NEW METHODS

SwRI techniques enhance quality, reliability in MEMS technology

MEMS technology is entering a critical transition period from research to widespread commercialization. While several of the simpler devices are being mass-produced, such as inkjet printer heads and airbag sensors, the more complex designs of new MEMS applications present significant challenges for manufacturing. Although current semiconductor processes are well suited to reliability at high volumes, MEMS devices that require movement are affected by additional parameters, such as fatigue strength, failure strength and the elastic modulus. A material's elastic modulus is determined by calculating the ratio of stress to strain or by determining the relative stiffness of a material within its elastic range.

SwRI has developed techniques to assist MEMS designers and manufacturers in these areas. Designers need to validate that their designs can meet lifetime requirements, while manufacturers need to monitor important properties to ensure that their processes are producing high-quality components.

The elastic modulus is one of the most important material properties required for MEMS design. It is used to set design limits on stress, strain and displacement. SwRI developed a technique that employs a resonating cantilever beam with an end mass on the MEMS chip. The beam is driven with a sinusoidal motion from a MEMS actuator comprised of interdigited fingers, or a comb-drive. As the drive signal frequency approaches the natural frequency of the beam, the amplitude of the vibration increases dramatically. The natural frequency is detected visually, or by using a laser-driven, optical system. Using the detailed computer model developed at SwRI, the elastic modulus can be determined. The test method was validated using atomic force microscopy.

Using SwRI's Displacement Mapping Software (DISMAP), three-point bending notch specimens are used to perform strain field measurements. A scratch drive actuator (SDA) MEMS device is used to apply a load to the beam. The beam deflects under the load and a digital image is captured before and after the load application. The digital images are imported into the DISMAP software to measure the motion of the grains on the surface of the beam and the strain field of the material. These parameters are important to understanding when a device will break under a given mechanical load.

Fatigue strength is most important for MEMS devices that operate in resonance, such as those in telecommunications applications, where large numbers of operational cycles are quickly accumulated. The Institute designs notched beams, attached to comb-drives, to determine this parameter based on the research of Van Arsdell and Brown[1]. The devices are operated at their natural frequency until failure occurs. The test devices are combined with advanced digital signal processing to automatically measure the natural frequency and amplitude, and to count the elapsed fatigue cycles. Using probabilistic techniques developed by SwRI, parameters derived from these devices can be used for reliability assessment and failure prediction.

[1]W.W. Van Arsdell and S.B. Brown, "Subcritical Crack Growth in Silicon MEMS," *IEEE Journal of Microelectromechanical Systems*, Vol. 8, No. 3, Sept. 1999, pp. 319–327.