INTRODUCTION

MEMS

DEFINITION:

Microelectromechanical systems (MEMS), *MicroElectroMechanical* or *microelectronic and microelectromechanical systems* and the related *micromechatronics* is the technology of very small devices; it merges at the nano-scale into nanoelectromechanical systems (NEMS) and nanotechnology.

MEMS are separate and distinct from the hypothetical vision of molecular nanotechnology or molecular electronics. MEMS are made up of components between 1 to 100 micrometres in size (i.e. 0.001 to 0.1 mm), and MEMS devices generally range in size from 20 micrometres to a millimetre (i.e. 0.02 to 1.0 mm). They usually consist of a central unit that processes data (the microprocessor) and several components that interact with the surroundings such as microsensors. At these size scales, the standard constructs of classical physics are not always useful. Because of the large surface area to volume ratio of MEMS, surface effects such as electrostatics and wetting dominate over volume effects such as inertia or thermal mass.

MEMS or Micro Electro Mechanical Systems are Semiconductor ICs that have combined the electrical and mechanical property of Silicon. There are actual moving mass, springs, cavities, dampers etc inside a MEMS structure. MEMS can detect motions such as acceleration, gravity, angular motion, magnetic field and pressure etc. Typical MEMS is SIP (system in package) IC consisting of two ICs. First IC senses the desired parameter and converts it into equivalent capacitance. Second IC converts the capacitance into equivalent voltage or digitally onto I2C bus.

Two principal components of MEMS:

- A sensing or actuating element and a signal transduction unit.

- MEMS as a microsensor:

ORIGIN:

Manufactured on to semiconductor material.

Used to make sensors , actuators, accelerometer , switches and light.

Used in automobiles , aerospace , biomedical app wireless ,optical communication.

(1)1947- invention of the point contact transistor uses electrical current (or) a small amt of voltage to control a larger change in current (or) voltage

-Transistor is a building blocks of computers, cellular phones other modern electronics .

(2)1954- Discovery of the piezoresistive effect in silicon and germanium to sense air (or) H2O pressure ,better then metal.

Eg. Strain gauges , pressure sensor and accelerometer utilize piezoresistive effect in silicon.

(3) 1958- First integrated circuit (IC). IC includes transistors , resistors , capacitors and wires.

(4) 1968-The resonant gate transistor patented this device . It joined a mechanical component with an electronic element and is called a resonant gate. 1mm size , it serves as a frequency filter in IC.

(5)1971- Invention of μ processor.

- Single chip microprocessor .
- Paved the way for the personal computer.

(6)1979- HP micro machined inkjet nozzle thermal inkjet technology (TIJ).

TIJ-heats ink-creating tiny bubbles , tiny bubbles collapse – ink squirts through an array of nozzle onto the paper.

(7)1982-LIGA process – manufacturing microstructure

(8)1986-AFM – scans the surface of an atomic structure by measuring the force acting on the tip of a micro scale cantilever

(9)1992 – Grating light modulator .

- It is a micro opto electro mechanical system (mems)
- Graphic printing , lithography and optical communication.

(10)1993- Multi user mems processes (MUMPs) a three layer poly silicon surface micro machining process to create their own design (1cm).

(11)1993-First manufactured accelerometer. The automotive industry used this accelerometer in automobiles for airbag deployment sensing, highly reliable , very small, inexpensive .

(12)1994-Deap reactive ion etching patened.

- DRIE – highly an isotropic etch process used to create deep ,steep sided holes and trenches in to H2o.

(13) Late 1990s early 2000 - biomem.

- Scientist are combining sensors and actuators with emerging biotechnology.

Application includes,

- Drug delivery system
- DNA array
- Insulin pump
- Lab – on – a – chip (LOC)
- Glucometers
- Neural probe arrays
- Microfluidics

Summary

Mems devises measured things as pressure in engines and motion in cars mems are controlling our communication network mems travel through human body to a monitor blood pressure.

The application and growth of mems and memes are endless. Mems are even getting smaller now have nano electro mechanical systems (nems).

TYPES:

MATERIALS USED FOR MEMS MANUFACTURING

The fabrication of MEMS evolved from the process technology in semiconductor device fabrication, i.e. the basic techniques are deposition of material layers, patterning byphotolithography and etching to produce the required shapes.

Silicon

Silicon is the material used to create most integrated circuits used in consumer electronics in the modern industry. The economies of scale, ready availability of cheap high-quality materials and ability to incorporate electronic functionality make silicon attractive for a wide variety of MEMS applications. Silicon also has significant advantages engendered through its material properties. In single crystal form, silicon is an almost perfect Hookean material, meaning that when it is flexed there is virtually no hysteresis and hence almost no energy dissipation. As well as making for highly repeatable motion, this also makes silicon very reliable as it suffers very little fatigue and can have service lifetimes in the range of billions to trillions of cycles without breaking.

Polymers

Even though the electronics industry provides an economy of scale for the silicon industry, crystalline silicon is still a complex and relatively expensive material to be produced. Polymers on the other hand can be produced in huge volumes, with a great variety of material characteristics. MEMS devices can be made from polymers by processes such asinjection molding, embossing or stereolithography and are especially well suited to microfluidic applications such as disposable blood testing cartridges.

Metals

Metals can also be used to create MEMS elements. While metals do not have some of the advantages displayed by silicon in terms of mechanical properties, when used within their limitations, metals can exhibit very high degrees of reliability. Metals can be deposited by electroplating, evaporation, and sputtering processes. Commonly used metals include gold, nickel, aluminium, copper, chromium, titanium, tungsten, platinum, and silver.

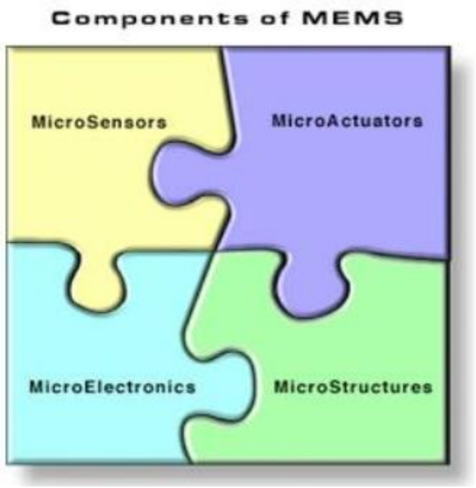
Ceramics

The nitrides of silicon, aluminium and titanium as well as silicon carbide and other ceramics are increasingly applied in MEMS fabrication due to advantageous combinations of material properties. AlN crystallizes in the wurtzite structure and thus shows pyroelectric and piezoelectric properties enabling sensors, for instance, with sensitivity to normal and shear forces. TiN, on the other hand, exhibits a high electrical conductivity and large elastic modulus allowing to realize electrostatic MEMS actuation schemes with ultrathin membranes. Moreover, the high resistance of TiN against biocorrosion qualifies the material for applications in biogenic environments and in biosensors.

MEMS TECHNOLOGY:

Micro-Electro-Mechanical Systems, or MEMS, is a technology that in its most general form can be defined as miniaturized mechanical and electro-mechanical elements (i.e., devices and structures) that are made using the techniques of microfabrication. The critical physical dimensions of MEMS devices can vary from well below one micron on the lower end of the dimensional spectrum, all the way to several millimeters. Likewise, the types of MEMS devices can vary from relatively simple structures having no moving elements, to extremely complex electromechanical systems with multiple moving elements under the control of integrated microelectronics. The one main criterion of MEMS is that there are at least some elements having some sort of mechanical functionality whether or not these elements can move. The term used to define MEMS varies in different parts of the world. In the United States they are predominantly called MEMS, while in some other parts of the world they are called "Microsystems Technology" or "micromachined devices".

While the functional elements of MEMS are miniaturized structures, sensors, actuators, and microelectronics, the most notable (and perhaps most interesting) elements are the microsensors and microactuators. Microsensors and microactuators are appropriately categorized as "transducers", which are defined as devices that convert energy from one form to another. In the case of microsensors, the device typically converts a measured mechanical signal into an electrical signal.



Over the past several decades MEMS researchers and developers have demonstrated an extremely large number of microsensors for almost every possible sensing modality including temperature, pressure, inertial forces, chemical species, magnetic fields, radiation, etc. Remarkably, many of these micromachined sensors have demonstrated performances exceeding those of their macroscale counterparts. That is, the micromachined version of, for example, a pressure transducer, usually outperforms a pressure sensor made using the most precise macroscale level machining techniques. Not only is the performance of MEMS devices exceptional, but their method of production leverages the same batch fabrication techniques used in the integrated circuit industry – which can translate into low per-device production costs, as well as many other benefits. Consequently, it is possible to not only achieve stellar device performance, but to do so at a relatively low cost level. Not surprisingly, silicon based discrete microsensors were quickly commercially exploited and the markets for these devices continue to grow at a rapid rate.

More recently, the MEMS research and development community has demonstrated a number of microactuators including: microvalves for control of gas and liquid flows; optical switches and mirrors to redirect or modulate light beams; independently controlled micromirror arrays for displays, microresonators for a number of different applications, micropumps to develop positive fluid pressures, microflaps to modulate airstreams on airfoils, as well as many others. Surprisingly, even though these microactuators are extremely small, they frequently can cause effects at the macroscale level; that is, these tiny actuators can perform mechanical feats far larger than their size would imply. For example, researchers have placed small microactuators on the leading edge of airfoils of an aircraft and have been able to steer the aircraft using only these microminiaturized devices.

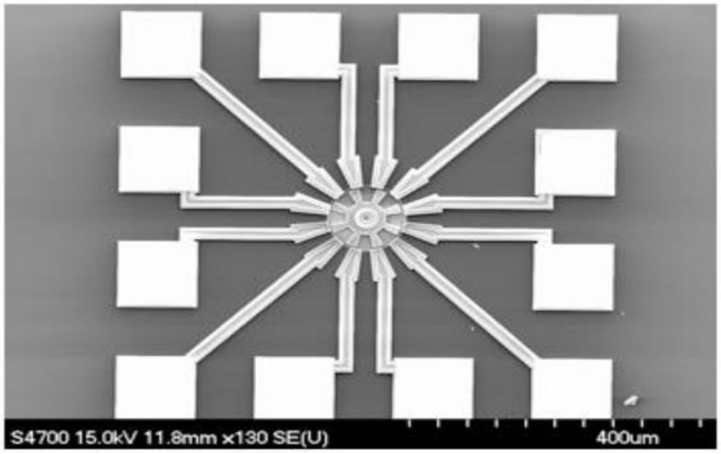


Fig: A surface micromachined electro-statically-actuated micromotor fabricated by the MNX. This device is an example of a MEMS-based microactuator.

The real potential of MEMS starts to become fulfilled when these miniaturized sensors, actuators, and structures can all be merged onto a common silicon substrate along with integrated circuits (i.e., microelectronics). While the electronics are fabricated using integrated circuit (IC) process sequences (e.g., CMOS, Bipolar, or BICMOS processes), the micromechanical components are fabricated using compatible "micromachining" processes that selectively etch away parts of the silicon wafer or add new structural layers to form the mechanical and electromechanical devices. It is even more interesting if MEMS can be merged not only with microelectronics, but with other technologies such as photonics, nanotechnology, etc. This is sometimes called "heterogeneous integration." Clearly, these technologies are filled with numerous commercial market opportunities.

The present MEMS involves a single discrete microsensor, a single discrete microactuator, a single microsensor integrated with electronics, a multiplicity of essentially identical microsensors integrated with electronics, a single microactuator integrated with electronics, or a multiplicity of essentially identical microactuators integrated with electronics.

This vision of MEMS whereby microsensors, microactuators and microelectronics and other technologies, can be integrated onto a single microchip is expected to be one of the most important technological breakthroughs of the future. This will enable the development of smart products by augmenting the computational ability of microelectronics with the perception and control capabilities of microsensors and microactuators. Microelectronic integrated circuits can be thought of as the "brains" of a system and MEMS augments this decision-making capability with "eyes" and "arms", to allow microsystems to sense and control the environment. Sensors gather information from the environment through measuring mechanical, thermal, biological, chemical, optical, and magnetic phenomena. The electronics then process the information derived from the sensors and through some decision making capability direct the actuators to respond by moving, positioning, regulating, pumping, and filtering, thereby controlling the environment for some desired outcome or purpose. Furthermore, because MEMS devices are manufactured using batch fabrication techniques, similar to ICs, unprecedented levels of functionality, reliability, and sophistication can be placed on a small silicon chip at a relatively low cost. MEMS technology is extremely diverse and fertile, both in its expected application areas, as well as in how the devices are designed and manufactured.

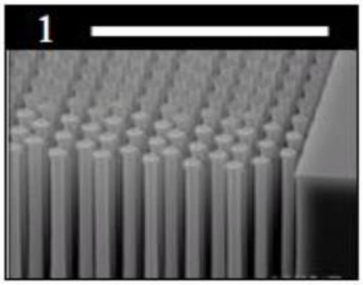


Fig: An array of sub-micron posts made using top-down nanotechnology fabrication methods.

Although MEMS and Nanotechnology are sometimes cited as separate and distinct technologies, in reality the distinction between the two is not so clear-cut. In fact, these two technologies are highly dependent on one another. The well-known scanning tunneling-tip microscope (STM) which is used to detect individual atoms and molecules on the nanometer scale is a MEMS device. Similarly the atomic force microscope (AFM) which is used to manipulate the placement and position of individual atoms and molecules on the surface of a substrate is a MEMS device as well. In fact, a variety of MEMS technologies are required in order to interface with the nano-scale domain.

Likewise, many MEMS technologies are becoming dependent on nanotechnologies for successful new products. For example, the crash airbag accelerometers that are manufactured using MEMS technology can have their long-term reliability degraded due to dynamic in-use stiction effects between the proof mass and the substrate. A nanotechnology called Self-Assembled Monolayers (SAM) coatings are now routinely used to treat the surfaces of the moving MEMS elements so as to prevent stiction effects from occurring over the product's life.