



Micromachining

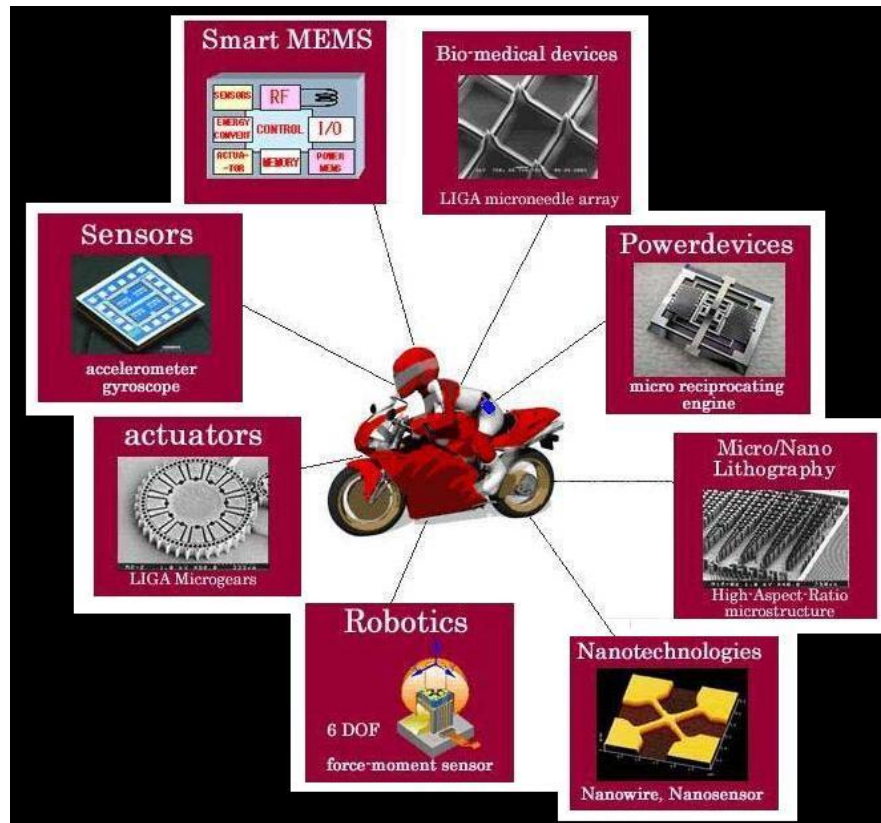
AMT 2505

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Introduction

Micromachining are inherently connected to the evolution of Micro Electro Mechanical Systems (MEMS). Decades earlier watch components were thought micro. Now, the electronic industry functions revolutionized the scope.





Techniques

- ❑ Bulk Micromachining
 - Wet etching.
 - Dry etching.

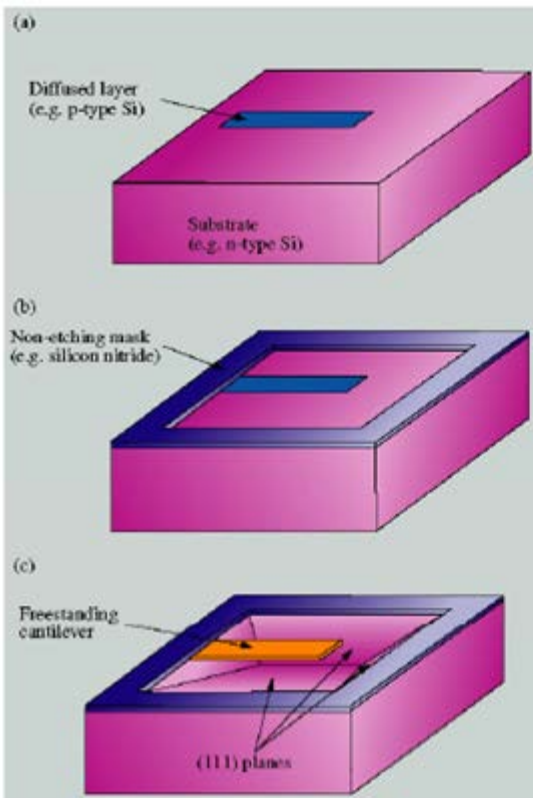
- ❑ Surface Micromachining
 - CVD.
 - Electro-deposition.
 - Epitaxy.
 - PVD.

❑ LIGA

- ❑ Non Traditional Micromachining
 - Micro Laser machining.
 - Micro EDM
 - Micro USM.

- ❑ Mechanical Micromachining.
 - Micro Milling.
 - Micro Turning.

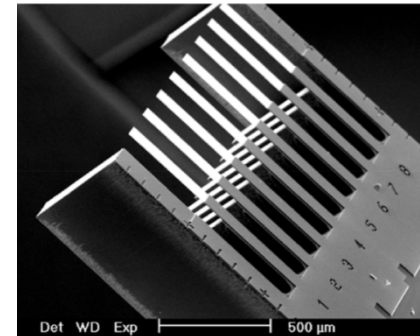
Bulk Micromachining is a subtractive technique of removing material from silicon wafer. 2 / 2.5 D etching is possible with Cantilever section.



Dopant Diffusion

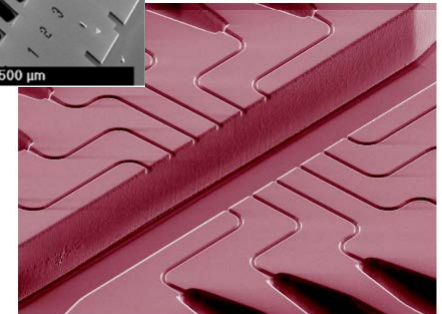
Masking

Anisotropic Etching



Micro cantilever chemical sensor array

Micro fluidic channel



Process:

- Wet Etching
- Dry Etching

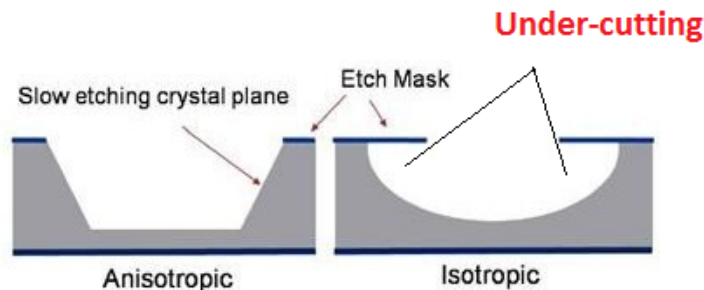
Is a method to remove material by the aggression of chemical liquid. Dependent on the material characteristics i.e. Isotropy or Anisotropy.

Isotropic etching.

- Same etch rate in all direction.
- Lateral etch is about same as vertical etch rate.
- Etch rate is not dependent on mask edge orientation

Anisotropy etching.

- Etch rate dependent on orientation of crystalline planes.
- Lateral etch can be larger or smaller than vertical.
- Orientation of mask edge define final shape.



Advantages:

- + Large bulk removal
- + Batch Process
- + Low cost

Disadvantages:

- Inadequate feature definition $< 1\mu\text{m}$.
- Chemical hazards.
- Wafer contamination.

Most widely used in semiconductor manufacturing. Produced by Ion bombarding or chemical reaction or mix of both.

Physical Sputtering.

Atoms of the solid target gets eroded due to the energized particles. The sputtering can be through,

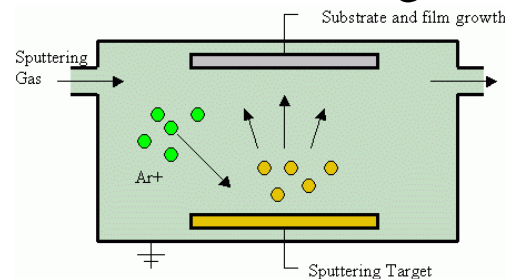
- Ion milling or Ion etching.
- Plasma sputtering.

Plasma Etching.

It is a Plasma assisted chemical reactive on the substrate which erodes.

Reactive Ion Etching (RIE).

Occur due to chemical reaction over bombarding ions on the material.



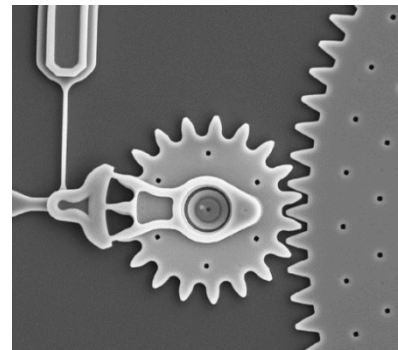
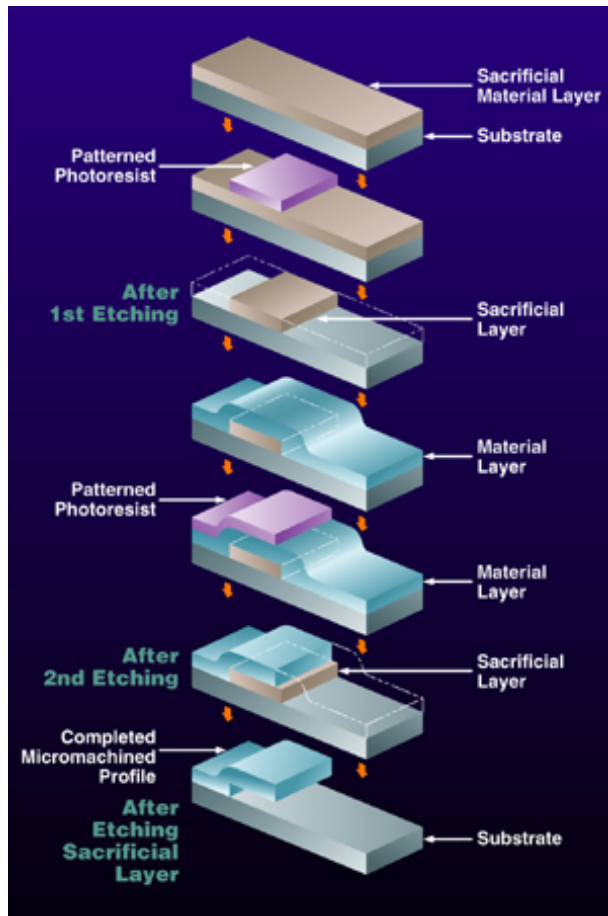
Advantages:

- + Capable for small feature definition <math><1\text{nm}</math>.
- + High quality etch.
- + Anisotropy etching possible.

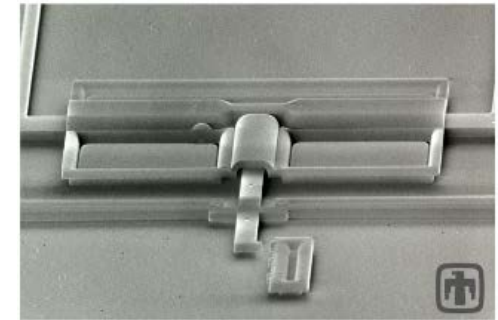
Disadvantages:

- High cost.
- Low throughput.
- Potential radiation damage.

Surface Micromachining is a additive manufacturing technique of depositing material on silicon substrate. Sacrificial layer is used as spacers which is etched to define the form.



Micro Gear



Comb drive

Process:

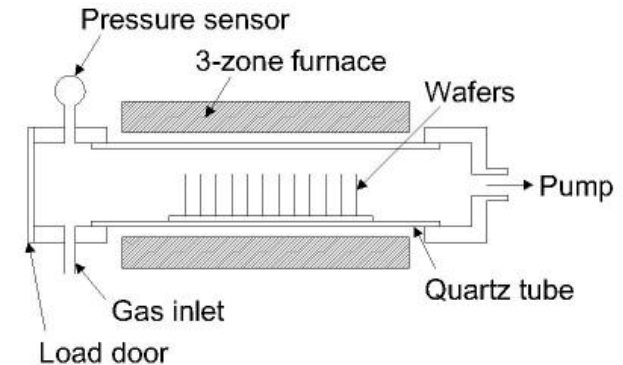
- Chemical Vapor Deposition (CVD)
- Electro-deposition.
- Epitaxy.
- Physical Vapor Deposition (PVD)

Chemical Vapor Deposition (CVD):

The substrate is placed inside the reactor, where the reactive gases are passed condensing the material on substrate.

- Low Pressure CVD (LPCVD)
- Plasma enhanced CVD (PECVD).

Useful when very thin deposition required.



Electro-deposition:

Also known as Electroplating, restrictive to electrically conductive materials.

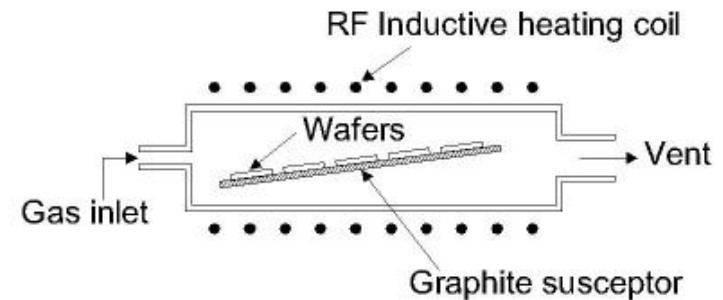
- Electroplating.
- Electro less plating

Coating process is spontaneous.

Epitaxy:

Similar to CVD process, however the crystallographic orientation can be controlled depending on the substrate. E.g. If amorphous substrate is used deposition will be amorphous.

An emerging technology with high growth rate of material.



Physical Vapor Deposition (PVD):

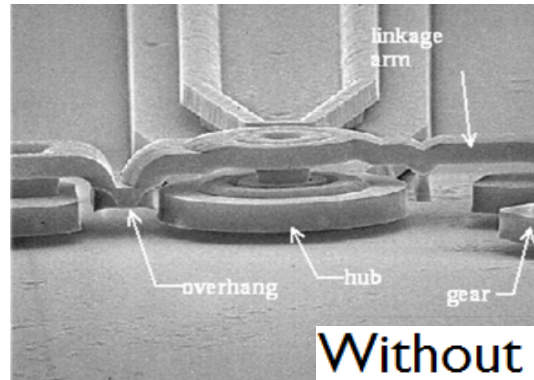
In this, the material is released from the source and gets deposited on the substrate through,

- Evaporation.
- Sputtering.

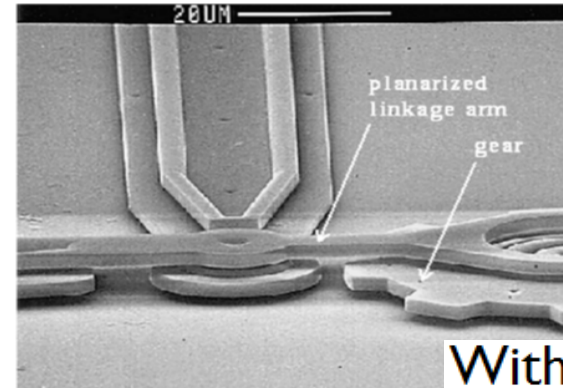
Cheaper in process, with quality inferior than CVD.

Chemical Mechanical Planarization (CMP)

The major drawback of surface Micromachining is the undulation in the topography. To overcome that, CMP is used.



Without CMP



With CMP

Surface Micromachining

Advantages

Complex components can be fabricated.

Under-cut are possible.

Metals, ceramics and plastics can be fabricated.

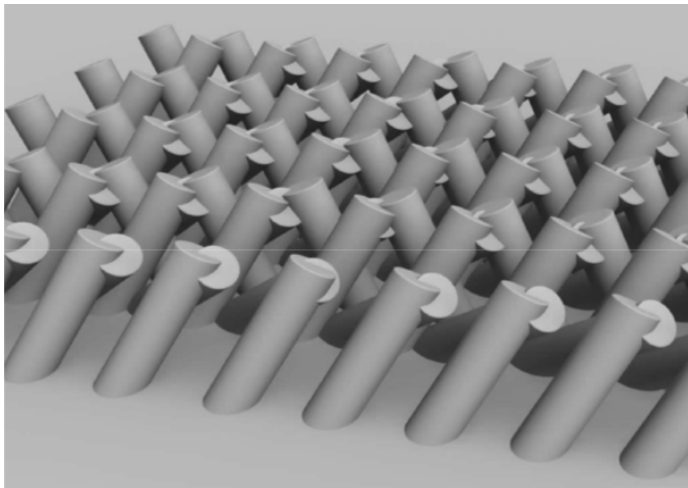
Disadvantages

Restricted to planar fabrication.

Cost is higher than Bulk machining.

Photolithography becomes mandatory.

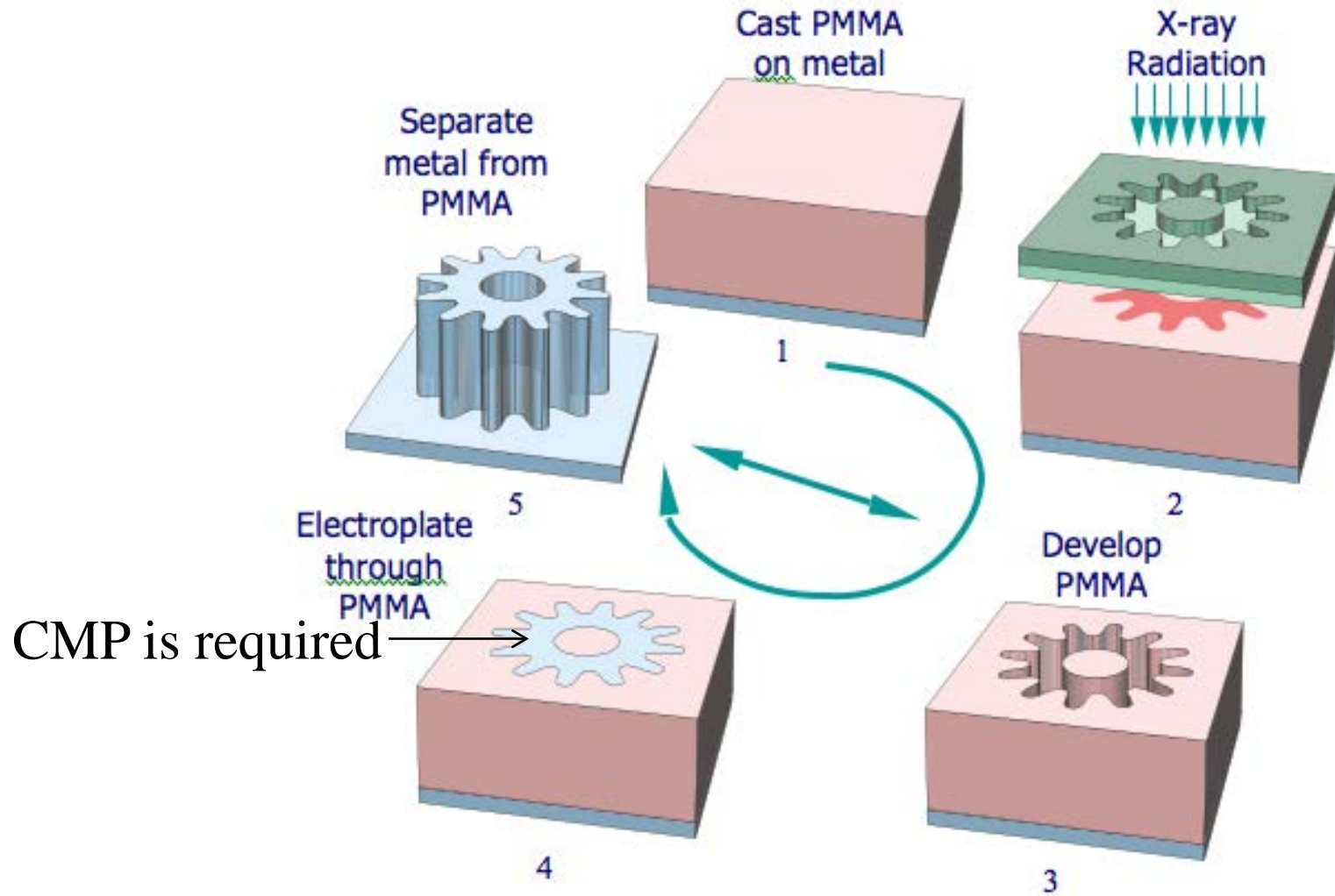
Lithographie (Lithography) Galvanoformung (Electroforming) and Abformung (Molding), is a technology allowing high aspect ratio manufacturing.



Angled LIGA
Structures

Characteristics:

- High aspect ratio of order 100:1
- Parallel side with flank angle of order 89.95°
- Smooth side walls $R_a=10\text{nm}$
- Structural heights from tens of micrometers to several millimeters.

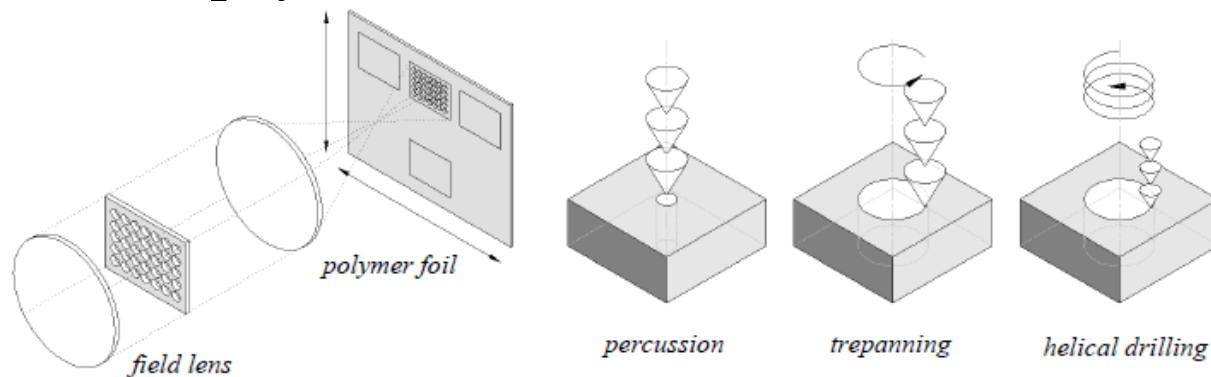


Non traditional machining also offers microscopic rendition to achieve 3D sculpture complex component. Some of the interesting process are,

- Laser Micromachining.
- Micro Electric Discharge Machining.
- Micro Ultrasonic machining.

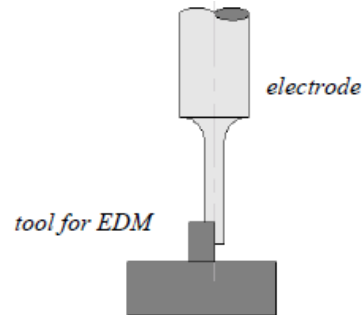
Laser Micromachining:

Uses a light radiation with high energy density to remove material without physical or chemical interaction.



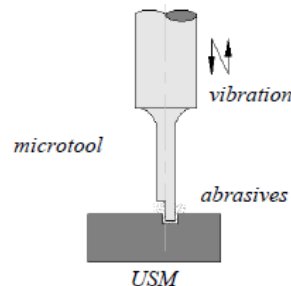
Micro Electric Discharge Machining:

Electric discharge is used to erode the material from work-piece. It uses Electro-Thermal reaction created between the electrode and work-piece at a certain gap known as Spark gap.



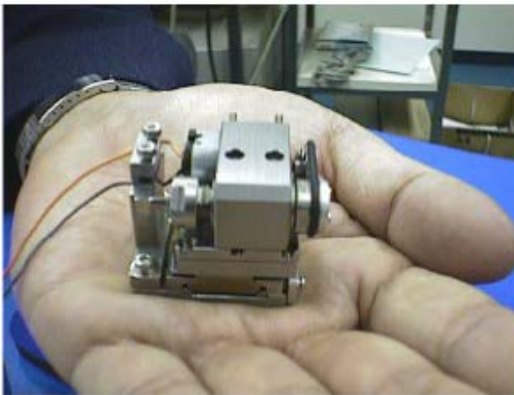
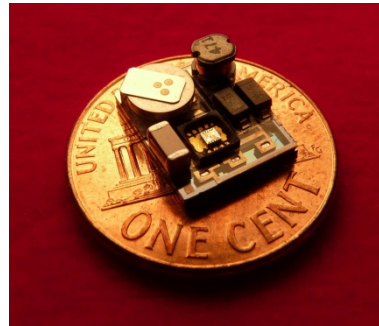
Micro Ultrasonic machining:

Ultrasonic vibrations of 30-40 KHz is created to generate accurate holes in hard and brittle of borosilicate glass, Quartz and ceramic.



Mechanical machining is a traditional method of removing material by physical contact between the tool and work-piece. Compared to other process, it is cost effective, but cutting dynamics and relation need to be confirmed for suitability.

- Micro Milling.
- Micro Turning.



Micro Lathe



Micro Factory



10 μ m tool with human hair



References

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