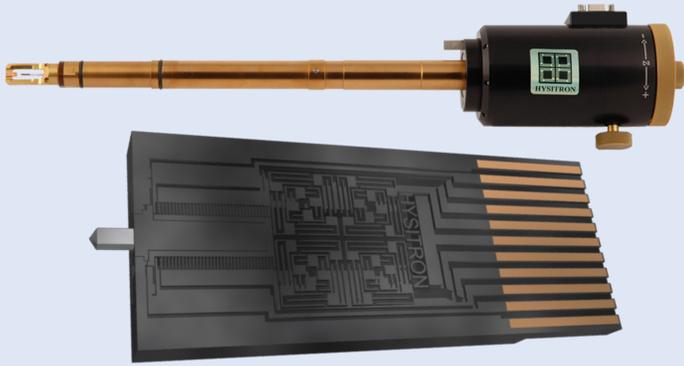


In Situ nanoScratch Testing

Tribology and Wear Using the PI 95 TEM PicoIndenter®



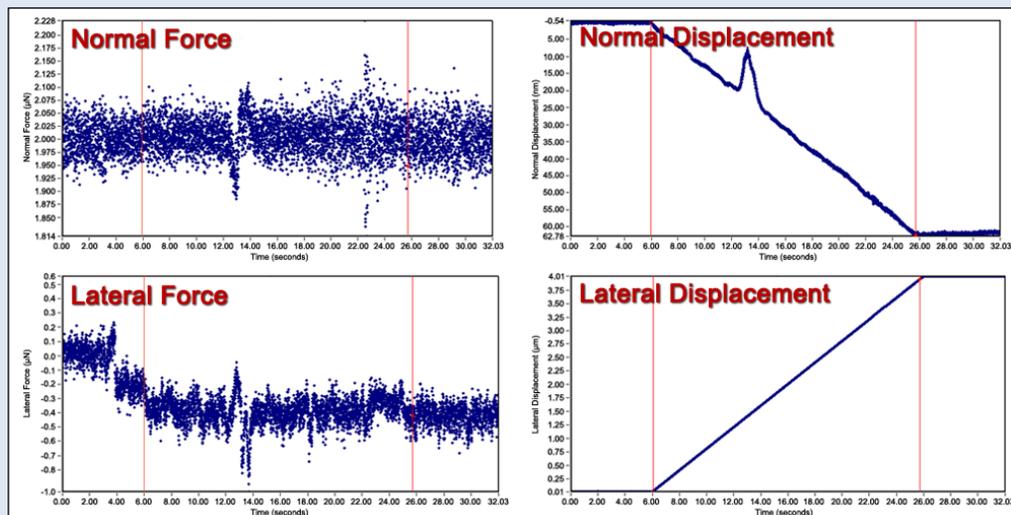
Nanoscale Wear

The study of sliding contacts typically involves a buried interface which makes it difficult or impossible to view nanoscale wear mechanisms in real-time. Such tribological measurements benefit directly from *in situ* techniques which shed light on deformation processes occurring at the sliding interface, such as atomic attrition, dislocations, flaking / exfoliation, and fracture. Single asperity contacts, the fundamental basis for all macroscale wear, can also be studied with confidence. In addition to enabling direct observation of wear evolution, *in situ* tribology can also be used for studies of friction, tribochemical reactions, interfacial adhesion, abrasion resistance, and nanoparticle rolling. Taken as a whole, these wear mechanisms give rise to failure rates in machinery or mechanical components and account for vast economic loss.

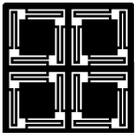
2D MEMS Transducer

The patented **2D MEMS Transducer** for Hysitron's **PI 95 TEM PicoIndenter®** instrument enables high resolution *in situ* tribological measurements with simultaneous normal and lateral force sensing. This combination of quantitative nanomechanical measurements with high resolution TEM imaging creates a powerful new tool for studying tribological behavior at the smallest possible scale.

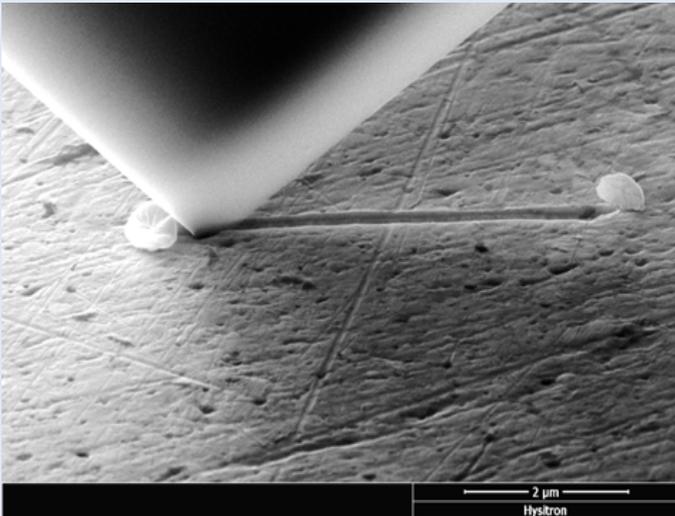
Nanoscratch testing is accomplished by applying a normal load in a controlled fashion while measuring the force required to move the tip laterally across the sample. By selecting the appropriate normal loading profile and lateral displacement pattern, many different types of tests can be performed. During a test, the sample position is held constant while the probe is moved laterally across the sample surface. This lateral motion is accomplished through a feedback-controlled piezo actuator while a patented two dimensional MEMS transducer simultaneously measures lateral force. From this data, useful information such as critical load, film adhesion, and delamination force can be measured. Reciprocating scratch tests can also be performed to study wear mechanisms over longer periods of time. This data provides a wealth of information concerning materials behavior under simultaneous normal and lateral stresses which is supplemented by direct observation TEM imaging.



2 μ N, 4 μ m scratch across a surface asperity on fused quartz.



The system features a newly developed patented 2D MEMS comb drive transducer for nanoscale normal and lateral force sensing. This proprietary design features electrostatic actuation and capacitive displacement sensing, giving the user a revolutionary level of control for quantitative *in situ* tribology on an unprecedented level.



nanoScratch test performed on a Au sample.

Control Software

The system's **TriboScan™ v.9** control software incorporates a flexible and intuitive graphical user interface for simplified test setup and execution, enhanced data analysis and plotting capabilities, and drift correction routines for accurate results during prolonged test durations. Integrated data analysis allows the user to easily calculate friction coefficients and identify behavior such as stick-slip motion or critical events resulting from interfacial delamination.

Specifications

- Maximum Normal Force: 500 μ N
- Maximum Normal Displacement: 2 μ m
- Normal Force Noise Floor: <200 nN
- Normal Displacement Noise Floor: <1 nm

- Maximum Lateral Force: 150 μ N
- Maximum Lateral Displacement: 10 μ m
- Lateral Force Noise Floor: <500 nN
- Lateral Displacement Noise Floor: <1.5 nm

HIGHLIGHTS

- Simultaneous lateral and normal force sensing for quantitative *in situ* tribology, nanoScratch, and wear
- Reciprocating wear testing elucidates phenomena that lead to device failure
- Easily transferrable 1D and 2D transducers enable indentation and scratch testing on a single platform
- Patented MEMS comb drive transducer provides quantitative nanoscale normal and lateral force measurement in a compact package
- Flexible graphical user interface for rapid test setup, execution, and increased data analysis and reporting capabilities
- Compatible with Hysitron's standard MEMS-based PI 95 TEM PicoIndenter instruments
- Feedback-controlled closed-loop testing modes for accurate normal loading and lateral displacement profiles
- A variety of probe materials and geometries available

APPLICATIONS

- Solid Lubricants
- Graphene / Fullerenes
- Protective Coatings (DLC, TiC, TiN)
- Multilayer Films
- Tribofilms
- Nanoparticles



PI 95 TEM PicoIndenter front end showing MEMS transducer and sample mount.