Measurement Facilities:
Small-Scale Mechanical Reliability

The Materials Reliability Division has established several capabilities for analyzing the reliability of small scale structures, including a number of custom instruments developed specifically for size-appropriate testing. Our capabilities include:

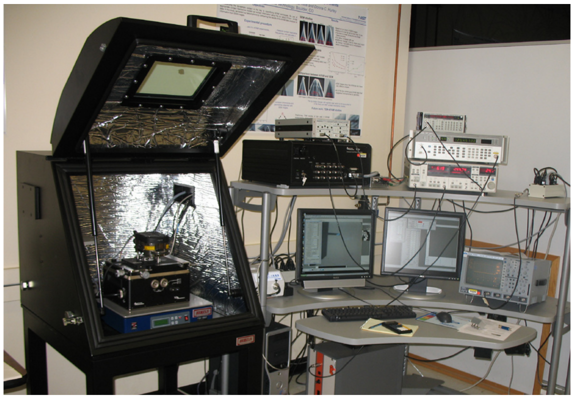
- field emission scanning electron microscope with automated electron backscatter diffraction system (EBSD)
- 200 kV transmission electron microscope
- microtensile testing apparatus *(custom)*
- contact-resonance force microscope *(custom)*
- surface acoustic wave spectroscopy system *(custom)*
- probe station equipped for automated AC electrical fatigue testing *(custom)*
- Brillouin light scattering system
- tip-enhanced Raman spectroscopy system
- nanoindenter
- scanning thermal microscope

Custom Capabilities

The microtensile testing system pioneered at NIST makes use of specimens fabricated by conventional semiconductor processing methods and has paved the way for a newer generation of MEMS-based test devices. The apparatus is used to record force-displacement response of free-standing films, providing the most basic of mechanical property measurements of materials. It features spring-steel strips calibrated by eddy current methods, providing a force range of 20 mN with measurement uncertainty of < 1 %. Displacement is determined by digital image-correlation methods; we can resolve 0.02 pixel, which provides strain sensitivity of approximately 55 x 10^{-6} for a gauge length of 180 μm. The system has been applied to many different as-fabricated thin film specimens, including electrodeposited copper, PVD aluminum and copper, gold, polyimide, and polysilicon.

NIST researchers have also developed a contact-resonance force microscopy method that can provide not only point measurements, but quantitative contact stiffness images from nanoparticles and surfaces of films as thin as 50 nm. The method is based on measurement of the mechanical resonances of an AFM cantilever, the tip of which is placed in contact with the structure of interest. Changes in cantilever resonant response from that measured for the free-space case are dependent on the localized stiffness of a small volume of material immediately below the tip. Beam dynamics models are used to relate resonant frequencies to contact stiffness, which is in turn related to indentation modulus through contact mechanics modeling. The system displays an intrinsic frequency resolution $\sim$ 12 Hz, which translates to a modulus uncertainty of several gigapascals.

The method has been used to map stiffness in films, nanocomposites, and nanoparticles; it has also been used to detect sub-surface effects such as adhesion variations.



Contact-resonance force microscope system, used for highly localized measurements of elastic response in films and nanoparticles.

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