MEMS (Microelectromechanical Systems) is a term introduced to represent a class of miniaturized mechanical or electro-mechanical devices.

Microelectromechanical systems are also referred to as:
- Micromachines (Japan)
- Micro System Technology (MST) (Europe)
- Microsystems
- Micro Sensors and Actuators
- Micro Transducers
What are MEMS?

The term MEMS generally refers to the micro-scale ‘components’ or micro-scale ‘devices’ within a system. Not the entire system itself. In this sense, the name MEMS is somewhat misleading.

In order to create a completely functioning ‘System’ that makes use of MEMS, the system will require various other sub-systems, such as: power, microelectronics, communication and software.
Why was MEMS Technology Developed?

MEMS is a ‘spin-off’ technology derived from the microelectronics industry.

Researchers investigated ways to create micro-mechanical devices using microelectronic fabrication methods.

The motivation was various. Nathanson sought better transistor performance. Petersen sought compact pressure sensors that could be inexpensively fabricated.

In other cases, it was just to prove micro-devices could be made.

History of MEMS Technology

1959 - “There's Plenty of Room at the Bottom” - Famous talk by Richard P. Feynman
1967 - Invention of surface micromachining (Nathanson, Resonant Gate Transistor)
1970 - Micromachined silicon pressure sensor demonstrated (Petersen)
1970 - First silicon accelerometer demonstrated (Kulite)
1977 - First capacitive pressure sensor (Stanford)
1984 - First polysilicon MEMS device (Howe, Muller)
1988 - Rotary electrostatic side drive motors (Fan, Tai, Muller)
1989 - Lateral comb drive (Tang, Nguyen, Howe)
1991 - Polysilicon hinges developed (Pister, Judy, Burgett, Fearing)
1992 - Multi User MEMS Process (MUMPs) is introduced by MCNC, (now MEMSCAP)
1993 - First surface micromachined accelerometer (ADXL50) sold, (Analog Devices)
1998 - Demonstration of DMD (Digital Mirror Device), (Texas Instruments)
How Small are MEMS?

Nanotechnology

Most MEMS

1nm 10nm 100nm 1µm 10µm 100µm 1mm

Atoms Protein Virus UV light Infrared light Cells Human hair

Visible light 0.4-0.7 µm

Why Go Small?

This is the KEY QUESTION!

For some applications, scaling devices down to the microscale may allow for some unique advantages. Physical size is only one of many considerations.

For micro-scale sensors:
- Higher Sensitivity
- Better Linearity
- Better Responsivity
- Dynamic Range
- Cost Reduction from Batch Fabrication

For micro-scale actuators:
- Dynamic Response Speed
- Lower Power Consumption
- Footprint
- Cost Reduction from Batch Fabrication
Why Go Small?

MEMS technology does not mean the ‘end system’ will be micro-scale. For most applications, only the sensor/actuator need be micro-scale, to take advantage of micro-scale properties.

However, some researchers are attempting to shrink the entire system down to the micro-scale.

SMART DUST, [K. Pister, B. Warneke]

How are MEMS made?

MEMS are fabricated with a unique set of technologies collectively referred to as ‘microfabrication’ or ‘micromachining’. These methods are quite different from macro-scale techniques.

Due to their small size, standard machine tools cannot be used to machine MEMS features.

Micromachining technology is closely related to IC (integrated circuit) fabrication, with some notable differences.

There are two main areas of micromachining:

• Surface Micromachining, which is based on the successive deposition and etching of thin films of material such as silicon nitride, polysilicon, silicon oxide and gold.

• Bulk Micromachining, which is based on the etching and bonding of thick sheets of material such as silicon oxides and crystalline silicon.
Surface Micromachining
Example of Creating Cantilever Beam

Expose with Ultra Violet light
Mask
Poly 0
Nitride
Silicon Substrate

Silicon Substrate
Surface Micromachining
Example of Creating Cantilever Beam

Solvent Wash

Silicon Substrate
Surface Micromachining
Example of Creating Cantilever Beam

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Surface Micromachining
Example of Creating Cantilever Beam

Lithography to Mask and Etch Oxide Layer (Steps Not Shown)
Surface Micromachining
Example of Creating Cantilever Beam

Lithography to Mask and Etch Poly 1 Layer (Steps Not Shown)

Release Poly 1 Layer by Dissolving Oxide Layer

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Surface Micromachining
Example of Creating Cantilever Beam

Silicon Substrate
Released Poly 1 Layers
Free Beam
Cantilever Beam
Patterned Poly 0

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Surface Micromachining

Gear Train with SUMMiT Process,
[Sandia National Laboratories]

Microgripper Tip with MUMPs Process,
[N. Dechev]

© N. Dechev, University of Victoria
Bulk Micromachining

Why use Silicon?

- A main goal of MEMS research is to integrate all components of a system or device as much as possible. Therefore, common materials and compatible fabrication processes are required.
- Silicon is a material with unique electrical and mechanical properties, such as semiconductivity, piezoresistivity, high mechanical strength, mechanically elastic behaviour, etc...
- Silicon is the base substrate for many microelectronic technologies.
- Microfabrication technology and infrastructure is well established to work with silicon.
- However, researchers constantly search for alternative materials to use for MEMS.
How do MEMS Work?

**Accelerometer Principle of Operation**

- Inertial Mass (M)
- Flexible Beams
- Applied Acceleration
- Deflected Beams
- Δx
- Capacitive Sensor
- Anchor Points

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How do MEMS Work?

Accelerometer Principle of Operation

[Diagram of a 2-Axis Accelerometer with components labeled: Anchor Points, Capacitive Sensor]

2-Axis Accelerometer, [Analog Devices]

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How do MEMS Work?

DMD (Digital Micromirror Device) Principle of Operation

[Images of an Array of Micromirrors and an Individual Micromirror]

Array of Micromirrors, [Texas Instruments]  Individual Micromirror

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How do MEMS Work?

DMD (Digital Micromirror Device) Principle of Operation

Note: a ‘Flash’ demo of the above device can be seen at:

http://dlp.com/includes/demo_flash.aspx

Redirection of Light using Mirrors
[Texas Instruments]

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What are the Future Applications?

Communications
- RF MEMS (Cell Phones, etc...)
- Optical Switches

Medicine
- Cell sorting and capture
- Implantable Sensors
- Internal Imaging Systems
- Drug Delivery Systems

Automotive
- Tire Pressure Sensors
- Sub-system Sensors

Entertainment
- Game Console Sensor
- Tactile Displays
- Speakers

Many, many more....