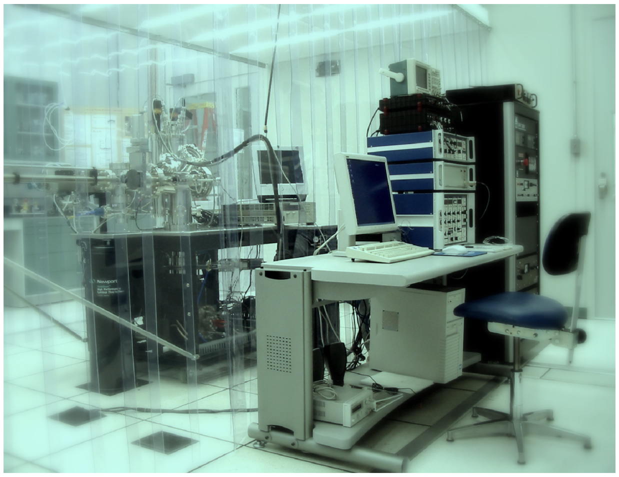
Measurement of Nanomechanical Properties

Facilities

MSEL researchers have established a state-of-the-art environmentally controlled facility for nanomechanical measurement science, standards, and technology development. The 150 m^2 integrated suite of laboratories and instruments is located in the NIST Advanced Measurement Laboratory and includes Class 100 cleanroom space with temperature and relative humidity controls to ±0.01 °C and ±5 %, respectively. The laboratories are mechanically isolated such that vibration velocities are less than 1 $\mu m\ s^{-1}$, with some instruments further isolated by pneumatically-supported inertial blocks. The facility includes capability for ambient and ultra-high vacuum scanning tunneling microscopy and atomic force microscopy (AFM, also possible in liquid), instrumented indentation testing ("nanoindentation") in controlled humidity, and multi-scale adhesion measurement. AFM capabilities include topography (for dimension measurements), force spectroscopy (adhesion), contact-resonance spectroscopy (stiffness), lateral force measurement (friction and nanotribology), and nanoparticle manipulation. Nanoindentation capabilities include topography and measurement of elastic, plastic, viscous, and fracture properties of materials with nano-scale depth profiling. The facility allows load and displacement measurement resolutions of 100 pN and 10 pm, respectively, such that the elastic, plastic, and fracture properties of materials (modulus, hardness, and toughness) can be measured with 5 % precision with 40 nm, 100 nm, and 300 nm spatial resolutions, respectively. The integrated nature of the facility enables cross-checking between instruments, further increasing accuracy and precision.

Significance

Development and cost-effective manufacturing of advanced devices in many industries—microelectronics, magnetic storage, micro- and nano-electromechanical systems (MEMS and NEMS), and optoelectronics, for example—depend critically on accurate knowledge of the mechanical properties of the constituent materials at the nano-scale. The Nanomechanical Properties Group uses the above facilities to develop measurements and standards for transfer to instrument vendors and users so as to enable development and manufacturing of such devices. For example, the metrology for nano-scale toughness measurement enables the microelectronics industry to optimize low dielectric constant materials via nanoindentation techniques. Development of measurement standards for cantilever stiffness calibration enables the magnetic storage and MEMS and NEMS industries to optimize adhesive properties of surfaces via AFM techniques. Development of contact-resonance AFM measurement technology enables the optoelectronics industry to optimize modulus- and stress-gradient structures in nanowires.



Ultra-high vacuum combined scanning tunneling microscope and atomic force microscope used for nano-scale topography and adhesion measurements.

Richard Gates
Dylan Morris
Frank DelRio

Robert Cook (Ceramics Division)
(301) 975-3207
robert.cook@nist.gov

FACILITIES