TECHNIQUE

Nanoscale Indentation

An Overview of Hysitron Quasistatic Nanoindentation

Quasistatic nanoindentation has become the standard technique used for nanomechanical characterization of materials. A quasistatic nanoindentation test is performed by applying and removing a load to a sample in a controlled manner with a geometrically well-defined probe.

During the nanoindentation a force is applied by the transducer and the resulting displacement is observed to produce a traditional force versus displacement curve. Hysitron measures the force and displacement of the nanoindentation probe with a unique patented three-plate capacitive transducer design. This transducer design provides an unsurpassed noise floor and ultra-low working force.

The tightly controlled construction and calibration standards used for the capacitive transducer in combination with the precisely machined, rigid nanoindentation probes produce quantifiable, reliable measurement on any material.

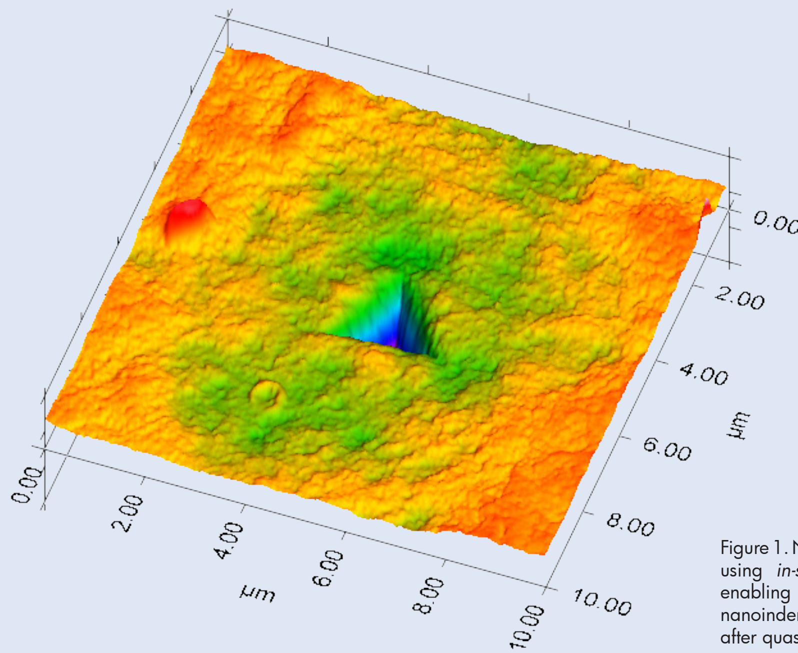

Figure 1. NiTi sample imaged using *in-situ* SPM imaging enabling visualization of nanoindentation impression after quasistatic testing.

Analysis of the measured force versus displacement curve (particularly the unloading segment) provides the user with information regarding the mechanical properties of the sample. Values typically obtained from quasistatic nanoindentation testing are Reduced Modulus [E_r] and Hardness [H]. However other information such as fracture toughness, stiffness, delamination force and film thickness can also be obtained.

All Hysitron nanoindentation systems are capable of *in-situ* SPM imaging. Using the same probe to scan a sample surface immediately before and/or after a test allows for precise placement of the test as well as near-instant observation of events or sample recovery.

Quasistatic nanoindentation from Hysitron is designed for maximum versatility. Standard with all Hysitron nanoindentation systems and equipped with a standard maximum force up to 10 µN and a noise floor of less than 30 nN, quasistatic nanoindentation covers a large range of sample testing possibilities.

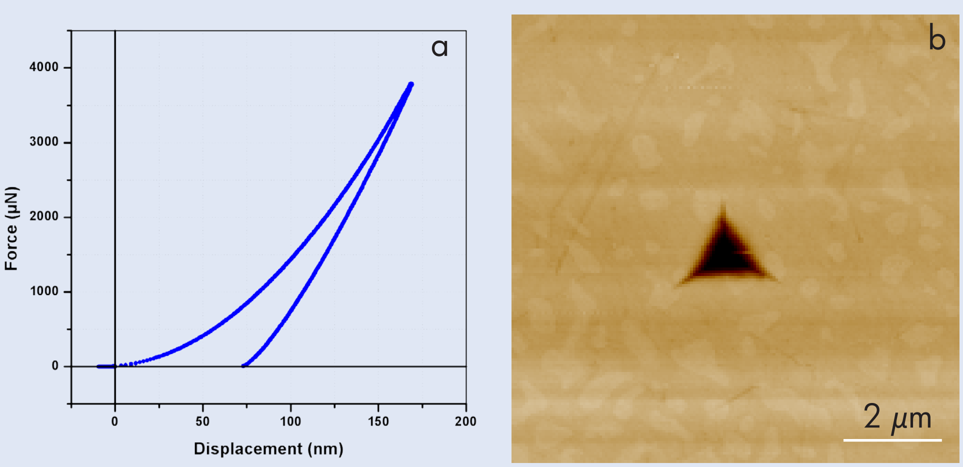

Figure 2. a) Force versus displacement curve on fused quartz showing typical response of elastic-plastic material.
b) Resulting *in-situ* SPM image of quartz surface after quasistatic indentation showing residual indent impression.

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How Quasistatic Nanoindentation Works

The Hysitron transducer is unique in its operation and is the only system in the world to use the patented three plate capacitive design. Displacement is measured by running two AC signals that are 180° out of phase with each other to the top and bottom plate of the three-plate capacitive sensor. The AC signals are observed by the center (floating) plate and the sum of the signals corresponds to a measured displacement. To apply a load, a DC offset is applied to the lower plate of the transducer that electrostatically attracts the center (floating) plate downward. The resulting difference in the sums of the AC signals results in an offset in the sum of the AC signals and thus a change in displacement.

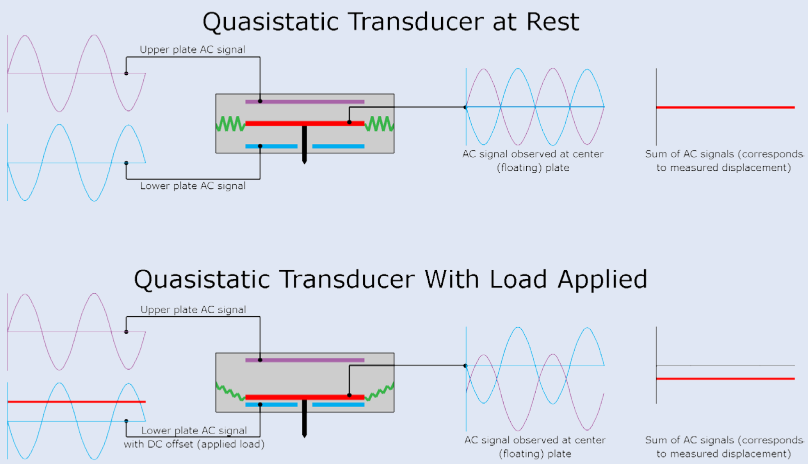
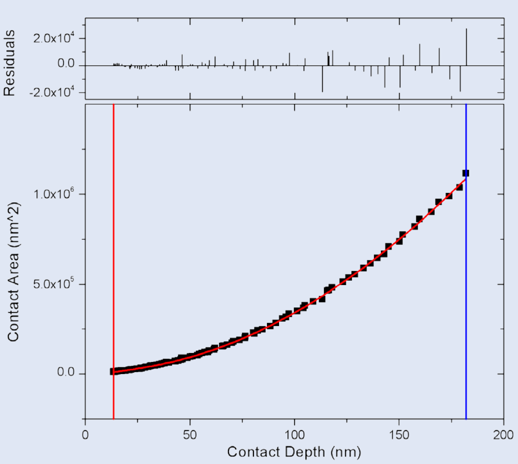


Figure 3. Schematic showing explanation of Hysitron's patented 3-plate capacitive transducer operation for accurate force application.

Hysitron nanoindentation systems include a quasistatic data analysis package that uses a standard model[1] to fit the initial unloading portion of the force versus displacement curve to extract the Reduced Modulus [E_r] and Hardness [H] values.

Quasistatic testing enables the nanoindentation probe area function to be calculated using an advanced analysis software package (figure 4) to ensure any variations in probe geometry are accounted for.



C0 = 2.450000e+01 R^2 = 0.99953
C1 = 9.949481e+03
C2 = -5.244866e+05
C3 = 4.441482e+06
C4 = -9.985048e+06
C5 = 6.041965e+06

	red line	blue line
Contact Depth (nm)	1.353e+01	1.820e+02
Contact Area (nm^2)	1.078e+04	1.115e+06

Figure 4. Analysis from quasistatic testing showing curve fit over increasing load indentation testing for calibration of probe shape.

HIGHLIGHTS

- Industry leading capacitive transducer design provides the most reliable, reproducible results with the lowest available noise floor
- Non-destructive testing provides quantifiable data for material testing
- Automated, advanced nano-indentation probe calibration procedure
- *In-situ* SPM imaging provides accurate probe placement and imaging of the tested location

POTENTIAL APPLICATIONS

- Hardness and reduced modulus information from a large array of samples including, but not limited to:
  - Ceramics
  - Metals
  - Wafers
  - MEMS devices
  - Biological samples
  - Composites
- *In-situ* SPM imaging of samples pre/post test

Reference

1. W. C. Oliver and G. M. Pharr, An improved technique for determining hardness and elastic modulus using load and displacement sensing indentation measurements, J. Mater. Res. 7 (6), 1564-1583 (1992).