Mechanical Properties

From Nano to Macro

Atomic Force Microscopy (AFM)

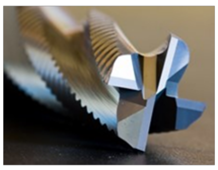
Nanoscale mechanical properties impact the behavior and performance of countless materials and help inform both our theoretical understanding of these materials and their development for commercial applications. As we continue to learn more about the critical role of nanomechanics, our need for techniques that more fully measure them grows in importance. The atomic force microscope (AFM) has powerful capabilities for nanomechanical characterization due to its inherent spatial resolution and force sensitivity. However, the sheer diversity of material properties prevents any single AFM technique from providing the most relevant or accurate data for every application. For this reason, Asylum Research offers a collection of AFM techniques, together called the NanomechPro Toolkit, to meet a broad spectrum of nanomechanical characterization needs.

Research Modes in the Asylum NanomechPro Toolkit	Elastic Modulus Range	Loss Modulus / Loss Tangent	Acquisition time (256x256 image)	Advantages	Disadvantages
Quasistatic Modes					
Force Curves / Force Volume Mapping	●●●●●●●○○ 1 kPa – 1 GPa	No	~3 hr (6 Hz ramp rate)	Many indentation models supported, including Hertz / Sneddon, Derjaguin-Müller-Toporov (DMT), Johnson-Kendall-Roberts (JKR), Oliver-Pharr	Impractically slow at higher pixel density
Fast Force Mapping Mode	○●●●●●●●● 10 kPa – 100 GPa	No	~9 min (300 Hz ramp rate)		Relatively slow
Instrumented Vertical Nanoindentation	○○○○●●●●● 10 MPa – 100+ GPa	No	Usually single points or very coarse mapping		Relatively large/deep indentations. Only single points or very coarse mapping.
Force Modulation Imaging	○○○●●●●○○ 1 MPa – 1 GPa	Dissipation, but not directly *tan δ*	~4 min (1 Hz line rate)	Can measure response at fixed frequencies over a wide range	Currently only qualitative analysis in Asylum software
Dynamic Modes					
Phase Imaging	●●●●●●●●● 1 kPa – 100 GPa	No	~10 s (20 Hz line rate using small cantilevers)	Rapid and simple	Only qualitative contrast, can be difficult to interpret
Bimodal Dual AC Imaging	●●●●●●●●● 1 kPa – 100 GPa	No	~10 s (20 Hz line rate using small cantilevers)	Rapid and simple. Can provide enhanced contrast and resolution vs. phase imaging.	Only qualitative contrast. Can be difficult to interpret.
Loss Tangent Imaging	●●●●●●●●● 1 kPa – 100 GPa	Yes	~10 s (20 Hz line rate using small cantilevers)	Rapid and simple. Quantifies loss tangent, simplifying interpretation of phase data.	Quantifies only loss tangent when used without full AM-FM Mode
AM-FM Mode	○○●●●●●●● 100 kPa – 100+ GPa	Yes	~10 s (20 Hz line rate using small cantilevers)	Rapid and simple. Measures both *E'* and *tan δ*.	Currently only supports Hertzian contact mechanics
Contact Resonance Mode	○○○○○○●●● 1 GPa – 100+ GPa	Yes	~4 min (1 Hz line rate)	Measures both *E'* and *E"*	Currently only supports Hertzian contact mechanics

Nanoindentation

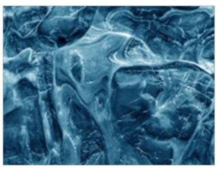
Nanomechanical testing encompasses a comprehensive set of techniques for determining a broad set of mechanical properties at sub-micrometer length scales. Indentation testing has been utilized for over a century to determine the hardness of materials. Advances in indentation-based mechanical testing over the past decades has enabled quantitative characterization of many additional material parameters at the nanoscale; such as elastic modulus, viscoelastic properties, creep and stress relaxation behavior, interfacial adhesion, and fracture toughness. The ability to quantitatively measure mechanical properties at the nanoscale has been critical for making revolutionary advances in materials development.

Elastic Modulus



Hardness

Viscoelastic Properties



Creep

Stress Relaxation

Inerfacial Adhesion

Fracture Toughness

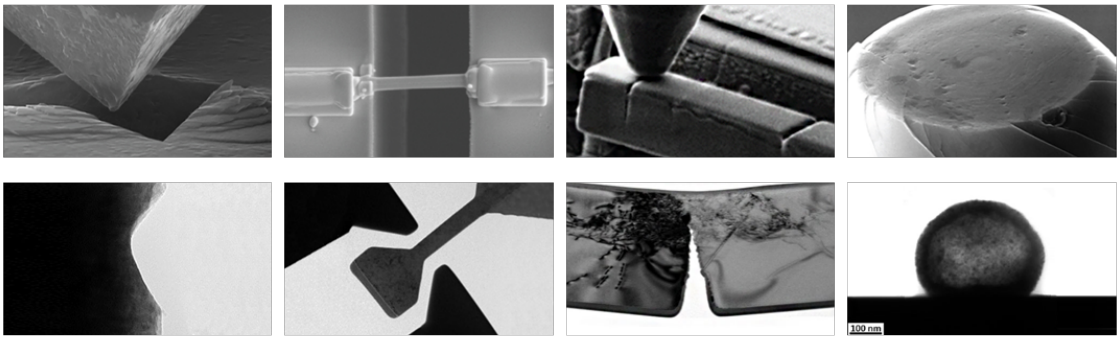
Mechanical Properties and Electron Microscopy

Nanoindentation in-situ

Bruker has developed a comprehensive suite of nanomechanical and nanotribological test instruments that operate in conjunction with powerful microscopy techniques. Combining the advantages of advanced microscopy technologies with quantitative in-situ nanomechanical characterization enables an accelerated understanding of material behavior at the nanoscale.

SEM

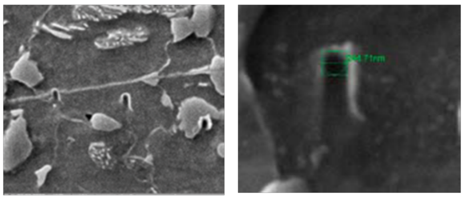
TEM



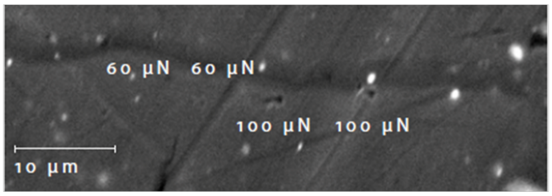
Nanoindentation | Tensile | Bending | Compression

Force Measurement in-situ

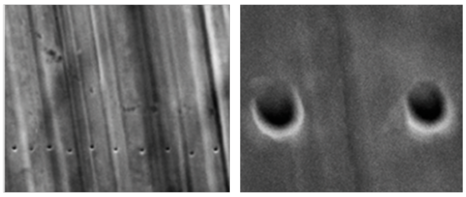
The FMS-EM is a compact force readout tool for the MM3A-EM micromanipulator of Kleindiek. It enhances thesystem by allowing the user to perform force measurements and nanoindentation. Smallest outer dimensions are possible by means of a force readout system that requires no laser. Force feedback on the display of the controller is coupled with a loudspeaker to enable you to intuitively characterize materials and micromechanical structures by their resonance frequencies. Sharp silicon tips allow nanoindentation in a wide variety of materials.



Quantitative measurements on steel



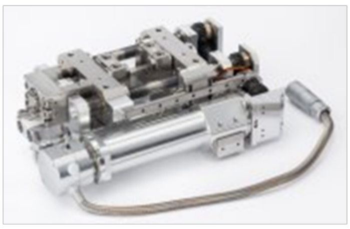
Nanoindentation in aluminium



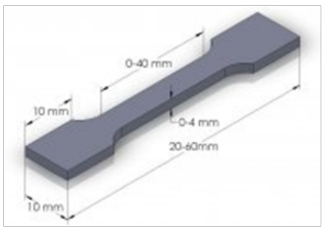
Nanoindentation in copper

Tensile module for macro probes in-situ

The tensile module for the SEM fits on the sample stage just like an oversize specimen. Accepts test objects between 20 and 60 mm long, not thicker than 5 mm. A great number of test parameters and experiments routines are menu-guided, and easy to use. Many sub routines, such as compensation of the device's individual flexure and online recording of the modulus of elasticity are integrated.

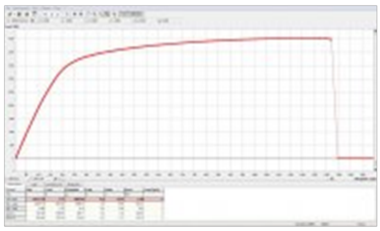


10 kN Tensile/Compression Module



Typical specimen dimentions

Remote control



Typical Tensile test curve