Minus K Educational Giveaway– May 2025

Negative-Stiffness Vibration Isolation Supports Micron-Level Wafer Characterization Research at Northwestern University's Hersam Research Group

The lab has pushed the limits of semiconductor wafer characterization in microscale electronic devices. Facilitating this research is Negative-Stiffness vibration isolation.

By Jim McMahon

The Hersam Research Group – part of the Department of Materials Science & Engineering, McCormick School of Engineering & Applied Science, at Northwestern University – studies, develops and manipulates hybrid hard and soft nanoscale materials for applications in information technology, biotechnology, nanotechnology and alternative energy. The lab's advanced electronic and chemical characterization techniques provide deep insight into these areas, with key examples including impedance spectroscopy for photovoltaics and scanning conductive ion microscopy for lithium ion batteries. Such techniques offer a better understanding of the key issues in enabling practical applications of these technologies.

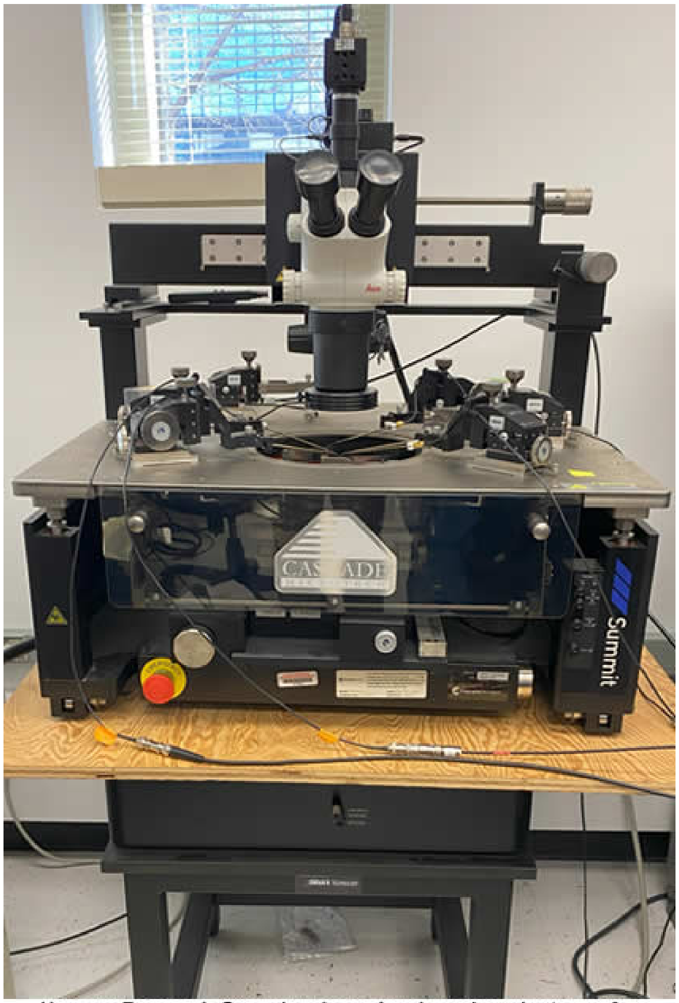
Micron-Level, Wafer Characterization

Another of the group's areas of interest is semiconductor micron-level, wafer characterization. Wafers, being a thin slice of semiconductor, such as crystalline silicon, are used for the fabrication of integrated circuits, and in photovoltaics, to manufacture solar cells. The wafer serves as the substrate for microelectronic devices built in, and upon the wafer.

During semiconductor device manufacturing, wafer testing is performed, where all individual integrated circuits that are present on the wafer are tested for functional defects by applying special test patterns. The wafer testing is performed by a piece of test equipment called a wafer prober. For electrical testing, a set of microscopic contacts or probes, called a probe card, are held in place while the wafer, vacuum-mounted on a wafer chuck, is moved into electrical contact.

The Hersam Research Group has developed a digital wafer map, allowing thousands of devices to be probed in an automated fashion.

“On some of these devices we have 1,000 transistors to characterize inside of a small sample,” said William A. Gaviria Rojas, with the Hersam Research Group. “We are using an automated probe station, manufactured by Cascade Microtech, for semiconductor micron-level, wafer scale characterization on the devices we fabricate.”



Hersam Research Group's micron-level semiconductor wafer characterization automated probe station on Minus K negative-stiffness WS-4 vibration isolation workstation.

Before, the experiments were performed with a manual probe station, taking 1 – 3 hours to complete. Then, the lab switched to the automated probe station which enabled it to collect data for 2 – 3 days.

“The manual process did not display small misalignments in the movement of the probes over the 1 – 3 hour characterization,” continued Rojas. “But the longer 2 – 3 day characterization experiments showed considerable interruptions during high traffic times – the small probes that were in contact with the devices were losing contact.”

Vibration Isolation

The Group determined that the problem was vibration caused by people walking by, opening and closing doors in, and near, the lab where the probe station was located. There was also vacuum and pump equipment located in the room which created vibration.

The probe station was positioned on top of cinder blocks, with plastic material between. This was the extent of vibration isolation being employed, which was inadequate.

A typical laboratory will almost always position sensitive micron-level instrumentation on a vibration isolation platform. Isolating such imaging equipment against low-frequency vibration has become increasingly more vital to maintaining imaging quality and data integrity. Indeed, the lab’s other Raman and AFM instrumentation all have a more sophisticated level of vibration isolation in place.

“We were looking for a vibration isolation solution that would require low maintenance, with no additional things like compressed air or electricity,” explained Rojas. “For these reasons we selected the Minus K, Negative-Stiffness WS-4 compact vibration isolation table.”

Negative-Stiffness Vibration Isolation

Negative-Stiffness vibration isolators are compact, and do not require electricity or compressed air which enables sensitive instruments to be located wherever a production facility, laboratory or observatory needs to be set up, whether that be in a basement, or on a building's vibration compromised upper floors, or rooftop. There are no motors, pumps or chambers, and no maintenance because there is nothing to wear out. They operate purely in a passive mechanical mode.

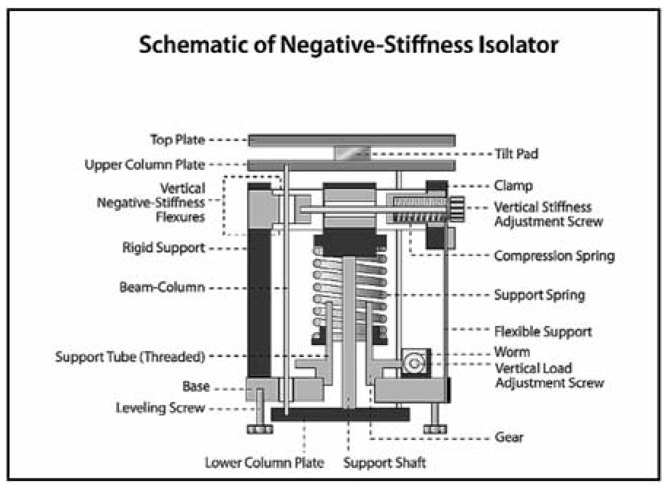
What is very advantageous about Negative-Stiffness isolators is that they achieve a high level of isolation in multiple directions. These isolators have the flexibility of custom tailoring resonant frequencies to 0.5 Hz* vertically and horizontally (with some versions at 1.5 Hz horizontally).

(*Note that for an isolation system with a 0.5 Hz natural frequency, isolation begins at 0.7 Hz and improves with increase in the vibration frequency. The natural frequency is more commonly used to describe the system performance.)

How These Isolators Work

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. 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 very high internal structural frequencies.

Negative-Stiffness isolators deliver very high performance, as measured by a transmissibility curve. Vibration transmissibility is a measure of the vibrations that are transmitted through the isolator relative to the input vibrations. Negative-Stiffness isolators, when adjusted to 0.5 Hz, achieve approximately 93 percent isolation efficiency at 2 Hz; 99 percent at 5 Hz; and 99.7 percent at 10 Hz.



Schematic of a negative-stiffness isolator.

Location Flexibility

If sensitive instrumentation can be isolated from vibrations without having to deal with compressed air or electricity, then it makes for a system that is simpler to transport, and easier to set-up and maintain.

"The Minus K Negative-Stiffness WS-4 isolator is not a complicated system to operate," explained Rojas. "We set it up, adjusted it for the load, and it was good to go. Essentially, the vibrations are now completely gone."

"Vibration isolation that requires compressed air lines and tanks, or electricity, is limited for use in only two rooms in our lab," added Rojas. "But the minus K allows the auto-probe station to be moved anywhere. It is totally flexible, which is really ideal for academia. Space is always a factor, and now we are able to use space that before we couldn't."

About the Hersam Research Group, Department of Materials Science & Engineering, McCormick School of Engineering & Applied Science, Northwestern University
Under the direction of Professor Mark C. Hersam Ph.D., the Hersam Research Group studies, develops and manipulates hybrid hard and soft nanoscale materials for applications in information technology, biotechnology, nanotechnology and alternative energy.

About Minus K Technology, Inc.
Minus K® Technology, Inc. was founded in 1993 to develop, manufacture and market state-of-the-art vibration isolation products based on the company's patented Negative-Stiffness technology. Minus K products are used in a broad spectrum of applications including microscopy, nanotechnology, biological sciences, semiconductors, materials research, zero-g simulation of spacecraft, and high-end audio. The company is an OEM supplier to leading manufacturers of scanning probe microscopes, micro-hardness testers and other vibration-sensitive instruments and equipment. Minus K customers include private companies and more than 300 leading universities and government laboratories in 52 countries.

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