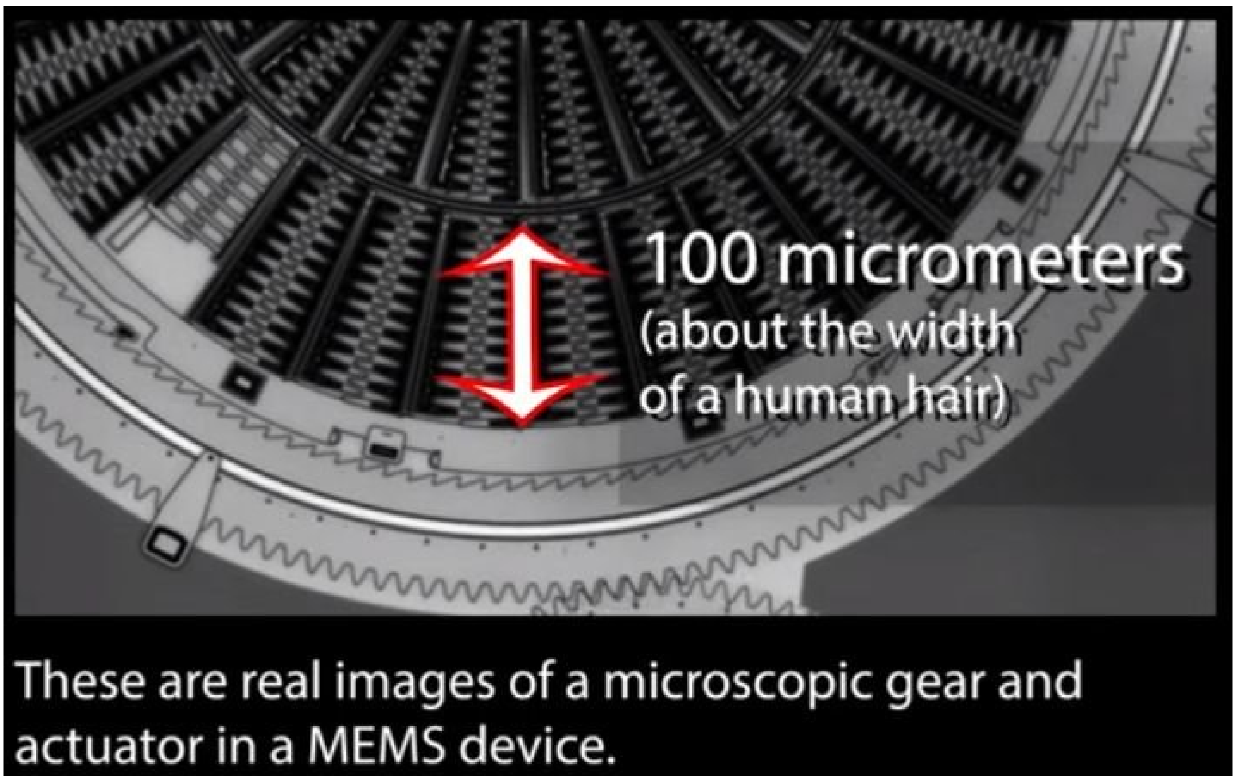
# How microscopic machines can fail in the blink of an eye

November 30 2018




How long can tiny gears and other microscopic moving parts last before they wear out? What are the warning signs that these components are about to fail, which can happen in just a few tenths of a second? Striving to provide clear answers to these questions, researchers at the National

Institute of Standards and Technology (NIST) have developed a method for more quickly tracking microelectromechanical systems (MEMS) as they work and, just as importantly, as they stop working.

By using this method for microscopic failure analysis, researchers and manufacturers could improve the reliability of the MEMS components that they are developing, ranging from miniature robots and drones to tiny forceps for eye surgery and sensors to detect trace amounts of toxic chemicals.

Over the past decade, researchers at the National Institute of Standards and Technology (NIST) have measured the motion and interactions between MEMS components. In their newest work, the scientists succeeded in making these measurements a hundred times faster, on the scale of thousandths, rather than tenths, of a second.

The faster time scale enabled the researchers to resolve fine details of the transient and erratic motions that may occur before and during the failure of MEMS. The faster measurements also allowed repetitive testing—necessary for assessing the durability of the miniature mechanical systems—to be conducted more quickly. The NIST researchers, including Samuel Stavis and Craig Copeland, described their work in the *Journal of Microelectromechanical Systems*.

As in their previous work, the team labeled the MEMS components with fluorescent particles to track their motion. Using optical microscopes and sensitive cameras to view and image the light-emitting particles, the researchers tracked displacements as small as a few billionths of a meter and rotations as tiny as several millionths of a radian. One microradian is the angle corresponding to an arc of about 10 meters along the circumference of the earth.

A faster imaging system and larger fluorescent particles, which emit more light, provided the scientists with the tools to perform their particle-tracking measurements a hundred times more rapidly than before.

"If you cannot measure how the components of a MEMS move at the relevant length and time scales, then it is difficult to understand how they work and how to improve them," Copeland said.

In their test system, Stavis, Copeland and their colleagues tested part of a microelectromechanical motor. The test part snapped back and forth, rotating a gear through a ratchet mechanism. Although this system is one of the more reliable MEMS that transfer motion through parts in sliding contact, it nonetheless can exhibit such problems as erratic performance and untimely failure.

The team found that the jostling of contacting parts in the system, whether contact between the parts occurred at only one point or shifted between several points, and wear of the contacting surfaces, could all play a key role in the durability of MEMS.

"Our tracking method is broadly applicable to study the motion of microsystems, and we continue to advance it," said Stavis.

**More information:** Craig R. Copeland et al, Particle Tracking of Microelectromechanical System Performance and Reliability, *Journal of Microelectromechanical Systems* (2018). DOI: 10.1109/JMEMS.2018.2874771

Provided by National Institute of Standards and Technology