MEMS & MICROSYSTEM

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Explain MEMS?

- MEMS, an acronym that originated in the United States, is also referred to as Microsystems Technology (MST) in Europe and Micro machines in Japan.

- Micro-electromechanical systems (MEMS) is a process technology used to create tiny integrated devices or systems that combine mechanical and electrical components.

- It can range in size from a few micrometers to millimeters.

- These devices (or systems) have the ability to sense, control and actuate on the micro scale, and generate effects on the macro scale.

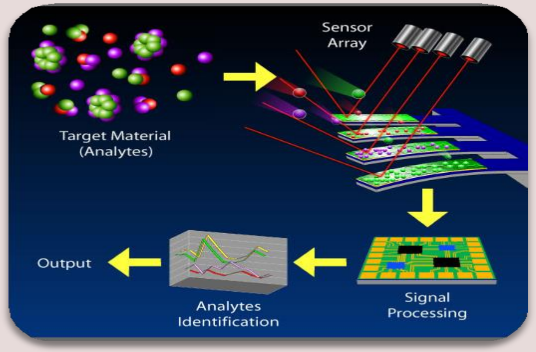
- MEMS consist of mechanical microstructures, micro sensors, micro actuators and microelectronics, all integrated onto the same silicon chip.

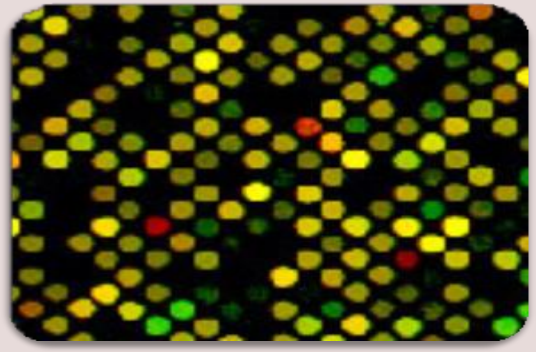
- Micro sensors detect changes in the system’s environment by measuring mechanical, thermal, magnetic, chemical or electromagnetic information or phenomena.

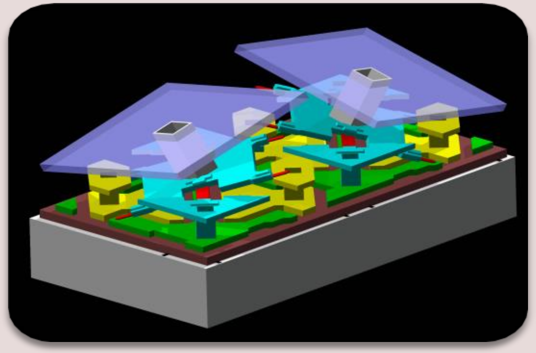
- Microelectronics process this information and signal the micro actuators to react and create some form of changes to the environment

- The device's electronic components are crafted using computer chip technology, whereas the small mechanical parts are created using a technique called micromachining. This involves carefully manipulating materials like silicon to either carve away sections or add new layers.

What do MEMS do?







Sense
- Movement
- Vibration
- Pressure
- Light
- Temperature
- Mass

Think
- Collect information
- Analyze data
- Interpret data
- Make decisions
- React to change

Communicate
- Send information
- Provide outputs
- Transmit data
- Provide warnings

Act
- Respond to changes
- Move devices
- Transmit light and fluids
- Transport particles

Materials for Micromachining

- The size of the microsystem has been decreasing continuously, fabrication of device component is not possible using traditional drilling milling casting and forging. The device used to produce these minute components are called microfabrication technology or micromachining.

- MEMS works by adding or removing thin layers on a substrate , usually silicon, using physical or chemical etching processing.

- The most common substrate material for micromachining is silicon. It has been successful in the microelectronics industry

Silicon as a Substrates

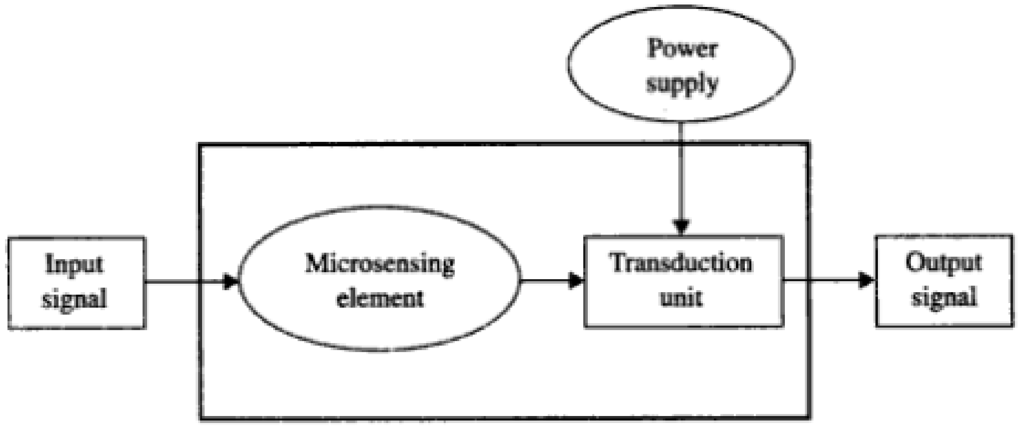
The most common substrate material for micromachining is silicon. It has been successful in the microelectronics industry due to following reason:

- i) silicon is abundant, inexpensive, and can be processed to unparalleled purity
- ii) silicon's ability to be deposited in thin films is very amenable to MEMS
- iii) high definition and reproduction of silicon device shapes using photolithography are perfect for high levels of MEMS precision
- iv) it can be readily oxidized to form a chemically inert and electrically insulating surface layer of SiO_2 on exposure to steam.

Chemical and Biological Sensors

- Chemical and biological sensors encompass a large and wide variety of devices that interact with solids, gases and liquids of all types and are therefore extremely diverse and interdisciplinary.
- These are different from previously described sensors in that they must directly interact with a chemical medium to connect the chemical and electrical domains.
- Hence they require 'openings' within their packaging to enable this interaction (like pressure sensors).

Figure 1.1 I MEMS as a microsensor.



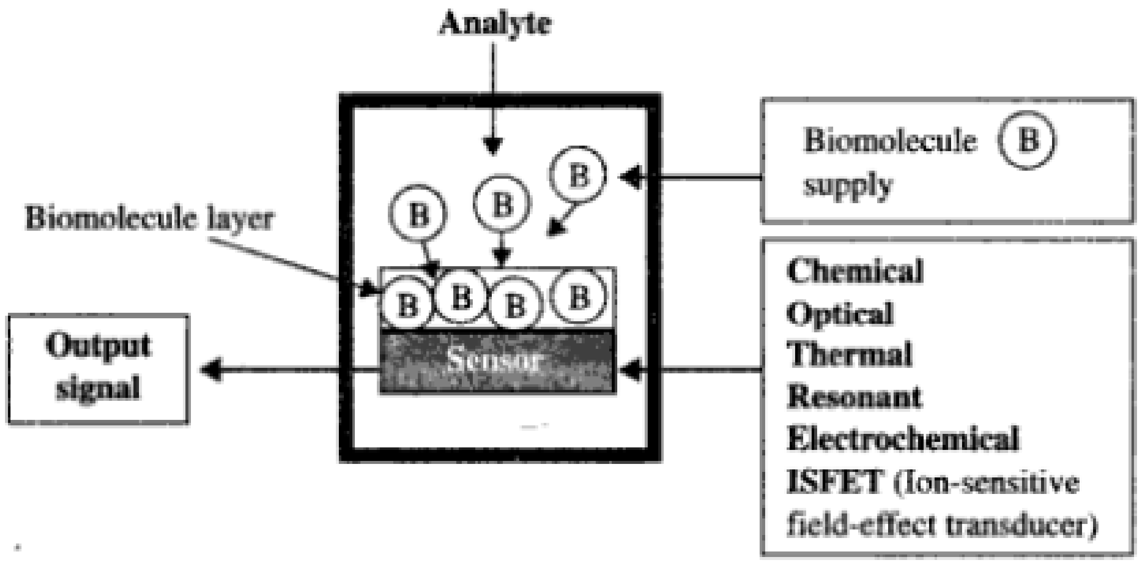
BIOMEMS:

Mems in biomedical industry term as BIOMEMS, which are encompasses 1) Biosensors, 2)Bioinstruments & Surgical tools and 3) System for biotesting & Analysis\

- **Biosensors :**

The short form of the biological sensor is known as a biosensor. In this sensor, a biological element is maybe an enzyme, a nucleic acid otherwise an antibody. The bio-element communicates through the analyte being checked & the biological reply can be changed into an electrical signal using the transducer. Based on the application, biosensors are classified into different types like bio-computers, glucometers & biochips

Figure 2.2 | Schematic of biosensors.



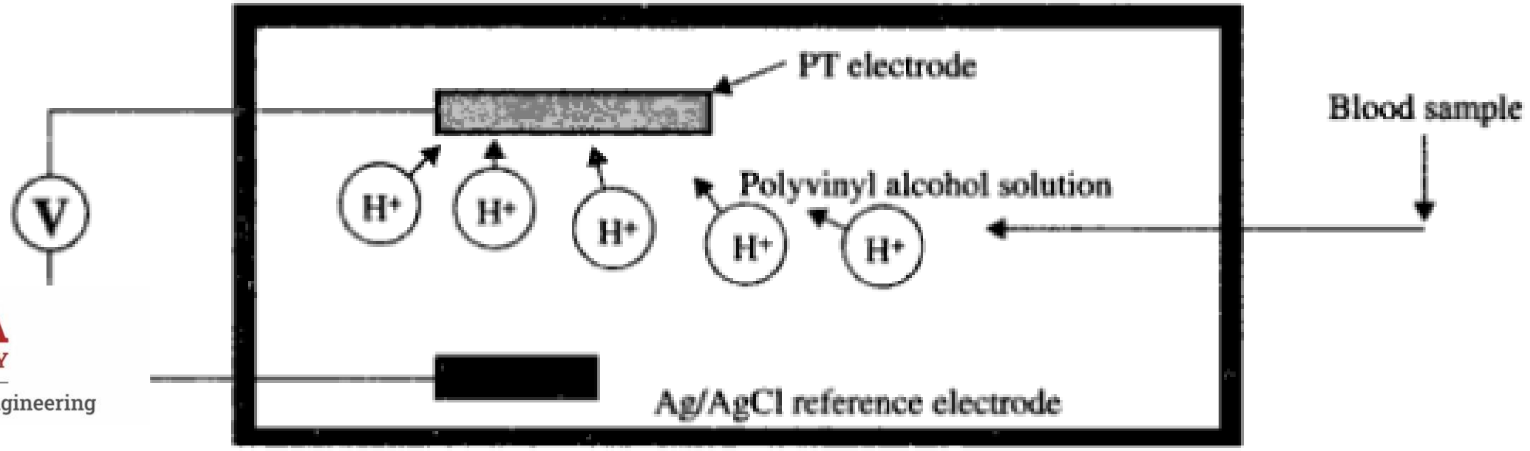
- The working principle of biosensors involves a few key components:
- **Recognition:** The biological element selectively interacts with the target analyte present in the sample.
- **Transduction:** This interaction leads to a change in the biological element, such as a change in electrical conductivity, pH, or light emission.
- **Signal Amplification:** Sometimes, additional components in the biosensor amplify the signal generated by the interaction between the biological element and the analyte.
- **Detection and Output:** The transducer detects the change and converts it into a measurable signal, which is then displayed or processed for interpretation by the user or an electronic device.

In Figure 2.1, a small sample of blood is introduced to a sensor with a polyvinyl alcohol solution. Two electrodes are present in the sensor: a platinum film electrode and a thin Ag/AgCl film (the reference electrode). The following chemical reaction takes place between the glucose in the blood sample and the oxygen in the polyvinyl alcohol solution:

$$\text{Glucose} + O_2 \rightarrow \text{gluconolactone} + H_2O_2$$

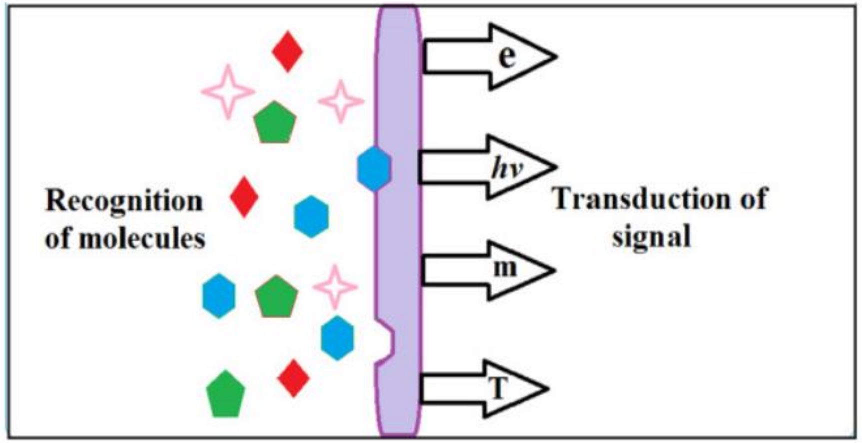
The H_2O_2 produced by this chemical reaction is electrolyzed by applying a potential to the platinum electrode, with production of positive hydrogen ions, which will flow toward this electrode. The amount of glucose concentration in the blood sample can thus be measured by measuring the current flow between the electrodes.

Figure 2.1 | A biomedical sensor for measuring glucose concentration.



Chemical Sensors:

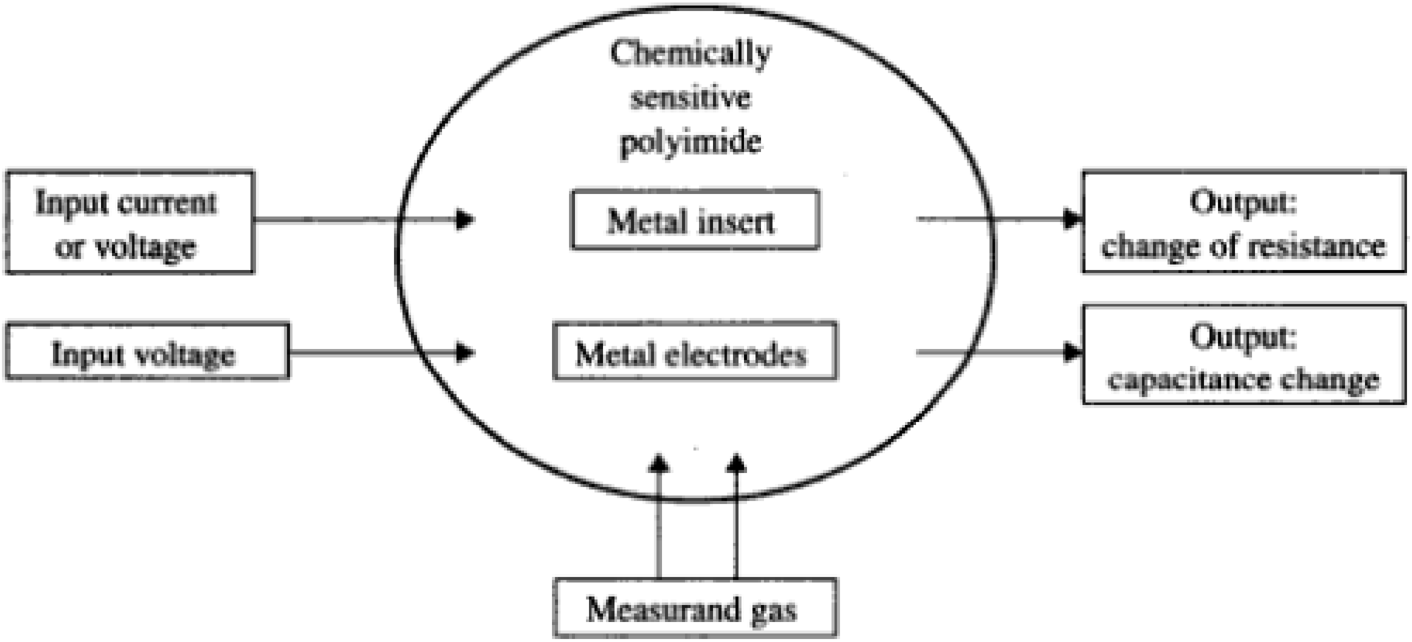
- Chemical sensors are sensor devices that convert chemical information (i.e., the amount of some individual compound) into a signal that can be analyzed.
- The sensing material and the transducer are generally the two main components. The target molecule interacts with the sensing material.
- This binding contact causes changes in a material attribute, such as mass and electrical conductivity, which will be converted into a quantifiable signal, generally an electronic signal, by the transducer
- The ideal chemical sensor should be an inexpensive, portable, reusable, and reliable device that quickly responds with a perfect choice for a certain target analyte present in any medium, at any concentration level.



- Chemical sensors are used to sense particular chemical compounds, such as various gas species.
- Many materials are sensitive to chemical attacks.
- For example, most metals are vulnerable to oxidation when exposed to air for a long time. Significant oxide layer built up over the metal surface can change material properties such as the electrical resistance of the metal. This natural
- phenomenon illustrates the principle on which many microchemical sensors are de- signed and developed.
- In principle oxygen gas can be sensed by measuring the change of electrical resistance in a metallic material as a result of the chemical reaction of oxidation. The presence of oxygen as detected by a chemical sensor, of course, needs to be much more rapid than that of natural oxidation of a metal, and the physical sizes of the samples are on the microscale.

- Based on material sensitivity to specific chemicals , different class of chemical sensor can be used as follows [Kovacs 1998].
- 1. Chemiresistor sensors: In Figure 2.4, organic polymers are used with embedded metal inserts. These polymers can cause changes in the electric conductivity of metal when it is exposed to certain gases. For an example, a special polymer called phthalocyanine is used with copper to sense ammonia (NH3) and nitrogen dioxide (NO2) gases.

Figure 2.4 I Working principle of chemical sensors.



2. Chemicapacitor sensors: Some polymers can be used as the dielectric material in a capacitor. The exposure of these polymers to certain gases can alter the dielectric constant of the material, which in turn changes the capacitance between the metal electrodes. An example is to use polyphenyl- acetylene (PPA) to sense gas species such as CO, CO2, N2, and CH4. (Figure 2.4)

3. Chemimechanical sensors: There are certain materials, eg. Polymers, that change shape when they are exposed to chemicals (including moisture).In this detection of chemicals by measuring the change in dimensions of material. An example of such sensor is a moisture sensor using pyraline PI-2722.

4. Metal oxide gas sensors. This type of sensor works on a principle similar to that of chemiresistor sensors. Several semiconducting metals, such as SnO2, change their electric resistance after absorbing certain gases. The process is faster when heat is applied to enhance the reactivity of the measurand gases and the transduction semiconducting metals. Figure 2.5 illustrates a microsensor based on the semiconducting material SnO2 [Kovacs 1998].

Some applications of chemical and biosensor technology include:

- General healthcare monitoring
- Screening for disease
- Clinical analysis and diagnosis of disease
- Veterinary and agricultural applications
- Industrial processing and monitoring
- Environmental pollution control
- Glucometers are a type Biosensors, which measure the concentration of glucose in blood.
- Agriculture Industry: Biosensors used for detection of pesticides and concentration of important nutrients.

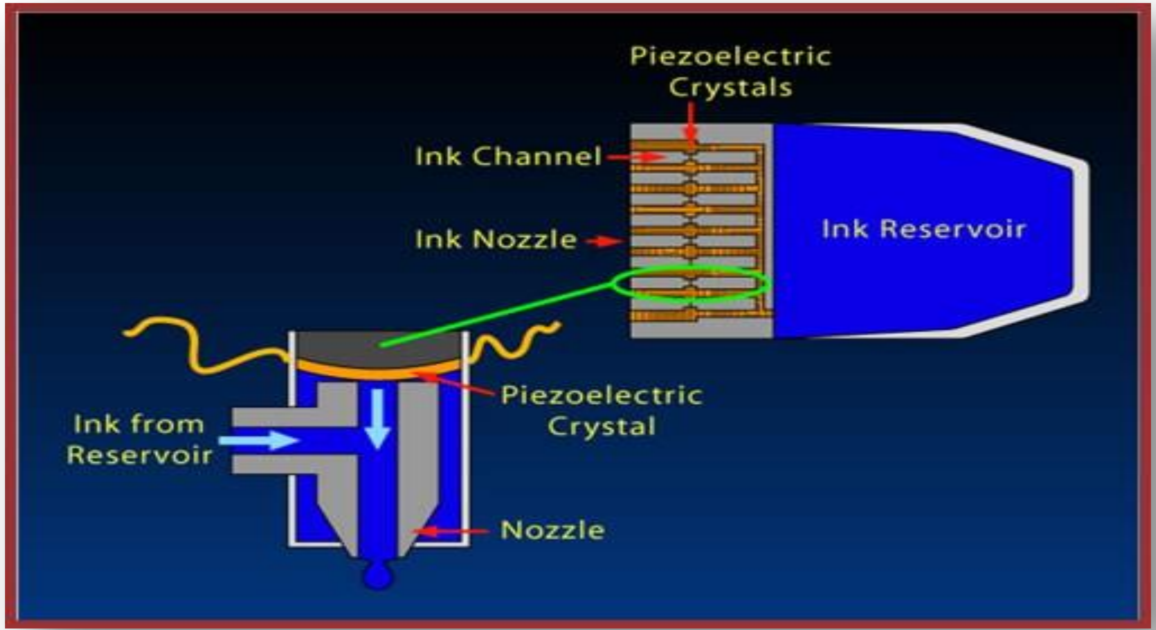
Applications of MEMS

Applications are developed where miniaturization is beneficial:

- Consumer products
- Aerospace
- Automotive
- Biomedical
- Chemical
- Optical displays
- Wireless and optical communications
- Fluidics

Specific Applications of MEMS

- MEMS nozzles and pumps for inkjet printers
- RF devices – Switches, phase shifter resonators, filters and variable antennas
- Fuel delivery systems that can control propellant motion
- Coating sensors that compensate for coating problems (adhesion, surface tension)

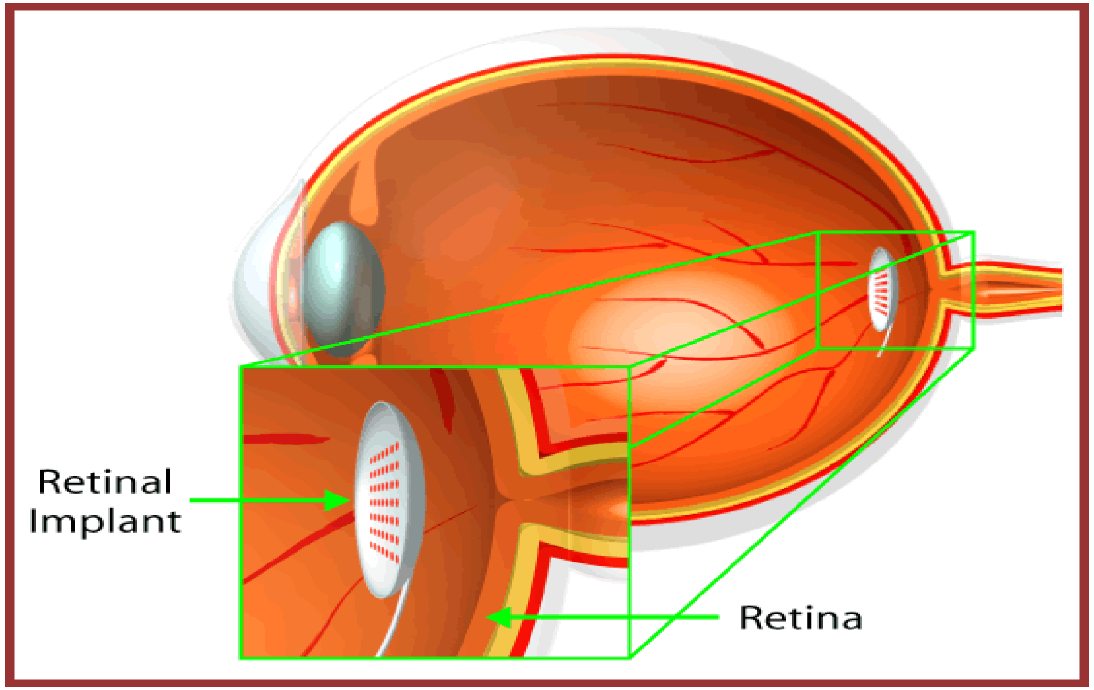


MEMS-based InkJet Printhead Piezoelectric or bubble jet based injection methods meeting the demand for higher and better resolution printing (smaller droplets). The graphic below illustrates a piezoelectric printhead. When a voltage is applied across the piezoelectric crystal, a minute amount of ink is released into the nozzle.

Retinal Prosthesis

- Medical MEMS – aka BioMEMS - can consist of in vivo (internal) components and in vitro (external) components such as this retinal prosthesis
- A microarray or retinal implant is implanted in vivo on the retina.
- An external camera and processor are mounted in a pair of glasses.
- Watch this video to see how it works.

https://youtu.be/Bi_HpbFKnSw



Retinal Prosthesis: What the patient sees

Images generated by the DOE-funded Artificial Retinal Implant Vision Simulator devised and developed by Dr. Wolfgang Fink and Mark Tarbell at the Visual and Autonomous Exploration Systems Research Laboratory, California Institute of Technology.
[Printed with permission.]

These images show what a patient with a MEMS retinal prosthesis should see. Increasing the number of electrodes in the retina array results in more visual perceptions and higher resolution vision.

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MEMS Sensors

Sensors are a major application for MEMS devices. Three primary MEMS sensors

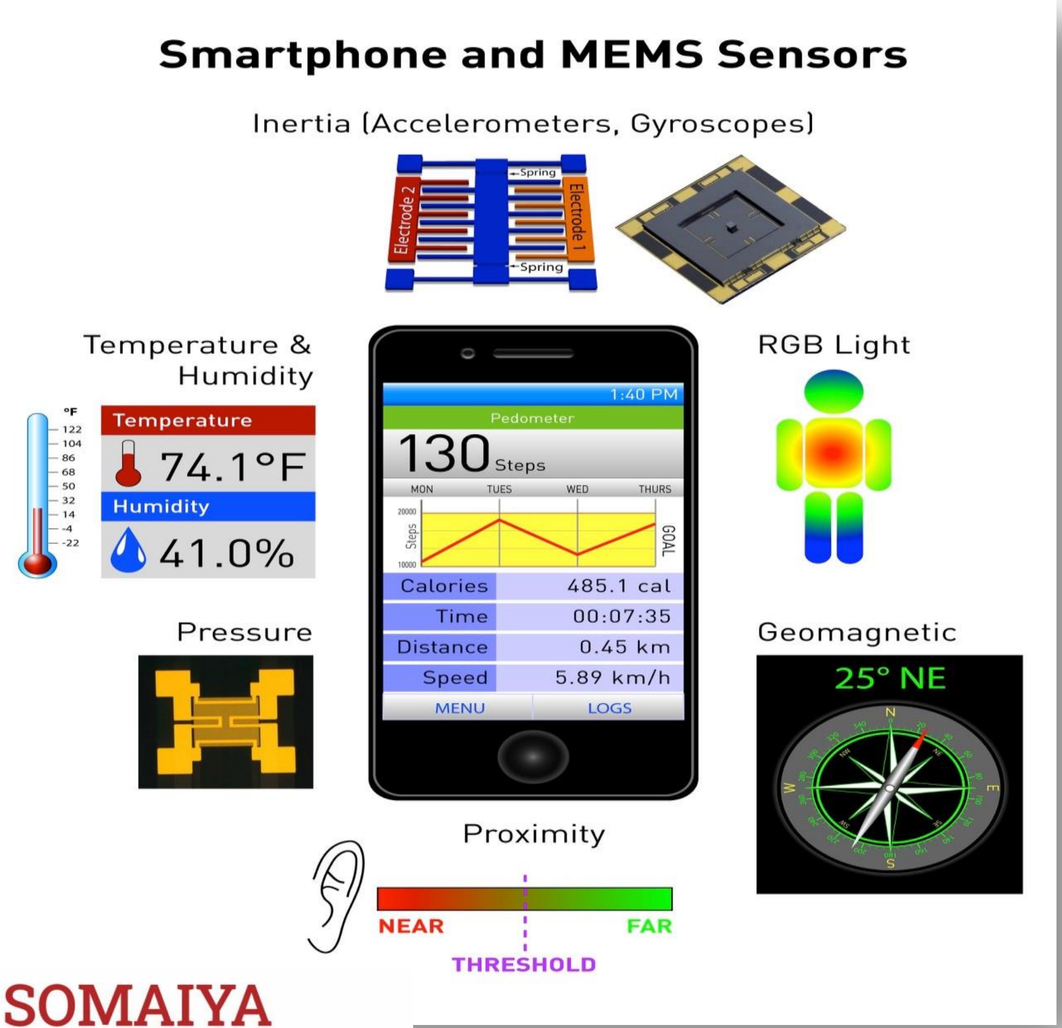
pressure sensors

chemical sensors

inertial sensors (accelerometers, gyroscopes)

MEMS sensors can be used in combinations with other sensors for multisensing applications. or example, a MEMS can be designed with sensors to measure the flow rate of a liquid sample nd at the same time identify any contaminates within the sample.

Smartphones and MEMS

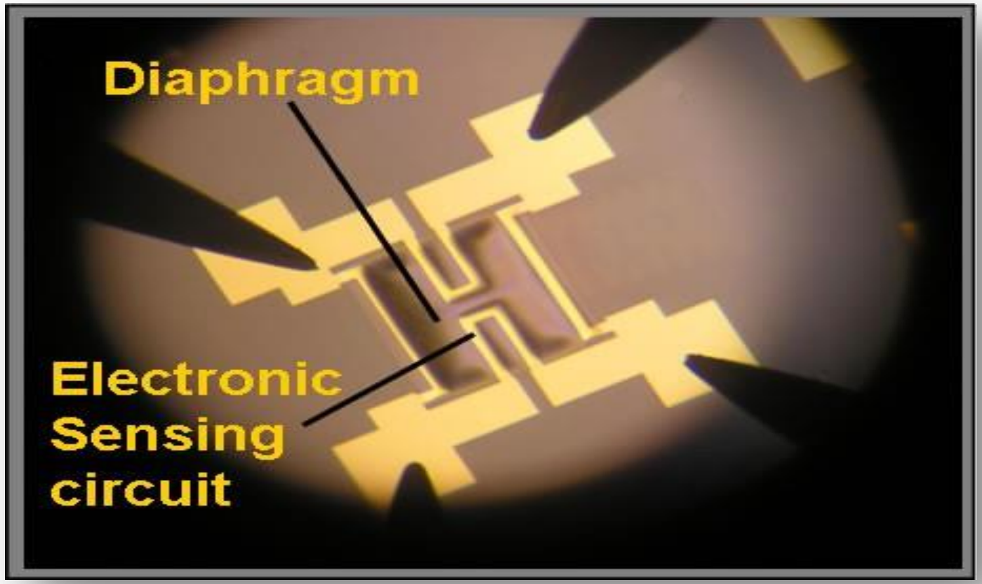


Smartphones can do much of what they do because of the various MEMS sensors built into them.

- Inertial
- Pressure
- RGB
- Geomagnetic
- Temperature
- Humidity
- Proximity
- To name a few

MEMS Pressure Sensor

- MEMS pressure sensors use a flexible diaphragm as the sensing device.
- One side of the diaphragm is exposed to a sealed, reference pressure and the other side is open to external pressure.
- The diaphragm moves with a change in the external pressure.



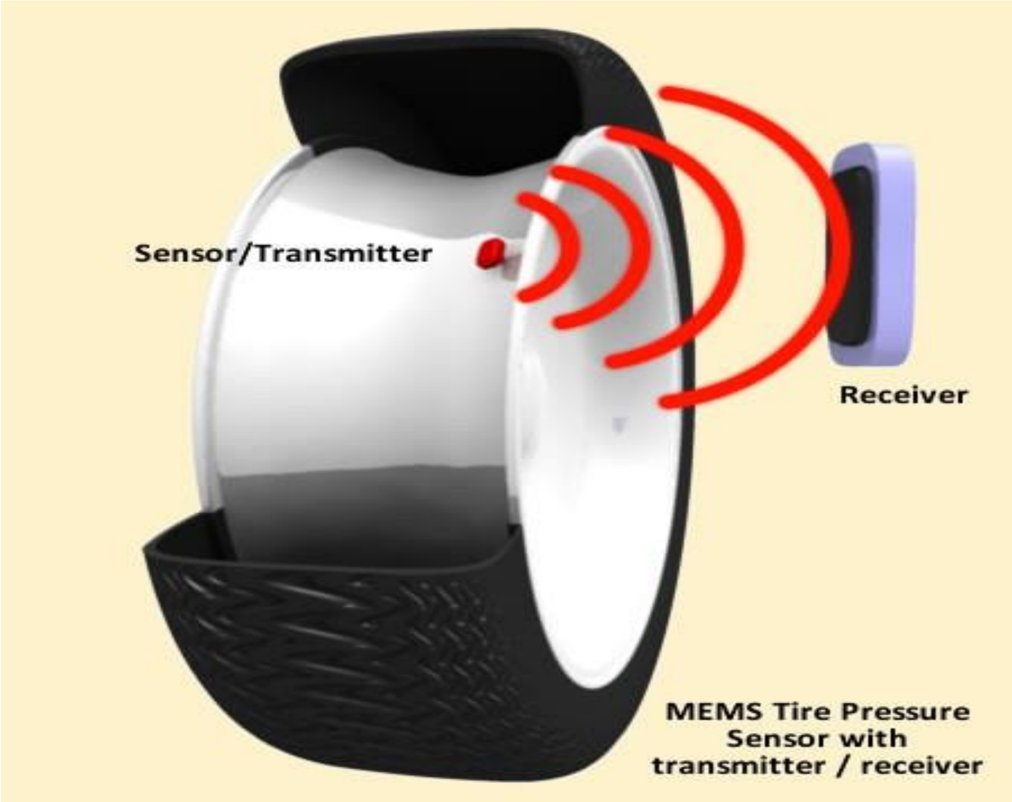
MEMS Pressure Sensor [Courtesy of the MTTC, University of New Mexico]

ssible applications for this type of sensor?

MEMS in the Automotive Industry

MEMS pressure sensors sense, monitor and transmit

- Tire pressure
- Fuel pressure
- Oil pressure
- Air flow
- Absolute air pressure within the intake manifold of the engine



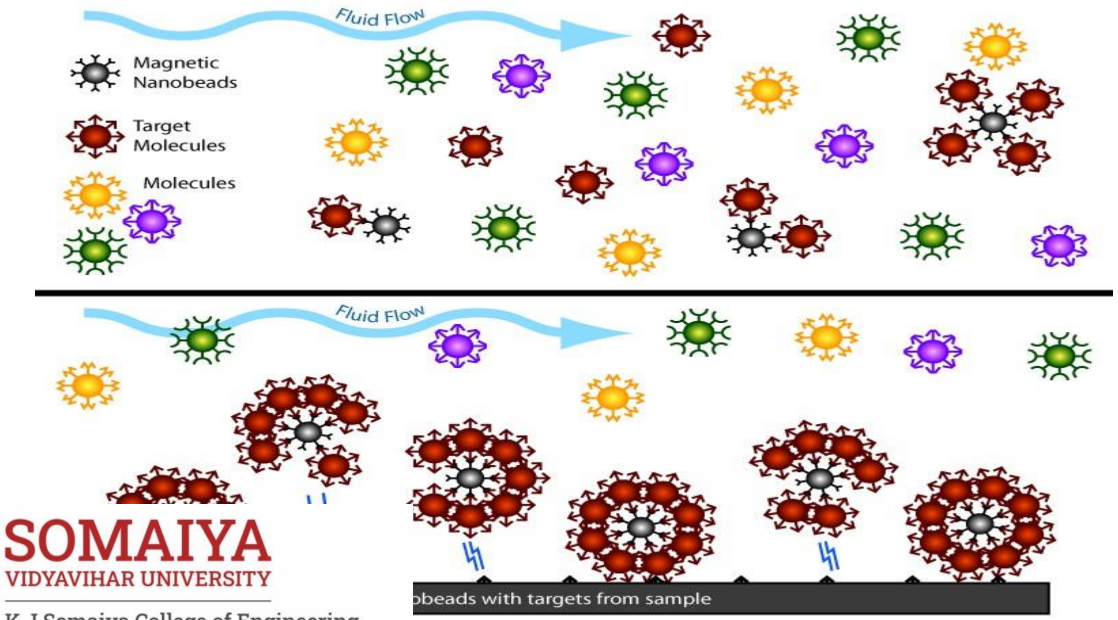
Pressure Sensors in BioMedical Applications

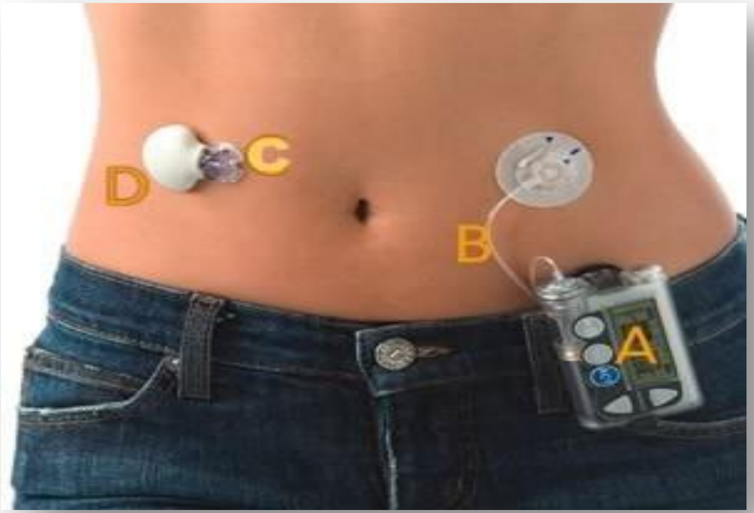
- Blood PS
- Intracranial PS
- PS in endoscopes
- Sensors for infusion pumps

RF (radio frequency) elements incorporated into the MEMS device allow the sensor to transmit its measurements to an external receiver.

MEMS in the Medical Field

- Drug delivery systems.
- Glucose monitors (chemical sensor)
- Clinical Lab Sample Analysis



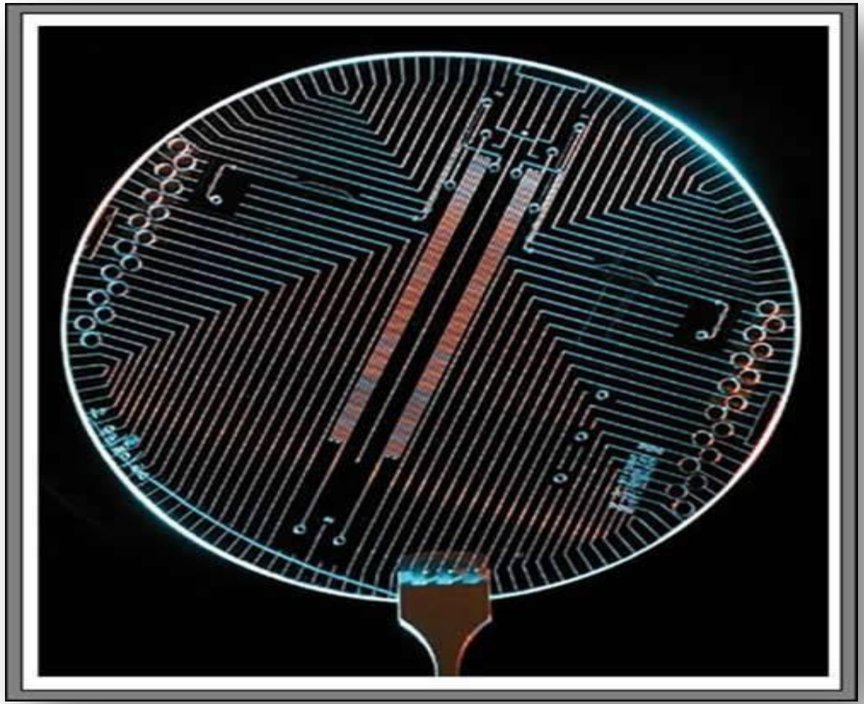


MiniMed Paradigm[R] 522 insulin pump, with MiniLinkTM] transmitter and infusion set.
A chemical sensor (C) measures the blood glucose and a transmitter (D) that sends the measurement to the a computer in (A). (A) also contains a
micropump that delivers a precise amount of insulin through the cannula (B) to the patient. This is a continuous bioMEMS monitoring and drug delivery system.
(Printed with permission from Medtronic Diabetes)

Clinical Laboratory Testing

A lab-on-a-chip (LOC) takes the laboratory testing of biomolecular samples (e.g. blood, urine, sweat, sputum) out of the clinical lab and places it in the field or point-of-care (POC).

LOCs use microfluidics and chemical sensors to simultaneously identify multiples analytes (substances being analyzed).



Lab-on-a-chip (LOC)

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