The MEMS 5-in-1 Test Chips (Reference Materials 8096 and 8097)

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The MEMS 5-in-1 Reference Material (RM) is a single test chip with test structures from which material and dimensional properties are obtained using five documentary standard test methods (from which its name is derived). Companies can validate their use of the documentary standard test methods by comparing their in-house measurements taken on the RM with the National Institute of Standards and Technology (NIST) measurements taken on the same test structures.

References:

- Overview articles
  - J. Cassard, J. Geist, C. McGray, R.A. Allen, M. Afridi, B. Nablo, M. Gaitan, and D.G. Seiler, "The MEMS 5-in-1 Test Chips (Reference Materials 8096 and 8097)," *Frontiers of Characterization and Metrology for Nanoelectronics: 2013*, NIST, Gaithersburg, MD, March 25-28, 2013, pp. 179-182.
  - J. Cassard, J. Geist, M. Gaitan, and D. G. Seiler, "The MEMS 5-in-1 Reference Materials (RM 8096 and 8097)," *Proceedings of the 2012 International Conference on Microelectronic Test Structures*, ICMTS 2012, San Diego, CA, pp. 211-216, March 21, 2012.
- User's guide
  - J.M. Cassard, J. Geist, T.V. Vorburger, D.T. Read, M. Gaitan, and D.G. Seiler, "Standards Reference Materials: User's Guide for RM 8096 and 8097: The MEMS 5-in-1, 2013 Edition," NIST SP 260-177, February 2013 (http://dx.doi.org/10.6028/NIST.SP.260-177).
- Standards
  - SEMI MS4-0212, "Test Method for Young's Modulus Measurements of Thin, Reflecting Films Based on the Frequency of Beams in Resonance," February 2012. (Visit http://www.semi.org for ordering information.)
  - SEMI MS2-0212, "Test Method for Step Height Measurements of Thin Films," February 2012. (Visit http://www.semi.org for ordering information.)
  - ASTM E 2245-11, "Standard Test Method for Residual Strain Measurements of Thin, Reflecting Films Using an Optical Interferometer," December 2011. (Visit http://www.astm.org for ordering information.)
  - ASTM E 2246-11, "Standard Test Method for Strain Gradient Measurements of Thin, Reflecting Films Using an Optical Interferometer," January 2012. (Visit http://www.astm.org for ordering information.)
  - ASTM E 2244-11, "Standard Test Method for In-Plane Length Measurements of Thin, Reflecting Films Using an Optical Interferometer," December 2011. (Visit http://www.astm.org for ordering information.)
- Thickness articles
  - J.C. Marshall and P.T. Vernier, "Electro-physical technique for post-fabrication measurements of CMOS process layer thicknesses," *NIST J. Res.*, Vol. 112, No. 5, pp. 223-256, 2007.
  - J.C. Marshall, "New Optomechanical Technique for Measuring Layer Thickness in MEMS Processes," *J. of Microelectromechanical Systems*, Vol. 10, No. 1, pp. 153-157, March 2001.
- Fabrication
  - The RM 8096 chips were fabricated through MOSIS on the 1.5 μm On Semiconductor (formerly AMIS) CMOS process. The URL for the MOSIS website is http://www.mosis.com. The bulk-micromachining was performed at NIST.
  - The RM 8097 chips were fabricated at MEMSCAP using MUMPs-Plus! (PolyMUMPs with a backside etch). The URL for the MEMSCAP website is http://www.memscap.com.

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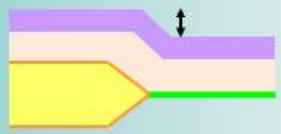
"Through their involvement, NIST plays a crucial role in the development of standards and shapes the future of the MEMS industry in the United States" - Chris Muhlstein, ASTM

Test Structures

Young's modulus

Residual strain

Strain gradient

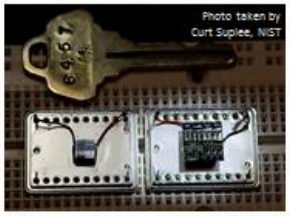


Step height

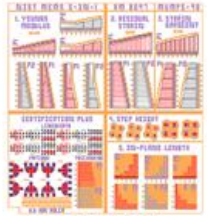
In-plane length

• MEMS 5-in-1 Reference Materials

CMOS RM 8096



(For release in 2013)



RM 8097

• Building Blocks

- **NIST Standard Reference Database 166**
  - MEMS Calculator Web Pages validate industry measurements
  - http://srdata.nist.gov/gateway/ with keyword "MEMS Calculator"
- **Documentary standards**
  - SEMI
    - MS4-0212: Young's modulus
    - MS2-0212: Step height
  - ASTM (Led Development of First Standards)
    - E 2245-11: Residual strain
    - E 2246-11: Strain gradient
    - E 2244-11: In-plane length
- **CMOS compatible MEMS test structures**
- **Fundamental measurement research**
  - Test structure design
  - Test structure measurement and analysis

Goal

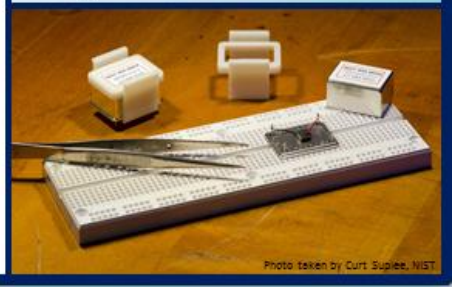
- Develop measurement methods to characterize MEMS devices for reliable manufacturing.

Deliverables

- R&D focused on
  - Test structure measurements
  - Measurement methods
- Scientific publications
- Documentary standards
- Standard Reference Database
- Reference Materials

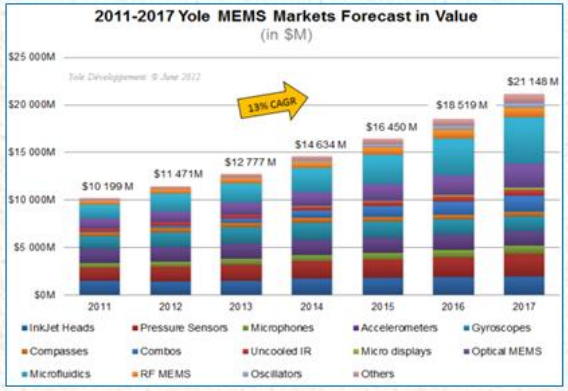
Customers & Collaborators

- MEMS designers
- Test equipment manufacturers
- IC and MEMS foundries & services
- Industry standards organizations



Why is MEMS Important?

- A $10.2B industry (in 2011)
  - Yole forecasts $21.1B industry (in 2017) – doubled from 2011
  - Growth rate (13 %/year) is healthy
    - MEMS being pulled into the market (esp. via the consumer market)
    - Spread out over numerous (say 100) smaller companies
  - MEMS acquisitions have soared in 2011 (> 300% increase)
- MEMS is an enabling technology
  - Improved medical device performance
    - In-vitro diagnostics
    - Micro dispensers for drug delivery
    - Accelerometers in pacemakers
    - Wireless implants
  - Puts the "Smart" in Smart Phones
    - Accelerometers, gyros, pressure sensors, microphones,....
    - The future will see combination sensors
  - Etc.



"MEMS technology has the potential to change our daily lives as much as the computer has."

Salvatore A. Vittorio
(CSA/Aerospace Access, Information Analyst)
Oct. 2001

(Are we there yet?)

- As the field continues to grow, NIST can facilitate the introduction of product data sheets to allow inter-comparisons of consumer products.