

Nanoscale Indentation: An Overview of Quasi-static Nanoindentation

● TN1500 RevA0

Nanoscale indentation or nanoindentation is a powerful technique used to quantitatively characterize the mechanical properties of small volumes of material. By fitting the appropriate models to the force vs. displacement curve obtained during the test, material properties such as elastic modulus, hardness, creep, stress relaxation, interfacial adhesion, and fracture toughness can be measured at the nanoscale and microscale.

A quasi-static 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 test, a force is applied by the transducer and the resulting displacement is observed to produce a traditional force vs. displacement curve (Figure 1). Bruker's Hysitron® nanoindenters measure the force and displacement of the nanoindentation probe with a unique 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 and reliable measurements on any material. Analysis of the measured force vs. displacement curve (particularly the unloading segment) provides the user with information regarding the mechanical properties of the sample. Values typically obtained

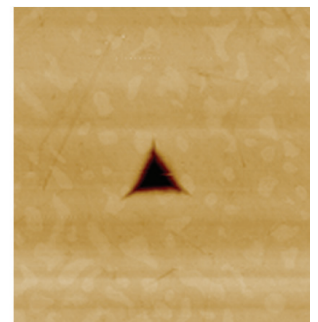
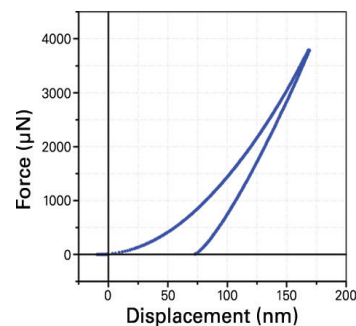


Figure 1. Force vs. displacement curve on fused quartz showing the typical response of elastic-plastic material (left) and resulting in-situ SPM image of quartz surface after quasi-static indentation showing residual indent impression (right).

from quasi-static nanoindentation testing are reduced modulus (E_r) and hardness (H). However other information, such as fracture toughness, stiffness, delamination force, and film thickness also can be obtained.

All Hysitron standalone 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.

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

Quasi-Static Nanoindentation Data Analysis

Hysitron nanoindentation systems include a quasi-static data analysis package that uses a standard model¹ to fit the initial unloading portion of the force vs. displacement curve to extract the reduced modulus (E_r) and hardness (H) values. Quasi-static testing enables the nanoindentation probe area function to be calculated using an advanced analysis software package (Figure 2) to ensure any variations in probe geometry are accounted for.

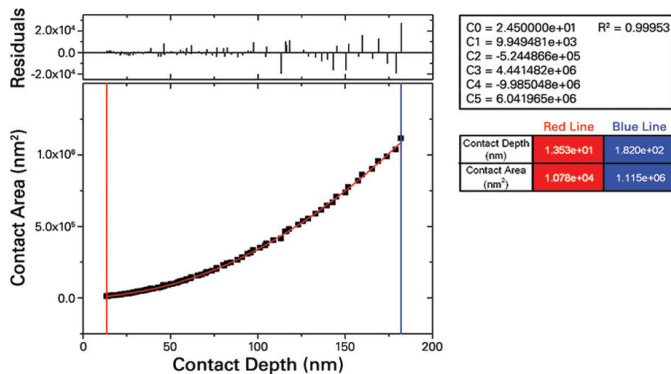


Figure 2. Analysis from quasi-static testing showing curve fit over increasing load indentation testing for calibration of probe shape.

How Quasi-Static Nanoindentation Works

Bruker's nanoindentation transducer is unique in its operation and is the only system to use the 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 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).

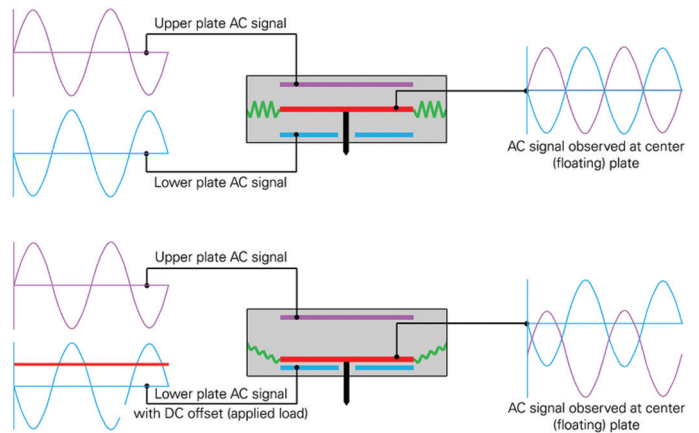


Figure 3. Schematic showing explanation of Bruker's three-plate capacitive transducer operation for accurate force application.

References

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), 1564-83 (1992).

● Bruker Nano Surfaces Division

Minneapolis, MN • USA
 Phone +1.952.835.6366
productinfo@bruker.com

www.bruker.com/nanomechanical-testing