

# Model 1010

## Ion Mill

Tabletop precision ion milling  
and polishing system



EXCELLENCE...MAGNIFIED

# Model 1010 Ion Mill

- *Fully programmable and easy to use.*
- *Two independently adjustable Hollow Anode Discharge (HAD) ion sources.*
- *High or low energy operation for either rapid milling or more gentle specimen polishing.*
- *Individual, automatic ion source gas control.*
- *Oil-free vacuum system.*
- *Continuously adjustable milling angle.*
- *Specimen rotation or rocking.*
- *Accommodates SEM samples.*
- *Chemically assisted and reactive etching.*
- *Automatic termination.*
- *Liquid nitrogen-cooled specimen stage.*
- *7 to 45X stereo microscope for direct specimen observation.*
- *High-magnification microscope and CCD camera.*

**Model 1010 Ion Mill** (shown with optional high magnification microscope and video monitor) is an advanced, compact precision ion milling and polishing system that consistently produces high-quality TEM specimens with large electron transparent areas from a wide variety of materials.



## Ion Milling

Ion milling is used on physical science specimens to reduce the thickness to electron transparency. Inert gas, typically argon, is ionized and then accelerated toward the specimen surface. By means of momentum transfer, the

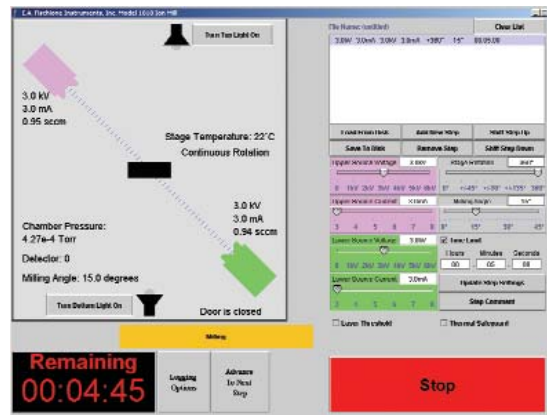
impinging ions sputter material from the specimen at a controlled rate. Alternatively, a reactive gas may be used to increase the effective milling rate since its chemical reactivity supplements momentum transfer.

## Advanced specimen preparation

For many of today's advanced materials, analysis by transmission electron microscopy (TEM) is the best technique for gathering valuable information about material structure and properties. For TEM analysis, the specimen needs to be thinned to electron transparency. Fischione's Model 1010 Ion Mill is an excellent tool for creating the thin specimens needed for TEM imaging and analysis.

## Easily programmable

The fully programmable Model 1010 operates with minimal user intervention. Milling parameters such as ion energy, milling angle, stage rotation or rock, termination sensitivity, temperature threshold, and milling time are programmed via an easy-to-use, window.



Ion Mill program window

For effective, unattended operation, a series of operational sequences can be established. Typical methodology starts with rapid milling; then as the specimen thins, a slower milling rate is employed to eliminate artifacts. Milling programs can readily be stored and recalled.

## Two ion sources

Two individually controlled hollow anode discharge (HAD) ion sources are focused on both specimen surfaces. The HAD ion source is small and requires only about 0.4 sccm of gas, but produces a wide range of ion beam energies.

When operated at low voltage and current, material is gently removed from the specimen without inducing artifacts. When operated at the upper energy range, rapid milling occurs, even at low milling angles.

Ion accelerating voltages are programmable and can be continuously controlled, from as high as 6.0 kV for rapid milling to as low as 500 volts for final specimen polishing. Ion source currents can be programmed from 3mA to 8mA.

During operation, ion source parameters are displayed in real time.

The ion sources can be visually aligned from outside the vacuum, if required, using a fluorescent target.

# Model 1010 Ion Mill

## **Minimal maintenance**

Material sputtered from the source is negligible, which minimizes both specimen contamination and component maintenance.

All system components are easily accessible for routine cleaning and service. An ion source can be replaced in as little as five minutes. Water cooling extends both HAD life and the time interval between cleanings.

## **Automatic gas control**

Gas is automatically regulated for each ion source by two independent mass-flow controllers. The gas control algorithm produces stable ion beams over a wide variety of ion source operating conditions and milling parameters.

## **Fully integrated dry vacuum system**

The fully integrated vacuum system includes a turbomolecular drag pump backed by a multi-stage diaphragm pump. This oil-free system assures a clean environment for specimen processing.

Because gas requirements of the HAD ion source are small, the 70 lps turbomolecular drag pump yields an operating system vacuum of between  $1 \times 10^{-5}$  and  $5 \times 10^{-4}$  Torr. The vacuum level is measured with a Pirani gauge and is continuously indicated on the program window.

The pump down and venting sequences are automatically controlled, optimizing vacuum performance and extending component life.

## **Non-contaminating specimen mounting**

Within the specimen holder, the specimen is secured between two molybdenum plates. Molybdenum was chosen for its low sputtering rate, which extends plate life. To prevent specimen shadowing, a unique plate design provides unobstructed ion flow to the specimen in the double-sided thinning mode, even at low angles.

Because the specimen is clamped, there is no possibility of specimen contamination from an adhesive. A loading station provides a platform for the specimen and allows easy positioning into the specimen holder. The loading station also activates the specimen clamping plates that retain the specimen within the holder.

An optional holder readily accommodates SEM samples for effective surface enhancement.

## **Quick specimen transfer**

Once the specimen has been installed into the specimen holder, it can be easily placed into the specimen stage in 30 seconds or less. After venting, the specimen can be rapidly transferred to the TEM, thus reducing specimen contamination from ambient conditions.

## Precise angle adjustment

The Model 1010's ion beam impingement angle range is programmable from 0° to 45°. With the ion sources fixed in position and directed at both specimen surfaces, the specimen stage is tilted to provide the desired milling angle. Both surfaces are milled simultaneously, which increases the effective milling rate and avoids redepositing sputtered material on the specimen surface.

Ion milling with low angles of incidence (less than 10°) means that irradiation damage and specimen heating are both minimal. Since it facilitates the uniform thinning of dissimilar materials, low angle milling is highly beneficial when preparing layered or composite materials as well as cross-section TEM (XTEM) specimens.

## Programmable rocking angle

The Model 1010 is ideally suited for preparing cross-section (XTEM) specimens from heterogeneous or layered materials. Rocking the specimen in relation to the ion beam minimizes both the preferential milling of the glue bond line in XTEM specimens and the faster milling materials contained in layered composite specimens.

Rocking angles are programmable between 1° and 179°. A programmed value of 360° results in continuous specimen rotation.

## Optional integrated stage cooling

Although milling at low angles and ion beam energies reduces specimen heating, highly temperature-sensitive specimens may require further cooling. Liquid nitrogen cooling of the specimen stage is very effective in eliminating heat-induced artifacts.

The liquid nitrogen system features an internal dewar that is fully integrated and interlocked through the Model 1010's advanced control. Stage temperature is continuously displayed.

At the conclusion of milling at cryogenic temperatures, an integral heater automatically raises the specimen stage temperature to 20°C before venting to avoid specimen contamination.

In addition, a thermal safeguard can be programmed to a specific temperature at which the ion sources will be automatically deactivated. This is particularly beneficial if the liquid nitrogen in the dewar becomes depleted.

## Automatic termination

The ion milling process can be automatically terminated by temperature, by elapsed time, or by a laser photodetection system.

**Temperature:** The thermal safeguard associated with the specimen cooling system will stop the process if the specimen stage reaches a preset temperature.

**Time:** A timer allows milling to continue for a predetermined time, and then automatically de-energizes the ion sources while keeping the specimen chamber under vacuum until the user vents the system to extract the specimen.

**Photodetector (optional):** A laser light source and a photodetector sense transmission of light through the specimen. A programmable sensitivity control automatically stops the ion milling process as the specimen becomes translucent.

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## Chamber

The easy-to-clean, small sized chamber allows the turbomolecular drag pump to evacuate the system to an operating vacuum level in less than three minutes. Additionally, it allows the ion sources to be appropriately positioned to create ideal ion beam properties.

## Specimen viewing

The specimen may be viewed in-situ at any time without breaking vacuum. The viewing windows are long lasting, scratch resistant sapphire. Shutters prevent the buildup of sputtered material, which could inhibit or prevent viewing.

The specimen is illuminated by two independently controlled light sources, one above the specimen (reflected light) and one below (transmitted).

**Stereo microscope (optional).** The Model 1010 Ion Mill accepts a stereo microscope to enhance specimen viewing.

**High-mag microscope (optional).** The Model 1010 can be configured with a high magnification imaging system comprised of a high magnification microscope coupled to a CCD camera and video monitor for image capture and display. This system is ideal for preparing site-specific specimens.

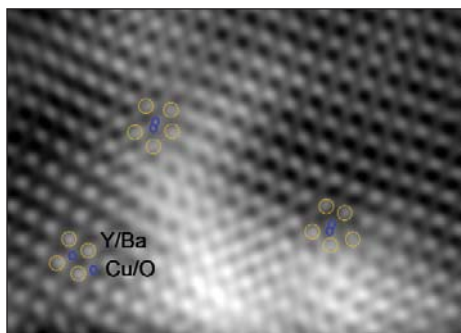
## Reactive gas milling

To further facilitate ion milling, particularly in the case of semiconductor materials, a reactive gas may be used to enhance the specimen preparation process. Gases are chosen to specifically interact with the specimen material in order to promote thinning as a function of both chemistry and momentum transfer.

## Optional chemically-assisted etching

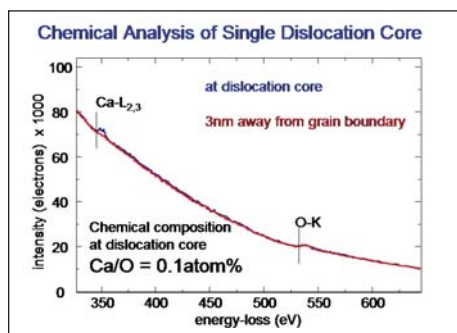
For some semiconductor materials, chemically assisted etching can minimize the artifacts that are commonly associated with argon gas milling. By means of sublimation, a molecular iodine vapor stream is directed at the specimen and is introduced at the impingement point of the argon ion beams. A chemical pumping system is used with an exhaust port that allows corrosive chemical fumes to be vented into a fume hood.

## Results



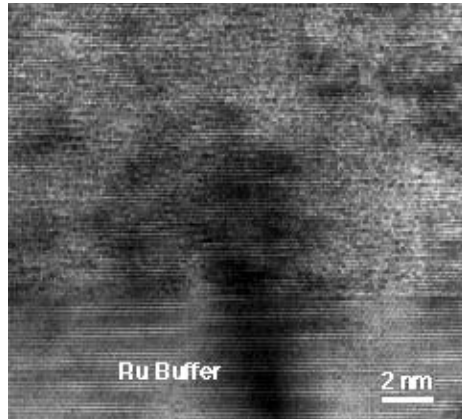
XTEM specimen consisting of a YBCO superconductor in the form of a bicrystal, ion milled at low angle, ion energy, and temperature.

*Image courtesy of G. Duscher and J. Luck, ORNL (U.S.A.)*



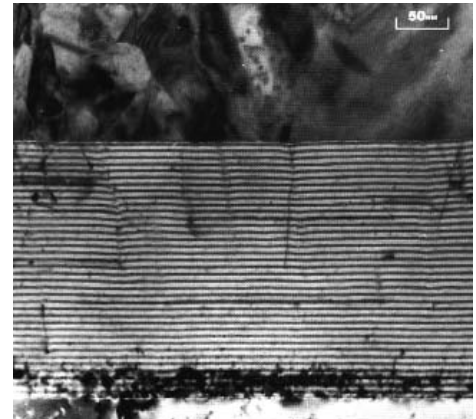
Parallel electron energy-loss spectroscopy (PEELS) data showing retention of Ca dopant distribution on the nanoscale following ion milling at cryogenic temperature.

*Image courtesy of G. Duscher and J. Luck, ORNL (U.S.A.)*



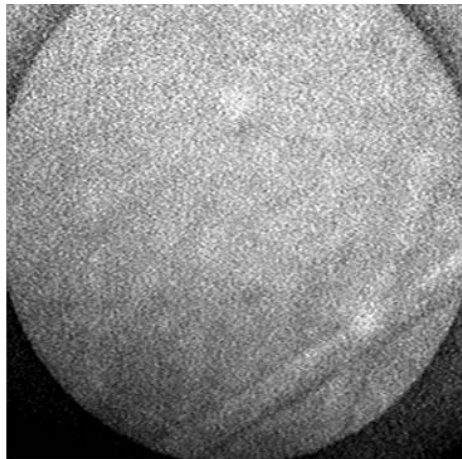
HRTEM image of an XTEM specimen showing a Co/Ru superlattice. The specimen was argon ion milled at a voltage of 4kV, a current of 4mA, and an incident milling angle of 7°. The specimen was cooled to LN<sub>2</sub> temperature and fully rotated (360°) during ion milling.

*Image courtesy of K. Hono and D.H. Ping, NIMS (Japan)*

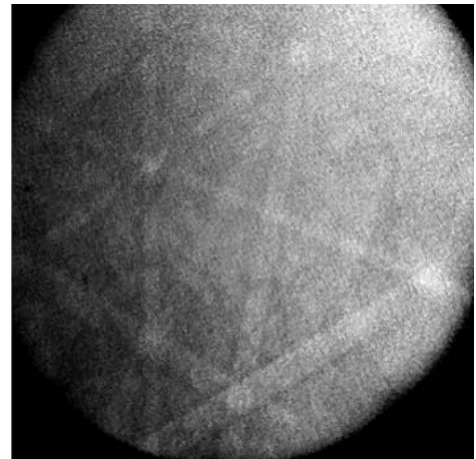


XTEM specimen showing a polycrystalline copper film on an epitaxial Ti<sub>0.5</sub>W<sub>0.5</sub>N/TiN superlattice on MgO.

*Image courtesy of I. Petrov, University of Illinois (U.S.A.)*



Pattern obtained by electron backscatter diffraction (EBSD) of a Si surface before low angle argon ion milling.



Pattern obtained by electron backscatter diffraction (EBSD) of a Si surface after low angle argon ion milling.



TEM image of GaSb after argon ion milling with liquid nitrogen specimen cooling showing no artifacts.

## Model 1010 specifications

<b>Ion sources</b>	Two, fixed position HAD ion sources Variable energy (0.5 to 6.0 kV) operation, continuously adjustable Ion source current 3mA to 8mA, continuously adjustable Beam current density up to 400 microamps/cm <sup>2</sup> Choice of single or dual ion source operation
<b>Specimen stage</b>	Standard Ion Mill: milling angle range of 0° to 45° High-Magnification Ion Mill: milling angle range of 0° to 30° 360° specimen rotation Specimen rocking with 1° increments adjustable from 1° to 179°
<b>Vacuum system</b>	Turbomolecular drag pump backed by an oil-free diaphragm pump Vacuum sensing with a Pirani gauge
<b>Gas</b>	Flow rate approximately 0.4 sccm/ion source, nominal 5 psi delivery pressure required Automatic gas control using two mass flow controllers for unattended operation Milling with either argon or a reactive gas
<b>User interface</b>	Menu-driven, programmable milling cycles with system status displayed
<b>Sample illumination</b>	Independently actuated transmitted and reflected lights
<b>Specimen cooling (optional)</b>	Liquid nitrogen conductive cooling with automatic temperature interlocks
<b>Automatic termination</b>	Automatic termination by laser detector (optional), timer, or temperature
<b>Chemical etching (optional)</b>	Molecular iodine vapor stream Fume exhaust system
<b>Microscope (optional)</b>	Viewport accommodates either a 7-45X stereo microscope attachment for direct specimen observation or a 1,960X high magnification microscope and camera system for site specific image acquisition and display
<b>Enclosure</b>	Weight: 161 lb (73 kg)
<b>Dimensions</b>	Standard Ion Mill: 33" (838mm) W x 14.5" (368mm) H (to top of cabinet) 26.5" (673mm) H (to top of microscope) x 19.5" (495mm) D High-Magnification Ion Mill: 48" (1,219mm) W including video monitor x 14.5" (368mm) H (to top of cabinet) 34" (864mm) H (to top of microscope) x 19.5" (495mm) D
<b>Power requirements</b>	110/220 VAC, 50/60Hz, 1,000 watts
<b>Warranty</b>	One year



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*Cover image: Sb doped Si that has been wedge polished, followed by argon ion beam etching at low angle, ion energy, and temperature. After plasma cleaning, atomic resolution was achieved with ADF-STEM. The image was Gaussian smoothed and thickness corrected. Atomic number contrast shows the Sb as brighter and the Si as darker.*

*Image courtesy of P.M. Voyles, D.A. Muller, J.L. Grazul, P.H. Citrin, H.J.L. Gossmann, Lucent Technologies (U.S.A.)*