# MEMS : an overview

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## 1) What are MEMS ?

Micro-Electro-Mechanical-Systems (MEMS) are machines which range in size from a micrometre to a millimetre (Figure 1). They may function as actuators, motors, generators, switches, sensors…. and have applications in fields as diverse as telecommunications, automotive and aerospace, astronomy and ophthalmometry, biotechnology, logistics…

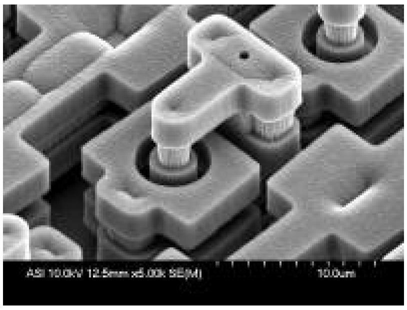


Figure 1a: MEMS Post Style Actuator (http://www.memx.com/products.htm)

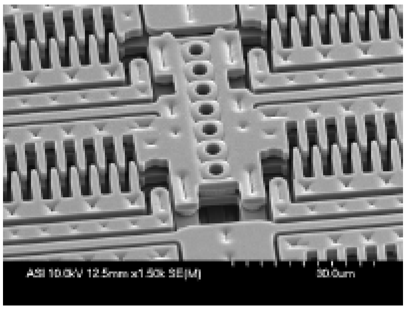


Figure 1b: Large Force Electrostatic MEMS Comb Drive

***Common examples*** include:
- inkjet printers
- accelerometers ( airbag deployment…)
- gyroscopes ( trigger dynamic stability control…)
- pressure sensors (car tires, blood…)
- displays (projectors…)
- optical switching technology (telecommunications)
-Bio-MEMS (Lab-On-Chip, MicroTotalAnalysis…)

## 2) Why are MEMS of interest?

MEMS are of interest for many reasons:

***COST*** : Batch processing of MEMS using techniques developed by the microelectronics industry means that the price of an individual machine is very low (some costing no more than a few cents !).

***SIZE*** : Their small size means that they don't take up much space and weigh little, with obvious benefits for portable applications (mobile phones, aerospace devices …) or applications with space limitations (implantable devices, micro-surgery,…..).

***ENERGY EFFICIENCY*** : MEMS hold great potential for the environment: they already increase fuel efficiency in modern cars and houses of the future will intelligently control energy consumption, by exploiting MEMS to regulate temperature and lighting in accordance with need (ambient temperature + human presence).

***INTELIGENT MACHINES***: As MEMS are made using microelectronics technology, electro-mechanical elements can be integrated with electronics onto one substrate, the former acting as the arms and legs of the machine, the latter as the brain.

***REDEFINING WHAT IS POSSIBLE***: MEMS challenge traditional engineering concepts, as gravity and inertia are of reduced importance and atomic forces and surface science may dominate. Scaling laws demonstrate that effects not exploitable at the macro-scale can become of interest at the micron-scale.

## 3) How are MEMS made?

There are a number of different categories of MEMS technologies:

***1) Bulk Micromachining:***

Bulk micromachining creates devices by wet etching into a wafer, typically Si.

***2) Surface Micromachining:***

Surface Micromachining builds devices up from the wafer layer-by-layer.
It requires more fabrication steps than Bulk Micromachining, and thus it is more expensive. However it enables the creation of more sophisticated devices of higher functionality.

***3) LIGA:***

LIGA is a relatively inexpensive fabrication technology which uses x-ray lithography to create small, but relatively high aspect ratio devices.

***4) Deep Reactive Ion Etching:***

Deep Reactive Ion Etching micromachining uses a plasma etch to create features. It is more expensive but also more flexible than traditional Bulk Micromachining based on wet etching.

These different categories use three basic building blocks:
I – Deposition
II - Lithography
III - Etching

*I – Deposition*

Deposition technology may be classified as **chemical** (Chemical Vapor Deposition, Electrodeposition, Epitaxy , Thermal oxidation…) or **physical** (Physical Vapor Deposition, Casting…).

*II - Lithography*

Lithography concerns the transfer of a pattern to a photosensitive material by selective exposure to a radiation source, the wavelength of which determines the achievable feature size.

*III – Etching*

Etching processes are classified as “wet” when a chemical solution is used to etch the material or “dry” when material removal is achieved by sputtering or dissolution using reactive ions or a vapour phase etchant.

## 4) What materials are used in MEMS ?

MEMS are made using a number of different materials, the choice depending on the functionality required and cost limitations. The tree main categories are:

***- Silicon***

Silicon is used in a wide variety of MEMS because of its intrinsic physical properties and the fact that its structuring is well mastered, thanks to its use in the microelectronics industry.

***- Polymers***

Polymers are used because they are relatively cheap and can show a great variety of material characteristics.

***- Metals***

Common metals such as Gold, Nickel, Aluminum, Chromium, Titanium, Tungsten, Platinum and Silver are used in many MEMS. More exotic metallic materials are exploited for very particular functionalities (see below).

## 5) What are the physical principles exploited in MEMS ?

Many different physical principles are exploited in MEMS. Owing to the fact that MEMS is an off-shoot of the microelectronics industry, the first MEMS were based on ***electrostatic*** principles. Following this, ***differential thermal expansion*** was exploited in bimorph actuators. Today's MEMS also exploit ***piezoelectricity, electromagnetism, ferromagnetism, magnetostricition, shape memory effects***….MEMS is a fast evolving domain and it is expected that other effects will also be exploited.

## 6) From MEMS to NEMS

Nanotechnology is advancing at such a rate that what is achieved at the micron scale is or soon will be achievable at the nanometre scale, extending the field to nano-electro-mechanical systems (NEMS). This evolution to ever smaller sizes will reinforce the above mentioned advantages of MEMS, and should even allow the exploitation of quantum effects.