

MEMS & Microsystem

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.**

Function of MEMS

- **Sensing:** MEMS devices excel in sensing various physical parameters such as pressure, temperature, acceleration, humidity, chemical composition, and more. These sensors are crucial in applications ranging from automotive (airbag deployment systems, tire pressure monitoring) to healthcare (biomedical sensors for monitoring vital signs).
- **Actuation:** MEMS devices incorporate actuators that respond to sensor data or external stimuli, allowing them to perform specific mechanical actions. Examples include microvalves, micro-mirrors (used in displays or optical devices), and micro-pumps.
- **Signal Processing and Control:** Integrated electronics within MEMS devices facilitate signal processing, data transmission, and control functions. This enables the devices to process the sensed data and make decisions or take actions based on the received information.
- **Miniaturization:** MEMS technology enables the creation of highly functional devices in a compact size, allowing for portable and wearable applications. Miniaturization also reduces power consumption and production costs.
- **Biomedical Applications:** MEMS-based devices have numerous applications in healthcare, such as lab-on-a-chip systems for diagnostics, drug delivery systems, implantable sensors, and microfluidic devices for medical testing.
- **Telecommunications:** MEMS technology is used in telecommunications for creating micro-electromechanical switches, enabling faster and more efficient data transmission.

- ❖ **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.**

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:

- **Mechanical Properties:** Silicon exhibits excellent mechanical properties, including high stiffness and strength, which are crucial for constructing MEMS devices. These properties enable the fabrication of intricate structures with high aspect ratios and precise dimensions.
- **Thermal Stability:** Silicon has a high melting point and thermal conductivity, making it resistant to thermal deformation and enabling MEMS devices to operate under a wide range of temperature conditions without significant performance degradation.
- **Compatibility with Microfabrication Techniques:** Silicon is highly compatible with microfabrication techniques such as photolithography, etching, and thin-film deposition. This compatibility allows for the mass production of MEMS devices with high precision and reproducibility, leading to cost-effective manufacturing.

Silicon as a Substrates Contd

- **Electrical Properties:** Silicon is a semiconductor material with well-established electrical properties, making it suitable for integrating electronic components and sensors into MEMS devices. This integration enables the development of complex MEMS systems with integrated signal processing and control capabilities.
- **Biocompatibility:** Silicon is biocompatible, meaning it is non-toxic and does not induce significant immune responses when in contact with biological tissues. This property is advantageous for developing MEMS devices for biomedical applications such as implantable sensors and drug delivery systems.
- **Chemical Inertness:** Silicon is chemically inert, which enhances the stability and reliability of MEMS devices when exposed to harsh environments or corrosive substances. This inertness also allows for the integration of various surface coatings or functionalization techniques to modify the surface properties of MEMS devices for specific applications.

MEMS used in bio and chemical sensors

Microelectromechanical Systems (MEMS) are widely used in chemical and biological sensors due to their ability to integrate miniaturized sensing elements with electronic components, enabling the development of compact, sensitive, and portable sensor devices.

Miniaturization: MEMS sensors allow for the miniaturization of sensing elements, such as microfluidic channels, electrodes, and sensing elements (e.g., antibodies, enzymes, or DNA probes). This miniaturization enables the fabrication of highly sensitive sensors that require small sample volumes and can be integrated into portable devices for on-site analysis.

High Sensitivity and Selectivity: MEMS sensors can achieve high sensitivity and selectivity by incorporating specialized sensing materials or functionalized surfaces onto microfabricated structures. For example, chemical sensors may use microcantilevers coated with specific receptor molecules to detect target analytes, while biological sensors may employ microarrays of immobilized biomolecules for multiplexed detection of biomarkers.

Real-time Monitoring: MEMS sensors enable real-time monitoring of chemical and biological processes by integrating transduction mechanisms that convert molecular interactions into measurable signals. These signals can be electrical (e.g., capacitance, resistance, or impedance changes), optical (e.g., fluorescence, absorbance, or refractive index changes), or mechanical (e.g., deflection of microcantilevers).

Biological Sensors

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.

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.

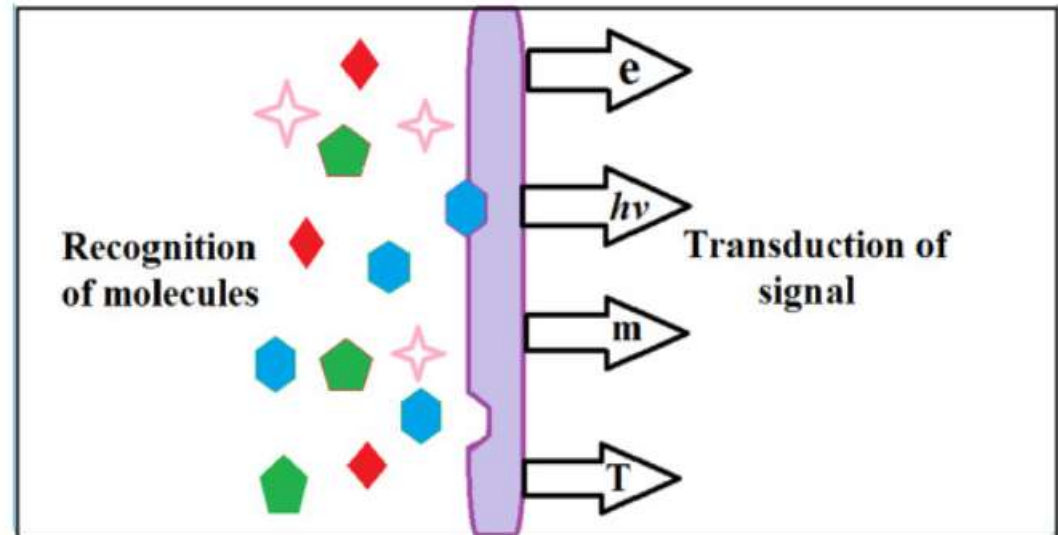
Signal Amplification: Sometimes, additional components in the biosensor amplify the signal generated by the interaction between the biological element and the analyte.

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.

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.

The magnitude of the measurable signal is proportional to the concentration of analyte. There are two major detection mechanisms in chemical sensors. They are photochemical and photometric, and are used to find the concentration or changes in the chemical reactions with most accuracy.



Applications of MEMS in chemical and biological sensors

- **Environmental Monitoring:** MEMS-based sensors are used for detecting pollutants, gases, and toxins in the environment. They can monitor air and water quality, detect hazardous chemicals, and provide early warning systems for environmental hazards.
- **Industrial Process Control:** MEMS sensors are employed in industrial settings for monitoring parameters such as temperature, pressure, humidity, and gas composition. They help optimize manufacturing processes, ensure product quality, and maintain safety standards.
- **Healthcare and Medical Diagnostics:** MEMS sensors play a crucial role in medical diagnostics, enabling the detection of biomarkers, pathogens, and disease-related molecules. They are used in point-of-care devices for diagnosing diseases, monitoring patient health, and managing chronic conditions.
- **Biomedical Imaging:** MEMS-based sensors are utilized in biomedical imaging techniques such as microfluidic systems, lab-on-a-chip devices, and miniature cameras. They enable high-resolution imaging, real-time visualization, and minimally invasive procedures for medical diagnosis and treatment.

Applications of MEMS in chemical and biological sensors

- **Drug Delivery Systems:** MEMS technology is employed in drug delivery systems for precise and controlled release of medications. Microfluidic devices, microneedle arrays, and implantable drug delivery systems utilize MEMS sensors to monitor drug dosage, release kinetics, and patient response.
- **Food Safety and Quality Assurance:** MEMS sensors are used in the food industry to detect contaminants, pathogens, and spoilage indicators in food products. They ensure food safety, quality control, and regulatory compliance throughout the production and distribution process.
- **Biological Research and Biotechnology:** MEMS sensors contribute to biological research by enabling the study of cellular processes, biomolecular interactions, and genetic variations. They are used in genomics, proteomics, and systems biology to analyze DNA, RNA, proteins, and other biological molecules.
- **Personalized Healthcare:** MEMS-based sensors are integrated into wearable devices, remote monitoring systems, and personalized health trackers to monitor vital signs, physiological parameters, and activity levels. They empower individuals to manage their health, prevent diseases, and track fitness goals.

Thank You