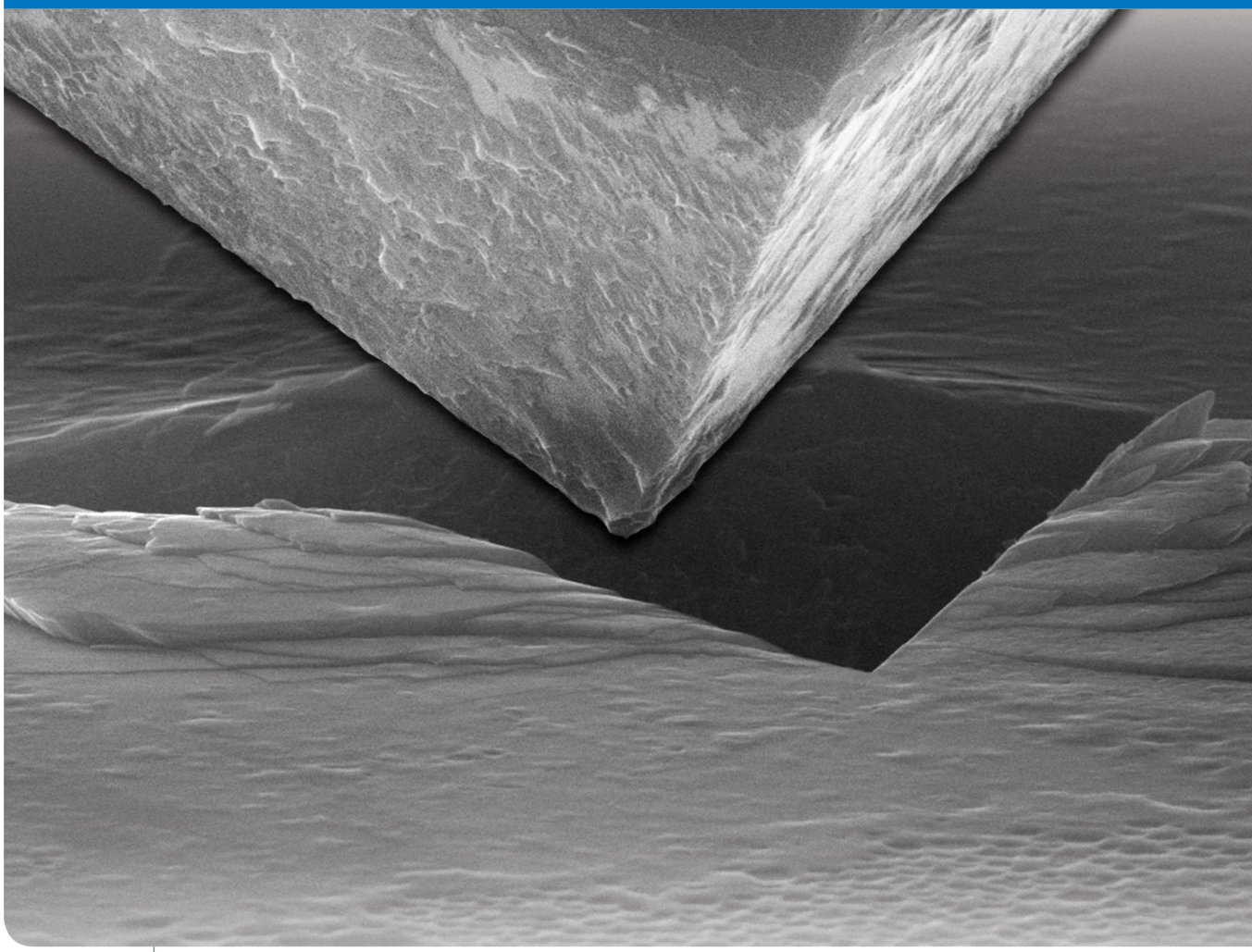


Hysitron PI Series PicoIndenters

- Quantitative In-Situ Nanomechanics Inside Your SEM or TEM

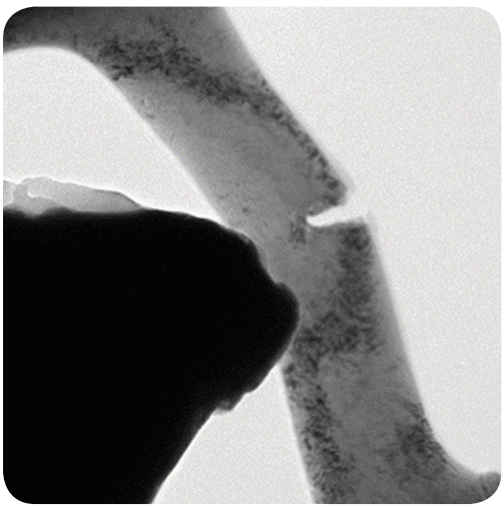
Innovation with Integrity

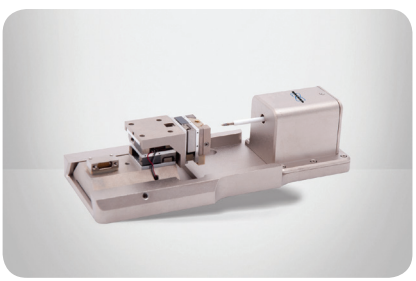
Tribology & Mechanical Testing

Hysitron PI Series

Quantitative In-Situ Nanomechanics

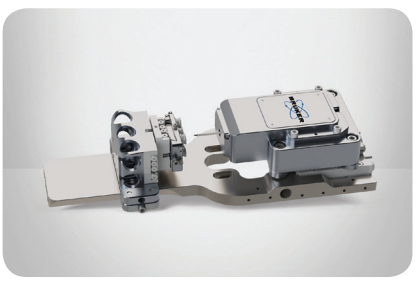
As the world leader in nanomechanical testing systems, Bruker makes it easy for you to conduct in-situ mechanical experiments in your scanning electron microscope (SEM) or transmission electron microscope (TEM) with the Hysitron PI Series PicoIndenters. Our unique transducer design delivers unmatched stability throughout your experiments, resulting in precise data even at the nanoscale. Video capture from the microscope enables real-time monitoring and direct correlation of mechanical data to microscope imaging. With solutions designed to fit many of the microscope brands in use, you are sure to find one that is ideally suited to your research.





Hysitron PI 85L SEM PicoIndenter

- Mounts directly to SEM stage for easy installation and superior stability
- Designed for maximum sample tilt and minimum working distance
- Features a low profile design ideal for SEMs, Raman and optical microscopes, beamlines, and more



Hysitron PI 89 SEM PicoIndenter

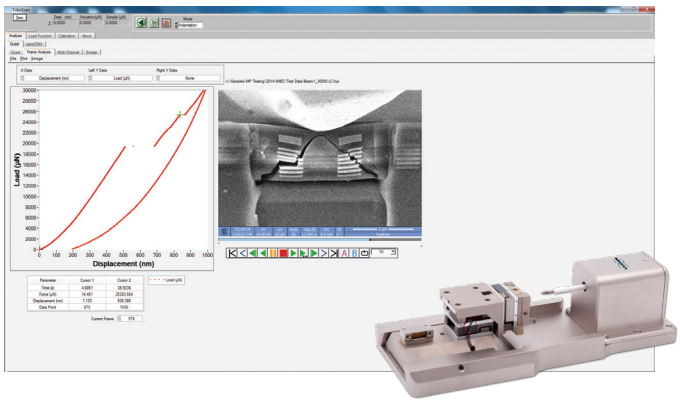
- Truly quantitative nanoscale mechanical characterization with direct observation
- Advanced XYZ sample positioning with optional tilt and rotation stage
- Modular design supports our full suite of testing techniques, including 800°C heating, scratch testing, electrical characterization, scanning probe microscopy (SPM) imaging, property mapping (XPM), dynamic fatigue testing, extended range load cell, and more

Hysitron PI 95 TEM PicoIndenter

- The first full-fledged depth sensing indenter for TEM
- Testing modes include indentation, compression, tensile, bend, 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



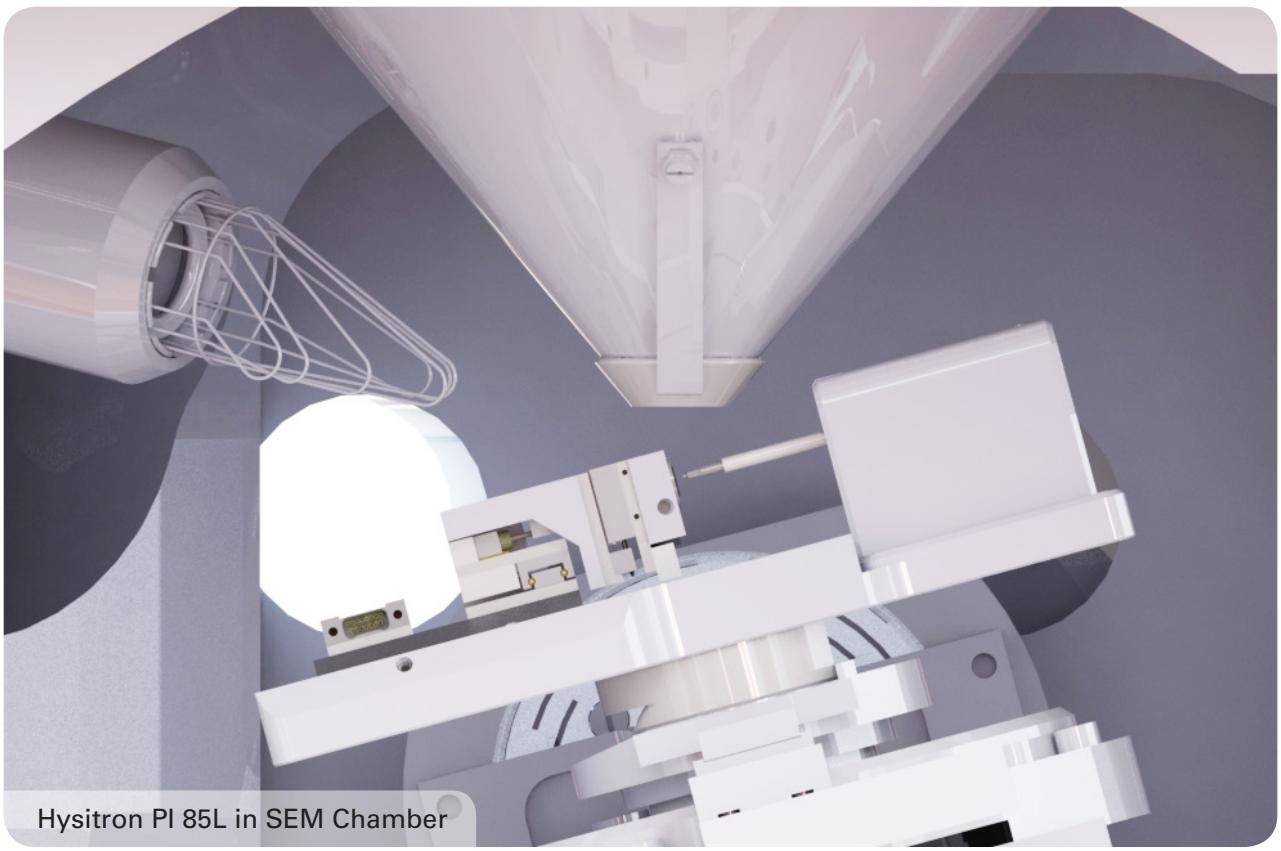
Acquire the mechanical data you need using familiar equipment already in your lab. Extend the capabilities of your microscope to include:

- Nanoindentation
- Microbeam Bending
- Pillar or Particle Compression
- Tensile Testing
- Nanoscratch

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.

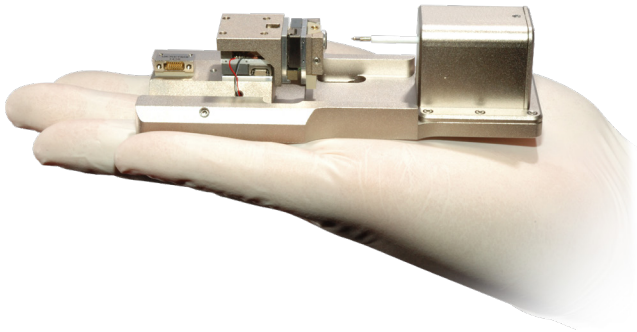


Hysitron PI 85L in SEM Chamber

In-Situ Nanomechanics Inside Your SEM

Hysitron PI 85L SEM PicoIndenter

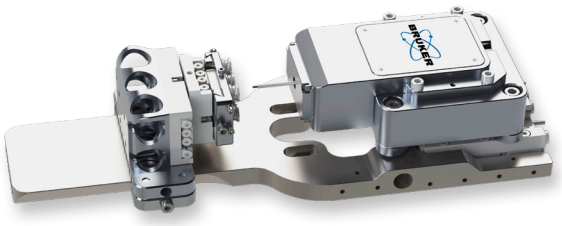
Versatile In-Situ Mechanical Testing Platform



The Hysitron PI 85L is the next-generation version of our dedicated in-situ nanomechanical test instrument, designed for use in SEM but suitable for a variety of platforms and environments. Featuring Bruker's capacitive transducer working in conjunction with an extremely fast 78 kHz control system, the Picoindenter provides exceptional performance and superior stability at the nanoscale. The compact, low profile design makes the system ideally suited for small-chamber SEMs, Raman and optical microscopes, beamlines, and more.

Hysitron PI 89 SEM PicoIndenter

Robust, Precise and Modular In-Situ SEM Nanomechanical Instrument

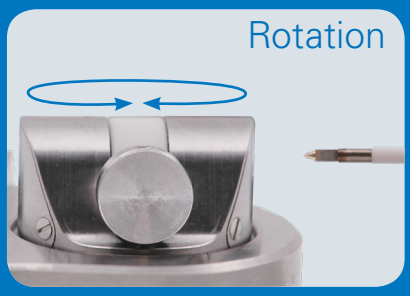


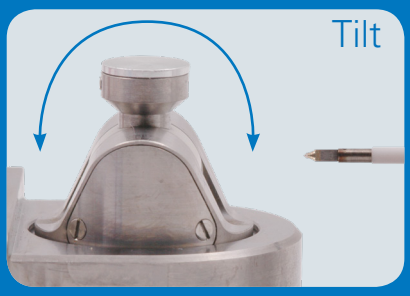
Hysitron PI 89 provides researchers in-situ nanomechanical testing capabilities inside a SEM from very low to high loads, and provides extreme environmental control. The system combines Bruker's high-performance controller with exclusive capacitive transducer and intrinsic displacement control flexure technology, enabling industry-leading force and displacement resolutions with extended force and displacement ranges. The PI 89 is the first in-situ SEM instrument in the market with two rotation and tilt stage configurations. This patented architecture 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. The modular design also supports a full suite of testing techniques for future upgradability, including heating, scratch testing, electrical characterization, dynamic fatigue testing, and interchangeable extended-range transducers.

True Displacement Control with Piezo-Driven Flexure Mode

Hysitron PI 89 utilizes Bruker's proprietary sub-nanometer sensitivity transducer and piezo-driven flexure for true displacement-controlled tests. The low-load transducer can apply force electrostatically while simultaneously measuring displacement capacitively. The displacement range can also be increased dramatically (max 150 µm) in flexure-driven mode. 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.

The Hysitron PI 89 is available with 3-axis (X, Y, Z) or 5-axis (X, Y, Z, tilt, rotation) sample-positioning stages.





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 possibly to image the mechanical response of nanoscale materials, but also to acquire load-displacement data simultaneously. Further, an integrated video interface allows for time syncronization between the load-displacement curve and the corresponding TEM video.

Experimental Control

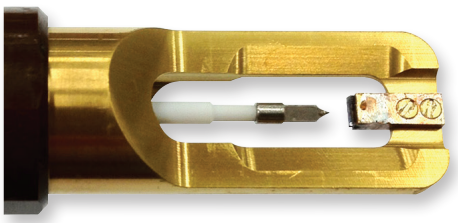
Coupling a nanomechanical test system with the TEM enables the researcher to determine certain test parameters *a priori*, such as variations in chemical composition or the presence of preexisting defects in the specimen. In addition to imaging, selected-area diffraction can be used to determine sample 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.

The Hysitron PI 95 was specifically designed to interface with major TEM models.
(FEI, Hitachi, JEOL, Zeiss)

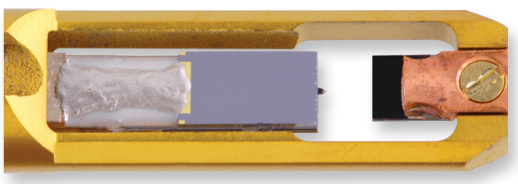
Unparalleled Performance

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.



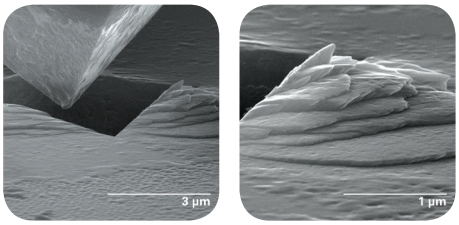
JEOL compatible front-end.



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

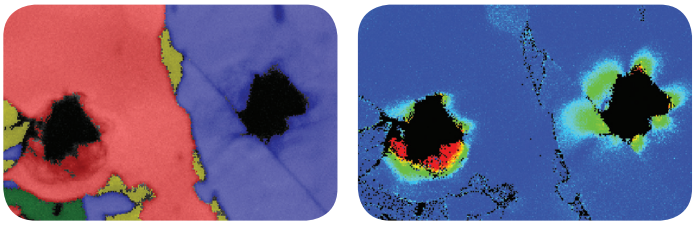
Hysitron PI Series Testing Modes

Nanoindentation



Real-Time Observation of Deformation

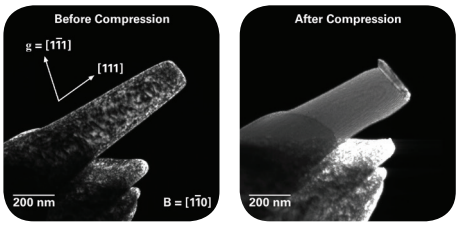
Targeted test placement for precise, site-specific measurement of hardness and elastic modulus, while observing the evolution of material deformation.



Nanoindentation Combined with EBSD

This combination of high spatial resolution techniques enables full microstructural characterization of metals and alloys. Measure hardness and elasticity of individual grains, then use EBSD mapping to correlate grain orientation with mechanical properties.

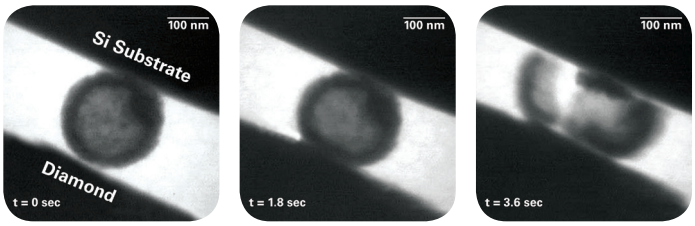
Pillar and Particle Compression



Nanopillars

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

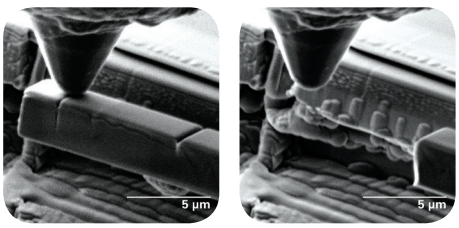
Nature Materials 7, 115-119 (2007)



Particles

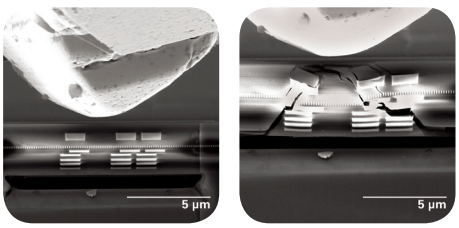
Verify proper tip alignment and test outcomes with SEM or TEM imaging and quantitatively evaluate new size/strength relationships of nano- and micro-sized particles for potential use as components in engineered materials.

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.



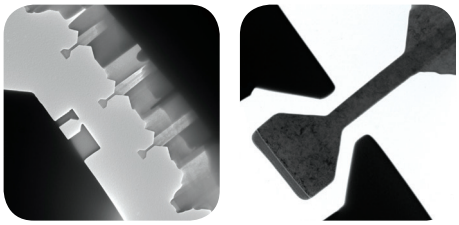
Predicting Failure in Multilayer Devices

Apply bending stresses to microbeams of layered, composite or multiphase structures to evaluate failure initiation points and observe damage progression through material and along interfaces.

Vanstreels, et. al., *Applied Physics Letters* 105, 213102 (2014)

Probe it. Bend it. Stress it. Measure it.

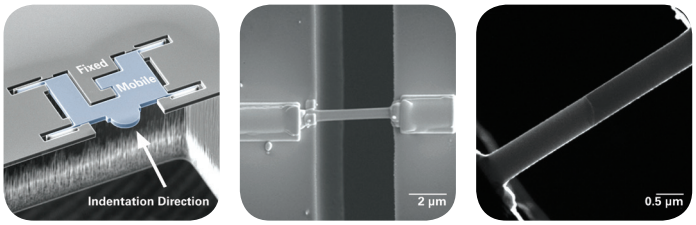
Tensile Testing



Quantitative Direct Pull

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

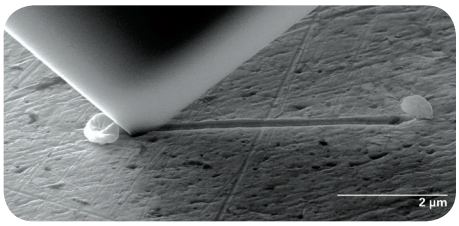
D. Kiener, et. al., *NanoLetters* 11, 9 (2011)



1D and 2D Materials

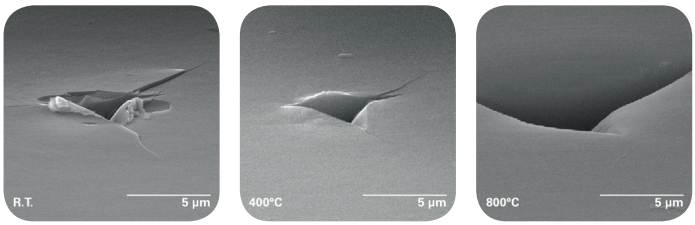
Nanowires and free-standing thin films can be mounted and tested in tension using a MEMS fabricated Push-to-Pull device. True stress and strain values are calculated directly from microscope measurements.

Nanoscratch



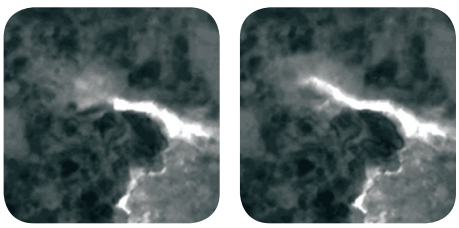
In-situ tribology sheds light on deformation processes occurring at the sliding interface. Friction properties can be measured while wear evolution is directly viewed.

Heating



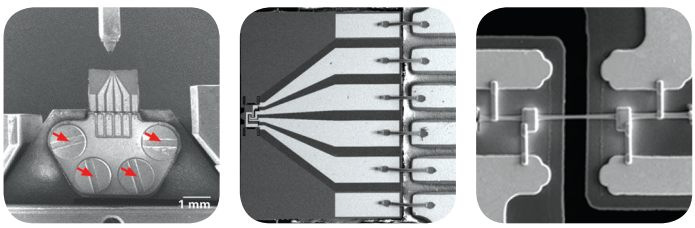
Add heating capabilities for direct measurement and observation of thermally initiated material transformations, ideal for testing materials that demand reliability under extreme conditions.

Dynamic



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

Electrical



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 85L	Hysitron PI 89
Max Force	10 mN / 30 mN	10 mN / 0.5 N / >3.5 N (optional)
Force Noise Floor	<0.4 µN	<0.4 µN / <5 µN / 30 µN
Max Displacement	5 µm	150 µm
Displacement Noise Floor	<1 nm	<1 nm
Feedback Control Rate	78 kHz	78 kHz
Max Data Acquisition Rate	39 kHz	39 kHz
Sample Positioning Range XYZ	>3 mm	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 µN	<0.2 µN
Max Displacement	1 µm	4 µm
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 µm / 50 µm / 3 µm	50 µm / 50 µm / 3 µm
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 µm / 750 µm / 5000 µm	750 µm / 750 µm / 5000 µm

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