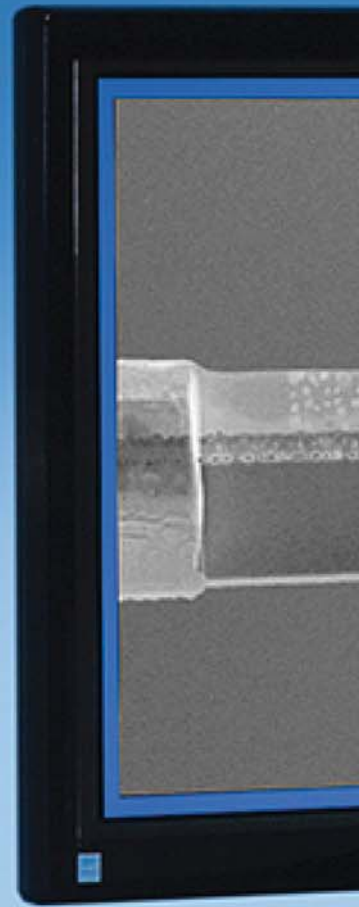


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## PicoMill® TEM specimen preparation system

Combines an ultra-low energy, inert gas ion source and a scanning electron column with multiple detectors to yield optimal TEM specimen preparation



FISCHIONE  
INSTRUMENTS





## POST-FIB PROCESSING PRODUCES THE HIGHEST QUALITY TEM SPECIMENS

Focused ion beam (FIB) milling is a widely used technique for today's cutting-edge materials that provides a means to prepare transmission electron microscopy (TEM) specimens.

The challenge in working with these advanced materials is to create specimens that are electron transparent and are free from artifacts.

The FIB is highly effective in preparing TEM specimens, but the use of a high-energy, liquid metal ion source can often result in specimen amorphization, gallium implantation, or both.

The PicoMill system is the ideal complement to FIB technology; it adds the increased capability of producing optimal specimen quality while enhancing the overall specimen preparation throughput by moving final thinning offline.

# MODEL 1080

## PicoMill® TEM specimen preparation system

Combines an ultra-low energy, inert gas ion source, and a scanning electron column with multiple detectors to yield optimal TEM specimens.

- **Achieve ultimate specimen quality – free from amorphous and implanted layers**
- **Complements FIB technology**
- **Milling without introduction of artifacts**
- **Advanced detector technology for imaging and precise endpoint detection**
- **In situ imaging with ions and electrons**
- **Microscope connectivity for risk-free specimen handling**
- **Adds capability and capacity**
- **Fast, reliable, and easy to use**

## A history of specimen preparation innovation

Since 2006, Fischione Instruments' revolutionary NanoMill® TEM specimen preparation system has set the standard for high-quality TEM specimen preparation.

The NanoMill system's unique combination of features – ultra-low energy ion source, low-angle milling capabilities, and submicron ion beam diameter – have been critical for uncovering specific features of interest within TEM specimens.

The NanoMill system has produced specimens with optimal quality for a number of research and industrial applications, including oxides, fuel cells, photovoltaics, battery materials, and many others.

For microelectronic and semiconductor applications, the NanoMill system's capabilities have played a critical role in producing pristine TEM specimens.

Since the introduction of the NanoMill system, the microelectronics industry has continued to

develop products that are increasingly smaller in size and increasingly complex in geometry, such as three-dimensional FinFET gate architectures and vertical NAND gates.

These intricate devices are comprised of varying densities of dissimilar materials with structures that can contain compounds, such as repeating layers of oxides, silicides, nitrides, various metals, and a mix of high-k and low-k dielectric materials.

These structures contain materials with very different atomic numbers, which can result in differing sputter rates. Preparing these unique specimens for high-resolution imaging by TEM has been consistently achieved with the NanoMill system's advanced technology.

Decreased device sizes coupled with increased materials complexity demand the next generation of TEM specimen preparation. Drawing on our history of innovation, Fischione Instruments developed the PicoMill TEM specimen preparation system, taking the NanoMill system technology to the highest possible level.



Fischione Instruments Model 1080 PicoMill® TEM specimen preparation system.

## Designed specifically to integrate into a FIB workflow

Focused ion beam (FIB) technology is frequently the choice for creating TEM specimens. The FIB is used to create a site-specific, extremely thin lamella that is extracted and mounted to a supporting grid for TEM imaging and analysis. The FIB is highly effective in preparing TEM specimens; however, the FIB's liquid metal (gallium) ion source can result in amorphization, gallium implantation, or both. These damaged layers can be as thick as 10 to 30 nm.

The FIB process is often started at high kilovolt energy levels and the voltage is decreased as the lamella thins. For very low-energy FIB applications, the operator may need to refocus the instrument and realign the beam. This can slow down the overall processing time per specimen. In addition, even low-voltage milling with the FIB may result in gallium implantation.

The PicoMill system is ideally suited to removing these damaged layers. It offers the key features of the NanoMill system – ultra-low energy, inert gas ion source, low-angle milling capabilities, and submicron ion beam diameter – with the added capability of a scanning electron column and multiple detectors. The scanning electron column provides the ability to image a lamella at a scale that is sufficient to view areas of interest.

## Let the FIB do what the FIB does best; let the PicoMill system do the rest

To maximize FIB capacity, specimens can be moved offline for final thinning on the PicoMill system. The PicoMill system provides the ability to precisely and predictably thin a specimen, which reduces the potential for rework and optimizes specimen processing time. This increases your capability by producing specimens of superior quality and enhances the overall specimen preparation throughput.

The PicoMill system will allow you to achieve **first time right** specimen preparation every time.

## THE IDEAL COMPLEMENT TO FIB TECHNOLOGY

By moving final specimen thinning offline, you increase the capability of producing optimal specimen quality while enhancing overall specimen preparation throughput.

### FIB

Lamella is prepared by FIB and mounted to a supporting grid.

### PicoMill system

The grid with lamella is mounted on the PicoMill specimen holder. The specimen holder is then inserted into the PicoMill system goniometer for final thinning by ion milling.

### TEM

PicoMill holder with specimen is plasma cleaned and then inserted into the TEM for imaging and analysis.

### Result

Improved specimen quality and enhanced throughput.

## From FIB to PicoMill system to TEM

A FIB-prepared lamella is mounted on a supporting grid and is loaded onto the PicoMill specimen holder, a TEM-style holder that can be used in both the PicoMill system and the TEM. The design of the holder allows for positive and negative tilt ion milling of the specimen in the PicoMill system and facilitates imaging of the specimen in the TEM.

Following pre-pump of the PicoMill system's standard side-entry goniometer, the specimen holder is inserted into the chamber and the specimen is positioned accordingly for ion milling operations and scanning electron microscope (SEM) imaging.



#### Site-specific, ultra-low-energy milling

The PicoMill system's ion source features a filament-based ionization chamber and electrostatic lenses. The ion source was specifically developed to produce ultra-low ion energies with a submicron ion beam diameter. It uses inert gas (argon) and has an operating voltage range of 50 eV to 2 kV.

The ion source's feedback control algorithm automatically produces stable and repeatable ion beam conditions over a wide variety of milling parameters. Redeposition of sputtered material onto the area of interest is avoided because the ion beam can be focused to a specific area. You can scan a region of the specimen's surface or target a specific area for selective milling. The ions only contact the area of interest on the specimen where they are needed to do the work. The ion beam is kept away from the grid, which prevents redeposition.

#### Precise milling angle adjustment

The ion beam impingement angle is programmable from -15 to +90°. The ion source is fixed in position and the goniometer tilts the specimen holder to achieve the programmed milling angle through the PicoMill system user interface. The specimen is positioned along the X,

Y, and Z axes to precisely orient the FIB lamella with respect to the ion and electron beams.

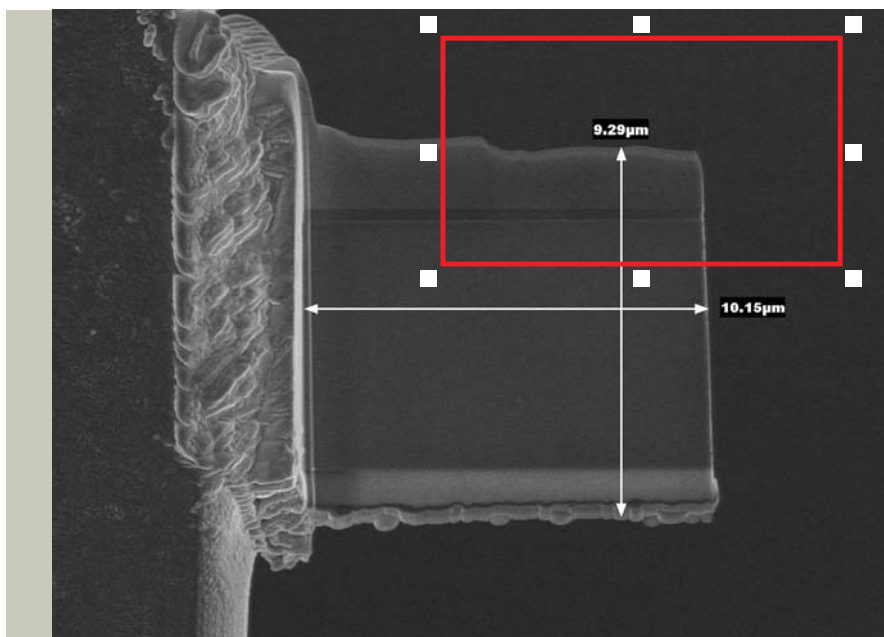
Milling specimens at a low angle of incidence (less than 10°) minimizes damage and specimen heating. Because low-angle milling, combined with ion beam rasterizing, facilitates uniform thinning of dissimilar materials, it is highly beneficial when preparing layered structures or composite materials.

#### In situ imaging

To complement the scanning electron column, the PicoMill system has multiple detectors:

- A **backscatter electron detector (BSE)** for in situ imaging with electrons
- A **secondary electron detector (SED)** for in situ imaging with ions and electrons
- A **scanning/transmission electron detector (STEM)** for electron transparency and endpoint detection

The detector combination allows you to perform in situ imaging of the specimen before, during, and after ion milling. The grid containing a FIB lamella or a specific site on a conventionally prepared specimen can be imaged.



#### FIB LAMELLA IN PICOMILL SYSTEM

The PicoMill system allows the operator to choose a specific area of interest for selective milling via a submicron-sized ion beam. The red raster box indicates the selected milling area. The ion beam can be targeted away from the grid, which reduces the likelihood of redeposition.

## MODEL 1080 PicoMill® TEM specimen preparation system

You can view specimens in situ on a dedicated monitor that displays both electron- and ion-induced secondary electron images. Image capture is as simple as a click of a mouse.

### Computer control

The PicoMill system is controlled via an intuitive user interface. You enter all milling parameters through the interface, such as milling angle, specimen position, and processing time. SEM control and detector selection are also user controlled.

### End-point detection/process termination

A specimen prepared with optimal electron transparency is the ultimate goal for the best quality TEM imaging and analysis. This is particularly key when employing today's aberration corrected TEM technology.

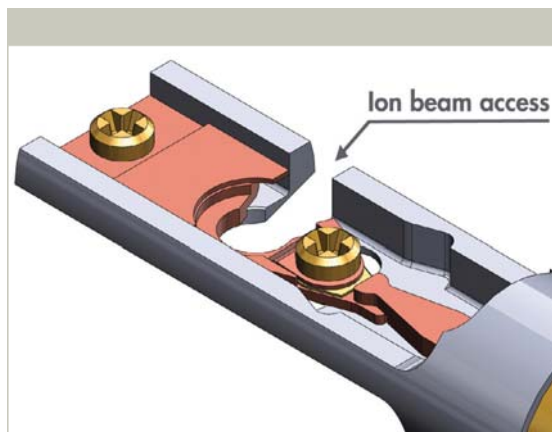
As the specimen thins, electron transmission increases and the leading edge recedes, which allows the STEM detector to provide end point information. The PicoMill system is also capable of time-based termination or it can be stopped manually.

### Plasma cleaning

For the PicoMilling<sup>SM</sup> process, Fischione highly recommends that you plasma clean the specimen and specimen holder prior to insertion into the TEM. During fine-probe microanalysis, organic contamination may build up on the specimen. A cleaning time of 10 seconds to 2 minutes in the Fischione Model 1020 Plasma Cleaner or Model 1070 NanoClean removes the contamination without altering the specimen's structure or composition. Longer cleaning times can remove contamination caused by previous TEM viewing of specimens that were not plasma cleaned.

### Microscope connectivity reduces specimen handling

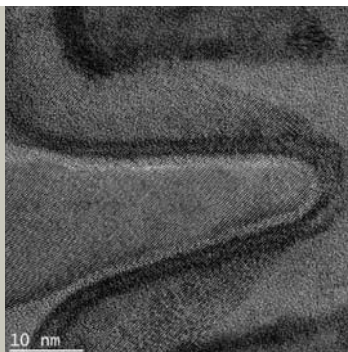
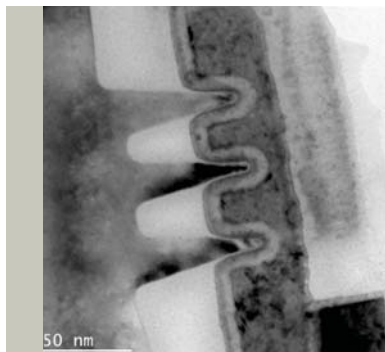
The ability to use the same holder in the PicoMill system and the TEM means that you can quickly and safely transport the milled specimen from the PicoMill system to the TEM, which is particularly advantageous when you are working with one-of-a-kind specimens.



### TEM-STYLE HOLDER

The PicoMill specimen holder was designed specifically for the PicoMill system. The design of the holder tip (top) allows positive and negative tilt ion milling of the specimen. The PicoMill specimen holder is inserted into the PicoMill system's side-entry goniometer (middle). The specimen holder can then go directly from the PicoMill system into the TEM for imaging and analysis (bottom).

## MODEL 1080 PicoMill® TEM specimen preparation system



### 3D STRUCTURES REVEALED

FinFET specimens prepared with the PicoMill system reveal three-dimensional structures for TEM imaging and analysis. A 22 nm Ivy Bridge microstructure imaged in a 300 kV scanning transmission electron microscope (STEM) with  $C_s$  correction is shown.

### Additional features

#### Automatic gas control

Gas is regulated automatically using precision mass flow technology. The low-flow ion source results in minimal gas consumption.

#### Contamination-free, dry vacuum system

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

The vacuum chamber is under constant vacuum, which means that ion milling can begin almost immediately after specimen insertion into the goniometer.

### Customer service that you can rely on

Fischione Service is always there for you and is dedicated to delivering exceptional customer service. Fischione Service provides onsite installation and operations training, onsite preventive maintenance and repair, and replacement parts and supplies. Be sure to protect your investment and your budget with a service contract to reduce the risk of unexpected repair costs and instrument downtime. Fischione Instruments offers service contract options for the level of coverage and peace of mind that you need.

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The PicoMill and NanoMill TEM specimen preparation systems are the subject of United States Patent Nos. 7,132,673 and 7,504,623. Other patents pending. NanoMill and PicoMill are registered trademarks of E.A. Fischione Instruments, Inc. PicoMilling is a service mark of E.A. Fischione Instruments, Inc. ©2015 E.A. Fischione Instruments, Inc. All rights reserved.

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