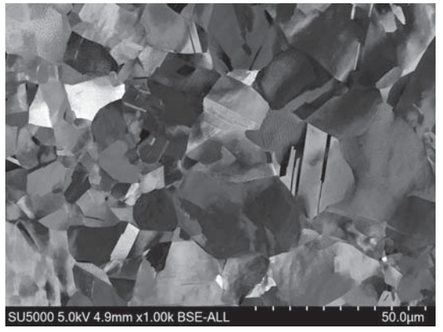
Main uses

- Remove mechanical artifacts from the polishing process (maximum diameter of 50 mm x thickness of 25 mm)
- Remove the surface or upper layers of multilayer film
- Discriminate layers of the cross section for multilayer film (emphasizing irregularities)
- Preprocess large areas for EBSD (reducing irregularities)

After mechanical polish



After mechanical polish and flat-milling

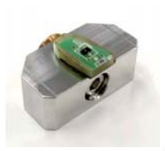


Specimen : Copper plate

Linkage with Hitachi Scanning Electron Microscopes (SEMs)

SEM observation after milling is possible without removing the specimen from the specimen stub or the holder as the cross section and flat-milling holders are directly compatible with multiple Hitachi SEM models.

Hitachi FE-SEM
(Field Emission Scanning Electron Microscope)



Specimen stub

IM4000Ⅱ

∗ The image on LCD screen is a specimen.

ArBlade 5000

∗ The image on LCD screen is a specimen.

Flat-milling Holder
Cross section Milling Holder

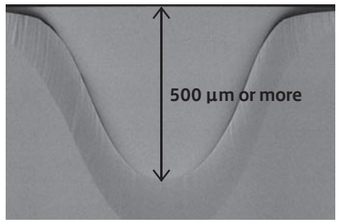
Draw-out style Hitachi SEM∗1

∗1 models compatible: SU3500, SU3800, SU3900, SU7000

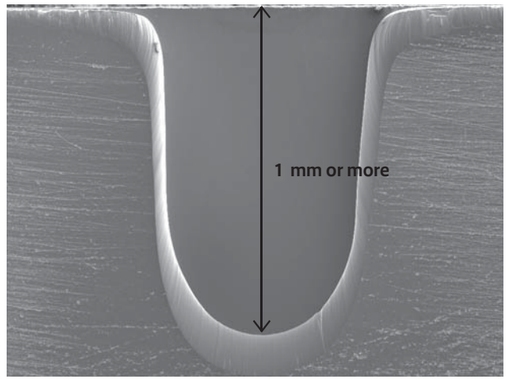
The cross section milling rate*1 of the IM4000 II is 500 µm/h or greater.
The ArBlade 5000 ion-gun, with higher accelerating voltage and increased current density, enables a milling rate of 1 mm/h or greater to allow the preparation of cross section specimen in less time, especially for hard materials that conventionally require extended processing.

*1 The maximum milling depth in one hour for Si protruding 100 µm from the maskedge.

IM4000II



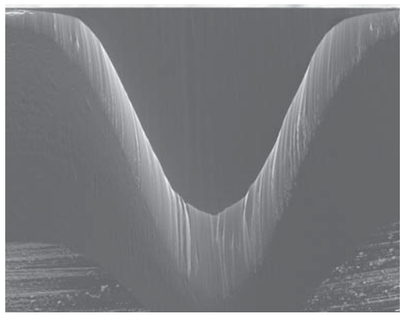
ArBlade 5000



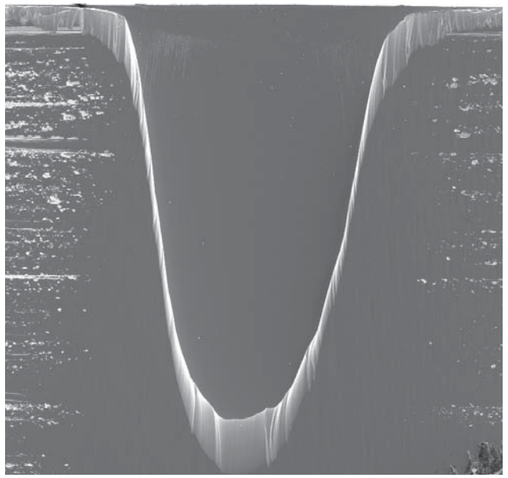
Specimen : Si wafer (2 mm thick)
Accelerating voltage : 6.0 kV (IM4000 II), 8.0 kV (ArBlade 5000)
Swing angle : ±30°
Milling time : 1 hour

When the swing angle during cross section milling changes, the corresponding processing width and depth change. The figure below shows the SEM images of a Si wafer after cross section milling. Processing conditions are the same as shown above for both systems except the swing angle has been reduced from ±30° to ±15°. It is demonstrated that the processing depth is deeper than the above results for both the IM4000 II and the ArBlade 5000 and therefore very effective for rapid cross section preparation of specimens with a target structure far from the top surface.

IM4000II



ArBlade5000



Specimen : Si wafer (2 mm thick)
Accelerating voltage : 6.0 kV (IM4000 II), 8.0 kV (ArBlade 5000)
Swing angle : ±15°
Milling time : 1 hour

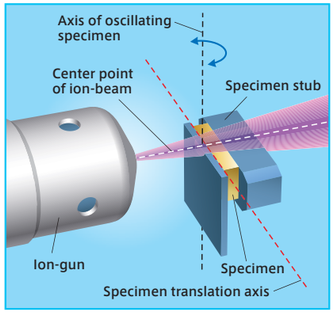
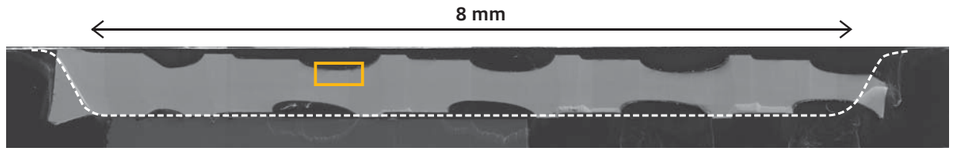


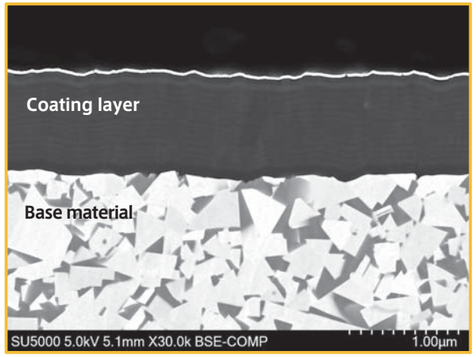
Diagram of Wide-area Cross section Milling

Processing extra wide areas can be achieved by oscillating (or swinging) the cross section milling holder and translating the holder at the same time. The width of the area on the specimen can be adjusted according to the purpose within the range of ±5 mm. This is particularly useful for electronic components and metallic specimen that require wide-area processing.

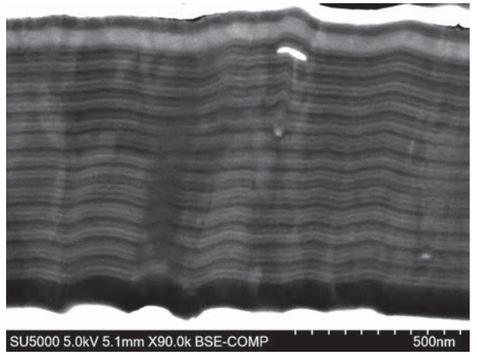
The result of milling a hardened carbide drill using the wide-area cross section milling function is shown below. The area enclosed by the dotted line is the processed area, with 8 mm width and 1 mm depth. After such milling, it is clearly revealed that the coating layer of the carbide drill has a consistent detailed multi-layer structure.



Overall image of the specimen after wide-area cross section milling



Enlarged image of the area marked above



Enlarged image of the coating layer

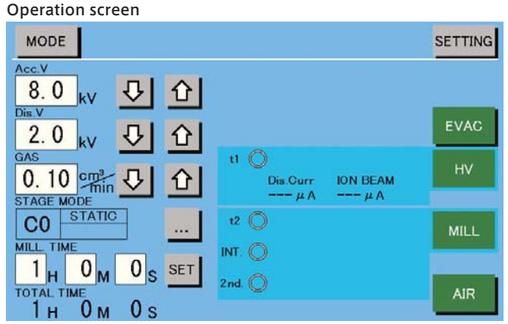
Specimen : Carbide drill
Milling time : 5 hours

*Only compatible with ArBlade 5000

Touch Panel

Milling conditions can be set-up and adjusted using the LCD touch panel.
An intuitive digital display makes programmed conditions clear and easy to understand for users of all experience levels.

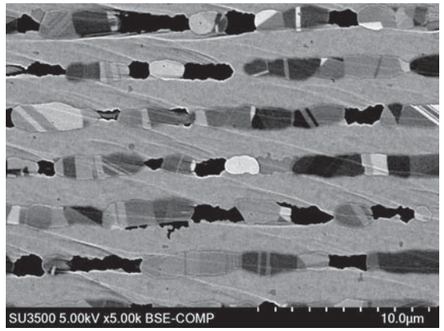
Operation screen



Second Milling Function

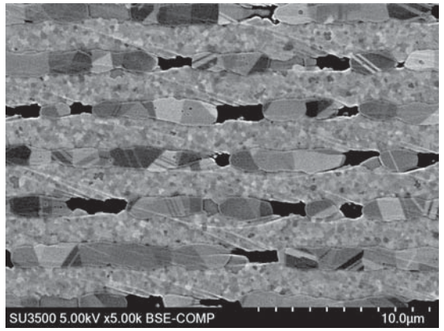
This function can be used to process the same area with two different milling conditions successively. The process is automatically carried out until the second milling condition is completed and works well for complex specimens. For example, by first processing with higher acceleration voltage to remove the major protrusions then switching to lower accelerating voltage for final polish, clear grain contrast of $BaTiO_3$ can be observed, as shown below.

Cross section milling with accelerating voltage of 8.0 kV



Automatic execution

Cross section milling with accelerating voltage of 2.0 kV



Specimen: Ceramic capacitor

Stand-by Function

This function allows users to automatically turn on the accelerating voltage and start processing after a defined period of time. The stand-by duration after reaching the appropriate vacuum level is user selectable so that the process completion time can be more easily controlled.

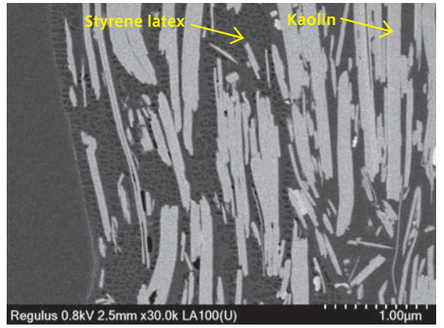
Cooling Temperature Control*1

*1 Option to deliver with the main unit.

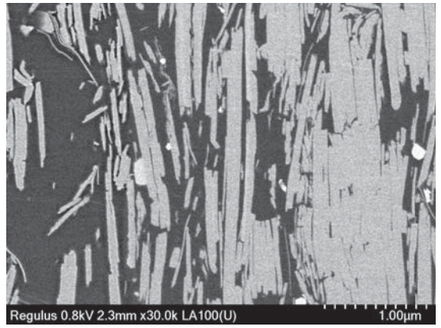
IM4000 II
with cooling temperature control

ArBlade 5000
with cooling temperature control

Sensitive specimens can be cooled with liquid nitrogen during processing. The cooling temperature control uses indirect cooling and maintains a temperature between 0 ℃ and -100 ℃ during processing in order to prevent phase transitions. The ArBlade 5000 is also capable of wide area cross section milling under cooled conditions.
In the example below, specimen cooling suppresses thermal deformation in the heat-sensitive styrene-based latex, resulting in a smooth processed surface.



Room temperature milling



Cooling milling (-100 ℃)

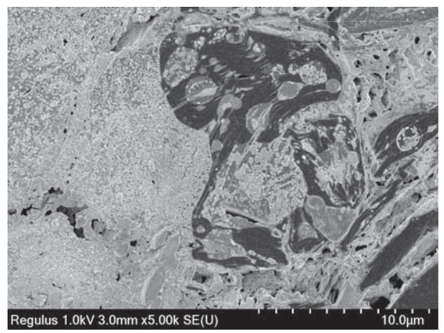
Specimen : Functional material to reduce plastic usage (Made of paper)

Air Protection Holder Unit

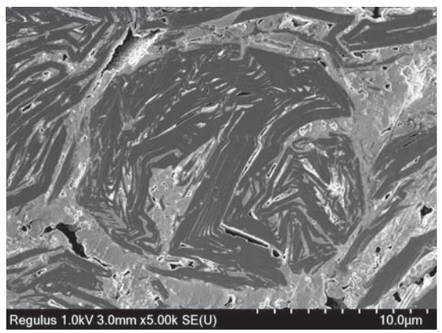
IM4000 II

ArBlade 5000

The Air Protection Holder can be used to keep air-sensitive specimens (such as battery material) isolated from the environment. A specimen fabricated using the IM4000 II / ArBlade 5000 can then be loaded into a SEM and / or Atomic Force Microscope (AFM) without exposure to the outside environment. This function can be used in combination with the cooling temperature control. The ArBlade 5000 also supports Wide-area Cross-section Milling using the Air Protection Holder Unit.



Without air protection holder



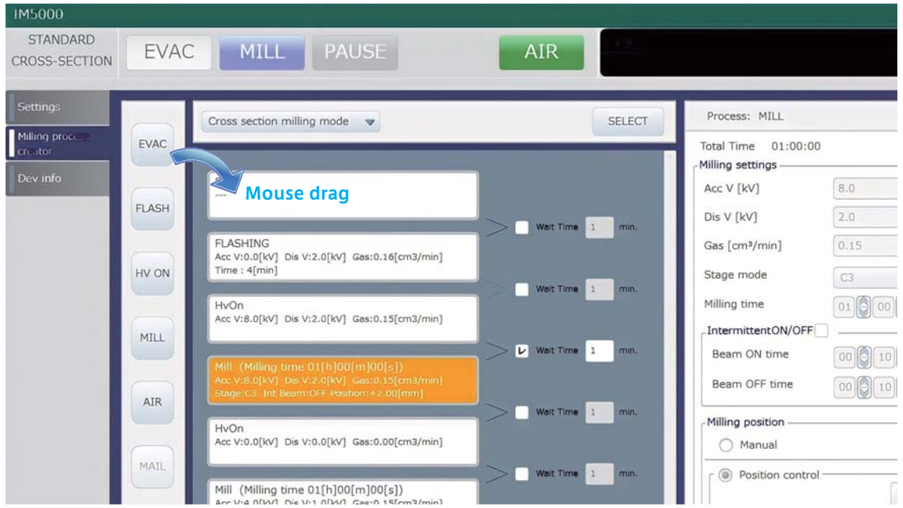
With air protection holder

Specimen: Li ion battery negative electrode (after charged)

* The image on the LCD screen is example of the GUI.

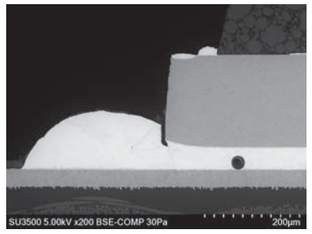
Advanced Control Software (ACS)*1

The ACS module features software to operate the ArBlade 5000 from a separate PC. It is possible to send and receive milling conditions as well as create desired milling recipes with a mouse drag-and-drop method making repeatability and accessibility even easier for all users.

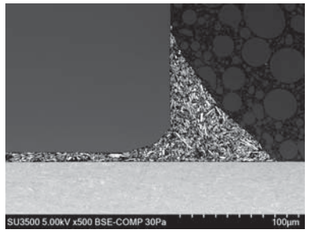


ACS operation screen

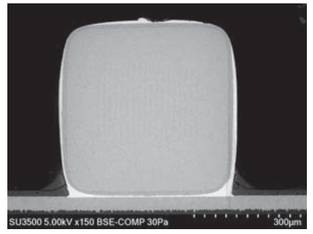
By using the ACS, it is possible to set multiple milling positions and execute multiple milling conditions in a single workflow. The figure below is an example of setting and processing 3 independent locations. After setting the processing width and conditions for each milling position, it is not necessary to return to the ArBlade 5000 until all processing is completed.



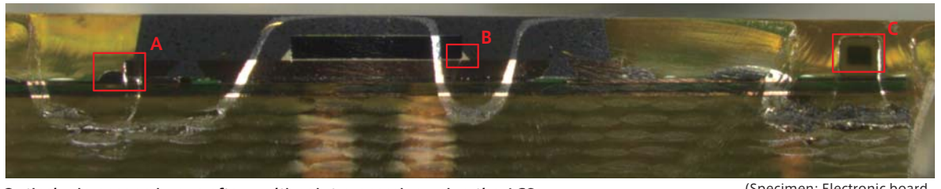
BSE image at A



BSE image at B



BSE image at C



Optical microscope image after multi-point processing using the ACS

(Specimen: Electronic board,
Total processing time: 4 hours)

2 mm

*1 Only compatible with ArBlade 5000

Ion-Gun Alignment System (IAS)*1

The Ion-Gun Alignment Unit enables a more precise X/Y/Z position adjustment of the ion-gun. Using a dedicated holder, the ion-beam center position can be set, and the ion-beam profile is optimized in order to increase the reproducibility of the final processed shape.

*1 IAS is option to deliver with only ArBlade 5000 main unit.

ArBlade 5000 IAS


Ion-Gun Alignment Unit

Higher Beam Tolerance Mask (Cobalt-free)

Masks are available for cross section milling which have ion-beam tolerance 2x greater than standard masks. These masks are well suited for milling hard materials which require long processing times. The Higher Beam Tolerance Masks are made of cobalt-free tungsten carbide.

Stereo Microscope Unit for Process Observation

A stereo microscope can be outfitted to observe the specimen during the milling process. Both binocular- and trinocular-type systems are available. The trinocular version (as shown below) allows for view streaming to an external monitor when equipped with a CCD camera*2.

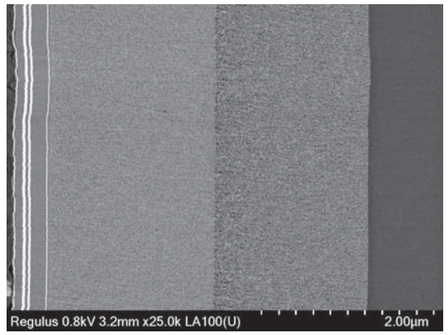
*2 CCD camera and monitor are not included. Please purchase separately.

IM4000 II

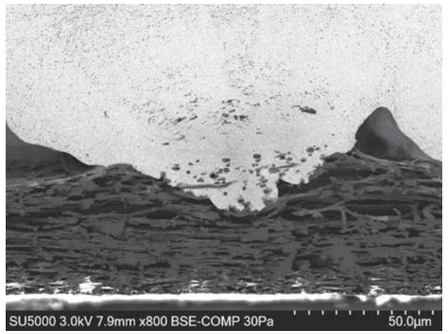
Stereo Microscope Unit for process observation (trinocular-type)

ArBlade 5000

A desired cross section region can be exposed while maintaining the inherent structure by cross section milling even for specimens that are difficult to mechanically polish or cut with a razor. For specimens where damage from the argon ion-beam is a concern, such as the eggshell example below, low-acceleration-voltage milling can be implemented to reduce beam impact.

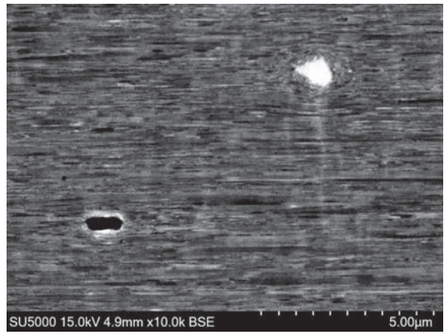


Specimen: Optical multilayer film

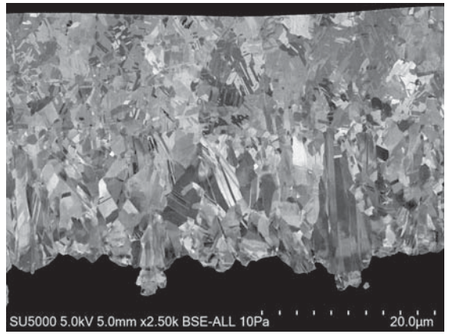


Specimen: eggshell

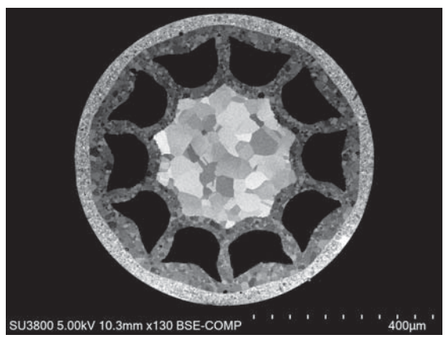
Below are examples from various materials after cross section milling. Ion milling can process a specimen without introducing external stress whereby enabling detailed SEM observation of fine internal structure.



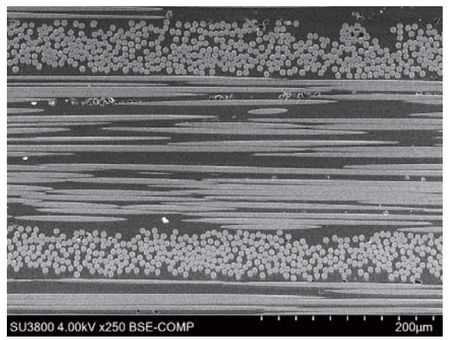
Specimen: Maraging steel



Specimen: Copper foil in flexible film

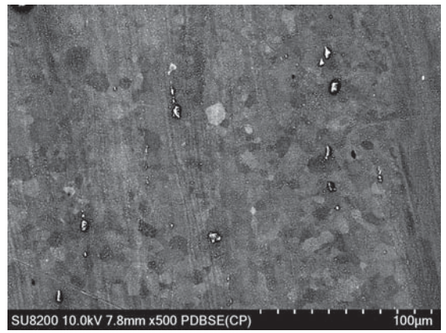


Specimen: Superconducting material

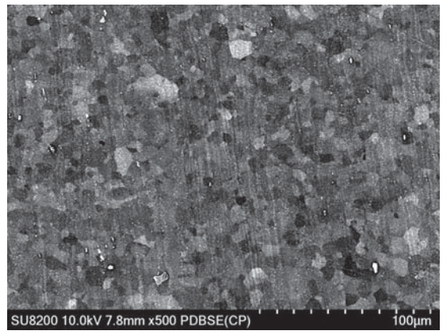


Specimen: Carbon Fiber Reinforced Plastics (CFRP)

Below are examples utilizing Flat-milling as a final cleanup after mechanical polishing. Residues (abrasives, etc.) and polishing strains during mechanical methods are removed, and clear grain contrast of crystalline materials can be obtained.

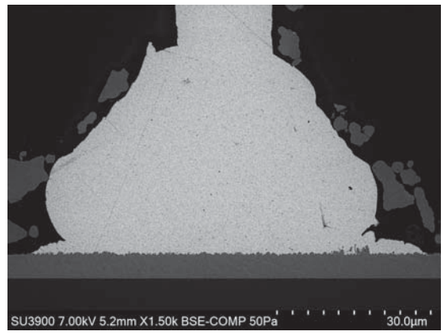


Before ion milling (Mechanically polished surface)

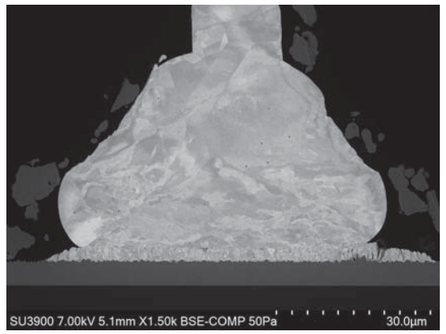


After ion milling

Specimen: Mg alloy (AZ31)



Before ion milling (Mechanically polished surface)



After ion milling

Specimen: Au bonding wire

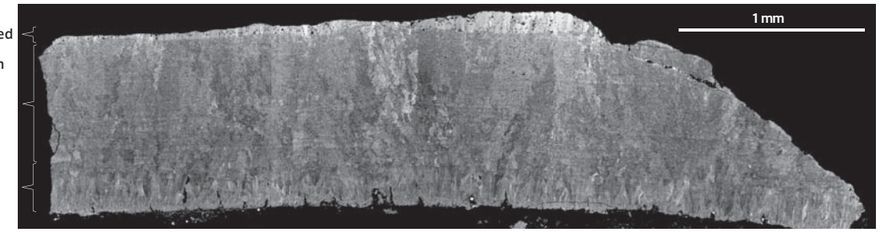
Below is an example where Flat-milling was used for post-processing of materials prepared with Focused Ion-Beam (FIB). The use of such ion milling allows for high-resolution, high-contrast observation of semiconductor devices.

Before ion milling (FIB fabricated surface)

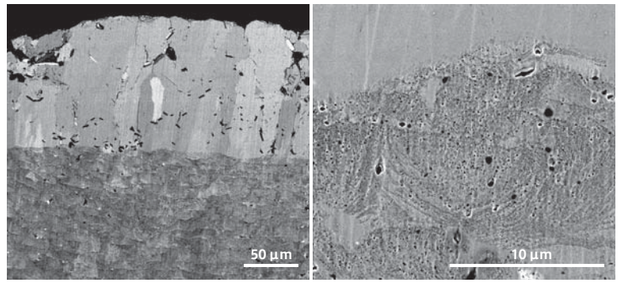
After ion milling (FIB fabricated & Ion milling)

Specimen: silicon carbide (SiC) power device

Wide-area Cross section Milling ArBlade 5000



Specimen: Fossil (dinosaur eggshell)

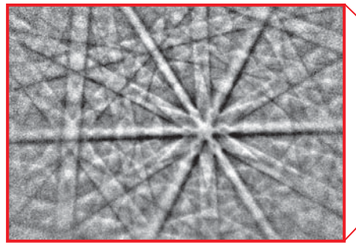


A flat and smooth milling surface, approximately 5.5 mm (W) x 1.5 mm (D), was attained from a fragile specimen.
Three layers of different compositions can be observed by varying grain contrast.
Countless pores throughout the eggshell were revealed at higher magnifications.

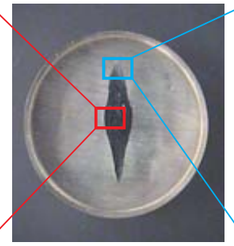
Specimen provided by Yasuhisa Nakajima,
Atmosphere and Ocean Research Institute,
The University of Tokyo

Below Flat-milling was used as a final step after mechanical polishing. Clear Electron Backscattered Patterns (EBSPs) were obtained at the center and tip of the specimen. A stripe structure containing small and large phases was clearly observed in the SEM and EBSD map.

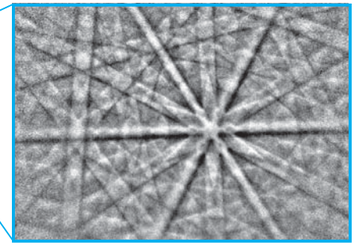
EBSP at the center part
(area enclosed by red line)



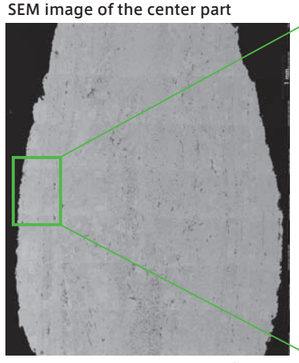
Kris sword after mechanical polishing



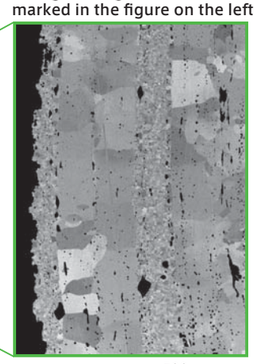
EBSP at the tip
(area enclosed by blue line)



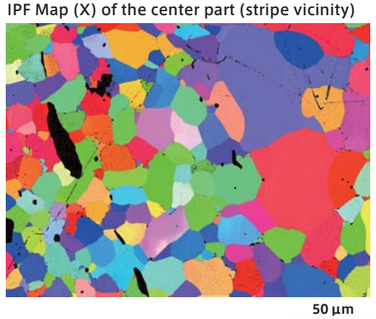
SEM image of the center part



Enlarged image of the area marked in the figure on the left



IPF Map (X) of the center part (stripe vicinity)



Specimen: Kris sword (dagger with double-edged wavy blade produced in south-eastern Asia)
Specimen provided by professor emeritus Masahiro Kitada,
Tokyo University of the Arts

IM4000 II

■ General

Items	Descriptions
Gas used	Ar (argon) gas
Ar gas flow control system	Mass flow controller
Accelerating voltage	0.0 to 6.0 kV
Evacuation system	Turbo-molecular pump (67 L/S)+ Rotary pump (135 L/min(50 Hz), 162 L/min(60 Hz))
Size	616(W)×736(D)×312(H) mm
Mass	Main unit: 53 kg+Rotary pump : 30 kg

■ Cross section milling

Maximum milling rate (Material : Si)	500 µm/h*1 or more
Maximum specimen size	20(W)×12(D)×7(H) mm
Specimen moving range	X±7 mm, Y 0 to +3 mm
Ion-beam intermittent irradiation	ON/OFF setting range 1sec to 59 min 59 sec
Swing angle	±15°, ±30°, ±40°
Wide-area cross section milling	—

■ Flat-milling

Maximum milling area	ϕ32 mm
Maximum specimen size	Φ50×25 (H) mm
Specimen moving range	×0 to +5 mm
Ion-beam intermittent irradiation	ON/OFF setting range 1sec to 59 min 59 sec
Rotation speed	1 rpm, 25 rpm
Swing angle	±60°, ± 90°
Ion-beam irradiation angle	0 to 90°

*1: The maximum milling depth in one hour for Si protruding 100 µm from the maskedge.

■ Optional

Items	Descriptions
Cooling temperature control*2	Indirect cooling by LN_2, Range of set temperature : 0 to -100 ℃
Higher beam tolerance mask	2× beam tolerance as compared to the standard mask (Cobalt-free)
Stereo microscope unit for monitoring the process	15× to 100×, Binocular type, Trinocular type (correspond to CCD camera)

*2: Option to deliver with the main unit. Some functions may be restricted during the use of cooling temperature control.

■ Installation conditions

Items	Descriptions
Room temperature	15 to 30 ℃
Humidity	Below70 % RH Condensation should be avoided
Power source	AC 100 to 240 V(Min 90 V, Max 250 V), 50/60 Hz, 1.5 kVA, 3P high tension cord
Grounding	Type D(below 100 Ω)

■ Products prepared by customer

Items	Descriptions
Ar gas	99.99 % purity
A gas pressure	0.03 to 0.05 MPa
Ar gas tubing*3	1/8 inch SUS pipe (correspond to 1/8 Swagelock), Pressure regulator
Oxygen content meter*4	Oxygen level of 19 % or more should be measurable
Recommended table	1,000(W)×800(D)×700(H) mm or larger The strength of the table should withstand the mass of the IM4000Ⅱ

*3: Piping to connect Ar gas supply (Ar gas cylinder) and the milling unit.
Pressure regulator for supply equipment (Ar gas cylinder) should be purchased together.
*4: An oxygen meter and adequate ventilation are required in the operation area to avoid danger of suffocation by Ar gas.

■ Example of installation layout