IMPROVING AFM Data Reliability

Negative-stiffness vibration isolation improves data set integrity.

At Arizona State Univ. (ASU), Tempe, the current interests of the Nanostructures Research Group lie in the areas of quantum dots, quantum wires, and ultra-small semiconductor devices. Led by David Ferry, the group conducts a wide spectrum of theoretical studies of quantum transport. Once such project is scanning gate microscopy at low temperatures. This involves taking the equivalent of an atomic force microscope (AFM) tip, putting bias on it, and studying the change in conductance of small semiconductor structures as this bias tip is moved around on a surface.

The system is mounted in a large cryogenic cooler with a vacuum jacket around it, and the AFM tip is on a cantilever. Normally, with the AFM, the cantilever is moved along the surface of the sample under test, and the change in position over the topography of the surface is recorded. Ferry's group, however, is utilizing a piezo-electric sensor. They metalicize the AFM cantilever tip so they can apply a voltage to it. They then use that voltage to perturb the structure of the sample under test. As the tip moves, it creates a voltage across the plane, which is measured to determine certain mechanical property values of the sample.

This type of experimentation is not uncommon, and similar experiments are being done by a large number of universities. But what is not common is the system that the Nanostructures Research Group is using for vibration isolation: negative-stiffness vibration isolation, developed by Minus K Technology, Inglewood, Calif. It provides a significantly greater and more stable attenuation of the critical lower vibration frequencies, and therefore more reliable data sets can be accrued.

The need for vibration isolation

Compared to other laboratory research instrumentation, the growth of AFM usage has been quite extensive over the past 10 years. AFM equipment placement has gone through a doubling phase pretty much every year during the last decade. Since its inception in 1988, it has continuously proven to be a key tool in moving nanotechnology research forward.

"More than half of the universities in the U.S., and worldwide, are engaging in nanotechnology research," says Ferry. "This is driven by the fact that in the semiconductor industry all things are getting smaller and smaller. Today, transistors have critical dimensions down around 25 nm, and the most critical dimension is the oxide thickness which is 1 nm. When you consider that you have to control 1 nm vertical thickness over 300 mm of lateral dimension, that is a difference of 10^8. That defines what modern manufacturing technology produces. The need for effective vibration isolation has never been greater and will continue to become more demanding as the nano-industry progresses."

Reducing vibration

When measuring a very few angstroms or nanometers of displacement, one must have an absolutely stable surface upon which to rest the instrument. If the surface isn't stable, any of that vibration coupled into the mechanical structure of the instrument will cause vertical noise and a fundamental inability to measure high-resolution features.

"Any kind of vibration noise in the system makes the AFM cantilever tip move, and that gives you bad signals and incorrect data," says Ferry "The entire system had to be isolated, not just the cantilever. We required an extremely high level of vibration isolation given our research parameters."

The negative-stiffness isolator is a passive isolation approach and has a key advantage in that it is not powered. So, in a site where heat buildup could be an issue, such as with enclosed cryogenic chambers, negative-stiffness becomes a highly efficient option.

Negative-stiffness isolators employ a unique—and completely mechanical—concept in low-frequency vibration isolation. Vertical-motion isolation is provided by a stiff spring that supports a weight load, combined with a negative-stiffness mechanism (NSM). 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 horizontal stiffness of the beam-columns is reduced by the "beam-column" effect. (A beam-column behaves as a spring combined with an NSM.) The result is a compact passive isolator capable of very low vertical and horizontal natural frequencies and very high internal structural frequencies. They achieve 93% isolation efficiency at 2 Hz, 99% at 5 Hz, and 99.7% at 10 Hz.

Negative-stiffness isolators provide a capability quite unique to the field of nanotechnology–specifically, the transmissibility of the negative-stiffness isolator. That is, the vibration that transmits through the isolator as measured as a function of floor vibrations is substantially improved over active isolation systems.

–Jim McMahon

The full text of this article is available online at: www.rdmag.com.

RESOURCES:

- **Arizona State Univ. (ASU),** Tempe, 480-965-9011, www.asu.edu
- **Minus K Technology,** Inglewood, Calif., 310-348-9656, www.minusk.com
- **Nanostructures Research Group, ASU,** Tempe, 505-272-7629, www.fulton.asu.edu/~nano