MEMS for Space Application:-

Accelerometer and Gyro chip are ~~also~~ used in space craft technology.

What ever the applications of space one of the major concern is weight. So miniaturization is one of the important issue.

MEMS technology finds one of it's best applications in space launching of satellites has become increasingly cost sensitive.

Ex:- Micro thrusters for micro satellite and pico satellite

Liquid Propellant MicroThruster For Aerospace Application:-

→ MEMS technology penetrates space market with the aim to ~~reserve~~ reduce cost & increase reliability. Micro propulsion is one of the application of the MEMS to the space environment.

→ The main application of the micro thruster is the micro propulsion for micro satellites (20 - 100kg) or nano satellites (<20kg).

Propulsion:- It is the act of changing the motion of the body.

Propulsion mechanism provides a force that moves bodies that are initially at rest.

Rocket propulsion provides thrust by ejecting stored matter called propellant.

Rocket propulsion system can be classified according to:-

- → Type of energy Source:- (chemical, nuclear or solar).
- → Basic function :- (attitude Control, orbit station keeping).
- → Type of Vehicle:- (aircraft, missile, etc).
- → Size
- → Type of propellant
- → Type of ~~[illegible]~~ Construction
- → Method of producing thrust.

Parameters of propulsion System:-

Thrust:- It is force produced by a rocket propulsion system acting upon a Vehicle or reaction experienced by it's structure due to the ejection of matter at high velocity.

Total Impulse:- (I_t)
It is the total energy released by the propellant in a propulsion system

$I_t = F \cdot t$ $\quad$ F = Thrust force
$\quad$ t = burning time.

Specific Impulse (I_s):-
It is Defined as total impulse per unit weight of Propellant.

Mass Ratio:-
Ratio of final mass and before rocket operation. (analyzing Flight performance).

Thrust to Weight Ratio:-
It expresses the acceleration that the engine is capable of giving to it's own loaded propulsion system mass.

Thrust of propulsion system:-

$$F = m * V_2 + (P_2 - P_3) \cdot A_2$$

P_2 = nozzle exit Pressure
P_3 = external pressure.
A_2 = Cross Sectional Area at nozzle exit.

→ Change in Ambient Pressure affect the pressure thrust i.e there is a Variation of rocket thrust with altitude.

→ Atmospheric pressure decreases with increase of altitude, So thrust and ~~spe~~ specific impulse will ~~decrease~~ increase as the vehicle is propelled to higher altitudes.

→ The change in pressure thrust due to altitude change Can be 10 – 30% of the over all thrust.

Propellant characteristics:-

* low absorption of moisture which often causes chemical deterioration.
* Safe, low cost, simple and reproducible.
* low technical risk, such as favorable history of Prior applications.
* Non toxic exhaust gases.

If any techical risk occurs it leads to loss of enormous amount not only effort but also money.

Solid Propellants:- Homogeneous mixtures of one or more Primary ingredients.

Examples:- DB:- double base
AP:- ammonium Per chlorate
Al:- Aluminium
HMX:- Cyclo tetramethylene tetranitramine etc.
DB, DB/AP/AL, DB/AP-HMX/AL.

liquid Propellant:-

Highest specific impulse chemical rockets use liquid Propellants. They Consist of a single chemical or a mix of two chemicals Called bipropellants.

i) oxidizer (liquid O_2, nitric acid)

ii) Fuel (alcohol, liquid H_2, gasoline).

Solid Propellant	liquid Propellant
Advantages:-	**Advantages:-**
→ Easier to store and handle than liquid propellant.	→ Liquid propellant Rockets have higher specific impulse thand Solid Propellant.
→ Simplicity and low Cost make Solid propellant rockets ideal for military.	→ Can be randomly stopped & restarted.
→ Can be stopped and restored. Few times if Programmed.	→ Most propellant have non-toxic exhaust which is environmentally acceptable.
→ It will not leak or spill.	→ Can be tested at ground or launch pad prior to flight.
→ It Can be stored for 5 to 25 Years.	
dis advantages:-	**dis advantages:-**
→ Exhaust gases are usually toxic	→ Relatively Complex design.
→ Cannot be tested prior to use	→ leaks or spills of several Propellants Can be hazardous. Can be minimized with gelled Propellants.
→ Need very much safety Precautions.	→ Few propellant gives toxic vapors (Red fuming Nitric acid)
→ Some propellant Can detoriate in storage (self decompose)	→ Cryogenic propellant Can not be stored for long period. except when the tanks are insulated.
→ Require an ignition system.	

Solid Propellant	Liquid Propellant
→ Preferred for missiles, ballastic missiles because instant readiness & their lack of leaks of hazardous liquids are important for these application.	→ Preferred for spacelaunched main propulsion units & upper stage because of their higher specific impulse. Favoured for post boost control systems and altitude control systems.

Different types of Micro Propulsion Developments:-

→ Cold gas system
→ Bi-propellant System
→ Mono propellant System
→ Field Emission Electric propulsion (FEEP)
→ Laser Plasma Thruster
→ Vaporizing Liquid Thruster (VLT).

In micro or pico Satellite program Vaporizing liquid Thruster is drawing lot of attention.

Vaporizing Liquid micro Thruster:-

→ VLT is a typical example for MEMS based micro Propulsion device.

→ It requires a heating resistor, a Vaporizing chamber, a nozzle, a propellant inlet and a micro channel.

→ Propellant can be fed into the thruster from a Propellant tank by Capillary force & Pressure.

Different structures of VLT Proposed:-

1) Side exit nozzle:-

Fluid enters through an etched inlet via hole into the vaporization chamber. The heater was placed on surface of the thruster. Glass used to seal the micro chambers. Glass was used only to provide window for visual observation of fluid flow.

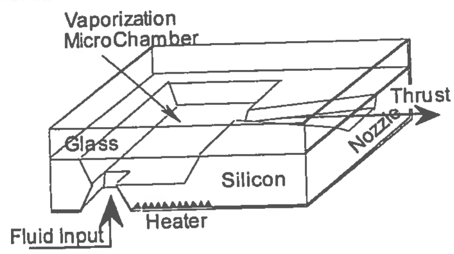


Fig. 1. Diagram of edge nozzle microthruster.

2) Top exit nozzle:-

The heater was placed on the surface of thrusted since Si is an excellent thermal conductor.

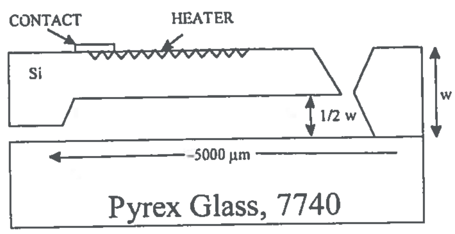


Fig. 2. Asymmetrical thruster design with side nozzle exit.

Vaporization of the fuel in the micro chamber has a longer pre vaporization warm up time because heat is delivered only to one side.

Diffused heaters provide sufficient thermal contact and conductivity to effectively heat the micro chamber.

This design is more power efficient and allows thermal input from heaters on both side of the micro chamber and utilizes the high thermal conductivity of silicon.

Fabrication process (Diffused heaters):-

→ P-type (1 0 0) oriented silicon

→ A thermal wet oxidation was performed at 1000°C to produce 0.8μm SiO_2.

→ Photolithography and oxide etching in HF performed to open the heater pattern. for diffusion of Phosphorous from solid wafers at 925°C.

Next a thin thermal oxide is grown at 1000°C in dry oxygen.

→ Deposition of 1500A° of LPCVD silicon nitride.

The heaters are created in the silicon on the side opposite to microchamber.

→ Anodic Bonding is done for bonding of substrate to glass.

→ Shadow masking is done for patterning of aluminium for electrical connection for diffuse heaters.

3.) Top exit nozzle design where identical wafers are silicon to silicon fusion bonded.

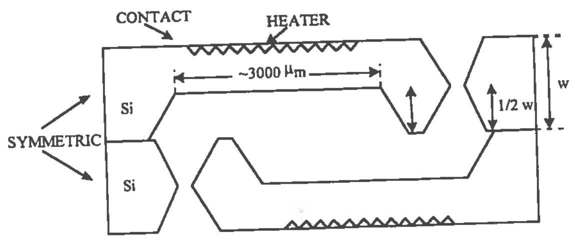


Fig. 3. Symmetrical thruster design with top nozzle exit.

This design is more power efficient allows thermal input from heaters on both sides of the micro chamber

The size and geometry of the exit nozzle, Vaporization chamber and heater are crucial in obtaining optimal Performance of linear thrust.

Application of Microthruster:-

→ Overcoming of rotational perturbations in Satellite orbits such as NSSK(North South Station keeping) of Satellite in geosynchronize orbits or alligning telescopes or antennas in low or medium earth orbits (LEO, MEO).

→ Potential mission such as interplanetary travel are also candidates for electrical propulsion. e.g mission to the moon, mission to mars, require high thrust & power.

→ For a typical NSSK task in a 350 km orbit a velocity increment of about 50m/sec every year or 500m/sec for 10 year might be needed.

Polymer MEMS & Carbon Nano Tubes (CNT)

Polymer MEMS:-

A considerable effort is focused on the use of polymers in microelectronics & MEMS. Polymers have been extensively used as both structural and functional materials for micro-devices.

Polymer based MEMS is rapidly gaining momentum due to their potential for conformability and their characteristics not available with silicon microsystems.

Polymers are materials that are organic compounds which have long molecular chains or networks.

The strength of polymers vary greatly ~~and~~ because of their atomic structure. most polymers are Poor electrical conductors, Some polymers are excellent insulators and are used in electrical insulation applications.

Features of Polymer MEMS:-

→ Flexibility and mouldability leading to ease of fabrication.

→ Intresting magnetic and optical behavior in some functional Polymers.

→ Wide choice to manipulate with their molecular structure and to synthesize polymers with tailor-made Properties. Possibility of building charged particles, Piezoelectric and Pyroelectric effect in the side chain.

→ BioCompatability, Easy packaging and scalability.

Why polymer MEMS:-

→ Polymers are flexible, chemically and biologically Compatible, available in many varieties and can be fabricated in truly 3D structures.

→ To make a fully functional microsystem necessary electronics have to be integrated:- Recent modified organic TFT may be a solution. TFT (Thin Film transistor).

→ The existing technology of organic TFT cannot rival well established silicon semiconductor technology, especially in terms of speed. ~~they are useful in~~ TFT are useful in displays, disposable devices and sensors where speed is not a major concern.

Advantages of Polymers:-

→ Light Weight
→ High Flexibility in Structures
→ High Corrosion resistance
→ low Cost fabrication process
→ Replicate :- Duplicate or Replicate large volume production which Can get from polymer devices.

→ Prototyping.

Issues in Silicon MEMS:-

→ Flexible, low cost and truly 3D MEMS not possible.

→ Not biocompatible.

→ Initial investment of clean rooms and equipment is very high.

→ Mask cost and aligning Problems.
(assembling different small pieces)

→ Planar sections at each stage for 3D MEMS

If the surface is not highly planar it is very difficult to go for lithography process and to get different structure one after another.

→ Integrated microsystems involve either
i.) MEMS first and CMOS second (or)
ii.) CMOS first and MEMS second

Thin film deposition and surface micromachining is difficult ∵ one have to protect the IC's or silicon chips when you go for micromachining of the silicon sensors or actuators.

From Silicon to polymers:-

← Microtechnology → ← Plasturgy →

Lithography-Etching		Replication-Milling	
0.1μm	1μm	100μm	1mm
Micro electronics	optical disc MOEMS	μFluidics μFuelcells	BioTech Connectors

← Polymer MOEMS →

From the diagram one side is Microtechnology other side is Plastrogy. nothing but polymers related processing.
In microtechnology we go for lithography and then etching it is the main process for MEMS in Micro technology.
The size of Real Micro electronics is 0.1μm and optical disc MOEMS size is 1μm.
In Replication the size is about 100μm this 100 micron designs are required for microfluidics and micro fuel cells if you go for 1mm, those are required for biotechnology connectors.
This microfluidics and Biotechnology Connectors which require a area of about 100 micron to 1millimeter fabrication is done by ~~rolling card~~ replication and milling technology.

Polymer MEMS → Issues & challenges:-

→ To design and develop flexible-light weight and low cost MEMS with organic electronics.

→ Should be easily scalable.

→ Incorporation of semiconducting properties. It is not easy although it is possible.

→ How to improve mobility and other characteristics?

→ Bottom up technology is not yet succesful in MEMS.

→ Integration of electronics such as organic ~~MC~~ TFT with MEMS structure.

→ Polymer MEMS

:- Polymer MEMS is a miniature device or an array of devices that combine electrical and mechanical components fabricated using either

i.) Self Assembly Monolayer (SAM) with polymer, Carbon and CNT (Carbon Nano Tubes).

ii.) Polymer based Micro Stereo lithography (MSL) technique with functionalized CNT and UV curable polymer.

Materials:-

→ UV curable semi conducting polymers
→ PVDF Poly Vinyl Dene Fluoride.
→ PVDF- TrFE (tri Fluro Ethylene)
→ Functionalized Carbon Nanotubes with Polymer.

3D patterning of polymers

→ Micro Fabrication, Replication.
→ Micro stereolithography, Micromolding
→ Jet molding.

Micro Stereo lithography For 3-D MEMS:-

→ Popular bulk and surface micromachining for silicon MEMS are not suitable for real 3D objects with high aspect ratio.

→ The LIGA process can create ~~microstructures~~ micro. structures with high aspect ratio.

→ All these processes are not suitable for curved surfaces.

→ The invention of new conducting polymer with piezo and ferro electric sub groups and organic thin Film transistor revolutionizes the MEMS industry for Conceiving micro chips that are cheap and long lasting.

→ With Combined architecture techniques, it is easy to integrate the silicon devices with polymeric 3D structures.

→ Micro stereo lithography is a Poor Man's LIGA for fabricating 3D high aspect ratio microstructures with curved surfaces; It employs surface micromachining techniques as in silicon processing.

MSL offers the opportunity to create:-

→ Implanted devices in the medical field.

→ High temperature SiC, TiC microdevices.

→ For Combined architecture with silicon too.

Polymer Surface Micromachining:-

Structural Polymer:-

→ Polymers which are basically used for structured devices. Electro Active Polymer (EAP) or Ionic Conducting Polymer (ICP) are UV curable polymer which provide mechanical strength, structural integrity, electrical conductivity.

→ New generation of ceramic side group material which are ferro electric and piezoelectric materials at nano-scale; which are made by using Sol-Gel, hydrothermal and Sintering techniques.

Sacrificial Polymer:-

Sacrificial polymer is an acrylic resin containing 50% silica and is modified by adding crystal violet.

The Etching Composition of sacrificial polymer is 2 mol/litre Caustic Soda at 80°c.

Carbon Nano Tubes:-

The Most significant spin-off product of fullerence research is the discovery of the C60 "bulky ball" and Nano-tubes by the 1996 Nobel Laureates Robert F. Curl, Harold and Richard E. Smalley.

These system Consists of graphic sheets seamlessly wrapped to cylinders with only a few nanometers in diameter and um long, thus the length to width aspect ratio is extremely high.

Applications:-

→ Nano size interconnect and packaging.

→ Effective structural material for 3D MEMS

→ Active layer for flexible organic Thin Film Transistor.

→ Gas Sensors with silica.

→ Bio-MEMS.

→ Artificial Muscles.

→ Use for Junction, a nano size transistors.

Processing challenges:-

→ Poor dispersion of Carbon Nanotubes in polymer.

→ Carbon Nanotubes are insoluble in any organic solvents.

→ High surface energy makes Carbon Nano tubes easy to agglomerate.

→ It is difficult to disperse Nanotubes in Matrix materials.

Chemical Functionalization of Carbon Nano Tubes:-

→ In functionalization a reagent is desired to selectively attack some π-bonds without bringing total destruction of the graphene structures of the nano tubes.

→ With the help of functional groups attached to the surfaces, CNTs could react readily with other chemicals and form well dispersion or even well aligned materials.

→ Polymerization of CNTs Using polymide:-

$$CNT \xrightarrow[\text{reflux}]{KMnO_4 + \text{Sulphuric acid}} CNT-\overset{O}{\overset{\|}{C}}-OH \qquad CNT-\overset{O}{\overset{\|}{C}}-OH \xrightarrow{SOCl_2 \text{ or } SOCl_3} CNT-\overset{O}{\overset{\|}{C}}-Cl$$

Functionalization

SWNT or MWNT (CNT).

SWNT → Single Wall Nano tube

MWNT → Multi wall Nano tube.

$$CNT-\overset{O}{\overset{\|}{C}}-Cl + HO-CH_2CH_2-O-\overset{O}{\overset{\|}{C}}-CH-CH_2 \rightarrow CNT-\overset{O}{\overset{\|}{C}}-CH_2CH_2-O-\overset{O}{\overset{\|}{C}}-CH-CH_2$$

$$PI + CNT-\overset{O}{\overset{\|}{C}}-O-CH_2CH_2-O-\overset{O}{\overset{\|}{C}}-CH-CH_2 \xrightarrow{UV} (CHCH_2)_2 - \text{ with } COOCH_2CH_3OOC\,CNT$$

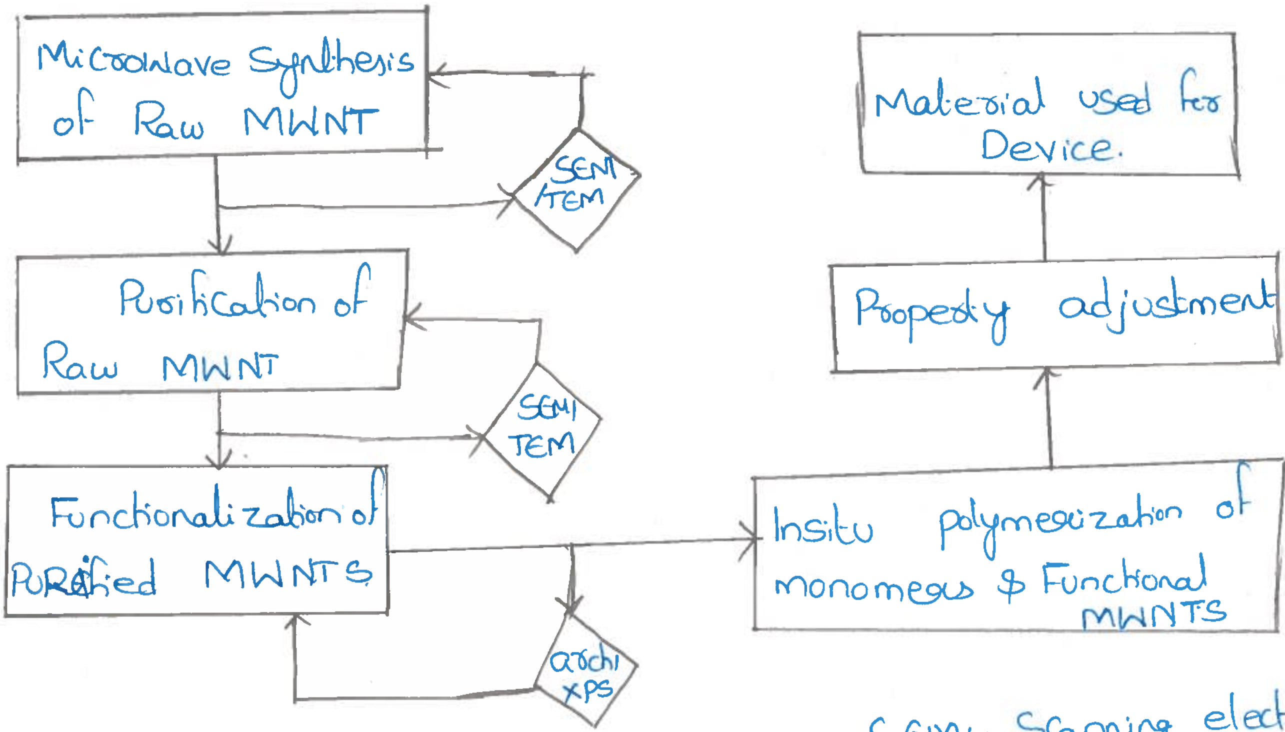
PI - Photo Initiator.

UV polymerization

after uv polymerization the reaction gets certain Carbon CNT with some organic functional groups attached with that to have certain desired properties in regardance with the reaction to the chemicals.

i.e Polymers and CNTs that can be ~~made~~ tailored by changing the synthesize by using a synthesis chemical.

Process Sequence for Device Fabrication:-



MWNTs ⇒ Multiwall Nano Tubes.

SEM:- Scanning electron Microscopy

TEM:- Transmission Electron Microscopy

→ First step is Microwave synthesis of Raw MWNT during that continuously you have to monitor by seeing the structure using SEM/TEM.

→ Purification of Raw MWNT i.e to purify the Nanotubes and continuously monitor by using SEM/TEM.

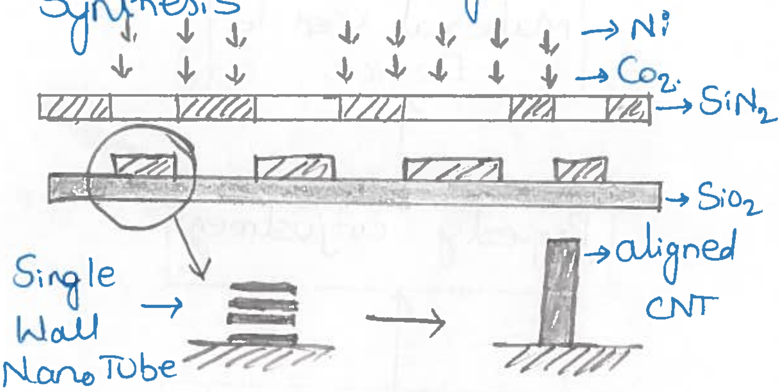
→ Functionalize the purified Raw MWNT's with some other chemical composition using photo Initiator or some other of certain mechanism monitored by tools XPS or arch.

→ In situ polymerization of monomers and functional MWNTS:- on site Polymerization.

→ Property adjustment:- Making of Tailored made approach to get desired properties of the polymer materials along with CNT which leads to the Material which can be used for Device making.

→ Types of Carbon Nano Tubes are either aligned or Coiled type CNT
→ Cost depends on type of Carbon Nano Tubes. and functionalization.
→ In-situ polymerization is an issue.
→ Functionalization issues of CNTs are Side, Surface and end (Shape)

Synthesis of aligned CNTS:-



→ Mixture of C60 and nickel is steered to specific surface sites by evaporating through Mask

→ The mask has an array of holes of 300nm and can be moved with a precision of 1nm.

→ The C60/nickel mixture is evaporated sequentially in ultra high Vaccum so as to form alternating layers of C60 and nickel with No impurities.

→ Finally heat it up in the presence of a magnetic field. In this step C60 molecules are transformed into bundles of perfectly aligned Nano tubes

Applications of Carbon NanoTubes (CNT):-

Biotechnology :- Lab-on-chip
miniaturized device for manipulating and sorting individual cells using Dielectrophoretic - DEP forces.

Energy:- Micro Fuel Cell:-
oxygen and hydrogen are the main sources of energy which is combined to form a Micro Fuel cell using two techniques:- 1.) Silicon substrate Technology on Silicon gound
2.) Planar technology on Polymer substrate technology on Polymer Pillar.

Wafer bonding & Packaging of MEMS:-

The major difference between VLSI and MEMS is in the Case of MEMS 2 or 3 even multiple layers of wafers has to be bonded together to get Complete structure.

VLSI directly may not be used in Case of MEMS since the requirements are different and have to satisfy a lot of special aspects in Case of MEMS.

Assembly & Bonding:-

→ Fabrication of a complete mechanical devices needs the assembly of the individual Components formed using micromachining technique.

→ Wafer Bonding in Conjuction with micromachining allows the fabrication of 3D structures that are thicker than a single wafer.

→ Bonding of two substrates provides improved Performance and functionality but critical in many MEMS applications.

Process developed for silicon bonding:-

→ Bonding of hydrophobic wafers.

→ Intermediate layer bonding

→ Fusion bonding (Direct bonding).

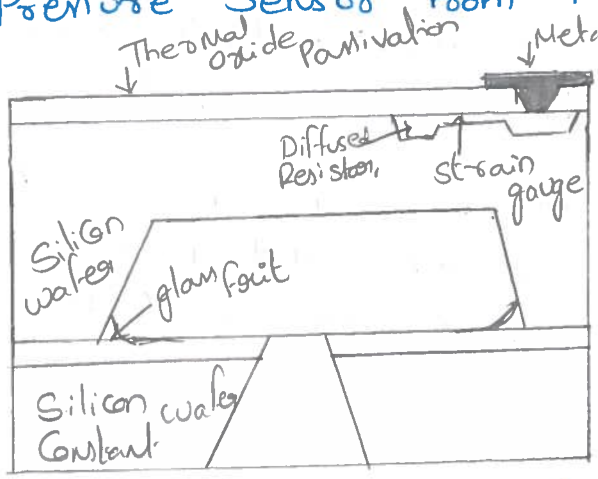
→ Contact substrates and thermal anneal.

→ Anodic bonding

→ Needs an electric field and temperature.

Examples of Sensors using Wafer bonding:-

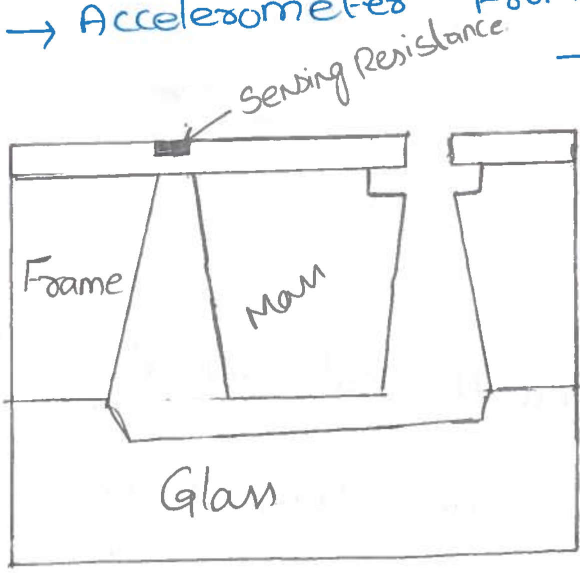
1.) Pressure Sensor from Motorola:-



→ Bottom layer is a silicon Constant wafer and top is a silicon wafer which has been etched on top layer it has strain gauge piezoresistive, Metallization and thermal oxide passivation.

The top wafer is bonded with Bottom wafer with the help of glass frit. Glass frit is basic glass powders which has got very low melting point.
Glass powders are distributed and put the top wafer and apply certain temperature or annealing so that glass frit will be melt and helps ~~for~~ as adhesion for top layer with Bottom layer.

→ Accelerometer From Lucas Nova:-

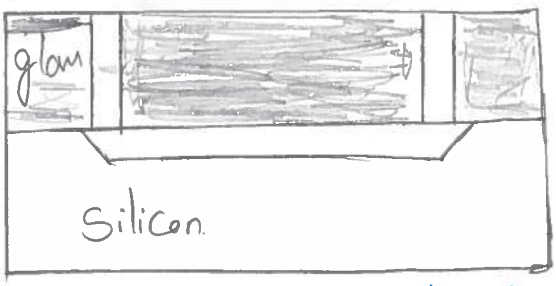


→ Basically it has 3 pieces one is Middle i.e Mass 2nd is Frame and 3rd is glass.

→ On top layer it has seismic mass Sensing Resistance and silicon Mass.

Here top layer is silicon and bottom layer is silicon glass and in this normally fusion bonding is used.

→ Micro Fluidic channel:-



top layer is a glass plate which has holes one for inlet and another for outlet of fuel. Bottom layer is silicon with channel and chamber. Here silicon and glass has to be bonded This is Silicon to glass bonding.

Accelerometer Packaging Trends:-

	Header	Cerdip/Cerpa	LCC	QFN	WSP
Xmm	10	10	5	4	2
Ymm	10	10	5	4	2
Zmm	7	5	2	1.45	0.9

All x, Y, Z are in millimeter.

→ In Header type packaging all the dimensions are 10mm x 10mm x 7mm. after that people shifted to Cerdip or Cerpa type of packages in this the dimensions are 10mm x 10mm and thickness reduced to 5mm.

→ Next in LCC package (leadless chip Carrier). which has a dimensions 5mm x 5mm x 2mm thickness.

→ Q FN (Quad Flat No leads). is a 4mm x 4mm x 1.45 mm thickness and next it is WSP and it has dimensions. 2mm x 2mm x 0.9mm thickness.

So the basic objective is to reduce the size of chip as well as thickness and dimensions. with not at the cost of Performance.

→ Bonding of Hydrophobic Wafers:-

→ two hydrophobic silicon wafers bonded together when pressed at a particular temperature.

→ Spontaneous bonding of hydrophobic wafer leads to very week bonding if not annealed.

→ Bonding energy obtained with hydrophobic wafers as low as $26 mJ/m^2$.

→ During annealing of the wafers, the bonding energy raises quickly when the temperature exceeds 400°C and reaches to 2.5 J/m² at 600°C.

Silicon Fusion Bonding:-

Direct bonding is possible between all materials if surface roughness is smaller than few nanometers and radius curvature is large. (<10A roughness)

→ The process of Si bonding is the mating together of a pair of wafers at room temperature followed by thermal annealing at temperature 700 to 1100°C.

→ Bonding Si/Si, Si/ox, Si/Nit, ox/ox, Nit/Nit

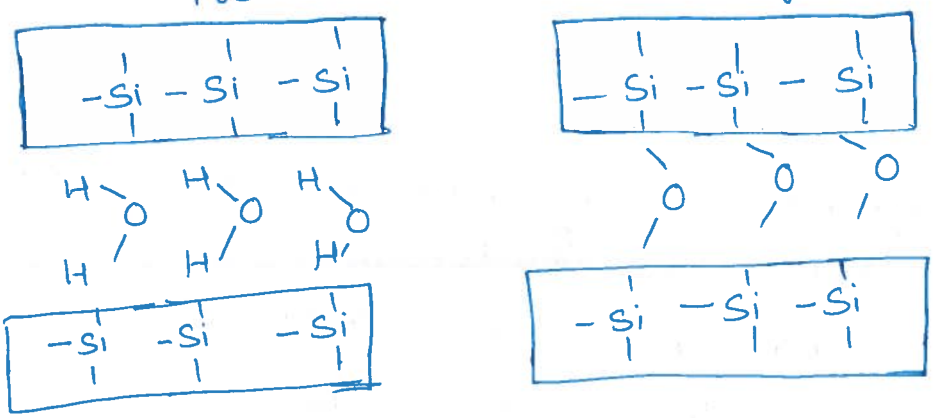
Si - silicon   ox - oxide   Nit - Nitride.

→ The wafers adhere at room temperature via hydrogen bridge bonds (water molecules) that subsequently react during the annealing process to form Si-O-Si bonds.

→ High annealing step is necessary to increase the strength of the bond.

→ 800°C anneal results sufficient bond strength for subsequent process such as grinding, polishing and etching.

Pre bond   Annealing at 1100°C



Problems of high Annealing Temperature:- (>800°C).

→ Doping Profile change:- Profile of Dopants may change.

→ Thermal stress:- When at high temperature coming to room temperature the stress development will be high.

→ Defect generation:- (Crystal defects).

→ Contamination:-

→ limits post metallization bonding because most of the Common metal used in metallization melt above 450°C.

Thus a low temperature bonding method with reasonable bond strength have to be developed.

Bond Quality for Different Annealing Temperature:-

A 1000°C anneal for 2 hours give sufficiently high bond strength and is not possible to seperate the two bonded Si wafers without breaking silicon.

Structure	Anealing temp (°C)	Bond strength (Jm^{-2})
Si/Si	450	0.5
Si/Si	800	0.6
Si/Si	1000	2.6
Si/Si_3N_4 (140nm)	800	0.9
"	1000	cleavage
Si/Si_3N_4 (300nm)	1000	cleavage.

Critical issues of Wafer bonding:-

→ Both the surfaces that are fusion bonded have to be perfectly smooth and clean.

→ Required optimized processing such as wafer surface inspection, surface pretreatment, mechanically controlled and aligned mating in a particle free environment.

→ Bonding of wafers covered with thin thermal oxide/nitride results in homogenous bonded wafers. thicker oxide or nitride films develop voids during annealing.

→ In case of poly-si bonding to Si, a polishing step is necessary to produce two smooth defect free surfaces.

Anodic Bonding:-

The term anodic bonding refers to bonding assisted by an electric field.

advantages:-

→ low process temperature (450°c)

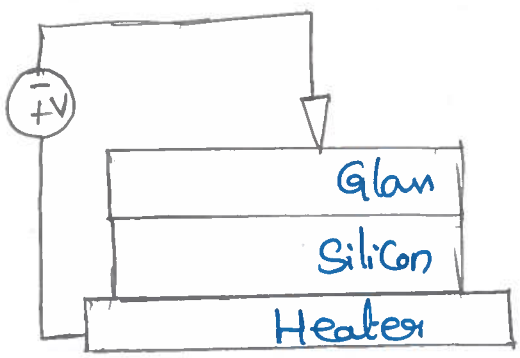
→ low Residual stress. (If temperature is low stress formation will be low).

→ less stringent requirements on the surface. Quality of the wafers as compared to fusion bonding.

→ A well developed Technology with high yield and it is a dust free environment.

Anodic Bonding Process:-

Anodic bonding is usually established between a sodium glass and silicon for MEMS.



For anodic bonding a cathode and anode attached to the glass and silicon wafer. voltages applied range from 200V to 1000V. and at the same time anode is put on a heater providing the bonding temperatures around 180 to 500°c.

During bonding oxygen ions in glass migrate into the silicon resulting the formation of silicon dioxide layer between silicon wafer and glass wafer and form a strong chemical bond.

Requirements for Anodic bonding process

The surface roughness of the wafers must be smaller than 1μm and the surfaces must be clean and dust free.

The native oxide layer on the silicon must be thinner than 200nm

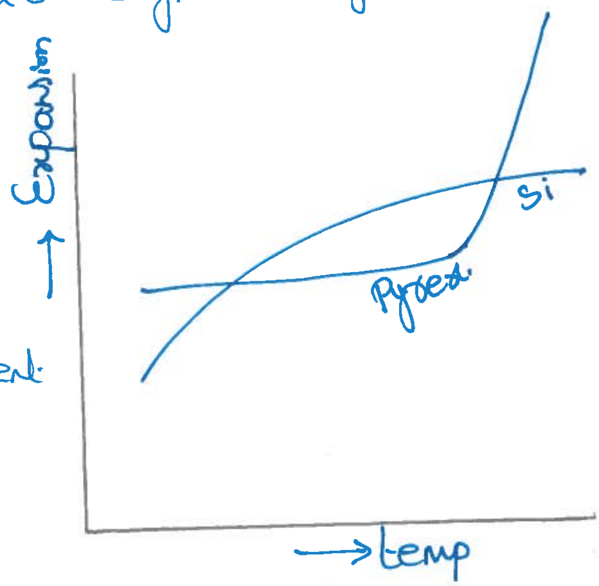
The metal must not inject charge carriers into the glass.

The thermal expansion coefficients of the bonded materials must match in the range of temperatures.

Corning 7740 glass wafers (Pyrex) most commonly used.

Bonding process limited to about 450°c since the expansion coefficient deviate significantly.

Anodic bonding is now a well developed technology. This process has high yield if care is taken to achieve good cleaning procedures and dust free environment and if polished wafers are used.



Intermediate layer assisted bonding:-

This type of bonding for MEMS requires an intermediate layer which can be polymer, solder, glasses etc. to fulfill the bonding.

~~To fulfill~~ one of the earliest wafer bonding is eutectic bonding utilized gold as the intermediate layer for Si-Si bonding.

Materials used as the intermediate layer for bonding ~~with~~ have to be done at low temperature should have high strength and low stress.

→ Main failure of this mechanism is the formation of voids in the bonding.

→ Voids are viewed using IR, ultrasound or x-ray topography.

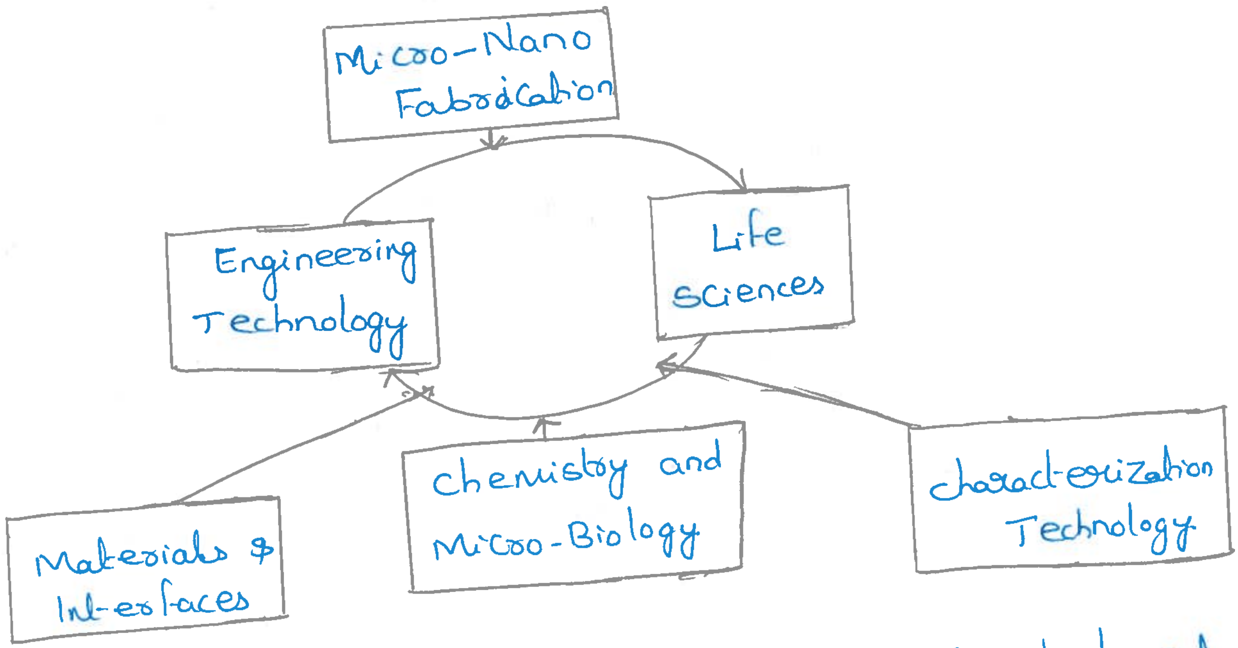
→ Voids appear as regions of different contrast.

MEMS for Biomedical Applications:-

If something is made for human body for biological applications one have to take 100 percent precaution before using it.

Sensors must be high precision and good quality. If sensors and actuators used for living beings it has to qualify some of the aspects.

MEMS which are coming up for biological application the real life practical testing is becoming more and more difficult until unless you get permission from different government authorities.



Understanding of materials which are going to use for biological application and their interfacing with biological system.

One must know in detail about micro-biology and Bio-chemistry and good knowledge about characterization technology. in many cases it should be noninvasive.

Biotechnology encompasses...

- → Micro and Nano-fabrication
- → System :- MEMS, NEMS
  - Micro Electro Mechanical System
  - Nano Electro mechanical system.
- → Biological & chemical systems ranging from cellular to molecular level. and must reach to cell level. For DNA Research or gene research then one have to know microbiology fully.
- → Techniques and materials to interface the biological and synthetic world.
- → Characterization of such hybrid bio-electronic systems characterization (how you get the output and functioning of sensors)

Bio-MEMS Can be defined as:-

Devices or Systems, Constructed using techniques inspired from micro/nano scale fabrication that are used for processing, delivery, manipulation analysis or Construction of biological and chemical entities

Analytical devices that Combine a biologically sensitive element with a physical or chemical transducer to selectively and quantitatively detect the presence of specific compounds in a given external environment.

→ Bio chips Can detect cells, microorganisms, Viruses, proteins, DNA, and small molecules, of biomedical, importance and interest.

→ Bio MEMS application ranges Diagonostics such as DNA and Protein microarrays, micro fluidics, tissue engineering, drug delivery systems, implantable BioMEMS, etc....

→ BioMEMS working Environment :- working environment of BioMEMS have to protect because should have extra precautions and one may be dangerous to mankind. dealing with chemicals, viruses,

Biological MEMS - Materials:-

→ Silicon and microelectronic materials:-
It is used but is not a good choice of material to be implanted into human body.

→ Glass & Quartz:- For external diagnostic purpose.

→ Polymers:- It is the most favorable material for bio-MEMS application.
Ex:- Poly dimethy siloxane → PDMS
Poly methy methacrylate → PMMA
Teflon

Micro Sensors For BioMechanics:-

Strain gauges (Piezoresistive):-

→ To characterize the forces in the body motion.

→ orthopedic research and the study of muscles in between cellular levels

→ understanding inner cellular muscle function would allow the development of improved locomotion therapies and prosthetic devices.

Accelerometers:-

→ Inertial micro sensors are useful to determine impact level and patient posture.

Pressure Sensors:-

→ Human body is a complex system of pumps, Valves, Vessels, and interconnects.

→ Health monitoring of a patient requires knowledge of blood pressure, bladder pressure.

→ Pressure sensors inserted into the body must be small and ideally disposable.

→ Applications includes medical diagnostic instruments drug screening, environment monitoring.

→ Challenges - delivery, reaction Control.

Impedance Sensors:-

Gases or Vapors and their relative Concentration changes conductivity of some materials e.g Conductive polymers Metal oxides.

Polymer Based Gas Sensors:-

Many polymers will geometrically swell reversibly when exposed to certain gases swelling to a greater or lesser extent depends on gases.

Polypyrrole:- It is a conductive polymer used as a chemiresistor.

Insulating polymers are doped with conductive Particles to reduce their Conductivity.

Resistance of doped polymer. will change as a function of chemically specific and Concentration dependent swelling.

certain diseases cause the body to generate specific gases that are not normally present gas-gas sensors may help diagnose patient health.

→ Response pattern of different polymer is needed to identify specific gases.

→ Capacitively detection of swelling may also be used for detection and Concentration of gases.

Electrochemical Sensors:-

oxidation/reduction of chemical species on a conducting electrode can be observed by measuring the movement of charge - potentiometric and amperometric (current generated by reaction) sensing.

Micromachining process can be used to accurately and reliable define the area number and relative Position of electrodes that are exposed to the solution.

Ex:- Glucose oxidase enzyme to detect glucose

→ local PH

→ oxygen Concentration

→ H_2O_2 "

Ion - Sensitive FET (ISFET):-

→ An ionic solution acts as gate of FET which makes the device sensitive to the overall ion Concentration of solution.

→ Good PH sensor.

→ By Coating the gate of FET with a Compound that will selectively bind or allow to pass only specific ions or molecules.

→ challenges are drift and repeatability.

Resonant Sensors:-

E.g SAW sensors to detect liquid density, viscosity.

→ Resonant frequency of a mechanical element is strongly dependent on its geometry, mechanical properties and mass.

→ Ion Concentration depends on mass loading and can be determined by measuring the corresponding shift in the resonant frequency.

→ challenges are temperature sensitivity, ion selectivity

Sensors and probes have been used to measure the electrical signals generated by neural tissue.

→ ECG (Electro Cardio Gram)
ENG (Electro Neuro Gram)
ERG (Electro Retini Gram)

MEMS technology offers fabrication of array of micro electrodes/micro probes on to a single substrate capable of monitored. Penetrating neural tissue and then can be monitored.

Applications:-

→ Micromachined Neural probes and stimulators are used to control Prosthetic limbs with processed signals recorded from the brain or spinal column.

→ Neuroscientists can now realistically envision sensing devices that allow real time measurement at cellular level.

* MEMS Biomedical actuators are used to control biological objects or their environment on microscopic scale.

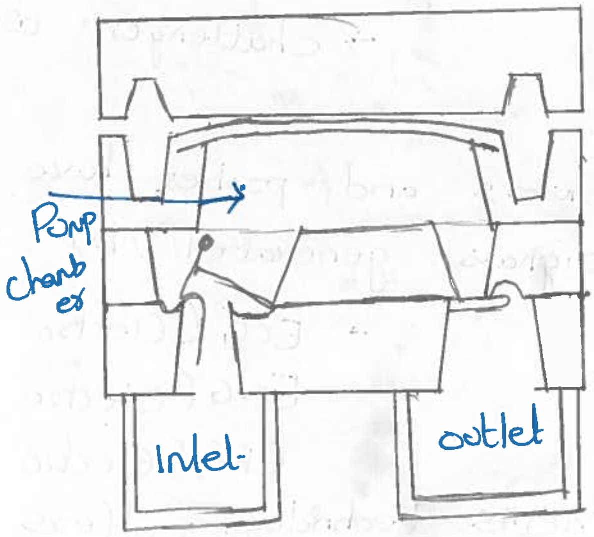
The capability of most microactuators to surgically interact with biological tissues is hindered by their inability to withstand forces on the scale of ~1mN.

MEMS technology offers a variety of capabilities to surgical microinstruments
e.g microheaters, microsensors, fluid delivery.

Micromachined ultrasonic cutting tools fabricated by bulk micro-maching. Piezoelectric material is attached to the cutter to resonate the tip of the tool at ultrasonic frequencies.
It can even cut tough tissues like cataracts.

→ Micro Pump:-

Electrostatic micropump with two one-way check valves produced by bonding multiple Si wafers.
one-valve is for inlet i.e for sucking of fluid and other valve is for ejection of fluid. it is done by electro static actuation.



It is made of 3 piece top, middle, bottom and they are conected together by wafer bonding technology and this kind of micropump is used for sucking fluid during surgical operation and some other cases.