MICROSYSTEMS AND MICROFLUIDS

Micro systems:

Microsystems are miniaturized (silicon or polymer) devices which perform non-electronic functions typically sensing and actuation

Microfluidics:

Microfluidics is a multidisciplinary field intersecting engineering, physics, chemistry, biochemistry, nanotechnology, and biotechnology, with practical applications to the design of systems in which low volumes of fluids are processed to achieve multiplexing, automation, and high-throughput screening.

MICROSENSORS

Sensors used in MEMS are termed microsensors. They have physical dimensions in the submicrometer to millimeter range. They have lower manufacturing cost (mass-production, less materials),wider exploitation of IC technology (integration) ,wider applicability to sensor arrays, lesss weight.

Sensors in mems are classified as

Acoustic wave sensor

These generally measure chemical composition in gas.

Generate acoustic wave by converting mechanical energy into electrical energy.

Biomedical sensors

It has bio-sensors , bio-instruments, surgery tools and system for analysing quick, accurate and low cost testing of biological substance.

They are used to measure biological substance as well as for diagnostic purpose.

Eg: glucose + O_2 $\rightarrow$ gluconaldehyde + H_2O_2.

Chemical sensors

Used to sense particular chemical compound

Very simple

Eg: metals are vulnerable to oxidation when exposed to air for long, oxide on the metal change in properties such as electrical resistance.based on this principle the microsensors are designed and developed.

Chemi-resistors

Polymers used in this sensors can cause change in electrical conducting of metal .Eg:NH3

Optical sensors

Principle of interaction between photons in light and electron in solid that receive the light have been well developed to sense the intensity of light.

Solid state material that provide strong photon electron interaction are used as sensing material.

Selection of this material are based on the quantum efficiency.

Pressure sensors:

They are generally used in automotive and aerospace industry.

Human body is a complex system of pumps, valves ,vessels and interconnections.health monitoring of a patient requires knowledge of blood pressure ,bladder pressure and cerebral spinal fluid pressure.

Pressure sensors are inserted in the human body to monitor the above, these sensors should be small and ideally disposable.

Sensors are inserted to catheter and then to the arteries.

Thermal sensors

Thermocouple are most common transducer used to sense heat.

The principle is when electromotive force produced at the open end of 2 dissimilar metallic wires ,the junction of the wire is heated. Temperature produced at junction due to heating can be correlated to magnitude of produced emf or voltage.

ACTUATORS

An actuator is a type of motor that is responsible for moving or controlling a mechanism or system.

It is operated by a source of energy, typically electric current, hydraulic fluid pressure, or pneumatic pressure, and converts that energy into motion.

Types:

There are four main types of actuators: Hydraulic, Pneumatic, Electric and Mechanical.

Hydraulic actuator:

Hydraulic actuators consist of a cylinder or fluid motor that utilizes hydraulic power to facilitate mechanical process. The mechanical motion gives an output in terms of linear, rotary or oscillatory motion. Since liquids are nearly incompressible, they take longer to gain speed and power and also slow back down, but they can exert great force. The hydraulic actuator also allows for very precise control of the movement produced. In linear hydraulic actuators, a typical set-up is made up of a hollow cylinder that contains a liquid, usually oil, and a piston that is inserted in it. When pressure is applied onto the piston, objects can be moved by the force produced. Hydraulic actuators can be operated manually, such as a hydraulic car jack, or they can be operated through a hydraulic pump, which can be seen in construction equipment such as cranes or excavators.

Pneumatic actuator:

Pneumatic actuators work on the same concept as hydraulic actuators except compressed gas is used instead of liquid. Energy, in the form of compressed gas, is converted into linear or rotary motion, depending on the type of actuator. Pneumatic energy is more desirable for main engine controls because it can quickly respond in starting and stopping as the power source does not need to be stored in reserve for operation. Also, pneumatic actuators are preferred in places where cleanliness is important, since the fluid in hydraulic actuators might leak and contaminate the surroundings. However, pneumatic actuators are still likely to leak, making them less efficient compared to mechanical actuators. Another downside is that they take up a lot of space, create a lot of noise and are difficult to transport once installed in a place.

Electric actuator:

Electric actuators are devices powered by motors that convert electrical energy to mechanical torque. The electrical energy is used to create motion in equipment that require multi-turn valves like gate or globe valves. Since no oil is involved, electrical actuators are considered to be one of the cleanest and readily available forms of actuators. Electric actuators are typically installed in engines, where they open and close different valves. There are many designs of electric actuators and this depends on their function in the engine that they are installed in.

Mechanical actuator:

Mechanical actuators function through converting rotary motion to linear motion.when a rotary motion. Devices such as gears, rails, pulley, chain and others are used to help convert the motion. Some of the simple mechanisms used to convert motion are screws, where the rotation of the actuator's nut causes the screw shaft to move in a straight line, the wheel and axle, where the rotating motion of a wheel causes a belt or something similar to move in a linear motion.

ELECTROSTATIC FORCES

Electrostatic force is the phenomenon that results from slow-moving or stationary electrical charges. electrostatic force is the physical reaction that holds together the electromagnetic field created by subatomic particles, such as electrons and protons.Electrostatic force between electrons and protons is one of the strongest forces in the universe, even more powerful than gravity. A hydrogen atom, which contains only one electron and one proton, has the fundamental force of gravity keeping it together.As two surfaces come in contact with each other, charge exchange occurs, resulting in the development of electrostatic forces.

INTELLIGENT/ SMART MATERIALS

A smart material is one which reacts to its environment all by itself. The change is inherent to the material and not a result of some electronics. The reaction may exhibit itself as a change in volume, a change in colour or a change in viscosity and this may occur in response to a change in temperature, stress, electrical current, or magnetic field.

These smart materials include shape memory alloys, piezoelectric materials, magneto-rheological and electro-rheological materials, magnetostrictive materials and chromic materials which change their colour in reaction to various stimuli.

A smart structure incorporates some form of actuator and sensor (which may be made from smart materials) with control hardware and software to form a system which reacts to its environment. Such a structure might be an aircraft wing which continuously alters its profile during flight to give the optimum shape for the operating conditions at the time.

The current generation of smart structures featuring piezoelectric materials is generally synthesized with polymeric fibrous composite laminates which readily accommodate embedded piezoelectric actuators and sensors. Any external force applied on the structure will set vibrations and cause deformations in the structure. These deformations will cause stresses and strains in the structure. If the structure is embedded with smart crystals, the effects of the vibration can be controlled using a feedback mechanism. Since piezoelectrics undergo surface elongation when an electric field is applied and produce charge when surface strain is applied, they can be used as both actuators and sensors. Some commonly used actuation materials are lead z ir cona t e tit ana t e (PZT) and polyvinylidenefluoride (PVDF). Some ceramic electrostrictive materials are also used as actuation materials among them are lead magnesium niobate(PMN) , Terfenol , a rare earth magnetic like material and Nitinol (nickel titanium alloy). They are available in the form of wires or sheets. These substances have the ability to change the shape, natural frequency,damping or other mechanical characteristics in response to change in environment.

Shape Memory Alloys

Shape memory alloys (SMAs) are one of the most well known types of smart material. The SME describes the process of a material changing shape or remembering a particular shape at a specific temperature (i.e. its transformation or memory temperature).

Shape memory alloys have found a large number of uses in aerospace, medicine and the leisure industry.

Medical applications- Nitinol is biocompatible, that is, it can be used in the body without an adverse reaction, so it has found a number of medical uses. These include stents in which rings of SMA wire hold open a polymer tube to open up a blocked vein , blood filters, and bone plates which contract upon transformation to pull the two ends of the broken bone in to closer contact and encourage more rapid healing. SMAs also find use in dentistry for orthodontic braces which straighten teeth.

SMAs can be used as actuators,They can be used in cut out switches for kettles and other devices, security door locks, fire protection devices such as smoke alarms and cooking safety indicators.

Piezoelectric Materials

The piezoelectric effect and electrostriction are opposite phenomena and both relate a shape change with voltage.

An electrical field is generated if a mechanical force is applied to the material to change its shape. This is the piezoelectric effect. When a electric field is applied to the piezoelectric material it changes its shape very rapidly and very precisely in accordance with the magnitude of the field.

The piezoelectric effect was first observed in quartz and various other crystals such as tourmaline. Barium titanate and cadmium sulphate have also been shown to demonstrate the effect but by far the most commonly used piezoelectric ceramic today is lead zirconium titanate (PZT).

The main use of piezoelectric ceramics is in actuators, in the microbiology field in microscopic cell handling systems, in fibre optics and acoustics, in ink-jet printers where fine movement control is necessary and for vibration damping. The most well known application is in the sensors which deploy car airbags. The material changes in shape with the impact thus generating a field which deploys the airbag. Ionic polymers work in a similar way to piezoelectric ceramics, However they need to be wet to function. An electrical current is passed through the polymer when it is wet to produce a change in its crystal structure and thus its shape. Muscle fibres are essentially polymeric and operate in a similar way, so research in this field has focussed on potential uses in medicine.

Magnetostrictive Materials

Magnetostrictive materials are similar to piezoelectric and electrostrictive materials except the change in shape are related to a magnetic field rather than an electrical field.

Magnetostrictive materials convert magnetic to mechanical energy or vice versa.

The most common magnetostrictive material today is called TERFENOL-D (terbium (TER), iron (FE), Naval Ordanance Laboratory (NOL) and dysprosium (D)). This alloy of terbium,

iron and dysprosium shows a large magnetostrictive effect and is used in transducers and actuators. Magnetic materials contain domains which can be likened to tiny magnets within the material. When an external magnetic field is applied the domains rotate to align with this field and this result in a shape change. Conversely if the material is squashed or stretched by means of an external force the domains are forced to move and this causes a change in the magnetisation. Magnetostrictive materials can be used as both actuators (where a magnetic field is applied to cause a shape change) and sensors (which convert a movement into a magnetic field).Ultrasonic magnetostrictive transducers have been used in ultrasonic cleaners and surgical tools. Other applications include hearing aids, razorblade sharpeners, linear motors, damping systems, positioning equipment, and sonar.

Magneto- And Electro Rheological Materials

Electro-rheological (ER) materials change their properties with the application of an electrical field and consist of insulating oil such as mineral oil containing a dispersion of solid particles. Magnetorheological materials (MR) are again based on a mineral or silicone oil carrier but this time the solid dispersed within the fluid is a magnetically soft material (such as iron) and the properties of the fluid are altered by applying a magnetic field. In both cases the dispersed particles are of the order of microns in size. In both cases the smart fluid changes from a fluid to a solid with the application of the relevant field. The small particles in the fluid align and are attracted to each other resulting in a dramatic change in viscosity.

The effect takes milliseconds to occur and is completely reversible by the removal of the field.

The first industries to identify uses were the automotive and aerospace industries where the fluids are used in vibration damping and variable torque transmission. MR dampers are used to control the suspension in cars to allow the feel of the ride to be varied. Dampers are also used in prosthetic limbs to allow the patient to adapt to various movements for example the change from running to walking.