



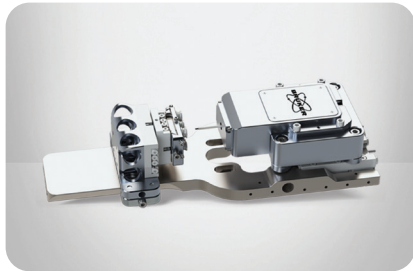
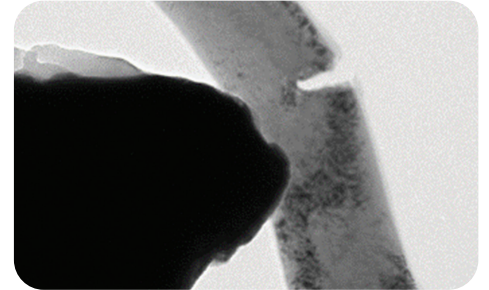
## **Hysitron PI Series PicoIndenter**

- Quantitative In-Situ Nanomechanics Inside Your SEM or TEM

# Hysitron PI Series

## Quantitative In-Situ Nanomechanics

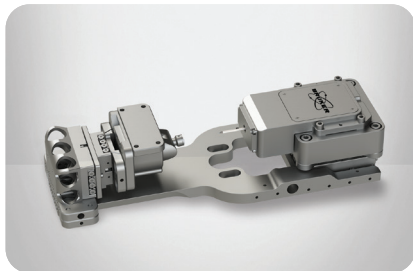
Bruker makes it easy for you to conduct in-situ mechanical experiments in your scanning electron microscope (SEM) or transmission electron microscope (TEM) with the Hysitron PI Series PicoIndenter. With solutions designed to fit most microscope brands, you are sure to find one that is ideally suited to your research.



### Hysitron PI 89 SEM PicoIndenter

Advanced Versatility for Testing in Extreme Environments

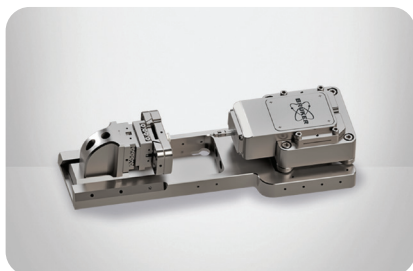
- Truly quantitative nanoscale mechanical characterization with direct observation, and up to 3.5 N load and 150  $\mu\text{m}$  displacement
- Encoded XYZ sample positioning, robust mechanical design, modular platform, and lower weight
- Modular design supports our full suite of testing techniques, including 1000°C heating, cryogenic temperature, scratch, electrical characterization, scanning probe microscopy (SPM) imaging, XPM property mapping, fatigue/nanoDynamic, and more



### Hysitron PI 89 Auto SEM PicoIndenter

Automated and High-Throughput Nanomechanical Instrument

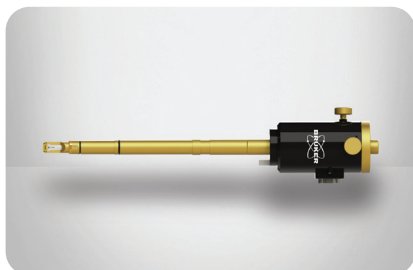
- Seamless EBSD/EDS interface leveraging encoded linear and patented dual-configuration rotation and tilt (R/T) stages
- Automated nanoscale mechanical characterization, and up to 300 mN load and 150  $\mu\text{m}$  displacement
- Structure-processing-property correlations for materials development



### Hysitron PI Envision SEM PicoIndenter

Extended Value and Capabilities for In-Situ Nanomechanical Testing

- Sub-nanometer precision and up to 250 mN force capacity for characterizing a wide range of materials
- Advanced upgrades for performing nanotribology, property mapping, and high temperature testing to 800°C
- Encoded stage control and 78 kHz feedback rate for obtaining fast, repeatable results from indentation, compression, tension, or fatigue testing



### Hysitron PI 95 TEM PicoIndenter

Quantitative, Direct-Observation Nanomechanical Testing Inside Your TEM

- The first full-fledged depth sensing indenter for TEM
- Testing techniques include indentation, compression, tension, bending, and scratch
- Specifically designed to interface with major TEM models (FEI, Hitachi, JEOL, Zeiss)

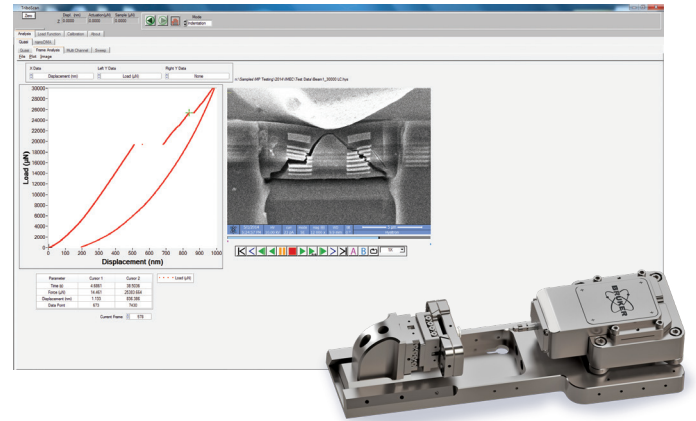
# ● Easily Add Quantitative Mechanical Testing

## Gain Insights Into Mechanical Performance at the Nanoscale

Acquire the mechanical data you need using equipment already in your lab. Extend the capabilities of your microscope to include:

- Nanoindentation
- Microbeam Bending
- Pillar or Particle Compression
- Tension Testing
- Nanoscratch
- nanoDynamic Testing

Pairing these capabilities with the real-time imaging provided by your microscope allows you to see the influence of defects, mechanical strain and thermal or electrical stimuli on the performance, lifetime and durability of engineered materials—from nanometer-to-micrometer scales.

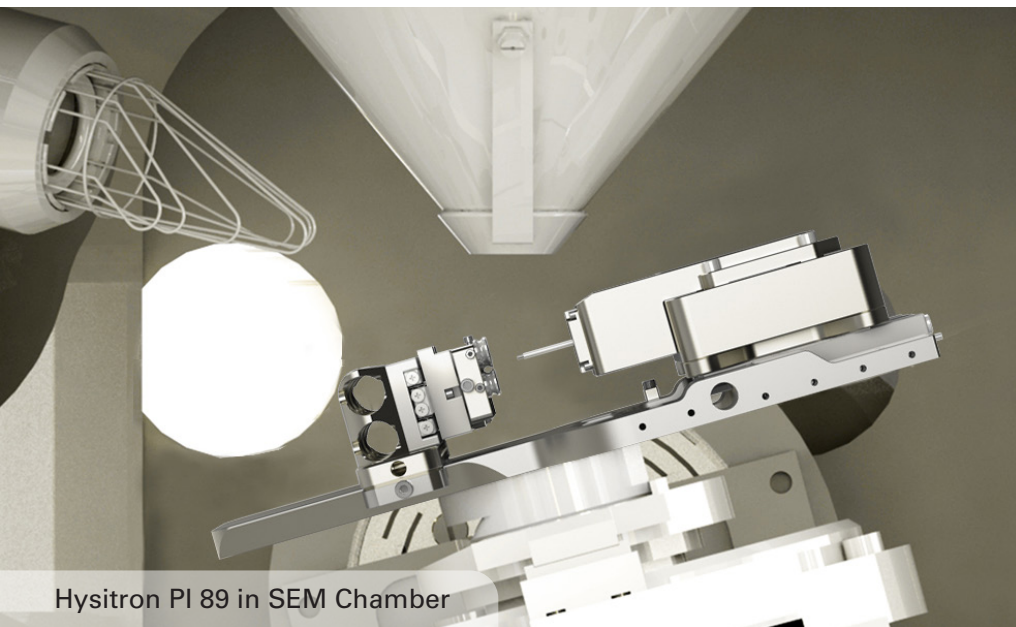


## Uncompromised Stability Throughout Your Experiment

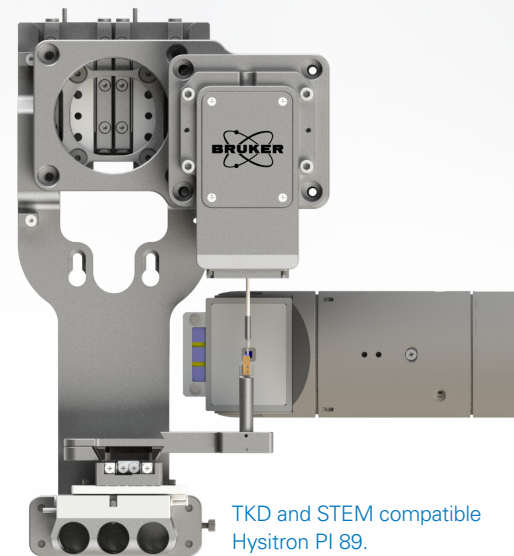
Bruker's in-situ solutions are designed for exceptional performance within the microscope environment. All considerations related to vacuum compatibility, detector positioning and frame compliance have been incorporated. Our proprietary transducer technology assures the highest degree of sensitivity and stability for superior nanomechanical measurements throughout your tests, while our digital controller provides ultra-fast feedback and data acquisition rates. High-magnification analysis is performed before, during, and after the stress-induced deformation process.

## True Displacement Control with Piezo-Driven Flexure

Hysitron PI 89 utilizes Bruker's proprietary subnanometer sensitivity transducer and piezo-driven flexure for true displacement-controlled tests. The transducer can apply force electrostatically while simultaneously measuring displacement capacitively. When using the flexure, the displacement range can also be increased dramatically (max 150 µm). The uniquely low-current design of the transducer minimizes thermal drift and provides unprecedented sensitivity. This is coupled to an encoded XYZ stage with 12 x 26 mm range for sample positioning and 29 mm in indentation axis, providing greater access to larger samples. This mechanical integration of sample stage and transducer on a single platform provides a stable foundation for superior lateral precision, linearity, and repeatability.



Hysitron PI 89 in SEM Chamber



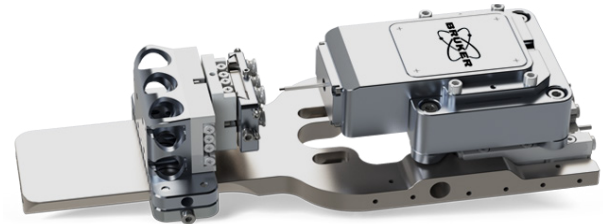
TKD and STEM compatible  
Hysitron PI 89.

## ● In-Situ Nanomechanics Inside Your SEM

### Hysitron PI 89 SEM PicoIndenter

Advanced Versatility for Extreme Environments

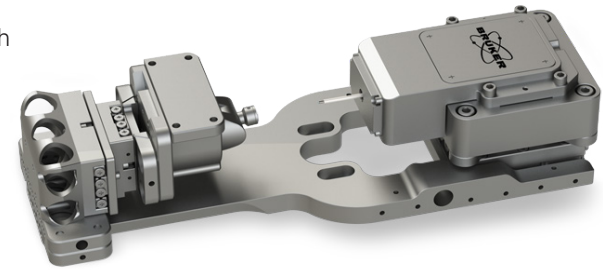
Hysitron PI 89 provides researchers in-situ nanomechanical testing capabilities inside a SEM from very low to high loads, and provides extreme environmental control. The system combines Bruker's high-performance controller with exclusive capacitive transducer and intrinsic displacement control flexure technology, enabling industry-leading force and displacement resolutions with extended force and displacement ranges. The modular design also supports a full suite of testing techniques for future upgradability, including heating, scratch testing.



### Hysitron PI 89 Auto SEM PicoIndenter

Automated and High-Throughput Nanomechanical Instrument

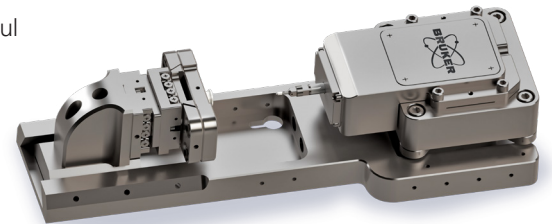
The PI 89 Auto is the first in-situ SEM instrument on the market with two rotation and tilt stage configurations. This patented architecture with TriboScan Auto software enables sample positioning towards the electron column for top-down imaging, or tilting towards the FIB column for milling, while maintaining compatibility for a wide range of detectors (EDS, CBD, EBSD, and TKD) for analytical imaging, phase mapping, and chemical analysis.



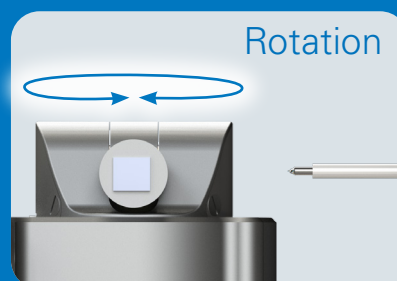
### Hysitron PI Envision SEM PicoIndenter

Extended Value and Capabilities for In-Situ Nanomechanical Testing

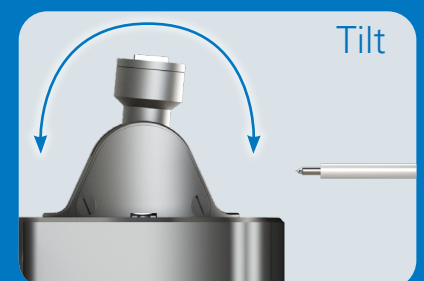
Hysitron PI Envision is an easily upgradable platform that offers a powerful suite of in-situ testing techniques. The system offers sub-nanometer force and displacement resolution, as well as support for advanced testing modes, including high-throughput nanoindentation, mechanical property mapping, nanotribology, and high-temperature testing. PI Envision's modular architecture makes it suitable for both specialized investigations and routine workflows, ensuring adaptability for evolving research programs and multi-user facilities that prioritize high data quality, experimental versatility, and long-term scalability.



**The Hysitron PI 89 Auto includes patented 5-axis (X, Y, Z, tilt, rotation) sample-positioning stage.**



Rotation



Tilt

## ● In-Situ Nanomechanics Inside Your TEM

# Hysitron PI 95 TEM PicoIndenter

Quantative Nanomechanical Testing Inside Your TEM

The Hysitron PI 95 instrument from Bruker is the first full-fledged depth-sensing indenter capable of direct-observation nanomechanical testing inside a TEM. With this side-entry instrument, it is not only possible to image the mechanical response of nanoscale materials, but also to acquire load-displacement data simultaneously. Further, an integrated video interface allows for time synchronization between the load-displacement curve and the corresponding TEM video.

### Experimental Control

Coupling a nanomechanical test system with the TEM enables the researcher to determine certain test parameters *a priori*, such as variations in chemical composition or the presence of preexisting defects in the specimen. In addition to imaging, selected-area diffraction can be used to determine sample orientation and loading direction. Moreover, with in-situ mechanical testing the deformation event can be viewed in real-time rather than “*post mortem*.” The pairing of these two high-resolution techniques provides the best of both worlds.

### Unparalleled Performance

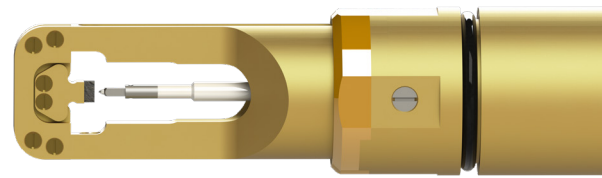
The Hysitron PI 95 utilizes three levels of control for tip positioning and mechanical testing. In addition to a three-axis coarse positioner and a 3D piezoelectric actuator for fine positioning, the instrument is equipped with a transducer for electrostatic actuation and capacitive displacement sensing. Two designs of transducers are currently available: a patented miniaturized transducer (JEOL compatible systems only) and a patented MEMS transducer. With these transducers, quantitative force-displacement curves can be acquired in-situ.

Unlike devices that rely on open-loop, piezo-controlled, series-loading mechanisms for indentation, which introduce unavoidable artifacts into the load-displacement curves, the Hysitron PI 95 transducer provides highly accurate depth-sensing capability. Furthermore, because of the electrostatic actuation aspect of the transducer, substantially larger forces can be realized without suffering a force sensitivity penalty.

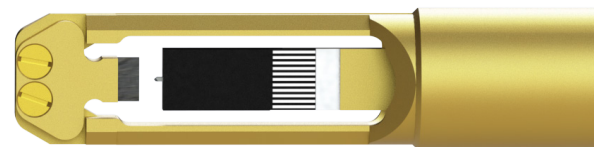


**The Hysitron PI 95 was specifically designed to interface with major TEM models.**

(FEI, Hitachi, JEOL, Zeiss)



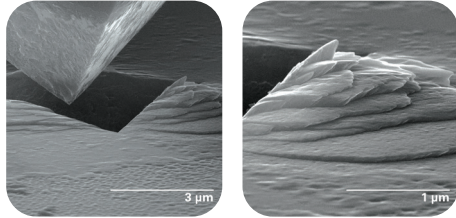
JEOL compatible front-end.



FEI/Hitachi/Zeiss compatible front-end with MEMS transducer.

# ● Hysitron PI Series Testing Modes

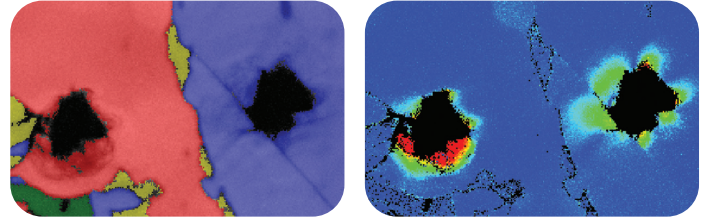
## Nanoindentation



Real-Time Observation of Deformation

Targeted test placement for precise, site-specific measurement of hardness and elastic modulus, while observing the evolution of material deformation.

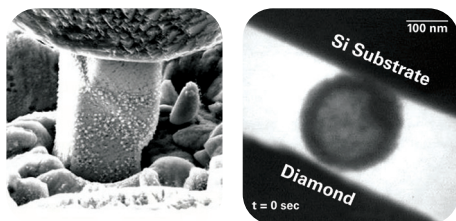
## EBSD with Rotation and Tilt Stage



Nanoindentation Combined with EBSD

Measure hardness and elasticity of individual grains, then use EBSD mapping to correlate grain orientation with mechanical properties. This process can be achieved automatically and in a co-localized manner with PI 89 Auto.

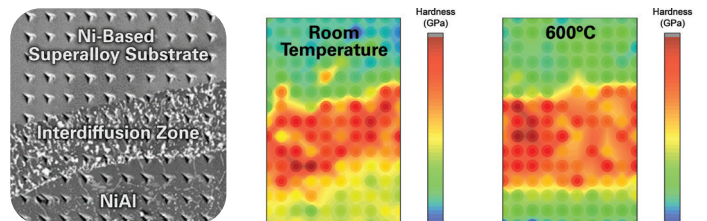
## Nanostructure Compression



Pillars and Particles

Observe the influence of compression on dislocations in material to measure yield strength and help predict material performance.

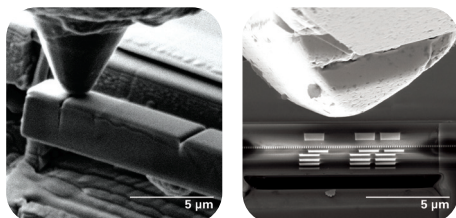
## Accelerated Property Mapping (XPM)



Ni-Based Superalloy and Aluminide Bond Coating

Rapid indentations across a sample surface provide a high spatial resolution mapping of hardness, modulus with distribution statistics.

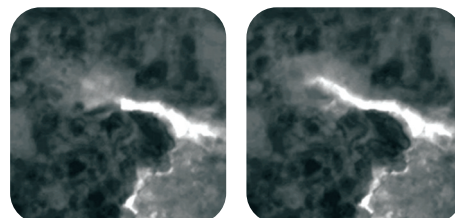
## Cantilever and Microbeam Bending



Fracture Toughness of Interfaces

Isolate the interface of interest for direct observation, measurement, and analysis of failure mechanics. Uniform sample geometry lends itself to comparison with MD or FEM simulations.

## Fatigue/nanoDynamic



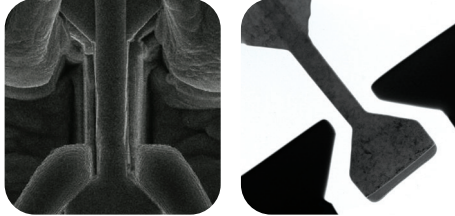
Metallic Thin Film

Apply an oscillating force to continuously measure viscoelastic and fatigue properties as a function of depth and frequency.

Courtesy: Khalid Hattar, Sandia National Laboratories

# ● Probe it. Bend it. Stress it. Measure it.

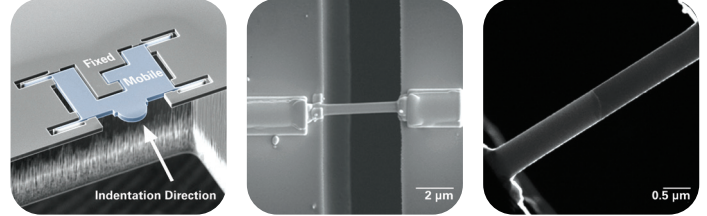
## Direct Pull Tensile Testing



### Quantitative Direct Pull

Measure tensile properties and observe dislocation initiation, pinning, and interaction with defects and other deformation mechanisms.

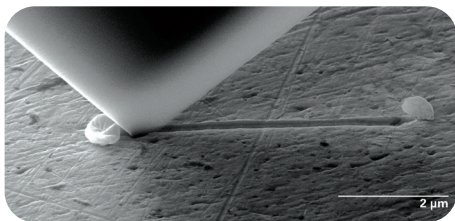
## Push-to-Pull Tensile Testing



### 1D and 2D Materials

Nanowires and free-standing thin films can be mounted and tested in tension using a MEMS fabricated Push-to-Pull device. True stress and strain values are calculated directly from microscope measurements.

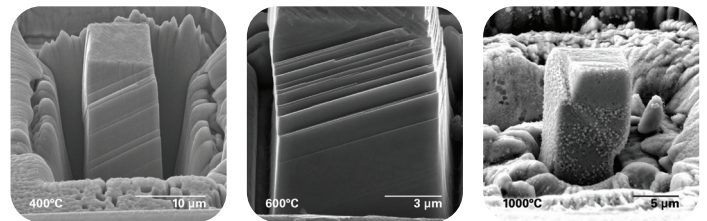
## Nanoscratch



### Tribology at the Nanoscale

In-situ tribology sheds light on deformation processes occurring at the sliding interface. Friction properties can be measured while wear evolution is directly viewed.

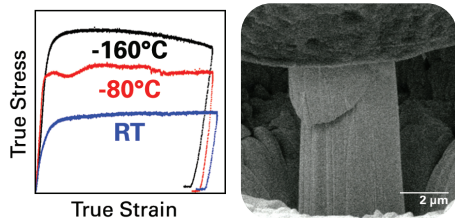
## High Temperature (800°C/1000°C)



### Testing in Extreme Conditions

Add heating capabilities for direct measurement and observation of thermally initiated material transformations, ideal for testing materials that demand reliability under extreme conditions.

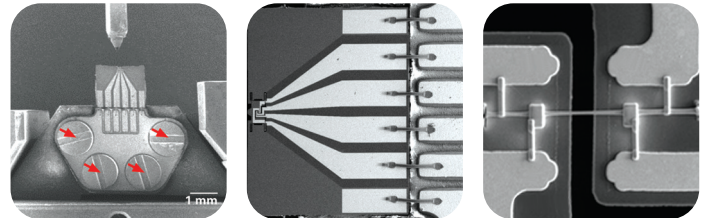
## Cryogenic Temperature



### Testing in Extreme Conditions

Add cryogenic testing capabilities for quantitative measurement of hardness, modulus, ductile–brittle transition, fatigue and fracture properties of metals and alloys.

## Electrical



### Material Response to an Applied Field

Add testing capabilities for simultaneous measurement of electrical and mechanical properties during nanoindentation, compression or tensile loading to understand origins of electrical property changes in materials or devices.

## SEM PicoIndenter Specifications

Feature	Hysitron PI Envision	Hysitron PI 89
Max Force	10 mN; 250 mN	10 mN; 500 mN; >3.5 N
Force Noise Floor* (inside an SEM, 60 Hz)	<0.4 $\mu$ N	<0.4 $\mu$ N; <5 $\mu$ N; 30 $\mu$ N
Force Noise Floor (in ideal environment, 60 Hz, 10 mN transducer)	<50 nN	<50 nN
Max Displacement	5 $\mu$ m; 30 $\mu$ m; 100 $\mu$ m	5 $\mu$ m; 30 $\mu$ m; 150 $\mu$ m
Displacement Noise Floor* (inside an SEM, 60 Hz)	<1 nm	<1 nm
Displacement Noise Floor (in ideal environment, 60 Hz, 10 mN transducer)	<0.1 nm	<0.1 nm
Feedback Control Rate	78 kHz	78 kHz
Max Data Acquisition Rate	39 kHz	39 kHz
Sample Positioning Range XYZ	12 mm x 12 mm (sample positioning); 16 mm (indentation axis)	12 x 26 mm (sample positioning); 29 mm (indentation axis)

## TEM PicoIndenter Specifications

Feature	Hysitron PI 95 for FEI / Hitachi / Zeiss TEMs	Hysitron PI 95 for JEOL TEM
Max Force	1 mN	1.5 mN
Force Noise Floor	<0.2 $\mu$ N	<0.2 $\mu$ N
Max Displacement	1 $\mu$ m	4 $\mu$ m
Displacement Noise Floor	<1 nm	<1 nm
Feedback Control Rate	78 kHz	78 kHz
Max Data Acquisition Rate	39 kHz	39 kHz
Fine Sample Positioning Range XYZ	50 $\mu$ m; 50 $\mu$ m; 3 $\mu$ m	50 $\mu$ m; 50 $\mu$ m; 3 $\mu$ m
Fine Sample Positioning Sensitivity XYZ	2 nm; 2 nm; 0.1 nm	2 nm; 2 nm; 0.1 nm
Coarse Sample Positioning Range XYZ	750 $\mu$ m; 750 $\mu$ m; 5000 $\mu$ m	750 $\mu$ m; 750 $\mu$ m; 5000 $\mu$ m

\*Guaranteed on install. For additional specifications, please visit the product webpages.

### Bruker Nano Surfaces and Metrology

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