MEMS in SEMI – The Role of a Global Industry Association in Advancing the MEMS Industry

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Outline

• Introduction to SEMI
• Global MEMS Activities
• SEMI MEMS/NEMS Standards Overview
• Challenges and Opportunities
About SEMI

• Global industry association
  – **HQ**: San Jose, CA
  – **Europe**: Berlin, Brussels, Grenoble, Moscow
  – **N. America**: San Jose, Washington, D.C.
  – **Asia**: Shanghai, Beijing, Bangalore, Tokyo, Seoul, Singapore/SEA, Taipei

• Established in 1970 to serve the semiconductor supply chain

• Over 1,800 member companies

• Industry Segments represented:
  – Semiconductors
  – Photovoltaic
  – LED, MEMS, Flat Panel Displays (FPD)
  – Emerging Electronics (Plastic Electronics, OLED, OPV, etc.)
About SEMI

Location of SEMI Member HQs

- Korea: 11%
- Americas: 25%
- Singapore: 2%
- Taiwan: 12%
- China: 15%
- Europe: 15%
- Japan: 20%
- India: 1%

Total Members

- Under $5M: 67%
- $5M-$25M: 22%
- $25M-$100M: 6%
- $100M-$500M: 3%
- $500M-$1B: 1%
- $1B-$2B: 1%
- Over $2.5B: <1%
- $1B-$2B: 1%

1,891 Members
As of April 2014
SEMI Activities and Initiatives

• International Standards Program
• Industry Research & Statistics
• Public policy and Advocacy
• Environmental, Health and Safety Initiatives
• Industry/Supply Chain Collaboration and Promotion
• Events
• Special Interest Groups and Committees
• Partnerships and Strategic Alliances
SEMI MEMS Activities

• MEMS Special Interest Groups active in Korea, Taiwan, Japan and Europe
  – Primarily focused on technical program content and market trends

• MEMS Technical and Business Programs
  – Held in conjunction with SEMICON expositions, some in partnership with other organizations

• MEMS/NEMS Standards Committee in North America
  – Includes contributing companies from other regions
  – 6 active Task Forces
Microelectromechanical Systems (MEMS) / Nanoelectromechanical Systems (NEMS)

Participating Companies

AIST
Applied Materials
Autodesk
Concurrent Analysis
Diagnostics Biosensors
FM Approvals
Fraunhofer
Fujifilm
GLOBALFOUNDRIES

HCL
Intel
ISMI
Kesar Technology
Lam Research
LG Innotek
Nikon
NIST
Nordson ASYMTEK

Novati Tehnologies
Pall Corporation
PandA Europe
Parksystems
Quartet Mechanics
Semilab
Sonoscan
Tesec
Yield Engineering Systems

* Partial List
Microelectromechanical Systems (MEMS) / Nanoelectromechanical Systems (NEMS)

Key Standards Developed

- MS1 – Guide to Specifying Wafer-Wafer Bonding Alignment Targets
- MS2 – Test Method for Step-Height Measurements of Thin Films
- MS3 – Terminology for MEMS Technology
- MS4 – Standard Test Method for Young's Modulus Measurements of Thin, Reflecting Films Based on the Frequency of Beams in Resonance
- MS5 – Test Method for Wafer Bond Strength Measurements Using Micro-Chevron Test Structures
- MS6 – Guide for Design and Materials for Interfacing Microfluidic Systems
- MS7 – Specification for Microfluidic Interfaces to Electronic Device Packages
- MS8 – Guide to Evaluating Hermeticity of MEMS Packages
- MS9 – Specification for High Density Permanent Connections Between Microfluidic Devices
- MS10 – Test Method to Measure Fluid Permeation Through MEMS Packaging Materials
• **SEMI MS1, Guide to Specifying Wafer-Wafer Bonding Alignment Targets**
  
  - This Guide provides a framework for specifying the dimensions, location, quantity and characteristics of alignment targets that are placed on each wafer of a pair of wafers. Such targets are used to align two patterned wafers prior to an operation that bonds them together.
Published Standards [2/10]

- **SEMI MS2**, *Test Method for Step Height Measurements of Thin Films*
  - This Test Method enables the determination of step height measurements of thin films. Step height measurements can be used to determine thin film thickness values. Thickness measurements are an aid in the design and fabrication of MEMS devices and can be used to obtain thin film material parameters, such as Young’s modulus.
Published Standards [3/10]

• **SEMI MS3, Terminology for MEMS Technology**
  
  – To promote common understanding and clear communication among suppliers, customers, and others in the field, these terms should be defined.
  
  – This terminology document covers definitions of terms used in MEMS technology, especially in those areas of greatest interest to the SEMI community.
Published Standards [4/10]

- **SEMI MS4, Test Method for Young's Modulus Measurements of Thin, Reflecting Films Based on the Frequency of Beams in Resonance**
  - This Test Method covers a procedure for measuring Young's modulus in thin films.
  - It applies only to films, such as found in MEMS materials that can be imaged using a noncontact optical vibrometer, stroboscopic interferometer or comparable instrument that is capable of obtaining the resonance frequency of a beam oscillating out-of-plane.
Published Standards [5/10]

- **SEMI MS5, Test Method for Wafer Bond Strength Measurements Using Micro-Chevron Test Structures**
  - This Test Method allows determination of the bond-interface strength, using micro-chevron test structures, of bonded wafer materials.
  - The bond-interface strength is expressed in units of energy per unit area and is technically the critical wafer bond toughness.
Published Standards [6/10]

- **SEMI MS6, Guide for Design and Materials for Interfacing Microfluidic Systems**
  - This document provides guidelines for general fluidic interface design and materials selection that can reduce redundant engineering effort and lead to improved design, manufacturability, and operation.
Published Standards [7/10]

- **SEMI MS7, Specification for Microfluidic Interfaces to Electronic Device Packages**
  - This document defines an industry-standard for fluidic interfaces with electronic devices.
  - The specification describes the connection attributes and specifies the interface dimensions required to design and build devices and systems that are compliant with this standard.
  - The goal is to enable devices from different vendors to interconnect via an open architecture.
Published Standards [8/10]

- **SEMI MS8, Guide to Evaluating Hermeticity of MEMS Packages**

  - This document is intended to provide an overview of hermetic packaging with emphasis on the evaluation of hermeticity of the smaller internal volumes typical of MEMS.
  
  - Hermeticity is critical to MEMS device functionality. In other cases, hermeticity is primarily important to reliability of MEMS devices, similarly to integrated circuits.
Published Standards [9/10]

• **SEMI MS9, Specification for High Density Permanent Connections Between Microfluidic Devices**
  
  - This Standard provides specification for interconnection dimensions and performance requirements for permanent microfluidic interfaces. It also provides guidance for interface design. This will help to enable low cost and high volume manufacturing of products having high density permanent interfaces between plastic tube adapters, plastic microfluidic cartridges, and electrofluidic devices.
Published Standards [10/10]

- **SEMI MS10, Test Method to Measure Fluid Permeation Through MEMS Packaging Materials**
  - This Standard is directed towards defining a common method of measurement of permeation through technical films that are used in sealing hermetic MEMS packages.
  - Areas to be addressed include materials and equipment for producing and evaluating hermetic seals; methods for detection and measurement of leakage; and considerations and recommendations on the evaluation of hermeticity.
Microelectromechanical Systems (MEMS) / Nanoelectromechanical Systems (NEMS)

Current Committee Structure

- NA MEMS / NEMS Technical Committee Chapter
  - MEMS Packaging TF
  - MEMS Wafer Bond TF
  - MEMS Microfluidics TF
  - MEMS International Terminology TF
  - MEMS Material Characterization TF
  - MEMS Reliability TF
Document Development Path – The Challenge of Adoption

INDUSTRY NEEDS

- Technology Trends
- Suppliers
- Users
- Other Stakeholders

Use

Does the published document really address the original need?

Idea to Committee

Authorize Activity

Document Development

Ballot Submission

Ballot Voting /Tallying

Ballot Adjudication

Publishing

Procedural Review

IEEE SF  Bay Area MEMS & Sensors Chapter Meeting  -  SEMI Presentation
Challenges

• Only 1 technical MEMS/NEMS Technical Committee Chapter in the SEMI Int’l Standards Program
  – Sufficient industry representation?
  – Lack of customer participation
  – Wide variety of applications
  – Are available Standards addressing industry needs and thus advancing the MEMS industry?
Opportunities

- Partner with IEEE and other Standards organizations to
  - Create a strong “handshake” for Standards in different parts of the value chain
  - Collaborate on one technology roadmap for the MEMS industry
  - Communicate updates to all communities served
  - Globalize the efforts as much as possible
  - Optimize available resources and avoid duplication of effort
MEMS Standards – ASTM

- ASTM E22-44 – 11el

- ASTM E2444 - 11el

- ASTM E2245 - 11el

- ASTM E2246 - 11el
  - Standard Test Method for Strain Gradient Measurements of Thin, Reflecting Films Using an Optical Interferometer

- ASTM E2456 - 06(2012)
MEMS Standards – IEC

- IEC 62047-2 ed1.0 (2006-08)

- IEC 62047-3 ed1.0 (2006-08)
  - Semiconductor devices - Micro-electromechanical devices - Part 3: Thin film standard test piece for tensile testing

- IEC 62047-4 ed1.0 (2008-08)
  - Semiconductor devices - Micro-electromechanical devices - Part 4: Generic specification for MEMS

- IEC 62047-5 ed1.0 (2011-07)
  - Semiconductor devices - Micro-electromechanical devices - Part 5: RF MEMS switches

- IEC 62047-6 ed1.0 (2009-04)
MEMS Standards – IEC (cont’d)

- IEC 62047-7 ed1.0 (2011-06)
  - Semiconductor devices - Micro-electromechanical devices - Part 7: MEMS BAW filter and duplexer for radio frequency control and selection

- IEC 62047-8 ed1.0 (2011-03)
  - Semiconductor devices - Micro-electromechanical devices - Part 8: Strip bending test method for tensile property measurement of thin films

- IEC 62047-9 ed1.0 (2011-07)
  - Semiconductor devices - Micro-electromechanical devices - Part 9: Wafer to wafer bonding strength measurement for MEMS

- IEC 62047-10 ed1.0 (2011-07)

- IEC 62047-11 ed1.0 (2013-07)
MEMS Standards – IEC (cont’d)

• IEC 62047-12 ed1.0 (2011-09)

• IEC 62047-13 ed1.0 (2012-02)

• IEC 62047-14 ed1.0 (2012-02)

• IEC 62047-15: Test method of bonding strength between PDMS and glass

• IEC 62047-16: Test methods for determining residual stresses of MEMS films; wafer curvature and cantilever beam deflection methods

• IEC 62047-17: Bulge test method for measuring mechanical properties of thin films
MEMS Standards – IEC (cont’d) and DIN

- IEC 62047-18: Bend testing methods of thin film materials
- IEC 62047-19: Electronic compasses
- IEC 62047-20: Test method for Poisson's ratio of thin film MEMS materials
- IEC 62047-22: Electromechanical tensile test method for conductive thin films on flexible substrates

- DIN EN 62047-18 [NEW]

- DIN 1495-3:1996
  - Sintered metal plain bearings subject to specific requirements for use in small-power and fractional horse-power electric motors - Part 3: Requirements and testing (FOREIGN STANDARD)
Upcoming MEMS / NEMS Meetings

• The next NA MEMS / NEMS meetings will be held in conjunction with the NA Standards Meetings at SEMICON West 2014 in the San Francisco Marriott Marquis Hotel at San Francisco, California
  – Times and dates are subject to change
  – All times are in PDT
  – For more information and the latest schedule: http://www.semi.org/en/node/49446

• Monday, July 7
  – Wafer Bond TF (9:00 AM - 10:00 AM)
  – Microfluidics TF (10:00 AM - 11:00 AM)
  – Packaging TF (11:00 AM - 11:30 AM)
  – Terminology TF (11:30AM - 12:30 PM)
  – Materials Characterization TF (1:30 PM - 2:30 PM)
  – NA MEMS / NEMS TC Chapter (2:30 PM - 4:30 PM)
Thank you!

For more information or to participate in any SEMI MEMS/NEMS Standards activities, please contact:

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Background Information – SEMI Draft Documents under Development
Microelectromechanical Systems (MEMS) / Nanoelectromechanical Systems (NEMS)
Documents in Development and Current Activities [1/2]

• Microfluidics TF
  – Doc. 5515, Revision to SEMI MS7, Specification for Microfluidic Interfaces to Electronic Device Packages

• Wafer Bond TF
  – 3DS-IC related activities from SEMATECH
  – Silicon on Insulators (SOI) for MEMS Applications

• International Terminology TF
  – Doc. 4719, Revision to MS03-07, Terminology for MEMS Technology with title change to: Terminology for MEMS / NEMS Technology
Microelectromechanical Systems (MEMS) / Nanoelectromechanical Systems (NEMS)
Documents in Development and Current Activities [2/2]

• Packaging TF
  – Outgassing for MEMS packaging

• Materials Characterization TF
  – Special Publications, 260-175, 2012 Standard Reference Material, User’s guide for RM 8096 and 8097:

• Reliability TF
New Standard: Test Method for Electroosmotic Mobility in Microfluidic Systems

- Rationale
  - Microfluidic MEMS systems require predictable fluid flow behavior in order to achieve proper device operation. Electroosmotic fluid flow behavior is governed by the surface charge/chemistry of the microchannel material and its interaction with the fluid medium and any other materials dispersed in the fluid. A key parameter that is used to describe the flow is the electroosmotic mobility, which links the applied voltage to the fluid flow rate in the system. A standard test method to determine the electroosmotic mobility of fluids conveyed in a micro-scaled channel will address the requirements for maintaining desired fluidic operation. Fluids may contain ions, particulates, and colloidal suspensions of organic and inorganic materials.

- Scope
  - This standard will describe a procedure for carrying out a measurement, collecting the data, and performing data analysis. Specifically, the standard will describe the design of a test structure, the experimental setup, the experimental procedure, and the calculation of the electroosmotic mobility parameter from the resulting data. It is intended to characterize the electroosmotic mobility of materials and changes that processes used in the fabrication and operation of a device have on it.
New Standard: Specification for Microfluidic Port and Pitch Dimensions

- Rationale
  - Microfluidics applications are gaining popularity in the consumer, medical and industrial markets. While there is a large variety of applications, there is also opportunity for standardized methods and practices to minimize manufacturing costs. Standardized interfaces can reduce component cost and assembly.

- Scope
  - This document will provide dimensions for mating of tubing to fluid ports. It will define standard diameters for tubing, and associated pitch over a range of sizes from 25 microns OD to 10 mm OD in reasonable increments.
Document 5268

• New Standard: Test Method for Autofluorescence of Materials

  – Rationale
  • The microfluidics community does not have a good method for determining the autofluorescence of materials. Autofluorescence is not desirable for a range of applications where a clear materials or background (field of view) materials needs to have a low autofluorescence or else the system will be subject to a high background fluorescence signal that may impact measurement of fluorescence in the fluid.

  – Scope
  • This document will result in a test method to quantify the autofluorescence of materials.
Document 5515

• Revision to SEMI MS7-0708, Specification for Microfluidic Interfaces to Electronic Device Packages
  – Rationale
    • This standard is due for 5 years review.
  – Scope
    • The Standard, MS7, Specification for Microfluidic Interfaces to Electronic Device Packages. The document defines an industry-standard for fluidic interfaces with electronic devices. The scope of the document is for intended to support development of new microfluidic products and hardware.
    • The standard main technical areas addressed are: Fluidic I/O design constraints, Micro-to-micro fluidic adapter design constraints, Fluidic routing card constraints, and mini-fluidic adapter constraints.
Document 4719

• Revision to MS03-07, Terminology for MEMS Technology with title change to: Terminology for MEMS / NEMS Technology

  – Rationale
    • Revise the existing MS-0307, Terminology for MEMS Technology standard to incorporate current MEMS- and NEMS-related terms.

  – Scope
    • This document will only cover MEMS- and NEMS-related terminology.
Document 4820

• Specification for MEMS Reliability Design, Materials Selection, Process and Testing Method
  – Rationale
    • As new devices are developed in the lab, the MEMS industry would benefit greatly from introducing and evaluating new process technologies for MEMS as well as provide technology transfer from the lab to prototyping fab and eventually high volume fabs. Standardization may also be achieved by adding consistency between measurement techniques. The industry must also investigate MEMS reliability issues such as yield, fatigue, creep, charging and contact physics.

To help achieve these goals, the MEMS Reliability task force will embarked on a mission to collaborate with SEMI member companies and with other standards organizations. The task force will develop standard MEMS reliability design, materials selection, process and testing method(s), to eliminate failure mechanisms and provide process reliability parameters guidelines.

– Scope
  • The task force will collaborate with members to execute the following focuses:
    – Identify design, materials, machines, process to fabricate specific MEMS structures
    – Determine the right reliability test standards for the process steps
    – Fabricate MEMS at foundries/university and test MEMS for its reliability
    – Provide guidelines to achieve high quality MEMS process and reliability test guidelines
Microelectromechanical Systems (MEMS) / Nanoelectromechanical Systems (NEMS) Committee Charter

• Develop standards for MEMS & NEMS devices that cannot be handled by existing technical committees.
  – Current topics include:
    • Wafer Bonding Alignment Targets
    • Step-Height Measurements of Thin, Reflecting Films using an Optical Interferometer
    • Ultra High Purity Microscale Fluidic Systems for Use in Scalable Process Environments