RME3102: Microelectromechanical Systems

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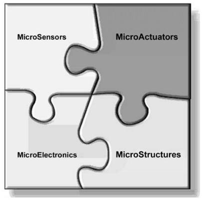
Micro-Electro-Mechanical-Systems (MEMS)



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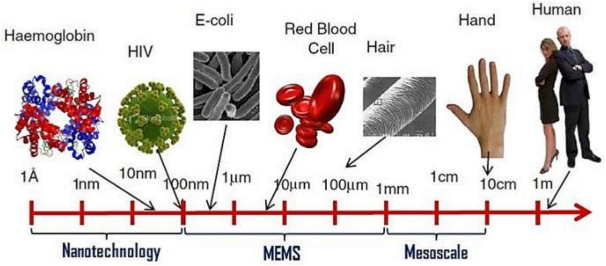

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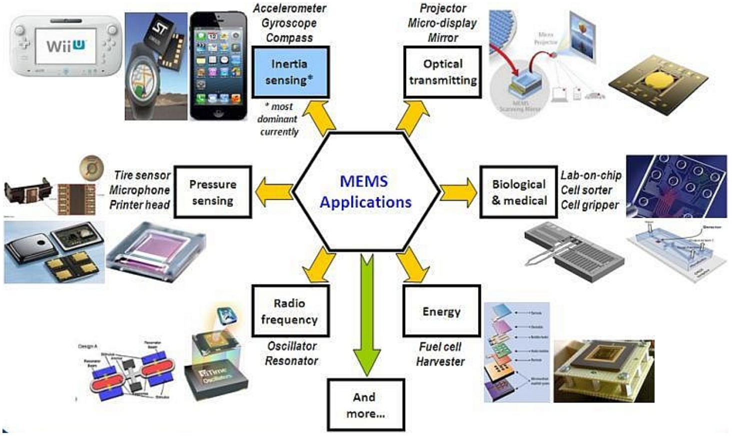
Applications of MEMS



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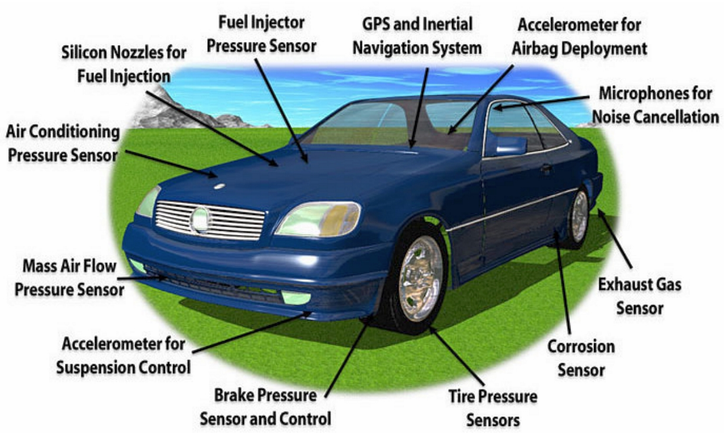

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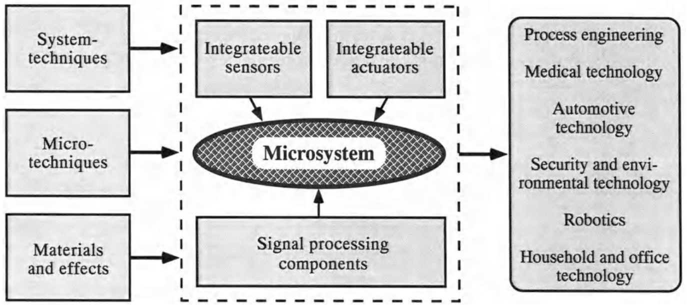

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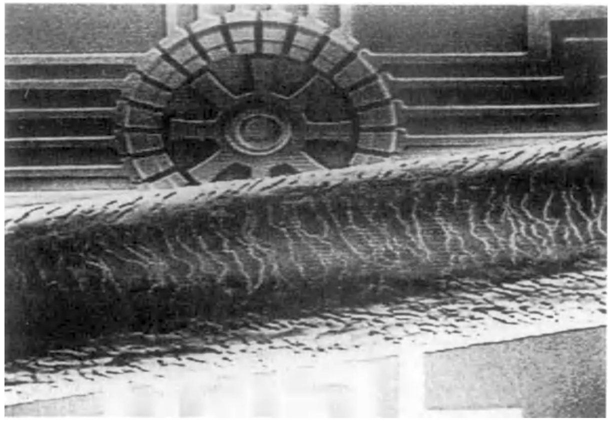
- MEMS is the functional integration of mechanical, electronic, optical and any other functional elements, using special techniques.
- The goal is to fabricate intelligent monolithic or integrated chips which can sense (with sensors), plan, make decisions (signal processing units) and actuate (with actuators).



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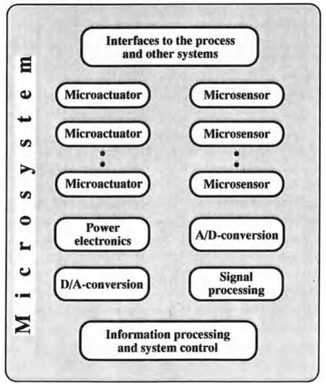
Dimensions of a polysilicon micromotor compared to the diameter of a human hair (diameter of 50 to 100 µm).

Microsystem Structure



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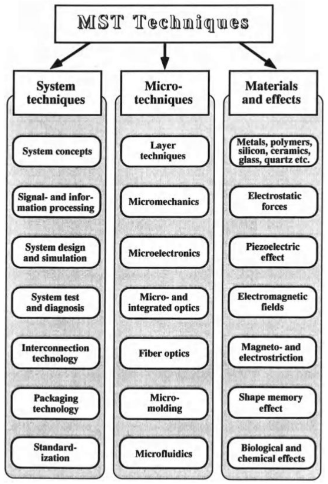
A complete microsystem should detect, process and evaluate external signals, should make decisions based on the obtained information, and finally should convert the decisions into corresponding actuator commands.

Microsystem Techniques



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Micro-techniques

- Layer techniques: Methods for producing layers of different materials on the surface of a substrate. Depending on the deposition method, the layer thickness can range from a few hundred µm to a few nm.
- Micromechanics: This technique comprises in general the 3-d structuring of solids, with at least one dimension in the micrometer range. Micromechanical materials include single-crystal silicon, polysilicon, metals, plastics and glass.
- Integrated optics: Analogous to microelectronics, the aim is to integrate all the named optical components onto one substrate, such as glass, semiconductor material or lithium niobate.
- Fiber optics: Used to transmit optical signals in light-conducting media.
- Microoptics: This technique deals with the design and production of miniaturized optical image processing elements such as mirrors, lenses, filters, etc., which are needed in hybrid microsystems with optical functions.
- Micromolding: Includes plastic and metal powder molding.
- Microfluidics: Technique for developing and producing fluid elements for many applications.

System Techniques

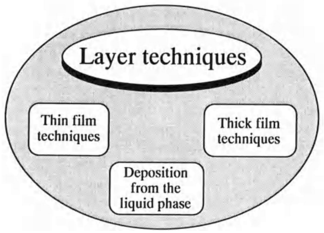
Defines the microsystem architecture and interface concepts for the different techniques.

- Signal and information processing: Describes the receiving and processing of primary electric sensor signals, the execution of algorithms, the transformation of output information into control signals. It is also concerned with the management of data storage and retrieval.
- Design and simulation tools: Defines the tools for computer-based micro-system analysis, simulation and design.
- Test and diagnosis of microsystems: Methods and tools to test the functionality of microsystems
- Interconnection technology: Deals with the technological operations need- ed to physically integrate components within a small amount of space.
- Casing technique: Design of the casing for a microsystem, which usually is an essential part of the system and may influence the overall system function and size.
- Standardization: As in many other branches of industry, very important for developing microsystems. It often can lead to the economical success of a research result.

Materials and Effects

- Biological materials and effects: Mainly used in biosensors to selectively measure concentrations of substances in fluids and to determine biological parameters, such as toxicity and the effect of allergens.
- Chemical materials and effects: Used almost exclusively in chemical sensors. These sensors can detect a specific component in a foreign substance as well as its concentration in this substance.
- Piezoelectric effect: The changing of the geometry of a piezocrystal when applying an electric voltage to it. This effect is used in actuators.
- Electrostatic force: Appears between two parallel metal plates when an electric voltage is applied between them.
- Electromagnetic field: Generated when current flows through a conductor or coil. This effect is often used for magnetic actuators.
- Magneto- and electrostrictive effect: is the deformation of a ferromagnetic (ferroelectric) material under the influence of a magnetic (electric) field.
- Shape memory effect: Describes the property of a shape memory alloy.
- Silicon, silicon oxide, silicon nitride, ceramics, quartz, metals (nickel, gold, aluminum, copper, etc.), polymers, glasses and other materials.

Microtechniques: Layer Techniques



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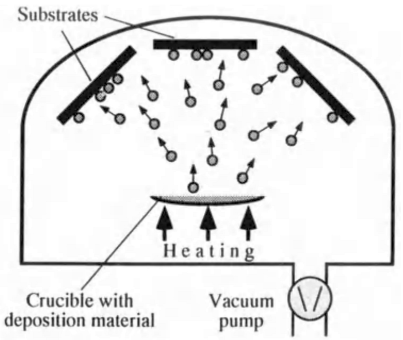
1. Thin film techniques:
    - Thermal deposition
    - Physical layer deposition
        - Vapour deposition
        - Sputtering deposition
    - Chemical layer deposition
2. Deposition from the Liquid Phase
3. Thick Film Techniques

Thermal Deposition

- Silicon is a semiconductor material which is quickly covered by a layer of oxide when exposed to air. Chemically resistant silicon oxide layers are often used for masking in connection with the chemical etching processes to obtain a defined surface structure.
- Thereby, certain areas of the substrate may not be exposed to the process during etching and are masked. These layers also serve as electrical insulators.
- Oxidation can significantly be accelerated by exposing the silicon in a reactor containing oxygen at temperatures of up to 1200°C. Such thermal oxidation is widely employed by industry.

Vapour deposition

With the vapour deposition method, the material to be deposited is heated up in a vacuum chamber to high temperature. The atoms of the evaporated material condense on the substrate to be processed. Vapour deposition is a conventional well under- stood method.



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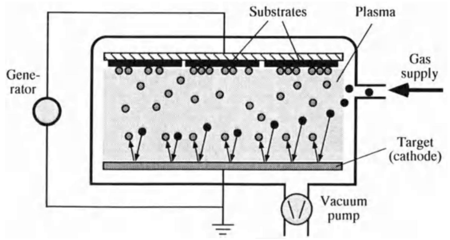
Sputtering deposition

The sputtering process is done in a vacuum chamber whereby the cathode is made of the metal to be deposited. Inert gas ions (e.g. argon) which are generated by the plasma in the chamber are used to bombard the cathode, they tear loose metal atoms which are then condensed on the close by substrate. This method is suitable for various materials. The adhesion of the layers is much greater than that obtained by vapour deposition.



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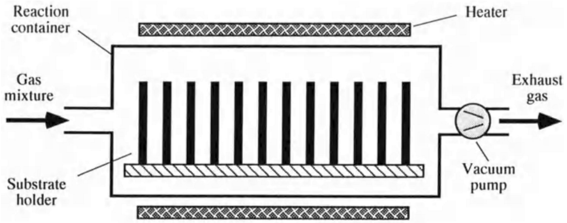
Chemical layer deposition

With this predominant method, a substrate is placed in a reactor and exposed to thermally instable gas which contains the material to be deposited. Under a high reactor temperature (up to 1250°C), a chemical reaction on the substrate surface decomposes the gas into a gaseous and a solid component. The latter is deposited on the surface of the substrate as a very thin and uniform film, and the gaseous component is sucked away.



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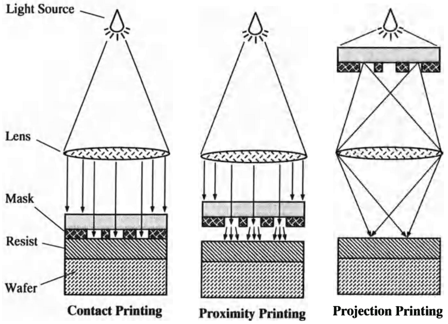
Silicon Fabrication Techniques: Lithography

Lithography is used for preparing the substrate of a wafer for subsequent processing stages. To etch the desired pattern, a photosensitive layer is applied to wafer surface. This photosensitive resist will be lithographically structured, and specified areas of substrate remain covered and protected.



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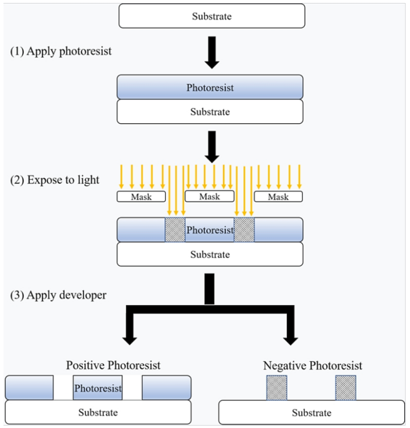
Exposing the resistive layer causes molecule chains to break or to cross-link, depending on the type of resist used. Either the exposed part, which is the positive resist, or the unexposed part, which is the negative resist.



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