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Atomic force microscope sees more through vibration isolation

Vibration isolation and better scan size enables atomic force microscopy (AFMs) to see more at the nanoscale level.

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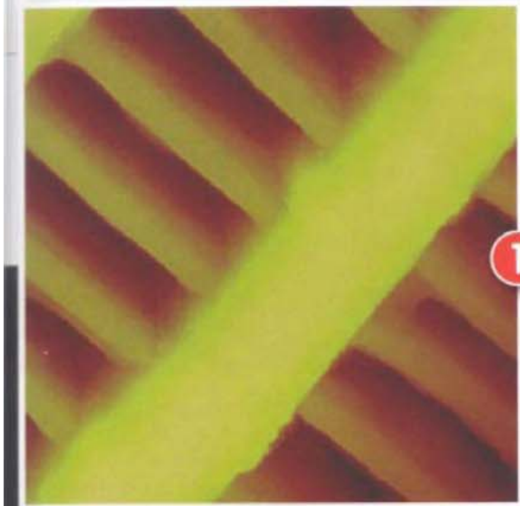
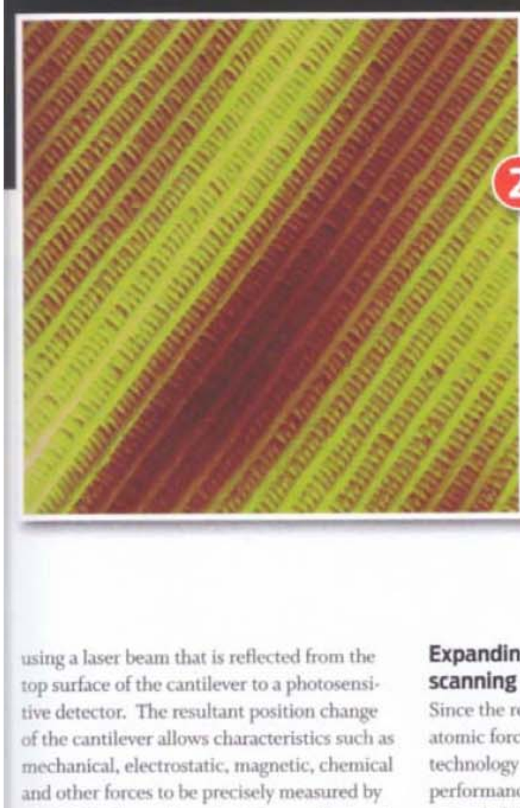
With its development in 1986, and subsequent commercial introduction in 1989, the atomic force microscope (AFM) is one of the foremost tools for imaging and measuring materials and cells on the nanoscale. Revealing sample details at the atomic level, with resolution on the order of fractions of a nanometer, the AFM is instrumental for imaging an array of applications, such as defining surface characterizations, lithography, data storage, and manipulation of atoms and nano-sized structures on a variety of surfaces.

The need for more precise vibration isolation with AFM, though, is becoming critical as resolutions continue to bridge from micro to nano. AFM systems are extremely susceptible to vibrations from the environment. When measuring a very few angstroms or nanometers of displacement, an absolutely stable surface must be established for the instrument. Any vibration coupled into the mechanical structure of the instrument will cause vertical and horizontal noise and bring about a reduction in the ability to measure with the highest resolution. The vertical axis is the most sensitive for AFMs, but these microscopes are also quite sensitive to vibrations in the X and Y axes.

The atomic force microscope uses a sharp tip (probe), with a radius of curvature on the order of nanometers attached to the end of a tiny cantilever used to scan across a sample surface to image its topography and material properties. When the tip is brought into proximity of a sample surface, forces between the tip and the surface lead to a deflection of the cantilever. This deflection is typically recorded

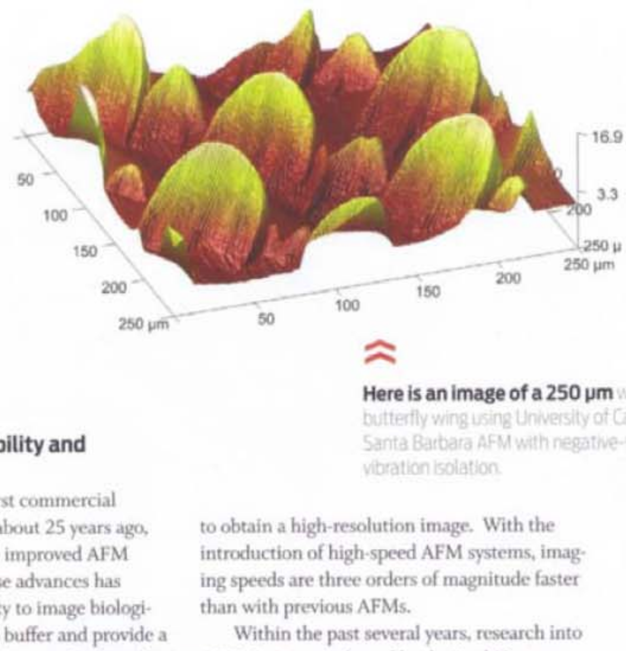




The following images demonstrate the resolution capable when using negative stiffness vibration isolation technology in atomic force microscopes.

1. This image is a 2.5 µm width of butterfly wing.

2. This image is of a 32 µm width of butterfly wing using the University of California, Santa Barbara AFM.



Here is an image of a 250 µm width of butterfly wing using University of California, Santa Barbara AFM with negative-stiffness vibration isolation.

using a laser beam that is reflected from the top surface of the cantilever to a photosensitive detector. The resultant position change of the cantilever allows characteristics such as mechanical, electrostatic, magnetic, chemical and other forces to be precisely measured by the AFM. These characteristics are displayed in a three-dimensional surface profile of the sample (in the X, Y and Z axes)—an advantage that the AFM can provide compared to other microscopy techniques, such as the scanning electron microscope (SEM) which delivers a two-dimensional image of a sample (in the X and Y axes).

Expanding AFM capability and scanning range

Since the release of the first commercial atomic force microscope about 25 years ago, technology advances have improved AFM performance. One of these advances has expanded the AFM's ability to image biological samples in an aqueous buffer and provide a range of physical data for the sample. Another has increased the imaging speed of AFMs. Unlike Scanning Electron Microscopes, which are capable of scanning in near real-time, conventional AFMs, prior to about five years ago, required between one and 100 minutes to obtain a high-resolution image. With the introduction of high-speed AFM systems, imaging speeds are three orders of magnitude faster than with previous AFMs.

Within the past several years, research into AFM design, conducted by the Paul Hansma Research Group, Department of Physics, at the University of California, Santa Barbara, has demonstrated success with AFM imaging of large-scale samples at nanoscale resolutions while extending the range of the Z-axis.

Mechanical ||||

To image at the extreme depths necessary in large-scale cracks and deep microcracks the AFM must have a Z-range of at least 200 microns and a cantilever tip long enough to probe the crack. As the vertical movement of the tip is increased, however, it brings into play a greater possibility for vibration. This issue was solved with the incorporation of negative-stiffness vibration isolation.

University of California, Santa Barbara atomic force microscope on its negative-stiffness vibration isolation platform.

Improving on AFM vibration isolation

Developed and patented by Minus K Technology, negative-stiffness isolators use a completely mechanical concept in low-frequency vibration isolation while achieving a high level of isolation in multiple directions.

In negative-stiffness vibration isolation, vertical-motion isolation is provided by a stiff spring that supports a weight load, combined with a negative-stiffness mechanism. The net vertical stiffness is made very low without affecting the static load-supporting capability of the spring. Beam-columns connected in series with the vertical-motion isolator provide horizontal-motion isolation. The beam-column behaves as a spring combined with the negative-stiffness mechanism. The result is a compact passive isolator capable of very low vertical and horizontal natural frequencies and very high internal structural frequencies.

The isolator provides 0.5 Hz* isolation performance vertical, and 0.5 Hz horizontal, using a totally passive mechanical system —no air or electricity required. (*Note that for an isolation system with a 0.5 Hz natural frequency, isolation begins at about 0.7 Hz and improves with increase in the vibration frequency. The natural frequency is more commonly used to describe the system performance.)

"The key factor for us was the incorporation of a true negative spring constant system, together with the positive spring constant, to achieve an effective and very soft spring constant," said Hansma. "This allows the

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