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Negative Stiffness Vibration Isolation Supports Atomic Force Microscopy

By Jim McMahon

The atomic force microscope (AFM) has become 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.

AFM in Studies

Although AFM technology has advanced considerably, its benefits have not always been easily accessible for researchers requiring it. Nor have AFMs been adequately accessible in nanotechnology student laboratories, because of lack of student skill in their operation, and budget limitations on the number of AFMs at their disposal.

Accessibility has improved because of more compact, portable and user-friendly AFMs, enabling quick setup and ease of transport, ideal for multi-use curriculum applications and short laboratory teaching sessions in universities.

Such a user-friendly AFM was recently put into service at the University of Wisconsin - River Falls campus, for its condensed matter physics studies. This advanced laboratory class for undergraduate students involves using the AFM for inspecting lithographically patterned metal films using thermal evaporation and patterning with photolithography.

The AFM is used by students to look at the surface quality of the patterned film after it is made ensuring the pattern is correct, measuring the profile and surface roughness of the film, and inspecting the integrity of the photolithography at the edges of the patterns.

The laboratory students can also use a scanning electron microscope (SEM) to create patterned films which are then examined with the AFM for quality. Using electron beam lithography, the SEM rasters a beam of electrons across the surface of the film, making features on the film. In this process, a thin film of poly methyl methacrylate (PMMA) is coated onto a surface, and an electron beam is guided over the sample to expose the PMMA in specific regions.

Developing the film afterward removes the exposed PMMA, leaving a pattern in the film. These patterns can have features as small as 100 nm in size. The SEM itself has a maximum photographic magnification of 300,000x, with an ability to see features as small as three nanometers in size.

Vibration Challenges

SEM and AFM systems are extremely susceptible to vibrations from the environment. The need for more precise vibration isolation with advanced microscopy tools, such as these, is becoming more critical as resolutions continue to bridge from micro to nano. When measuring a very few angstroms or nanometers of displacement, an absolutely stable surface must be established for the instrument.

Vibration can reach AFMs through the floor, not just from building pumps and motors, but also from elevators, HVAC systems, from the movement of outside vehicle traffic, and ancillary equipment providing support to the microscope. Both vertical and horizontal vibration will negatively influence the quality and resolution of the image being viewed. AFMs are most sensitive to low frequency vibration, in the range of a few Hertz. These vibrations are challenging to eliminate.

“We tried a number of options to mitigate vibrations to the AFM, including a small air isolation table, but this did not solve the problem,” says McCann. “Just last year, our physics department was selected to receive a complimentary negative-stiffness vibration isolator from Minus K Technology. This has since resolved all of the vibration issues with our AFM.”

Vibration Isolation

Developed and patented by Minus K Technology, negative-stiffness isolators provide a unique capability to the field of AFM performance. They employ a completely passive, mechanical concept in vibration isolation, with no air or electricity required. There are no electronics, motors or pumps. They operate completely in a passive mechanical mode, while achieving a high level of isolation in multiple directions. “Vertical-motion isolation is provided by a stiff

spring that supports a weight load, combined with a negative-stiffness mechanism,” says Erik Runge, vice president of engineering at Minus K. “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. A beam-column behaves as a spring combined with a negative-stiffness mechanism. The result is a compact passive isolator capable of very low vertical and horizontal natural frequencies and high internal structural frequencies.”

Just as newer AFMs have been designed for adaptability, so have better vibration isolation solutions become available to support these AFMs. Negative-stiff- ness vibration isolation makes any laboratory environment suitable to achieve excellent AFM results.

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