



Active Piezoelectric Vibration Cancellation Enables Advanced Electron and Ion Beam Instruments in Harsh City Environment



The Center for Electron Microscopy and Nanofabrication (CEMN or Center) at Portland State University (PSU) houses sophisticated state-of-the-art electron microscopes, dual-beam focused ion beam microscopes, thin

film deposition and E-beam lithography instruments. As one of the Oregon Nanoscience and Microtechnologies Institute (ONAMI) Signature Facilities, researchers and industry scientists from Oregon and throughout the Pacific Northwest rely on the Center for semiconductor, materials science, metrology and nanotechnology research. The CEMN is located at a busy city intersection and adjacent to the street car in downtown Portland. While conveniently located for Oregon's research community, the city location is not ideal for hosting these state of the art microscopes without proper vibration cancellation. The popular surface rail, the Portland Streetcar, along with additional street traffic and other noise sources common to city activity, dramatically impact the performance of a few of the instruments critical to user activity at the popular facility. Working with TMC to understand the CEMN environment and identify critical solutions, the Center has been able to mitigate the



vibration sources leading to significant improvement of tool performance and increased productivity. (www.pdx.edu/cemn/welcome)



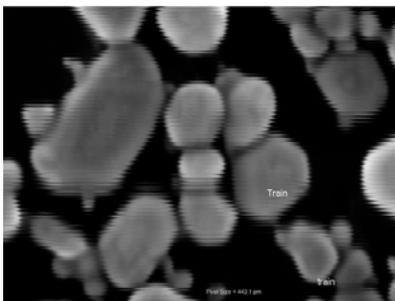
As the capabilities of Transmission and Scanning Electron Microscopes (TEM and SEM) and other charged beam instruments increase, their resolution and overall performance are increasingly limited by (continued)



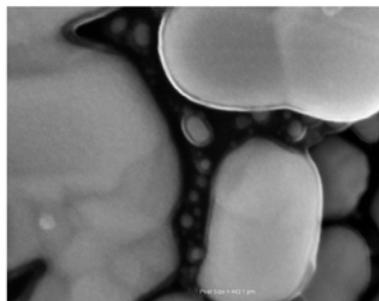
SEM-Base™

SEM-Base with STACIS® technology provides the ideal solution for SEM in a noisy environment

- ▶ Center for Electron Microscopy and Nanofabrication (CEMN) at Portland State University (PSU) is a signature research facility of the Oregon Nanoscience and Microtechnologies Institute (ONAMI), a collaboration between Oregon's research universities, Pacific Northwest National Laboratories and industry partners
- ▶ City location is less than ideal for operating state-of-the-art imaging and milling tools, but is conveniently located in downtown Portland, central to Oregon's research community
- ▶ When SEM and Dual Beam installation sites do not meet manufacturer site environment specification, a point-of-use mitigation solution is required
- ▶ City traffic, including the public street train (Portland Streetcar) adjacent to the facility, limited the usage, performance and productivity of a Field Emission SEM and a FIB/SEM
- ▶ TMC worked closely with the SEM team and the CEMN to measure, analyze, and identify the source of the vibration
- ▶ TMC active vibration cancellation system for SEMs and other small beam instruments, namely SEM-Base, reduces the floor vibration to within specification
- ▶ The FE-SEM and Dual Beam FIB/SEM can now be utilized to their full potential even with the passing street train
- ▶ Particularly effective in allowing the FIB Lift-Out process to be performed even when the street train (Portland Streetcar) passes by, FIB/SEM usage increased significantly allowing the Center to recover the original investment within 4 months



Zeiss Sigma VP SEM before TMC SEM-Base was installed



Zeiss Sigma VP SEM with TMC SEM-Base™ installed and ON

Active Piezoelectric Vibration Cancellation Enables Advanced Electron and Ion Beam Instruments in Harsh City Environment *(continued)*

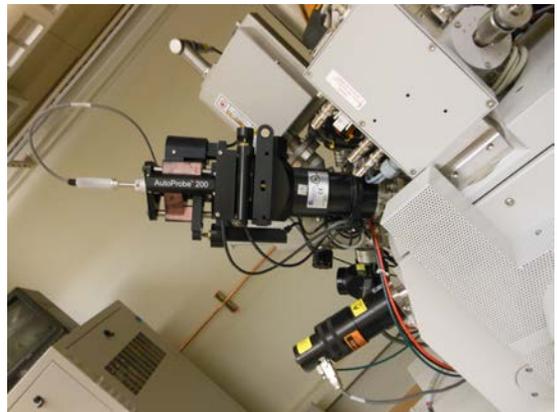
floor vibration. In 2009, the new manager of the CEMN correctly anticipated potential problems related to floor vibration due to their location. When it came time to install their new variable pressure field emission SEM, equipped with EDS/WDS and E-beam lithography, the CEMN realized the low frequency (sub-5Hz) nature of the mechanical vibration in the building and surrounding area was the killer issue impacting the high resolution performance of their microscope. Without proper vibration cancellation, the apparent zigzag artifacts appear in the SEM image with a magnification of 100,000 and above. Knowing the SEM was capable of much more, PSU and the SEM service team worked closely with TMC to measure and analyze the characteristics of the environment and identify the ideal solution to mitigate the problematic vibration: the serial architecture inherent in TMC's [STACIS® technology](#). This led to the installation of the TMC SEM-Base™, with STACIS technology inside, and to immediate positive results. The CEMN was quickly achieving resolution at 250,000x to 300,000x with high quality images not seen before on that device. The SEM service engineer commented “The images are the best I’ve taken here on this instrument. On at least one image scan, I heard the train but did not see a spike in the image.” It was the combination of the aggressive piezoelectric-based low frequency vibration cancellation with a stiff, hard-mount support unique to TMC’s serial design which enabled this higher performance in the advanced, multi-purpose FE-SEM in the otherwise unacceptable vibration environment.

Following this successful installation, and knowing TMC’s experience and the ability of STACIS to truly cancel floor vibration down to 1Hz and below, the CEMN again engaged TMC. This time it was to pursue a solution for their Dual Beam Scanning Electron Microscope/Focused Ion Beam (SEM/FIB) workstation. A FIB uses a focused beam of ions instead of electrons, a technique common in materials science, with usage growing in semiconductor failure analysis, nanopatterning, TEM sample preparation, biology, and other materials research applications.

When combined with a SEM, the operator can view the FIB milling process in real time. The FIB/SEM at CEMN is equipped with gas injectors, EDS, STEM, and TEM sample preparation with an OmniProbe and flip stage. As with the FE-SEM, usage of the FIB/SEM, originally installed in 2006, was very limited because of the vibration environment. More specifically, each passing Streetcar would result in what is known as sample “fly-away” during the FIB Lift-Out process for sample preparation. [reference “FIB Lift-Out for Defect Analysis, Giannuzzi, et. al.”](#) If the Streetcar passed by while the OmniProbe was attached to the specimen, the sample would fly away (separate) from the probe, and lift-out was not possible during the passing of the Streetcar.



FEI Strata™ FIB-SEM installed on TMC SEM-Base™



OmniProbe mounted directly to FIB-SEM column



SEM images of Step-by-Step Lift-out process (courtesy of PSU-CEMN)

The sample was no longer usable, and the process would need to be restarted at the deposition step. With a train passing every 7-15 minutes, the process required extra attention and lift-out efficiency from an experienced operator, special planning and clever scheduling. More importantly, usage was limited over time.



Although the Dual Beam instrument incorporates internal passive isolators, these are not designed to reduce floor vibration at 5Hz and below. To cancel the low frequency vibration continuously, a true and highly effective active inertial vibration cancellation base is required, supporting the entire SEM/FIB column console. The serial piezoelectric technology of TMC's SEM-Base is the ideal solution to cancel floor vibration, even with the street car passing by. Additionally, the unique hard-mount design allows the internal isolators to be fully optimized (See Performance Loss In Stacked Pneumatic Vibration Isolation Systems and "Serial vs. Parallel Type Active Systems in Vibration Cancellation Applications," Published in Controlled Environments, March 2015). The SEM-Base was easily installed under the existing FIB utilizing TMC's SEM-Lift and unique Roll-Off crate. Up and running again in the same day, the Center was able to perform "Lift-Out" with the omniprobe while the Streetcar was passing by without sample fly-away. This key step in TEM sample preparation could now be completed at any time of day rather than carefully planned and controlled by outside time pressures. Very quickly, performance of the FIB/SEM improved, usage increased by four to five times, and within 4 months the Center had recovered the original investment of the point-of-use vibration cancellation platform. The Dual Beam system features 2-nm imaging resolution and 15-nm milling resolution.

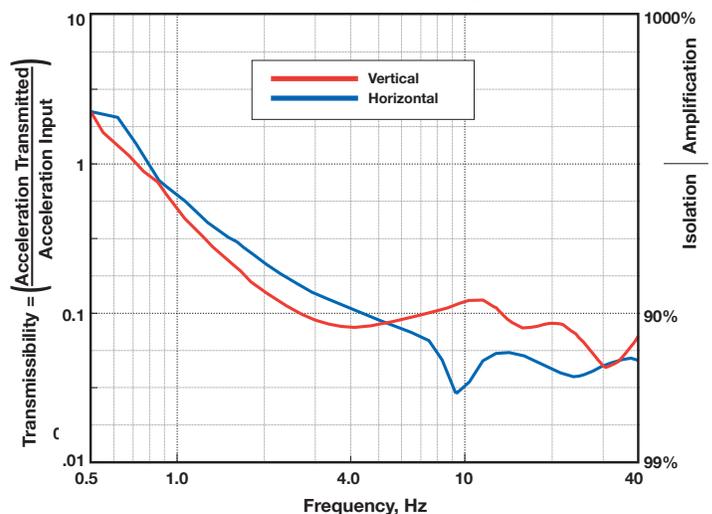
Recently, the CEMN has embarked on the installation of the newest generation Dual Beam thanks to a very generous donation for advanced nanoscale research. This system will also be installed on the TMC SEM-Base. Combining these two leading technologies will allow scientists and industry leaders in the area to further their research. While walking through the CEMN, or while operating one of the many advanced research tools, one can feel the vibration of the city activity outside the building. Fortunately, thanks to the unique and industry leading active vibration technology from TMC, the SEMs and FIBs do not. And, Portland State University, CEMN, and ONMAI can continue to provide a fully utilized signature research shared-user facility to the Pacific Northwest, conveniently located in downtown Portland.

STACIS® iX SEM-Base™

Active Piezoelectric Vibration Cancellation
Floor Platform for Scanning Electron Microscopes



Transmissibility*



* 2,150 lb. (980 kg) payload with simulated floor vibration at VC-C (500 micro-inches per second, 12.5 microns per second)



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