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Atomic Force Microscopy Enhances The Nanoscopy Toolkit

ATOMIC FORCE MICROSCOPES ARE IDEAL FOR NANOMECHANICAL CHARACTERIZATION, BRINGING UTILITY TO NANOSCOPY APPLICATIONS AND EXCELLING IN CONDITIONS WHERE LOW LIGHT PRESENTS CHALLENGES OR SAMPLE INTEGRITY IS VITAL.

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Imaging and morphology represent a critical puzzle piece when trying to understand nanoscale structures, whether they are naturally occurring, such as viruses, or engineered structures, such as nano-antennas, layered structures, and photonic devices.

While atomic force microscopes (AFMs) have been embraced as a tool for imaging surface morphology, AFM capabilities in nanomechanical characterization typically are overlooked by non-AFM users. The AFM's extreme sensitivity to small forces make it an ideal tool for nanomechanical characterization of materials and molecular structures, from gauging friction on surfaces and nanomagnetic fields to quantifying spring constants of materials. The utility spans numerous applications in biophysics, virology, molecular biology, surface science, condensed matter physics, quantum computing, and photonics. Additionally, AFM capabilities complement many optical microscopy techniques — including fluorescence microscopy and super-resolution microscopy — making AFM an essential component in any nanoscopy toolkit.

More Than Just An Imaging Tool

An AFM's core concept is not that of an imager, but a tool measuring the force between its tip and a sample, revealing insight into its functionality but, for the most part, that tip-sample interaction is at the heart of atomic force microscopy. Many of the mechanical experiments an AFM conducts are not themselves revolutionary, but have already been conducted at the "macro" scale. The AFM simply has made such testing accessible at the nanoscale, before analyzing some of the mechanical cases for AFM.

Friction Forces — By dragging the probe tip across the surface, an AFM can measure frictional forces at that surface. The surface can be anything from diamond to a biomaterial, and the AFM is effective whether the surface is rough or very smooth.

The Functionalization — Early in the development of AFM, experiments learned to functionalize the probe tip to change the surface force interaction. For example, tips were coated with a magnetic material, making the system sensitive to magnetic forces, thus creating a magnetic force microscope. With this method, magnetic domains and structures on a surface can be probed, as well as imaged. This type of functionalization isn't

limited to magnetism, either; complex polymers or single molecules have been used to change the nature of an AFM tip's interaction with a material.

Surface Hardness — An AFM user can push on a surface with the probe tip to study that surface's mechanical properties. Basic questions of hardness and deformation still exist at this level, and the surface can range in hardness from a metal to a biomaterial, such as living cells. The AFM's enhanced sensitivity effectively enables it a (low-force) indicator for some of these measurements.

Nano-Manipulation — In addition to pushing with a probe tip, we also can pull with it, as many molecules will readily attach to the tip. An example is a virus, a fundamental building block of muscle tissue. An AFM probe can be attached to a repair fiber to pull it or hold it with a constant force. The probe also can be used to untangle proteins. Conversely, a pharmaceutical could be added to the sample to make it stick.

Fundamental material questions from macroscopic material study apply equally to the nanoscopic world: How does the material work as a spring? How does it fail, and at what force and distance of movement does it fail?

Tip Enhancement — Sometimes, the tip itself can change an experiment. For example, it has been found that a conductive tip's presence can alter the interaction of light with surface properties. Surface-enhanced Raman scattering can occur when a tip is illuminated with a laser. An Raman is a very minute effect, but the enhancement — sometimes tenfold — is extremely beneficial in the study of both engineered surfaces and biological samples.

How AFMs Enhance The Nanoscopy Toolkit

In many ways, the above listed techniques combine well with biological imaging. Many biological samples are semi-transparent and may be imaged from below using well-established techniques and inverted optical microscopes. Inverted optical microscopes are a common tool for biological imaging, and they are available in a broad range of styles from general usage instruments. Alternatively, researchers also custom build microscopes to meet their specific needs.

Atomic Force Microscopy Enhances the Nanoscopy Toolkit

Imaging and morphology represent a critical puzzle piece when trying to understand nanoscale structures, whether they are naturally occurring, such as viruses, or engineered structures, such as nano-antennas and photonic devices. In addition to imaging, atomic force microscopy (AFM) is ideal for nanomechanical characterization, bringing utility to nanoscopy applications and excelling in conditions where low light presents challenges or sample integrity is vital.

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