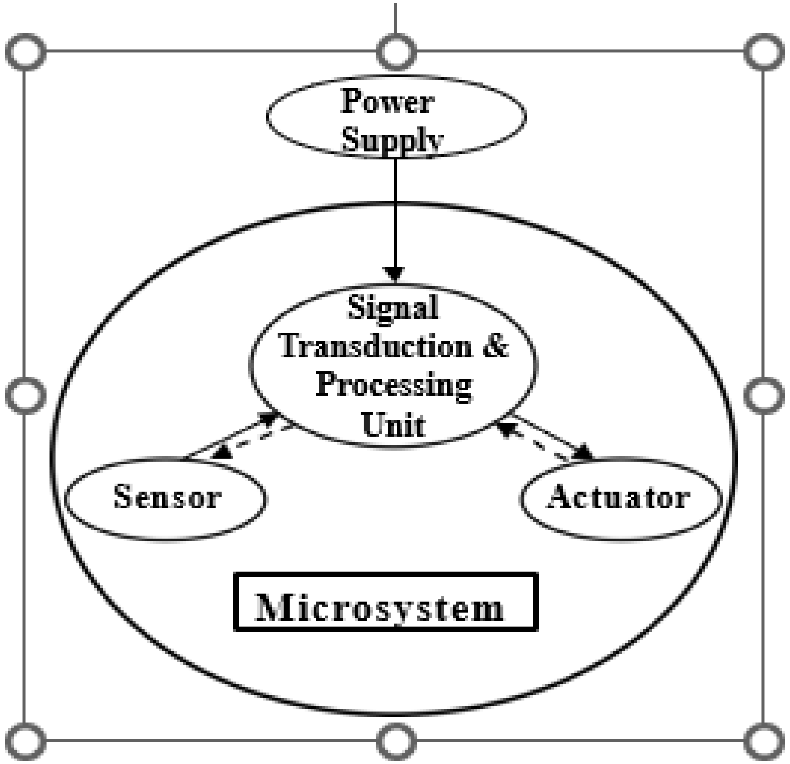
18ECO134T – Sensors and Transducers

Unit IV : Session 6 : SLO 2

MICROMACHINING

- MINIATURIAZATION – The Principal Driving Force for the 21st Century Industrial Technology



Components of Microsystems

Comparison of Microelectrics and Microsystems

Microelectronics	Microsystems (silicon based)
Primarily 2-dimensional structures	Complex 3-dimensional structure
Stationary structures	May involve moving components
Transmit electricity for specific electrical functions	Perform a great variety of specific biological, chemical, electromechanical and optical functions
IC die is protected from contacting media	Delicate components are interfaced with working media
Use single crystal silicon dies, silicon compounds, ceramics and plastic materials	Use single crystal silicon dies and few other materials, e.g. GaAs, quartz, polymers, ceramics and metals
Fewer components to be assembled	Many more components to be assembled
Mature IC design methodologies	Lack of engineering design methodology and standards
Complex patterns with high density of electrical circuitry over substrates	Simpler patterns over substrates with simpler electrical circuitry
Large number of electrical feed-through and leads	Fewer electrical feed-through and leads
Industrial standards available	No industrial standard to follow in design, material selections, fabrication processes and packaging
Mass production	Batch production, or on customer-need basis
Fabrication techniques are proven and well documented	Many microfabrication techniques are used for production, but with no standard procedures
Manufacturing techniques are proven and well documented	Distinct manufacturing techniques
Packaging technology is relatively well established	Packaging technology is at the infant stage
Primarily involves electrical and chemical engineering	Involves all disciplines of science and engineering

Scaling Laws in Miniaturization

- In this era of "think small," one would intuitively simply scale down the size of all components to a device to make it small. Unfortunately, the reality does not work out that way.

- It is true that nothing is there to stop one from down sizing the device components to make the device small. There are, however, serious physical consequences of scaling down many physical quantities.

- <u>TYPES OF SCALING</u>

- Scaling in Geometry
- Scaling in Rigid-Body Dynamics
- Scaling in Electrostatic Forces
- Scaling in Electromagnetic Forces
- Scaling in Electricity
- Scaling in Fluid Mechanics
- Scaling in Heat Transfer

SUBSTRATES AND WAFERS

- The frequently used term ***substrate*** in microelectronics means a **flat macroscopic object on which microfabrication processes take place.**

- There are two types of substrate materials used in microsystems: (1) active substrate materials and (2) passive substrate materials

- Active substrate materials are primarily used for sensors and actuators in a microsystem or other MEMS components(Si,Ge,GaAs,Quartz)

Silicon – an ideal substrate material for MEMS

- **Silicon (Si) is the most abundant material on earth. It almost always exists in compounds with other elements.**

- **Single crystal silicon is the most widely used substrate material for MEMS and microsystems.**

- **The popularity of silicon for such application is primarily for the following reasons:**

  (1) It is ***mechanically stable*** and it is ***feasible to be integrated*** into electronics on the same substrate.Electronics for signal transduction such as the p or n-type piezoresistive can be readily integrated with the Si substrate-ideal for transistors.

  (2) Silicon is almost an ***ideal structure*** material. It has about the same Young's modulus as steel ($2x10^5$ MPa), but is as light as aluminum with a density of about 2.3 g/cm^3.

(3) It has a **melting point at 1400^{o}C**, which is about twice higher than that of aluminum. This high melting point makes silicon *dimensionally stable* even at elevated temperature.

(4) Its **thermal expansion coefficient is** *about 8 times smaller* than that of steel, and is more than *10 times smaller than that of aluminum*.

(5) Silicon shows virtually **no mechanical hysteresis.** It is thus an ideal candidate material for sensors and actuators. Silicon wafers are extremely flat for coatings and additional thin film layers for either being integral structural parts, or performing precise electromechanical functions.

(6) There is a **greater flexibility** in design and manufacture with silicon than with other substrate materials. Treatments and fabrication processes for silicon substrates are well established and documented.