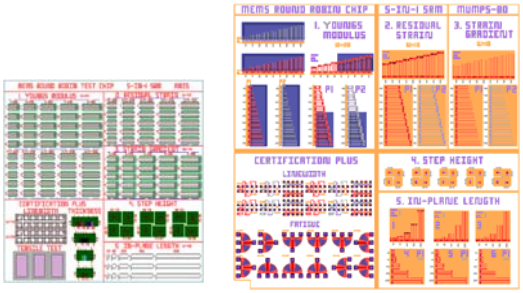
An SRM for Five Key Properties of MEMS Devices:
The MNT 5-in-1 SRM




**Objective:**

*A new Standard Reference Material (SRM)* is being proposed that contains test structures with five well-defined geometric and material properties of crucial importance to Micro-Electro-Mechanical Systems (MEMS) device performance: 1) In-Plane Length, 2) Residual Strain, 3) Strain Gradient, 4) Step Height, and 5) Young's Modulus. Under NIST leadership, documentary standard methods for measuring these properties have recently been developed by ASTM [1-3] and SEMI [4-5].

*This SRM will advance NIST's Measurement Services* by providing NIST traceability for measurements of these quantities under conditions similar to those encountered when measuring these properties on MEMS devices.

*The major customers for this service include* MEMS designers, equipment manufacturers, and IC and MEMS foundry service providers. We have received correspondence from potential users voicing strong support: Mark Crockett at Applied Materials states, "Having seen your proposed work and timetable for producing the SRM, we support your work in this area and see value in the semiconductor and MEMS arena." Erik Novak of Veeco, the leading manufacturer of interferometer systems that would benefit from this tool, stated that "We have more than 100 unique MEMS customers, from Fortune 500 companies to small university labs, and believe the proposed standard would be of high interest to all of them." ASTM and SEMI have also provided letters of support. Furthermore, the two foundry service providers (MOSIS and MEMSCaP) have such a strong interest in the proposed SRMs that they have offered to supply routine fabrication services free of charge to support the project.

**Technical Approach:**

*The proposed technical approach to developing this new SRM* is to utilize microfabricated silicon test structures with static and dynamic measurements taken with an optical interferometer and a laser Doppler vibrometer. These static and dynamic measurements will be used to determine the underlying geometric and material properties. This SRM will utilize on-line data sheets on the SED web site [6] to calculate these properties. Prototype test structures will be distributed for Young's modulus and step height round-robin validation, and an accompanying user's guide detailing the necessary measurements will be included on the web. The Web-based data sheets will also be used to collect data on these validation experiments, and the data will be subjected to statistical analysis. Once the prototype test structures have been validated through round-robin measurement, the SRMs will be fabricated, the five geometric and material properties individually measured on each SRM, and the SRMs and Certificates will be delivered to the SRM Program office.

*There are no major known technical barriers*, but the round robin is necessary a) to obtain validated Young's modulus and step height standards (the other test methods have already been validated) and b) to verify that the proposed SRMs will really meet the needs of the user community.

**Annual Checkpoints:**

FY08: Round robin test chips submitted for fabrication; user's guide, and data sheets available to participants.
FY09: Round robin complete; draft article written on the results of the round robin. SRM chip measurements in progress.
FY10: Completion and release of first Five-in-One SRMs.

**Impact**:

NIST's 2006 assessment of the U.S. Measurement System identified "Accurate materials property measurement" as a critical barrier to the continued growth of the MEMS industry [7]. The proposed SRM addresses this need by allowing customers to obtain NIST traceability for these measurements. Due to the size of the MEMS industry and the metrology challenges this industry faces, we expect the demand for this SRM to be significant, with the added benefit of acquainting potential customers and collaborators with NIST's MEMS activities. SRM Working Capital Funds will be used to replenish the supply of this SRM after the first released is sold out.

**Measurement Need (MN) addressed:**

The USMS assessment of measurement needs has included Young's modulus, residual stress, and stress gradient as critical measurement targets to accelerate innovation in Micro Nano Technology [7]. Young's modulus is included in the proposed SRM. Residual stress and stress gradient are found on the SED Web pages [6] given the residual strain and strain gradient material properties included in the SRM. Therefore, this SRM can actually be called the MNT 7-in-1 SRM, instead of the MNT 5-in-1 SRM. Step height [4] and in-plane length [1] measurements are used to determine Young's modulus [5] and residual strain [2], respectively.

**REFERENCES**


[1] ASTM E 2244-05, "Standard Test Method for In-Plane Length Measurements of Thin, Reflecting Films Using an Optical Interferometer"
[2] ASTM E 2245-05, "Standard Test Method for Residual Strain Measurements of Thin, Reflecting Films Using an Optical Interferometer"
[3] ASTM E 2246-05, "Standard Test Method for Strain Gradient Measurements of Thin, Reflecting Films Using an Optical Interferometer"
[4] SEMI MS2-0307, "Test Method for Step-Height Measurements of Thin, Reflecting Films Using an Optical Interferometer"
[5] SEMI MS4-1107, "Test Method for Young's Modulus Measurements of Thin, Reflecting Films Based on the Frequency of Beams in Resonance"
[6] http://www.eeel.nist.gov/812/test-structures/MEMSCalculator.htm
[7] An Assessment of the US Measurement System: Addressing Measurement Barriers to Accelerate Innovation, Appendix B, "Case Study – Measurement Needs Technology at Issue: Micro-/Nano-Technology", (NIST Special Publication 1048, page 309, 2006).