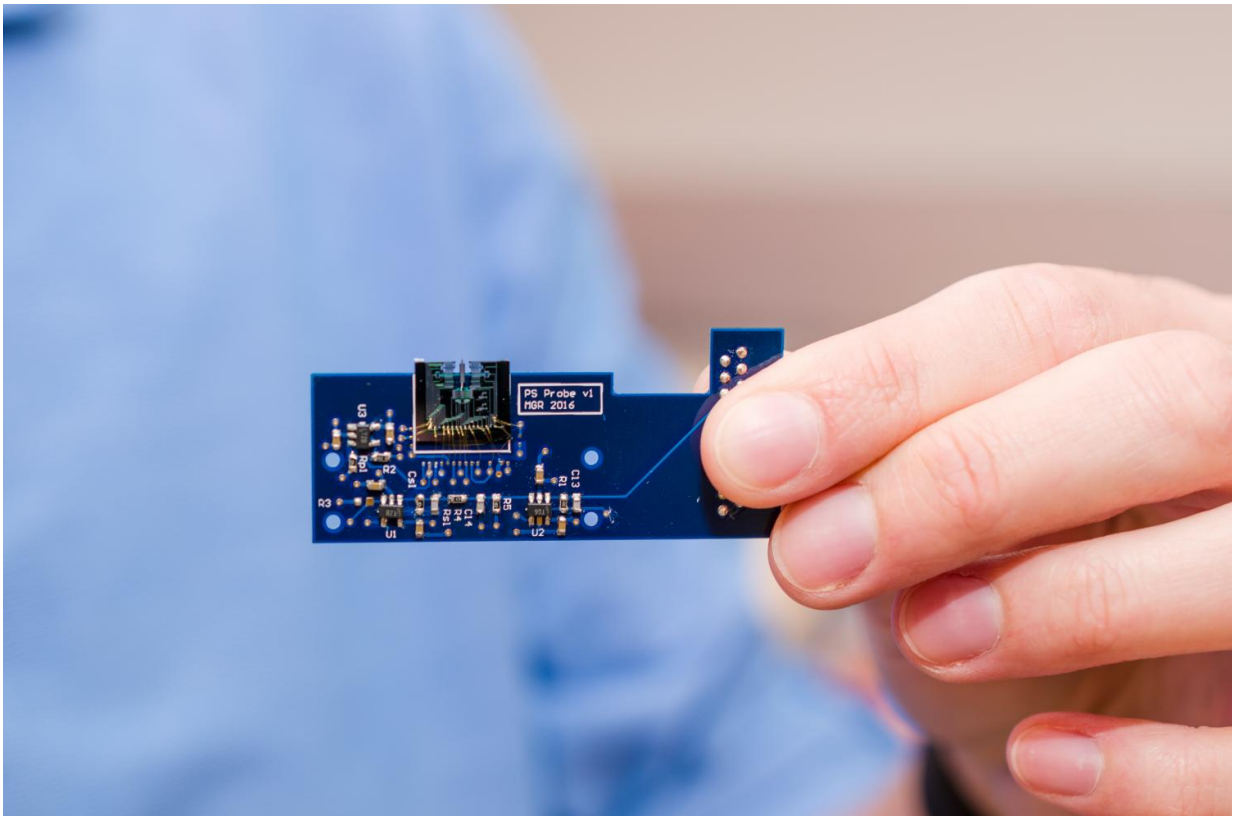


# Engineers shrink microscope to dime-sized device

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A MEMS-based atomic force microscope developed by engineers at the University of Texas at Dallas is about 1 square centimeter in size (top center). Here it is attached to a small printed circuit board that contains circuitry, sensors and other miniaturized components that control the movement and other aspects of the device. Credit: University of Texas at Dallas

Researchers at The University of Texas at Dallas have created an atomic force microscope on a chip, dramatically shrinking the size—and, hopefully, the price tag—of a high-tech device commonly used to characterize material properties.

"A standard atomic force microscope is a large, bulky instrument, with multiple control loops, electronics and amplifiers," said Dr. Reza Moheimani, professor of mechanical engineering at UT Dallas. "We have managed to miniaturize all of the electromechanical components down onto a single small chip."

Moheimani and his colleagues describe their prototype device in this month's issue of the *IEEE Journal of Microelectromechanical Systems*.

An [atomic force microscope](#) (AFM) is a scientific tool that is used to create detailed three-dimensional images of the surfaces of materials, down to the nanometer scale—that's roughly on the scale of individual molecules.

The basic AFM design consists of a tiny cantilever, or arm, that has a sharp tip attached to one end. As the apparatus scans back and forth across the surface of a sample, or the sample moves under it, the interactive forces between the sample and the tip cause the cantilever to move up and down as the tip follows the contours of the surface. Those movements are then translated into an image.

"An AFM is a microscope that 'sees' a surface kind of the way a visually impaired person might, by touching. You can get a resolution that is well beyond what an optical microscope can achieve," said Moheimani, who holds the James Von Ehr Distinguished Chair in Science and Technology in the Erik Jonsson School of Engineering and Computer Science. "It can capture features that are very, very small."

The UT Dallas team created its prototype on-chip AFM using a [microelectromechanical systems](#) (MEMS) approach.

"A classic example of MEMS technology are the accelerometers and gyroscopes found in smartphones," said Dr. Anthony Fowler, a research scientist in Moheimani's Laboratory for Dynamics and Control of Nanosystems and one of the article's co-authors. "These used to be big, expensive, mechanical devices, but using MEMS technology, accelerometers have shrunk down onto a single chip, which can be manufactured for just a few dollars apiece."

The MEMS-based AFM is about 1 square centimeter in size, or a little smaller than a dime. It is attached to a small printed circuit board, about half the size of a credit card, which contains circuitry, sensors and other miniaturized components that control the movement and other aspects of the device.

Conventional AFMs operate in various modes. Some map out a sample's features by maintaining a constant force as the probe tip drags across the surface, while others do so by maintaining a constant distance between the two. "The problem with using a constant height approach is that the tip is applying varying forces on a sample all the time, which can damage a sample that is very soft," Fowler said. "Or, if you are scanning a very hard surface, you could wear down the tip,"

The MEMS-based AFM operates in "tapping mode," which means the cantilever and tip oscillate up and down perpendicular to the sample, and the tip alternately contacts then lifts off from the surface. As the probe moves back and forth across a sample material, a feedback loop maintains the height of that oscillation, ultimately creating an image.

"In tapping mode, as the oscillating cantilever moves across the surface topography, the amplitude of the oscillation wants to change as it

interacts with sample," said Dr. Mohammad Maroufi, a research associate in [mechanical engineering](#) and co-author of the paper. "This device creates an image by maintaining the amplitude of oscillation."

Because conventional AFMs require lasers and other large components to operate, their use can be limited. They're also expensive.

"An educational version can cost about \$30,000 or \$40,000, and a laboratory-level AFM can run \$500,000 or more," Moheimani said. "Our MEMS approach to AFM design has the potential to significantly reduce the complexity and cost of the instrument."

"One of the attractive aspects about MEMS is that you can mass produce them, building hundreds or thousands of them in one shot, so the price of each chip would only be a few dollars. As a result, you might be able to offer the whole miniature AFM system for a few thousand dollars."

A reduced size and price tag also could expand the AFMs' utility beyond current scientific applications.

"For example, the semiconductor industry might benefit from these small devices, in particular companies that manufacture the silicon wafers from which computer chips are made," Moheimani said. "With our technology, you might have an array of AFMs to characterize the wafer's surface to find micro-faults before the product is shipped out." The lab prototype is a first-generation device, Moheimani said, and the group is already working on ways to improve and streamline the fabrication of the device.

"This is one of those technologies where, as they say, 'If you build it, they will come.' We anticipate finding many applications as the technology matures," Moheimani said.

**More information:** Michael G. Ruppert et al, On-Chip Dynamic Mode Atomic Force Microscopy: A Silicon-on-Insulator MEMS Approach, *Journal of Microelectromechanical Systems* (2017). [DOI: 10.1109/JMEMS.2016.2628890](https://doi.org/10.1109/JMEMS.2016.2628890)

Provided by University of Texas at Dallas

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