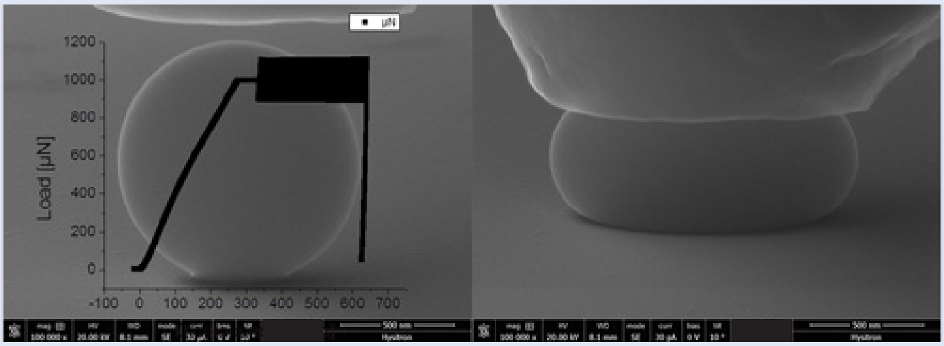
UPGRADE OPTIONS

HYSITRON®

# nanoDMA® PI

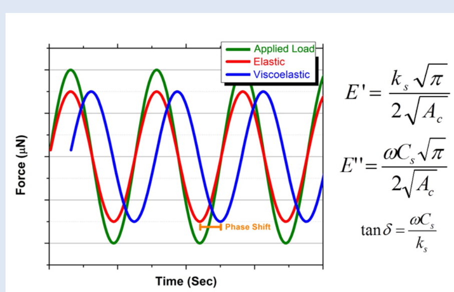
Continuous Dynamic Mechanical Analysis for the SEM PicoIndenter®




Silica particle compression with 1 mN DC, 100 µN @ 10 Hz AC load. Particles shown exhibit viscoplastic creep under load.

Traditional analysis techniques for nanomechanical testing assume elastic-plastic material behavior. However, this does not accurately describe the response of time dependent materials which benefit from dynamic characterization. Hysitron has developed the **nanoDMA® PI** *in situ* testing option for the **SEM PicoIndenter®** instrument as a solution for measuring the properties of such materials. nanoDMA PI offers several testing modes in which a sinusoidal force is applied to a sample and the resultant displacement amplitude and phase shift are measured using a lock-in amplifier. The dynamic mechanical response of the transducer in contact with the sample is modeled using two Kelvin-Voigt mechanical equivalents, from which the contact stiffness and damping properties of the material can be accurately determined. From this the storage (E') and loss (E'') moduli can be calculated, as can their ratio tan delta. Additionally, this technique has been expanded to include additional testing modes for characterizing creep and fatigue.

The system's **TriboScan**™ v.9 control software incorporates a flexible and intuitive graphical user interface to speed test setup and execution, enhance data analysis and plotting capabilities, and drift correction routines enabling tests of prolonged duration, such as creep.




Schematic of sinusoidal force and resultant displacement data as measured using nanoDMA PI. Equations for storage (E') and loss (E'') modulus are given on the right.

## Highlights

- Newly developed *CMX* algorithms, providing a truly Continuous Measurement of X (X = hardness, storage modulus, loss modulus, complex modulus, tan-delta, etc.) as a function of contact depth, frequency, and time
- *In situ* fatigue testing elucidates phenomena that lead to device failure
- Universally applicable technique for the thorough nanoscale characterization materials, from ultra-soft hydrogels to hard coatings
- Enhanced dynamic characteristics and dynamic testing range (1 Hz to 300 Hz), enabling increased accuracy and applicability on the broadest range of materials
- Flexible graphical user interface for rapid test setup, execution, and increased data analysis and reporting capabilities
- Coupled AC and DC force modulation for reliable and quantitative nanoscale dynamic characterization from the initial surface contact
- Operates by directly controlling the load amplitude rather than relying on a displacement amplitude feedback loop
- Drift correction capabilities for maximum accuracy during long test cycles

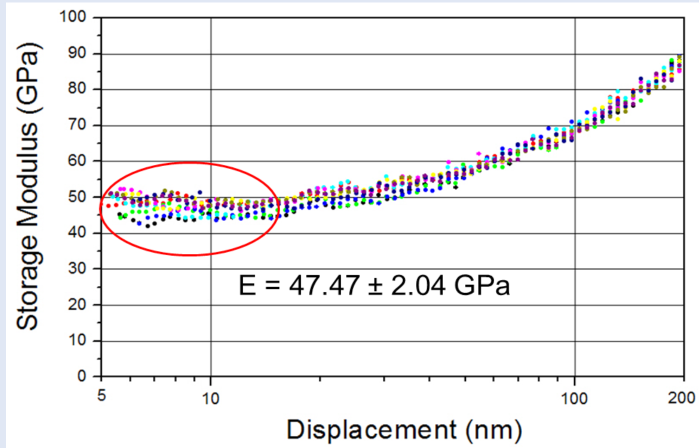
HYSITRON®

9625 WEST 76TH ST. MINNEAPOLIS, MN 55344
TEL: 1-952-835-6366 FAX: 1-952-835-6166
WWW.HYSITRON.COM

## *CMX* Algorithms

Hysitron's powerful *CMX* algorithms lie at the core of nanoDMA PI. *CMX* provides a continuous and quantitative measurement of mechanical properties — including hardness, storage modulus, loss modulus, complex modulus, and tan delta — as a function of indentation depth, frequency, and time. The nanoDMA PI force modulation technique with *CMX* enables thousands of mechanical property measurements to be continuously taken during a single test, increases sensitivity to nanoscale elasto-plastic deformation including creep and fatigue, and allows for the viscoelastic properties of materials to be measured.

High bandwidth transducer and control electronics are fully optimized for nanoscale dynamic testing and provide industry-leading performance, sensitivity, and a broad dynamic range. Hysitron's unique coupled AC/DC force modulation routine enables true nanoscale mechanical characterization and is not subjected to the slow feedback response times that plague other nanoscale dynamic stiffness techniques.

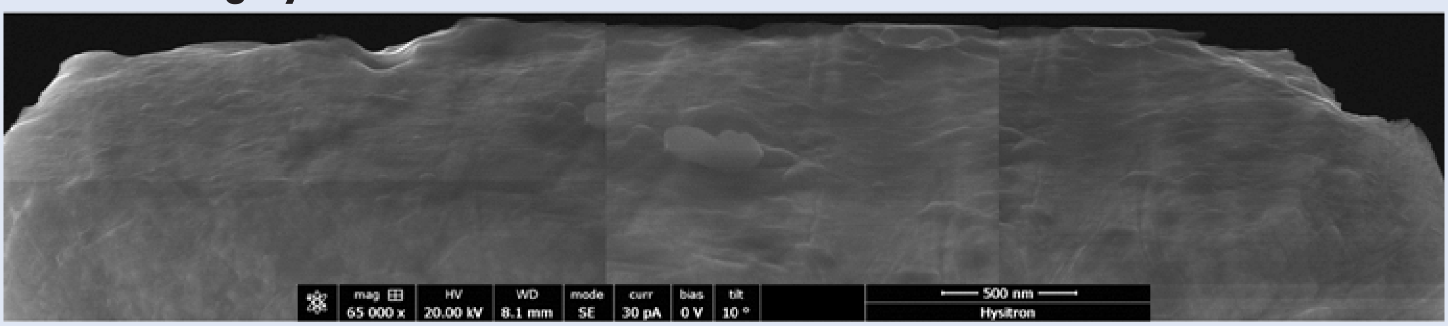



Modulus depth profile on a TEOS thin film. Data below 20 nm is consistent and shows the film modulus independent of the substrate.

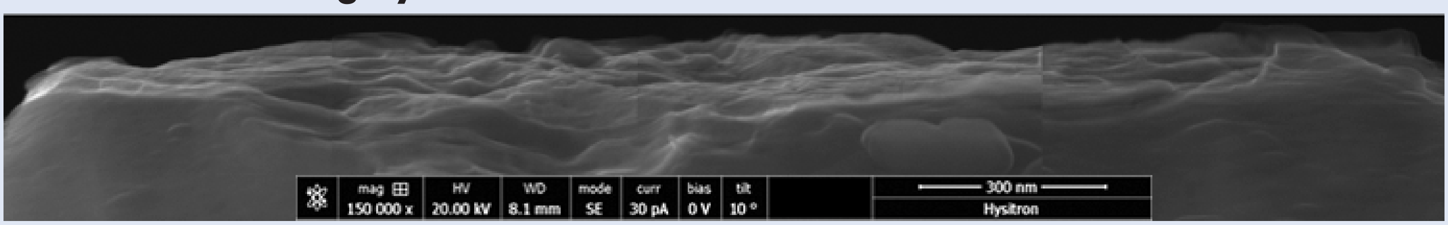
## Reference Frequency Technique

nanoDMA PI incorporates a unique reference frequency technique for thermal drift correction during the course of a nanoindentation experiment. The reference frequency technique allows for the measurement of contact area without relying on the raw displacement data. Measured stiffness is proportional to contact area and can therefore be used to accurately determine contact area and contact depth. This technique is insensitive to changes in drift rates and allows nanoindentation tests lasting 1 hour or more to be routinely and reliably performed.

## First Loading Cycle




## 1,000,000 Loading Cycles




Rough surface contact fretting fatigue on an Au post before and after 1 million dynamic loading cycles.