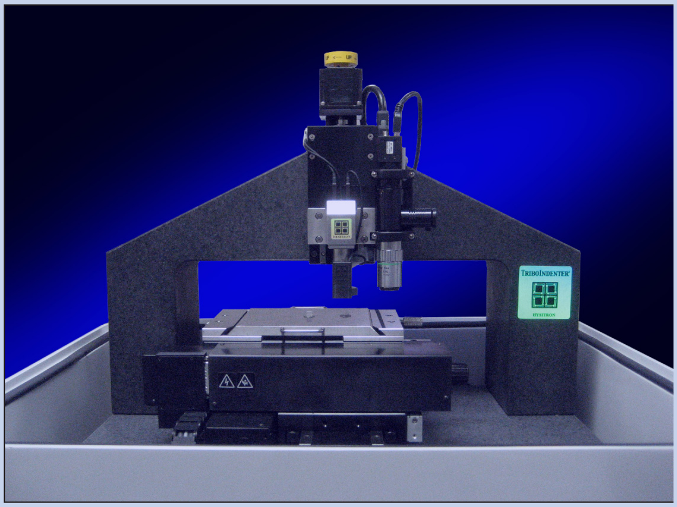
TI-SERIES

HYSITRON®

TI 900 TriboIndenter®



Hysitron **TI 900** system showing fully automated stage, optics column and granite bridge.

TI 900 TriboIndenter

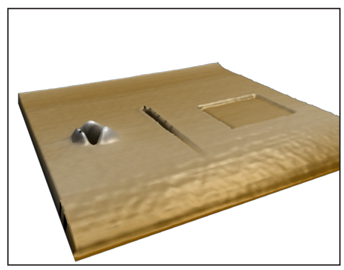
Nanomechanical test instrument

The **TI 900 TriboIndenter** has been developed as an automated, high-throughput instrument that has been built on a single platform designed to support the numerous nanomechanical characterization techniques developed by Hysitron. This high-performance staging system offers superior stability and flexibility to accommodate a wide range of applications, sample types and sizes. Hysitron offers the largest range of testing solutions, making the **TI 900** the most versatile nanomechanical test instrument available to scientists and engineers.

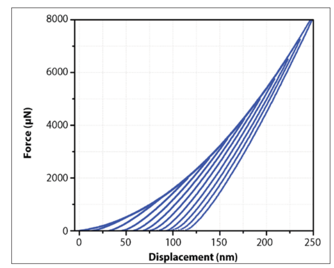
The **TI 900** brings unprecedented capabilities to nanomechanical testing through the wide range of testing techniques developed by the scientists at Hysitron. The **TI 900** incorporates Hysitron's patented three-plate capacitive transducer* technology known for its industry-leading sensitivity and stability with a superior staging design to deliver outstanding performance in nanomechanical characterization. Test placement on surface features or individual material phases is accomplished using high performance top-down optics in combination with *in-situ* SPM imaging. Hysitron's exclusive *in-situ* imaging* capability provides unparalleled precision in test placement and data repeatability.

Software automation

A user-friendly software package has been developed for the **TI 900** that allows automated acquisition of nanoindentation, scratch, and wear data. The software provides both pre-programmed and user-definable automation routines for customizable high-throughput testing. This allows for a true statistical sampling of material properties through the capability of performing thousands of tests per day. The automation of nanomechanical testing greatly enhances productivity by eliminating the need for user intervention.



A scratch, indent and **ScanningWear**™ test shown on a 5 μm SPM scan.



Multiple indentation experiments showing the high data repeatability of the **TI 900**.

Environmental isolation

Potential detriments to test stability and accuracy such as ambient acoustic noise, air currents, laboratory temperature variations, and vibration are minimized through active and passive damping and a custom instrument enclosure. The engineered enclosure is constructed from double-walled fiberglass which encapsulates three separate polymer insulation layers. These isolate the instrument from a wide range of noise frequencies, and allow it to operate in a stable environment independent of the external conditions. For accurate testing, piezoelectric anti-vibration stages actively dampen vibrations under 200 Hz and passively dampen those over 200 Hz. The enclosure is a key component in a complete system that is designed to provide quantitative data with maximum speed and repeatability. Utilization of a granite frame yields exceptional dimensional stability in any environment. The stability of the **TI 900** is unsurpassed in the nanomechanical testing market.

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Transducer design

Low drift

The heart of Hysitron's testing instruments is the patented three plate capacitive transducer that is used as both the actuator and sensor of the instrument. The force is applied electrostatically while the displacement is simultaneously measured by the change in capacitance. Electrostatic actuation requires almost no current, which results in virtually no drift due to heating during actuation. This provides superior drift characteristics relative to many other actuation methods, such as electromagnetic devices, which intrinsically introduce significant thermal drift during actuation due to high current requirements. Low drift means that data can be acquired faster with more accuracy and repeatability.

The acoustic/thermal enclosure of the **TI 900 TriboIndenter** provides stable measurements in variable environments.

Dynamic characteristics

The sensitivity and dynamic characteristics of the transducer allow high frequency testing for investigation of viscoelastic materials. The low mass of the indenter probe and driving transducer plate, combined with low damping make this a versatile tool for testing over a wide range of frequencies. Hysitron's transducer technology and testing modes have been developed to extend nanomechanical testing capabilities to polymers and biomaterials.

Hysitron's patented three plate capacitive transducer on the **TriboScanner**™.

High-resolution optics

Top-down optics with a CCD camera have been incorporated into the **TI 900 TriboIndenter** for high magnification and visual observation of sample surfaces and selection of testing locations. Digital zoom optics allow selection of magnification and field-of-view to accommodate virtually any sample size. The optics utilizes bright-field illumination and polarized light to view the sample surface and allows differentiation of phases within many materials. With the ability to resolve one-micron features and sub-micron stage resolution, the tip can be placed within a micron of the desired surface feature or test location optically. For greater precision in probe placement, *in-situ* imaging can be used to refine the probe position. The dual modes of imaging provided by the **TI 900** allows customizable precision of the probe position to accommodate the multitude of applications for which it is used.

Optics specifications:

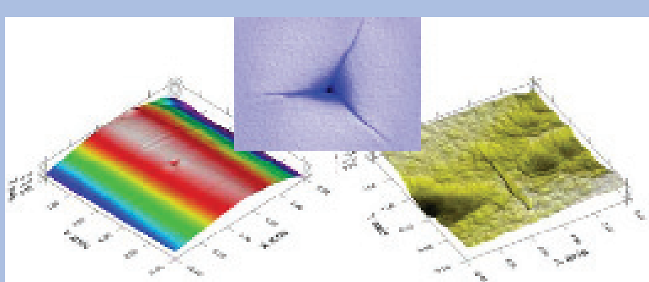
- **Normal field of view**
  Maximum: 625 µm x 550 µm
  Minimum: 28 µm x 22 µm
- **Magnification**
  Optical: 20X
  Digital Zoom: 0.5X - 11X
  Effective: 10X - 220X

320 µm X 266 µm view of hard disk head slider.

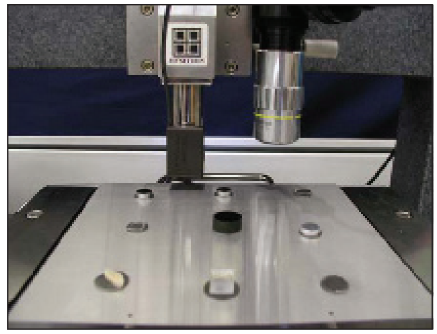
In-situ imaging

Hysitron offers *in-situ* scanning probe microscopy (SPM) imaging standard with each nanomechanical testing instrument. The *in-situ* SPM imaging capability of the **TI 900 TriboIndenter** is critical for precise test placement and microstructure identification. The *in-situ* images are obtained by raster scanning the indenter probe over the sample surface to allow for pre- and post-test observation of the material surface. This feature provides the capability to position the indenter probe within ten nanometers of the desired testing location. Identification and characterization of phases in multi-phase materials or fine sample surface features can only be reliably carried out by employing *in-situ* SPM imaging. Post-test imaging also provides the ability to verify that the test was performed in the anticipated location, which maximizes the reliability of data and aids in the explanation of unexpected test results.

Quantification of material deformation features is necessary for many analyses that have been derived for analysis of nanoindentation and nanoscratch tests. *In-situ* imaging allows observation and quantification of deformation, such as pile-up, wear volume or crack length, incurred by testing. A versatile software package has been developed that allows for automated testing on site-specific sample locations identified through *in-situ* imaging. The software package also includes real-time and off-line image processing and analysis tools designed by scientists for quantification of deformation incurred by testing.



Images of indentations and a scratch test acquired using the *in-situ* imaging capability of the **TI 900 TriboIndenter**.



Multiple sample mounting capability of magnetic stage.

Applications

The applications of the **TI 900** are virtually endless as a result of the flexible design and numerous add-on options designed by Hysitron to meet the needs of the current market, as well as new and emerging markets. Some of the markets that have already utilized Hysitron's nanomechanical characterization capabilities include:

- **Data storage** – Measure hardness, modulus on ultra-thin films.
- **Semiconductors** – Quantify fracture toughness and interlayer adhesion.
- **Telecommunications** – Wear resistance and multi-layer adhesion of optic cables.
- **Combinatorial materials science** – Provides the high throughput mandated by technique and vector-based profiling of interfaces.
- **Biomaterials** – Characterize compatibility of proposed bio-replacement materials.
- **MEMS/NEMS** – Quantify static and dynamic mechanics of devices.
- **Microtechnology** – Assess adhesion of bond pads.
- **Nanotechnology** – Perform nanomechanical characterization of nanoscale components.
- **Lubrication** – Quantify friction coefficient measurements on lubricating layers.
- **Polymers** – Measure viscoelastic properties using dynamic testing technique.
- **Composites** – Evaluate interfacial toughness, mechanical properties of individual phases.
- **Paints** – Mar testing using scratch capability.
- **Protective coatings** – Quantify wear resistance of wear-resistant coatings.

Available testing modes

Standard

- **Quasistatic nanoindentation** – Measure Young's modulus, hardness, fracture toughness and other mechanical properties via indentation
- **Scratch testing** – Quantify scratch resistance, critical delamination forces, friction coefficients and more with simultaneous normal and lateral force and displacement monitoring
- **Top-down optics** - Color CCD camera for individual structure identification prior to testing
- **SPM imaging -** *In-situ* imaging using the indenter tip provides nanometer precision positioning and SPM topography
- **ScanningWear** – Observe and quantify wear volumes and wear rates using *in-situ* imaging capability
- **Feedback control** – Operate in closed loop load or displacement control to allow testing techniques such as creep and stress relaxation

Upgrade options

- **nanoDMA®** – Investigate time-dependent properties of materials using a dynamic testing technique designed for polymers and biomaterials
- **Modulus Mapping™** – Quantitatively map the storage and loss stiffness and moduli over an area from a single SPM scan
- **TriboAE™** – Monitor fracture, delamination and phase transformations that occur under nanoscale contacts
- **AFM imaging** – Provides ultra-low contact force and intermittent contact imaging for imaging and selection of test locations on soft polymer and biomaterials
- **Multi-Range Nanoprobe™** – Provides loads of up to 10 N for fracture and depth-sensing micro-indentation studies
- **Thermal control** – Heating or heating/cooling stages can be added for investigation of mechanical properties at non-ambient temperatures
- **Vacuum chuck** – Wafer mounting system that eliminates necessity of gluing or cutting wafers
- **nanoECR®** – Conductive nanoindentation system capable of providing simultaneaous *in-situ* electrical and mechanical measurements for investigating material deformation and stress induced transformation behavior

Highlights

- Hysitron's patented capacitive transducer provides industry-leading sensitivity and stability
- Automated testing for high throughput and statistical sampling of materials
- *In-situ* imaging provides nanometer precision positioning and the convenience of SPM topography
- Acoustic and thermal enclosure, along with stable transducer design, minimizes set-up and stabilization time
- Top-down optics for viewing and selection of testing sites
- Sub-micron resolution staging for sample positioning
- Numerous add-ons that allow the widest array of testing capabilities on the market
- Active vibration dampening systems ensure low noise and uncompromised sensitivity

Transducer specifications

- **Load**
  Resolution: <1 nN
  Noise Floor: 100 nN
- **Displacement**
  Resolution: 0.0004 nm
  Noise Floor: 0.2 nm
  Drift: <0.05 nm/sec

Stage specifications

- **X and Y stages**
  Travel: 250 mm x 150 mm
  Encoder Resolution: 500 nm
- **Z stage**
  Travel: 50 mm
  Resolution: 3 nm

*Covered under US patents: 5,553,486; 5,576,483; 5,661,235; 5,869,751; 6,026,677; 7,107,694

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