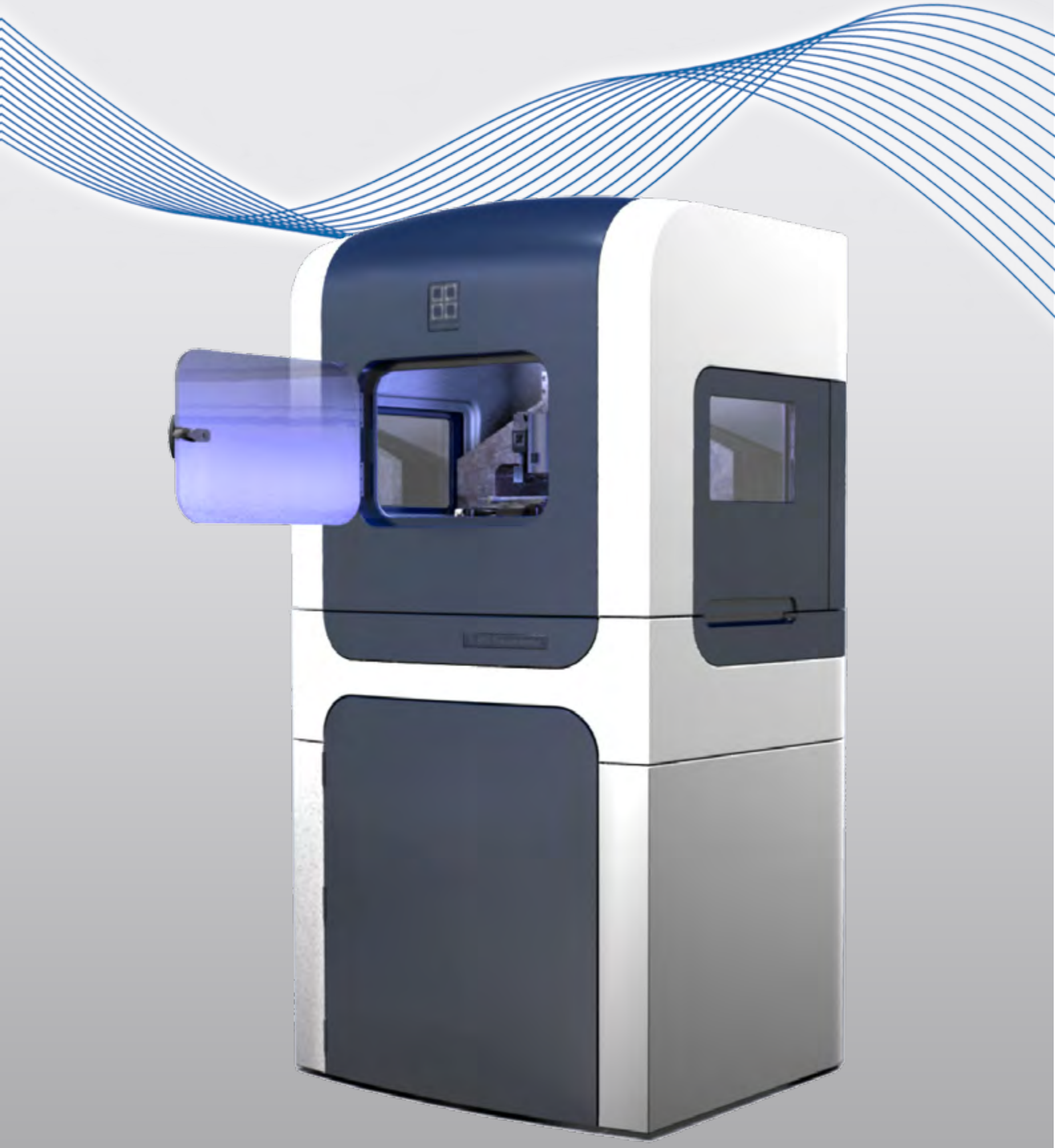
EDEN INSTRUMENTS
In Situ NanoCharacterization Solutions

TI 950 TriboIndenter®

Nanomechanical test instrument



TI 950 TriboIndenter®
Nanomechanical test instrument

The **TI 950 TriboIndenter** is the next generation nanomechanical test instrument providing industry leading sensitivity and unprecedented performance. The **TI 950** has been developed as an automated, high throughput instrument to support the numerous nanomechanical characterization techniques developed by Hysitron.

The system incorporates the newly developed **performech™** advanced control module, which greatly improves the precision of feedback-controlled nanomechanical testing, provides dual head testing capability for nano–micro scale connectivity, and offers unprecedented noise-floor performance. The numerous nanomechanical testing techniques currently offered, as well as new testing methods currently being developed, make the **TI 950** system an exceptionally versatile and effective nanomechanical characterization tool for the broadest range of applications.

Hysitron's TI 950 featuring an enhanced environmental isolation system and unparalleled measurement sensitivity.

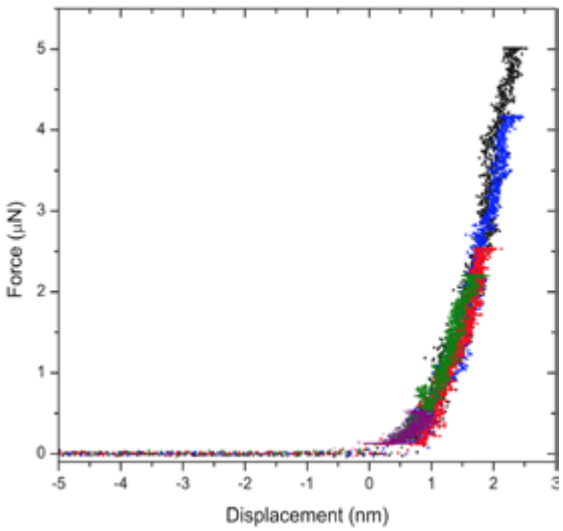
Highlights

- ✓ Hysitron's patented capacitive transducer provides industry leading sensitivity and stability
- ✓ Hysitron's **performech™** advanced control module with performance leading force and displacement feedback control algorithms with a 78 kHz feedback loop rate and user definable data acquisition rates up to 30 kHz for superior control over all nanomechanical testing techniques
- ✓ Dual head testing capability providing an available force range from ≤30 nN to 10 N for true nano–micro scale connectivity
- ✓ Conforms to ISO 14577 with temperature and humidity measurement
- ✓ Automated testing for high throughput and statistical sampling of materials
- ✓ *In-situ* imaging provides nanometer precision test positioning and the convenience of SPM topography
- ✓ Engineered acoustic and thermal enclosure, along with a stable transducer design and active vibration dampening, minimizes test set-up and stabilization time
- ✓ Top-down, high resolution color optics for viewing and selection of testing sites
- ✓ 500nm resolution staging for precise sample positioning
- ✓ Numerous add-ons that provide the widest array of testing capabilities on the market

The **TI 950** combines Hysitron's patented three plate capacitive transducer* technology with state-of-the-art control technology to achieve unmatched performance in nanomechanical characterization. The system features a sub 30 nN force noise floor, ultra-fast feedback control, user-definable data acquisition rates up to 30 kHz, the widest range of nanomechanical testing techniques, and the ability to test with various Hysitron heads seamlessly. The superior staging system on the **TI 950**, along with the *in-situ* Scanning Probe Microscopy (SPM) imaging capability, provides unparalleled precision in test-placement accuracy and data repeatability.

Superior Control

The combination of Hysitron's performance-leading feedback control algorithms and superior measurement sensitivity provides precise control for all Hysitron nanomechanical testing techniques. All feedback control functionalities on the **TI 950** are carried out by a dedicated digital-signal processor (DSP) and field-programmable gate array (FPGA) embedded control system to accurately follow the inputted request of the user.



Five Low Force Indentation Tests on (100) Si

A series of five low force indents on (100) Silicon showing the industry leading noise-floor performance and data repeatability of the TI 950 nanomechanical testing system.

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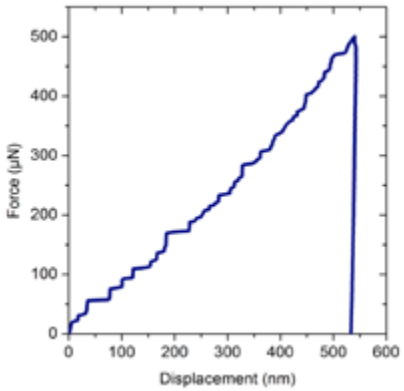
The internal feedback loop rate of 78 kHz assures that the requested load/displacement function tracks even the fastest transient events that may occur during the indentation process. Additionally, the fast control loop provides the ability to capture data precisely at user-definable data acquisition rates up to 30 kHz. The **TI 950** operates in both load and displacement control, allowing the operator to perform nanoscale creep and stress relaxation studies with superior control over tip-sample contact conditions.

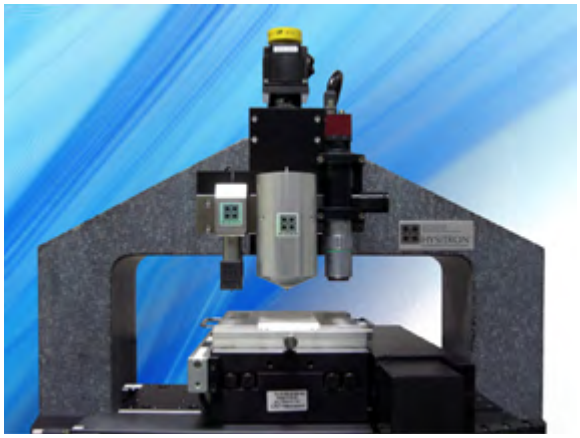


Load-controlled nanoindentation test on single crystal (100) Al showing dislocation activity throughout the testing cycle

Dual Head Capability

The **TI 950** provides the ability to incorporate Hysitron's capacitive transducer technology, renowned for its industry- leading sensitivity, with a higher load head (**3D OmniProbe™** or **MultiRange Nanoprobe™**). This provides seamless nanometer- micrometer scale connectivity. This unique combination of heads provides the broadest force range available for nanomechanical testing (≤30 nN to 10 N) and is specifically designed to accomodate the widest range of applications.

In-situ SPM Imaging



TI 950 TriboIndenter configured for seamless operation between Hysitron's capacitive transducer, 3D OmniProbe, and high-resolution optics.

Hysitron offers *in-situ* scanning probe microscopy (SPM) imaging as standard with each nanomechanical testing instrument. The *in-situ* SPM imaging capability of the **TI 950 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 exclusive capability to position the indenter probe within ten nanometers of the desired testing location. Identification and characterization of individual phases in multi-phase materials or fine sample surface features can only be reliably carried out by employing Hysitron's patented *in-situ* SPM imaging.

Post-test imaging also provides the ability to verify that the test was performed in the desired location. This maximizes the reliability of data and aids in the explanation of unexpected test results.

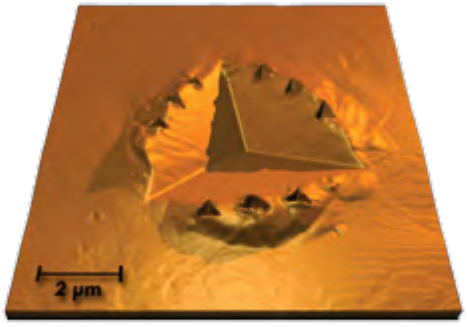


Image showing a residual high-load indent impression with low-load indentation tests placed along the pile-up.

The **TI 950** offers quantitative topographical imaging with an extremely low imaging contact force (≤70 nN). This is particularly well suited for soft material and delicate structure characterization. Quantification of material deformation behavior is necessary for many analyses that have been derived for nanoindentation and nanoscratch testing results.

In-situ SPM imaging allows observation and quantification of material deformation, such as pile-up, wear volume, crack length and scratch morphology, incurred during 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 the quantification of deformation incurred during testing.

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 very little current, which results in virtually no drift due to heating during actuation. This provides superior drift characteristics relative to other actuation methods, such as electromagnetic devices, which intrinsically introduce thermal drift during actuation due to high current requirements. Low drift conditions result in faster data acquisition with higher accuracy and repeatability.

Dynamic characteristics

The sensitivity and dynamic characteristics of the transducer enables high frequency testing for the 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 (up to 300 Hz). Hysitron's transducer technology and dynamic testing modes have been specifically developed to extend nanomechanical testing capabilities to polymers and biomaterials.

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Environmental Isolation

Potential detriments to test stability and accuracy such as ambient acoustic noise, air currents, laboratory temperature variations, and vibration are minimized through an active and passive damping system and a custom instrument enclosure.

The engineered enclosure is constructed from double walled fiberglass which encapsulates three separate polymeric insulation layers. These layers isolate the instrument from a wide range of noise frequencies and allow it to operate in a stable environment independent of external conditions. For accurate nanoscale testing, a piezoelectric anti-vibration system actively dampens vibrations under 200 Hz and passively dampens those over 200 Hz.

The enclosure is a key component in the complete **TI 950** system designed to provide quantitative data with maximum speed and repeatability. Additionally, the utilization of a granite frame yields exceptional dimensional stability in any environment. A temperature and humidity sensor is provided with each system to record the environmental conditions within the enclosure accurately. The environmental stability of the **TI 950** is unsurpassed in the nanomechanical testing market.

High-resolution optics

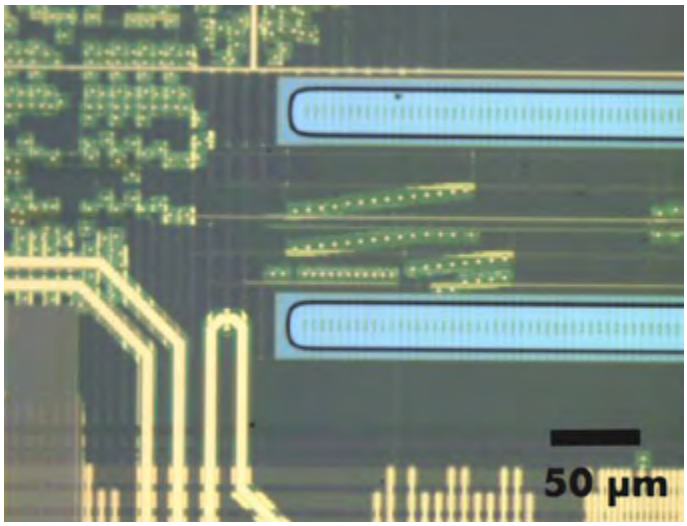
Top-down optics with a color CCD camera have been incorporated into the **TI 950 TriboIndenter** for high magnification and visual observation of sample surfaces and the selection of testing locations. Digital zoom optics allow selection of magnification and field-of-view to accommodate virtually any sample size. The optics utilize bright-field illumination and polarized light to view the sample surface and allow differentiation of phases within many materials. With the ability to resolve one-micron features and a sub-micron stage resolution, the tip can be coarsely positioned within a micron of the optically defined surface feature. For greater precision in probe placement, *in-situ* SPM imaging can be used to refine the probe position to within ±10 nm. The dual modes of imaging provided by the **TI 950** allow precise positioning of the probe to accommodate the multitude of applications for which it is used.

Optics specifications

- **Normal field of view**
  Max: 625 µm × 550 µm
  Min: 28 µm × 22 µm
- **Magnification**
  Optical: 20X
  Digital Zoom: 0.5X–11X
  Effective: 10X–220X

Software Automation

A user friendly software package has been developed for the **TI 950** that allows automated acquisition of nanomechanical testing data. The **TriboScan v.9** software package provides both pre-programmed and user-definable automation routines for high-throughput testing. This allows for 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.



540 µm × 400 µm (2X zoom) view of a patterned wafer as viewed using the **TI 950** optics

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Available Testing Modes

Standard

- **Quasistatic nanoindentation** - Measure Young's modulus, hardness, fracture toughness and other mechanical properties via nanoindentation
- **Scratch testing** - Quantify scratch resistance, critical delamination forces, and friction coefficients with simultaneous normal and lateral force and displacement monitoring
- **Top-down optics** - High- resolution, color CCD camera for individual structure identification and coarse test positioning
- **SPM imaging** - *In-situ* imaging using the indenter tip provides nanometer precision test positioning and surface topography information
- **ScanningWear™** - Observe and quantify wear volumes and wear rates using the *in-situ* imaging capability
- **Feedback control** - Operate in closed loop load or displacement control for superior nanoindentation and creep and stress relaxation studies

Upgrade options

- **nanoDMA®** - Investigate time-dependent properties of materials using a dynamic testing technique designed specifically for polymers and biomaterials
- **Modulus Mapping™** - Obtain quantitative maps of the storage and loss stiffness and moduli from a single SPM scan
- **Closed-loop scanner** - Provides an increased scan range (100 µm × 100 µm × 15 µm) and superior test placement accuracy and stability
- **AFM imaging** - Provides ultra-low contact force and intermittent contact imaging for surface topography and selection of test locations on soft polymer and biomaterials
- **3D OmniProbe** - Provides forces up to 10 N and scratch lengths up to 150 mm for depth-sensing micro-indentation and tribological studies
- **Thermal control** - Heating/cooling stages can be added for the investigation of mechanical properties at non-ambient temperatures
- **Vacuum chuck** - Wafer mounting system that eliminates necessity of gluing or cutting wafers prior to testing
- **nanoECR®** - Conductive nanoindentation system capable of providing simultaneaous *in-situ* electrical and mechanical measurements for investigating material deformation and stress induced transformation behavior

Transducer Specifications

Load

Resolution: <1 nN
Noise Floor: <30 nN
Imaging Contact Force: ≤70 nN

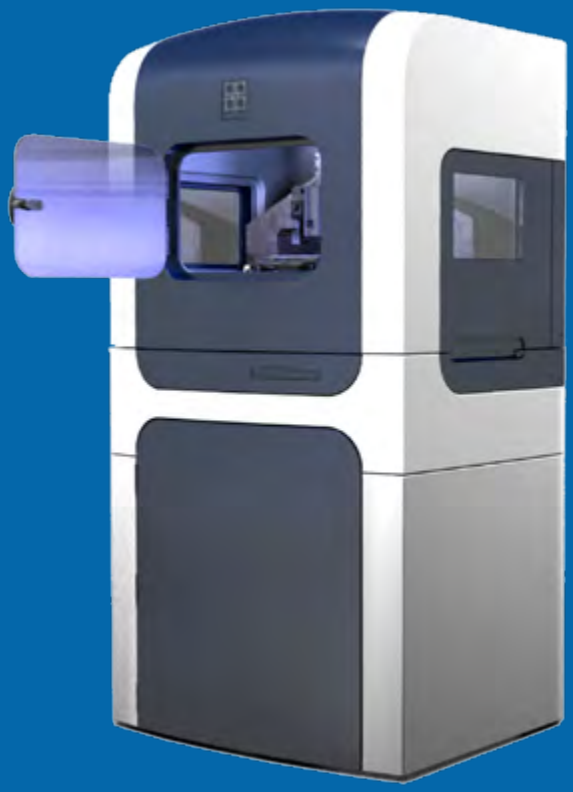
Displacement

Resolution: <0.02 nm
Noise Floor: <0.2 nm
Drift: <0.05 nm/sec

Stage Specifications

X and Y stages

Travel: 250 mm × 150 mm
Encoder Resolution: 500 nm



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