

# Nanoindentation

Nanoindentation is an analytical technique for testing mechanical properties of materials at the nanoscale. Properties that can be measured using nanoindentation including Young's modulus, hardness, and fracture toughness. Some nanoindenters are also equipped to do mechanical analysis of materials in two dimensions, including lateral force measurements, nano-scratch testing, and wear testing.

In nanoindentation, a small rigid probe with a well defined geometry is forced into a sample with an increasing force until the force reaches the maximum force desired. The force, or load, is slowly lowered and the indenter tip is retracted from the sample. In some cases, the load is held at the maximum target value for a period of time. During this controlled loading-unloading sequence, the probe is displaced vertically and both the vertical displacement and applied load are measured. This force-displacement is recorded continuously to determine hardness and modulus of the material tested.

Indenter tips come in a variety of shapes including the traditional 3-sided pyramid (Berkovich), cube-corner, conical, and spherical. The tips of these probes can range in radial size from 50nm to hundreds of nanometers. Selection of the proper tip is critical to proper analysis. For most samples, the Berkovich tip is used; for softer samples such as biological samples and polymers, conical tips with larger radii are better.

Nanoindentation software relies on mathematical models that consider the area of the probe and the area of contact that the probe has with the sample during loading and unloading. These models assume the probe indents into the sample on a flat, smooth interface. Practically speaking, no sample will have a perfectly flat, smooth surface – therefore, it is of utmost importance to be able to control where the probe will indent into the sample. For this reason, most nanoindenters also function as contact-mode Scanning Probe Microscopes. This means that the probe is scanned over an area with very low force to produce an image of the sample surface. Displacement of the probe provides height values that are used to generate an image of the sample. This aids in helping to find an appropriate area to indent into to ensure that the models used to calculate the properties will be representative of the sample. Often, it is also important to re-image the surface of the sample after indentation to observe the indentation profile and to determine fracture toughness.