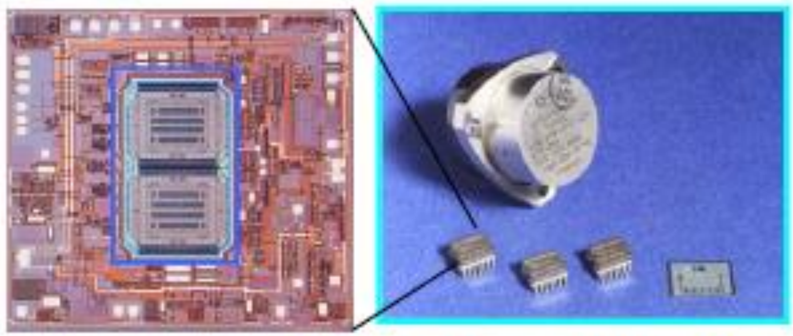
MEMS & NEMS

Nano devices and machines having nano sized components

What is MEMS? Microsystems?

MEMS:

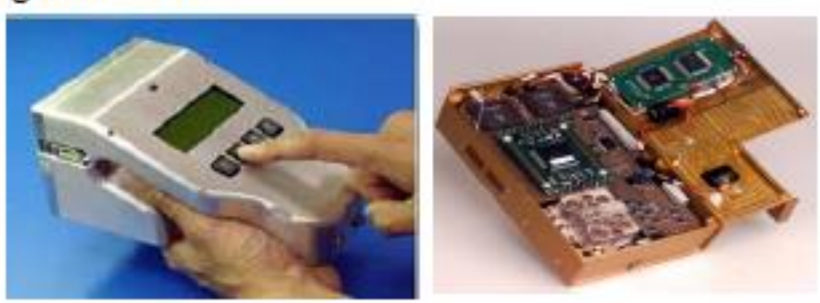
Micro-Electro-Mechanical Systems (MEMS) is the integration of mechanical elements, sensors, actuators, and electronics on a common silicon substrate through microfabrication technology.



Micro accelerometer and Comparison with Conventional one (Courtesy of NASA Glenn Research Center)

Microsystems:

Engineering systems that could contain MEMS components that are design to perform specific engineering functions



μChemLab™ by Sandia National Laboratory

Common Microfabrication techniques

Process Type	Examples
Lithography	photolithography, screen printing, electron-beam lithogaphy, x-ray lithography
Thin-Film Deposition	chemical vapor deposition (CVD), plasma-enhanced chemical vapor deposition (PECVD), sputtering, evaporation, spin-on application, plasma spraying, etc.
Electroplating	blanket and template-delimited electroplating of metals
Directed Deposition	electroplating, stereolithography, laser-driven chemical vapor deposition, screen printing, transfer printing
Etching	plasma etching, reactive-ion enhanced (RIE) etching, deep reactive ion etching (DRIE), wet chemical etching, electrochemical etching, etc.
Directed Etching	laser-assisted chemical etching (LACE)
Machining	drilling, milling, electric discharge machining (EDM), diamond turning, sawing, etc.
Bonding	fusion bonding, anodic bonding, adhesives, etc.
Surface Modification	wet chemical modification, plasma modification
Annealing	thermal annealing, laser annealing

Applications of MEMS and Microsystems

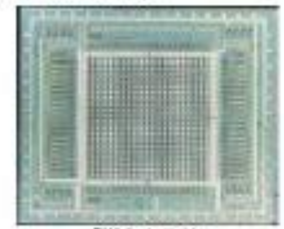
MEMS/ Microsystems

Automotive applications...

Biomedical...

- Biochips, blood pressure sensing, genetic analysis, proteomics, diagnostics, drug delivery ...

Disposable lab on a chip
(Caliper Technologies Inc.)

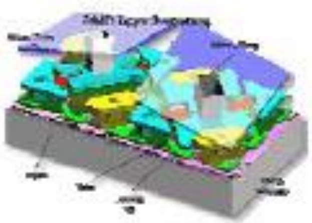


DNA Analysis chip
(Fabricated at Standard MEMS, Inc.)

Microneedles
(Fabricated at Standard MEMS, Inc.)

Communications...

- Optical switching and routing, relays, wireless communication, information systems ...

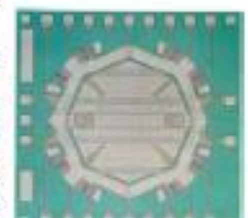


Digital Mirror Device (DMD) Light Switch
(Texas Instruments)

Micro-Fresnel Lens
(Fabricated at
Standard MEMS, Inc.)

Aerospace...

- Aircraft, micro-satellites, space exploration ...



MEMS Gyroscope
(Fabricated at Standard MEMS, Inc.)

Advantages

- **Miniaturization, multiplicity and the ability to directly integrate the devices into microelectronics**

- **Multiplicity refers large number of devices and design that can be rapidly manufactured lowering the price per unit**

- **The size of MEMS device is comparable to electronic chips allows their integration directly on chip**

- **The surface area: volume ratio is so large that surface effects are very important in microregime. Hence the mechanical behavior can be altered by a thin coating of material.**

MEMS accelerometer technology

To activate airbag in automobile

•The core element of a typical MEMS accelerometer is a moving beam structure composed of two sets of fingers: one set is fixed to a solid ground plane on a substrate; the other set is attached to a known mass mounted on springs that can move in response to an applied acceleration.

•When the car is suddenly come to a halt because of impact, the horizontal bar is accelerated to the right which causes change in separation between the plates of capacitor.

•This applied acceleration (**Figure 1**) changes the capacitance between the fixed and moving beam fingers which in turn electronically triggers a pulse of current through heating coil embedded in sodium azide, NaN3

•The instantaneous heating causes a rapid decomposition of the azide material thereby producing nitrogen gas which inflates the airbag

$$2NaN_3 > 2Na + 3N_2$$

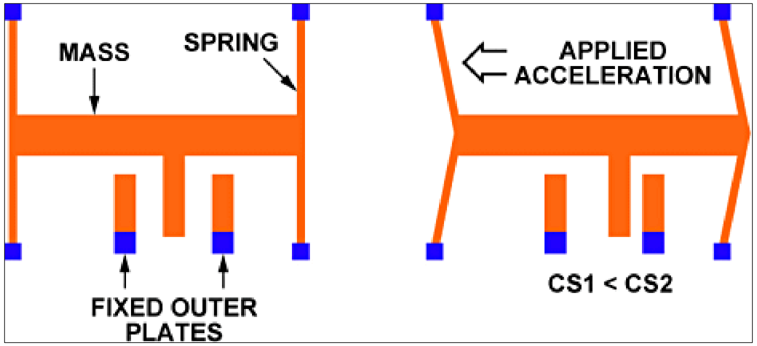
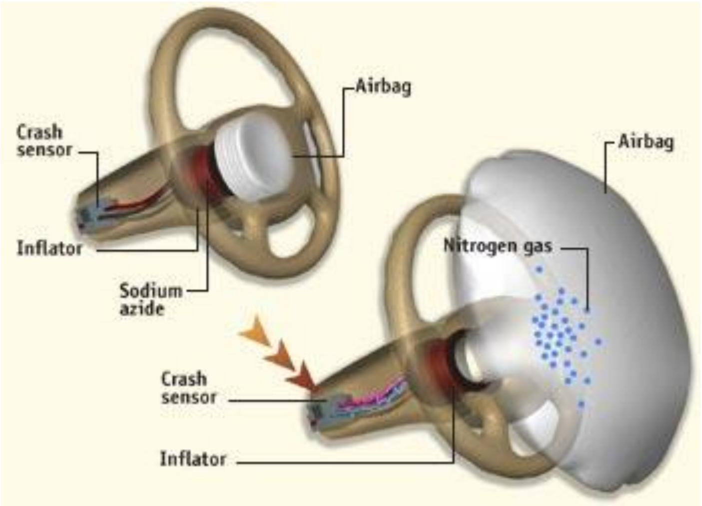


Figure 1. The structure of a MEMS accelerometer



Nano electromechanical systems (NEMs)

NEMS: Definitions

NEMS or **nanoelectromechanical systems** are similar to MEMS but smaller. They hold promise to improve abilities to measure small displacements and forces at a molecular scale.

There are two approaches most researchers accept as standard paths to NEMS. The top-down approach can be summarized as "a set of tools designed to build a smaller set of tools". For example, a millimeter sized factory that builds micrometer sized factories which in turn can build nanometer sized devices. The other approach is the bottom-up approach, and can be thought of as putting together single atoms or molecules until a desired level of complexity and functionality has been achieved in a device. Such an approach may utilize molecular self-assembly or mimic molecular biology systems.

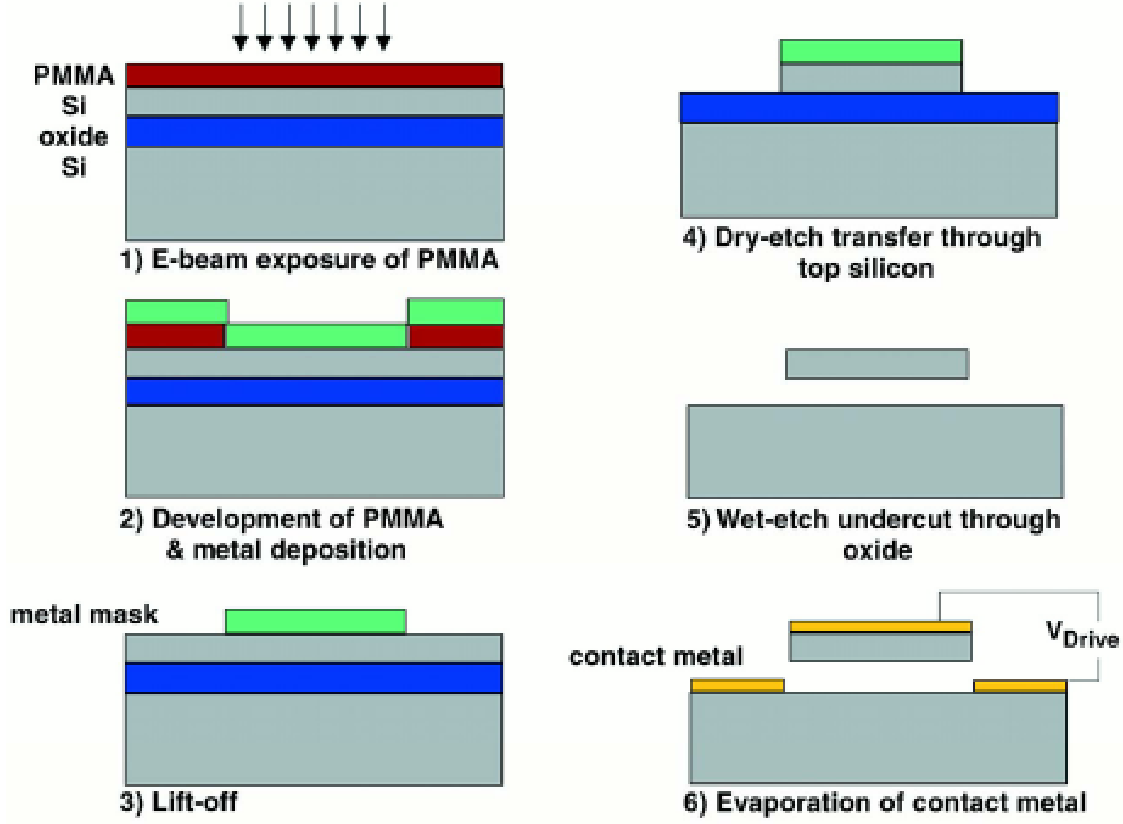
A combination of these approaches may also be used, in which nanoscale molecules are integrated into a top-down framework.

Electron beam lithography

The electron beam lithography uses a finely focused beam of electrons which is scanned in a specific pattern over the surface of a material.

It can produce patterned structure on a surface having 10 nm resolution.

NEMS Fabrication Process



Schematic of surface micromachining approach used to nanofabricate NEMS devices. The pattern shapes are created by a scanning electron beam (E-beam) exposing a polymeric polymethylmethacrylate (PMMA) resist. The motion may be actuated by applying a voltage between the electron on the moving element and the electrode on the substrate

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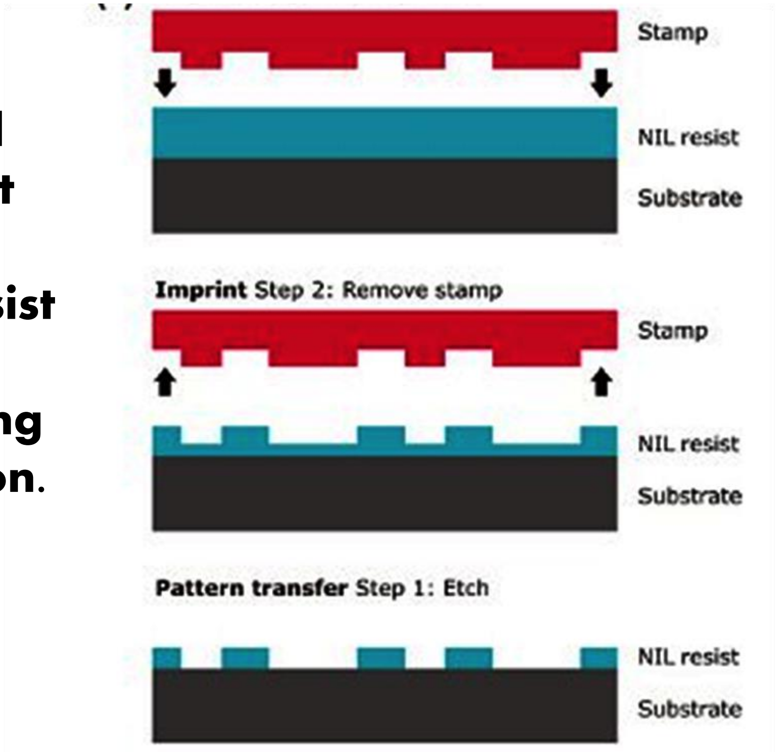
Nano imprint lithography

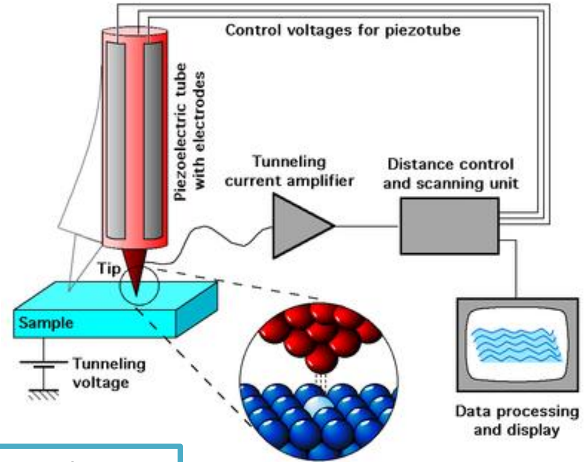
Nanoimprint lithography is a method of fabricating nanometer scale patterns.
It is a simple nanolithography process with low cost, high throughput and high resolution.
It creates patterns by mechanical deformation of imprint resist and subsequent processes.

- A mold having a nanoscale structured pattern on it is presses into a thin resist coating on a substrate
- It creates a contrast pattern in the resist
- After the mold is lifted off an etching process is used to remove the remaining resist material in the compressed region.



Scanning Tunneling Microscopy

It uses narrow tip to scan across the surface of material about nanometer above it
When a voltage is applied electron tunnel from the surface and the current can be detected
The current will vary as tip scan the surface and it depends on the electron density
Hence scanning tip provides image of the atomic or molecular structure of surface



STM can be used to build nanosized structures atom by atom on the surface of materials
A chemically bonded adsorbed atom with the atoms on the surface is imaged using an STM has a trajectory as shown fig (a)
The force between the tip and adsorbed atom is small compared with forces binding atom to the surface.
If the tip is moved closer to the adsorbed atom such that interaction b/w tip and atom is greater than that b/w atom and surface, atom can be dragged along by the tip (Fig b)
At any point the atom can be reattached to the surface by increasing the separation between tip and surface
In this way, adsorbed atoms can be rearranged on the surfaces of materials and structures can be formed on the surface atom by atom
The surface of material has to be cooled to liquid helium temperature in order to reduce thermal vibrations
Ultra high vacuum condition is required in order to keep the surface clean