UNIT-5

POLYMERS AND CARBON NANO TUBES:

- Polymer MEMS has got enormous potential in comparison to silicon.
- Carbon Nano tubes have got enormous potential in today's micro technology.

POLYMER MEMS-INTRODUCTION:

- So polymer has drawn considerable amount of interest in recent years in microelectronic and MEMS.
- It is 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.
- Certain characteristics which we get in case of polymer, which is never achievable in case of silicon and that is why it is gaining its momentum.

FEATURES OF POLYMER MEMS:

- Flexibility and moldability leading to ease of fabrication
- Interesting semiconducting properties, metallic behavior, and magnetic optical behavior.
- Wide choice to manipulate the polymer material during synthesization, during the development stage of polymer, so that you can have tailor made properties.
- That means whether the polymer will show as a metal or it will show semiconductor or it will show as a magnetic material or an optical material or a ferroelectric material a pyroelectric material, that mean tailor made.
- Biocompatibility
- Easy packaging and Scalability

WHY POLYMER MEMS?

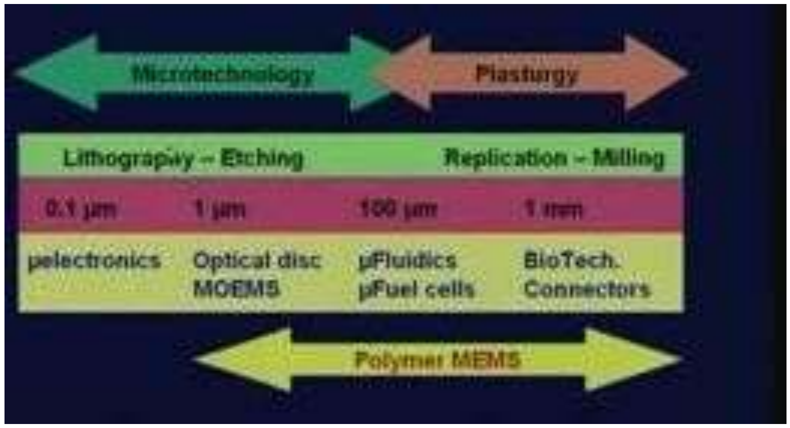
- Polymers are flexible chemically and biologically compatible, available in many varieties and can be fabricated in truly 3D shapes.
- To make this fully functional micro system necessary electronics have to be integrated: recent modified organic TFT may be a solution
- TFT is thin film transistor and that has helped a lot, prices gone down drastically.
- Although the existing technology of organic thin film transistor cannot rival the well-established silicon semiconductor technology especially in terms of speed, in case of silicon technology.
- Silicon devices the speed you achieve that is not possible polymer devices polymer transistor.

ADVANTAGES OF PLASTIC POLYMERS:

- Transparency
- Large surface
- Replication
- Prototyping
- Low cost fabrication process/ high volume

SILICON MEMS – ISSUES:

- Flexible low cost and truly 3D MEMS are not possible with the silicon.
- Silicon integrated micro systems involved either MEMS first and CMOS second or CMOS first and MEMS second.
- Silicon is not at all biocompatible
- Initial investment of clean rooms and equipment is very high
- Mask cost and aligning problems
- Planarization one important issue in case of silicon technology because you are fully dependent on what lithography



POLYMER MEMS- ISSUES & CHALLENGES:

- Design and develop flexible light weight and low cost MEMS with organic electronics so that is the main objective.
- It is easily scalable
- Incorporation of semiconducting properties
- How to improve the mobility and other characteristics of the devices.
- Integration of electronics such as organic TFT with MEMS structures
- Bottom up technology is not yet successful for MEMS in polymer MEMS.

POLYMER MEMS:

- Polymer MEMS miniature devices, they require combination of electrical and mechanical components fabricated using basically two technology.
- Because in MEMS you have to have some mechanical components other than electrical components.
- So these two methods are one is **self-assembly monolayer** which is known as SAM with polymer carbon and CNT. CNT is a carbon Nano tubes it is not form a CNT and the second approach is polymer best **Microstereolithography** with functionalize CNT and UV curable polymer.
- These are the two methods which have followed for getting polymer MEMS.
- So materials we use for getting those MEMS are PVDF, TRFE and other conjugated polymers, functionalize carbon Nano tubes with polymers.

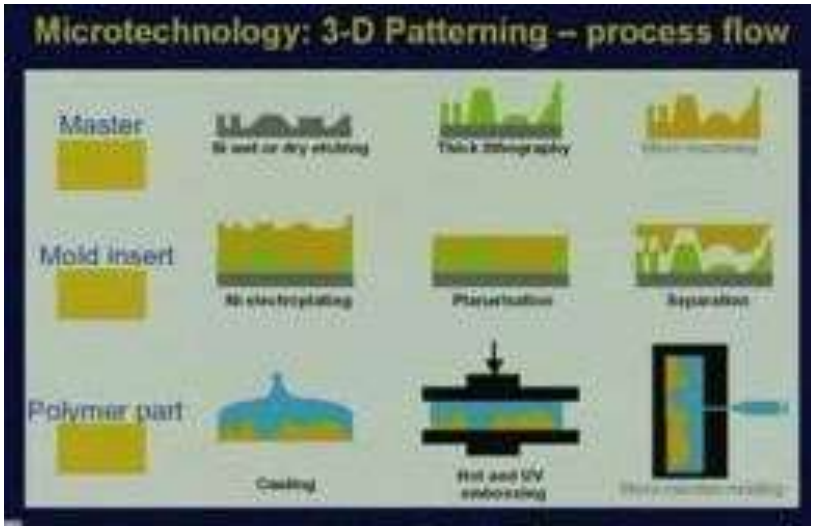
- So these are some of the material issues which we have to properly build up and develop the technology for getting those materials.

MICROTECHNOLOGIES FOR POLYMER MEMS:

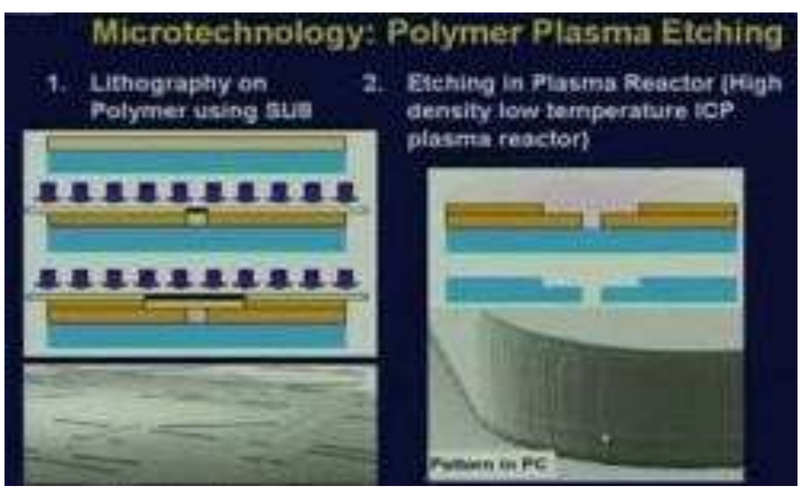
- One is 3D patterning of polymers; it requires micro-fabrication, replication, Microstereolithography, micro molding, jet molding, and etcetera.
- Surface energy modification that is one issue we need complex function in polymer devices.
- Self-assembly will involves electrostatic functional groups
- Packaging involves Hybridization of electronic components alignment assembling of components.

MSL FOR 3D MEMS:

- Microstereolithography is one of the important micro technology which is being used in case of polymer MEMS.
- Popular bulk and surface micromachining for silicon MEMS. But this MSL which is conventionally used for silicon MEMS are not suitable for real 3D objects with high aspect ratio
- LIGA process which can create micro structure with excellent aspect ratio
- If you want to have curved surface with regular curvature, that is not possible on those conventional methods for silicon.
- The invention of new conducting polymer with piezo and Ferro electric subgroups and organic thin films transistor revolutionizes the MEMS industry for conceiving micro devices. That is cheap and long lasting.
- With combined architecture techniques it is easy to integrate the silicon devices the polymeric 3D structure.
- MSL offers the opportunity for implanted devices in the medical field. High temperature silicon carbide, titanium carbide, micro devices or combine architecture with silicon too.


Microtechnology: 3-D Patterning – process flow
Master
Si wet or dry etching
Thick lithography
Mold insert
Ni electroplating
Planarisation
Separation
Polymer part
Casting
Hot and UV embossing


Thick Lithography : Master fabrication & prototyping
SU8 photoresist / Substrates: Si, glass, polymers, metallic layer
Thickness : 50 – 1500 µm
Aspect Ratio : 1 to 10
SU-8 fluidic chamber on silica
Multilevel lithography 2 level 120/80 µm
Multidirectional Inclined Exposure Lithography (MIEL) – 3D pattern


Microtechnology: Polymer Plasma Etching
1. Lithography on Polymer using SU8
2. Etching in Plasma Reactor (High density low temperature ICP plasma reactor)
Pattern in PC

POLYMER SURFACE MICROMACHINING:

STRUCTURAL POLYMER:

- These are basically used as a structure of the devices, not as sacrificial layer which may be removed later on.
- So electro active polymer or ionic conducting polymer, they are known as EAP or ICP they are UV curable and they provide mechanical strength structural integrity and electrical conductivity. So these materials are used for structural purposes.
- New generation of ceramic side group materials which are ferroelectric and piezoelectric materials at Nano scale. They are made using sol-gel technique hydrothermal technique microwave calcining technique and sintering.

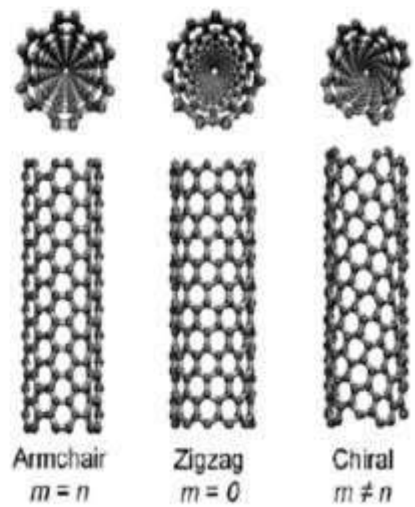
SACRIFICIAL POLYMER:

- For sacrificial polymer we use acrylic resin which contains 50 percent silica and it is modified by adding some crystal violet it is another chemical.
- This composition is dissolved with 2 mol per liter caustic soda at 80 degree C.

CARBON NANO TUBES:

- Carbon nanotubes is a very recent one and this particular the material magic material some people are called it is bulky ball and for that in 1996 Robert F Curl, Harold W Kroto and Richard E Smalley got noble prize for this carbon nanotubes is not very far away phenomena.
- Recent phenomena in 1996 and basically is a product of fullerene research and they discovered C_{60}.
- C_{60} is the carbon nanotube, this composition and that the picture of the carbon nanotube the assembly is shown also left side.
- This system consists of graphic sheets seamlessly wrapped to cylinders with only a few nanometers in diameter and micron in long.

- Thus length width aspect ratio is extremely high.
- You can see here few nanometer in diameter each of the C_{60} atom and they are formed a chain and they are wrapped just like a cylinder of few micron length.
- So nanometer in diameter to micrometer in length. So automatically aspect ratio is very high the carbon nanotubes.



APPLICATIONS:

- Useful for heterogeneous junction.
- A Nano size transistor between Nano electronics is also coming in future Nano devices lot of research is going on.
- Effective structural material for 3D MEMS.
- Active layer for flexible organic think film transistor
- Gas sensor with silica
- Enormous application in Bio-MEMS,
- Artificial muscle we can create with the help of the carbon Nano tubes.

Fig: Bulky ball

NANO TUBES BASED POLYMER DEVICES AND MEMS:

Processing Challenges:

- Poor dispersion of carbon nanotubes in polymer
- Carbon nanotubes are insoluble in any organic solvent
- Carbon nanotube is having high surface energy which prevents CNT to easily agglomerate.
- It is difficult to disperse nanotubes in the matrix materials.

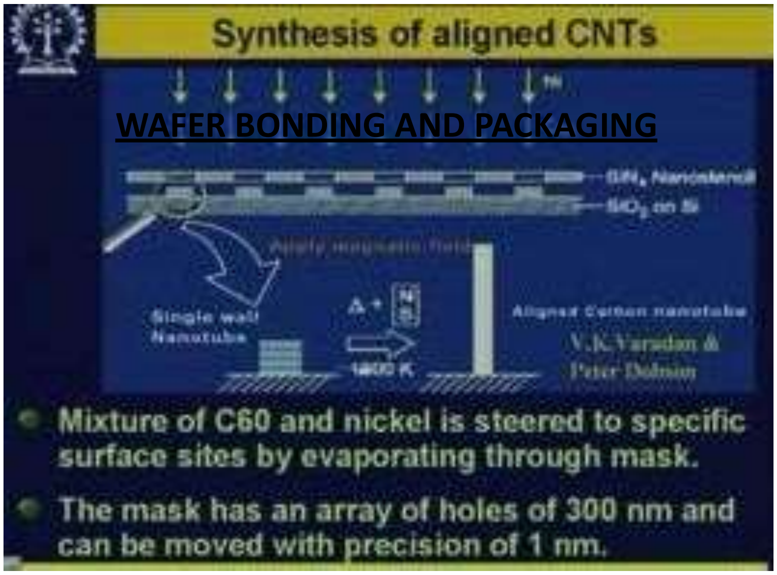
CHEMICAL FUNCTIONALIZATION OF CNT'S:

- In Functionalization a reagent is desired to selectively attack some of the pi bonds without bringing a total destruction of the graphene structures of the nanotubes.
- With the help of functional groups attach to the surfaces CNTs could react readily with other chemical reagents and form well homogeneous dispersion or even well aligned materials.
- Functionalization means using some organic or some other chemical composition, the function functional property of the complete composition is changed that is known as the Functionalization.

TYPES OF CNT AND FUNCTIONALIZATION:

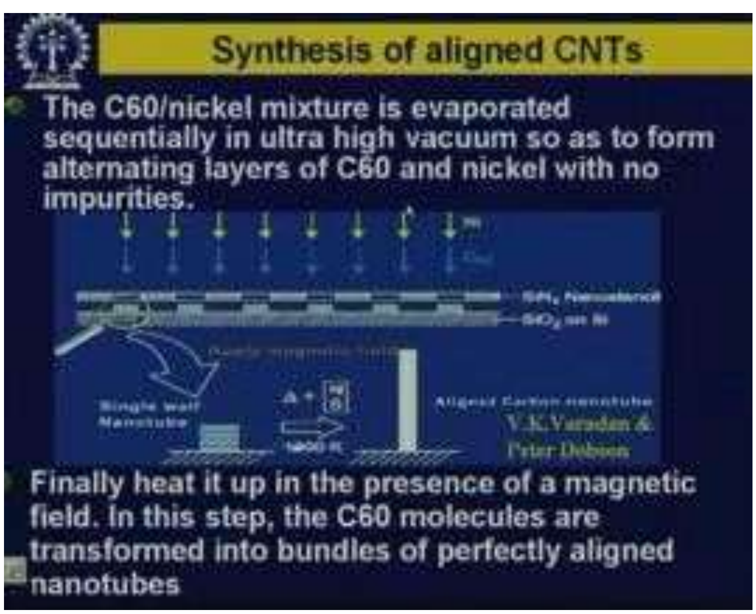
- Single-walled.
- Multi-walled.
- Junctions and crosslinking.
- Other morphologies.
- Extreme **carbon nanotubes**.
- Mechanical.
- Electrical.
- Optical.

WAFER BONDING AND PACKAGING



INTRODUCTION:

- Wafer bonding and packaging of MEMS is very important topic because in this particular point there is a lot of difference between the conventional VLSI bonding and packing and MEMS devices bonding and packing.
- In case of MEMS devices, in many applications you need the outside environment should be reflected into the devices.



- For example in case of pressure sensor the bonding and packing should be such that the device should be exposed to outside pressure or environment.
- In case of optical or thermal sensors, the complete device should be exposed to thermal radiation or optical radiation. So in those cases a special kind of bond and packaging is used in MEMS devices.
- So each device require custom package and the wafer bonding technology is again very crucial.
- Because in case of harsh environment or lot of mechanical movement or hesitation like the acceleration sensor, rotation sensor if the bonding between the wafer are now rigid, then during the course of operation, they may come out and total device may be destroyed.

ASSEMBLY AND BONDING:

- Actually since it is a micromachining device, so there will be some mechanical movement among the different components of the devices.
- So those mechanical movements should not be disturbed by the package itself.
- So it needs the assembly of the individual components formed using micromachining technique.
- In this case the wafer bonding in conjunction with micromachining allows the fabrication of 3D structures that are thicker than a single wafer.
- Basic 3D structure means here apart from the x and y direction the thickness direction which we call as a z direction.
- That is not very small, that is very large. Because we are going to bond several layers of wafer.
- By bonding multiple wafers sometime we can get improved performance and functionality of the devices.

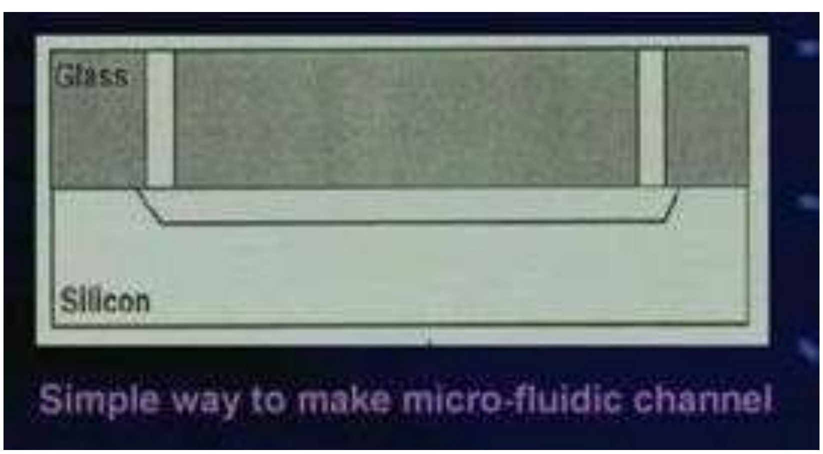
PROCESS DEVOLOPED FOR SILICON BONDING:

- There are various processes normally used to develop the bonding mechanizing in MEMS devices.
- And in case of the MEMS devices not always you are going to bond silicon.
- To silicon in many cases we require bonding between silicon to glass, silicon to nitrite, nitrite to nitrite, oxide to oxide, glass to glass.
- So various kinds of the levels of wafers are bonded together.
- So in this particular area we normally use 3 to 4 kinds of bonding mechanism.

PROCESS:

- Bonding of hydrophobic wafers
- Intermediate layer bonding: eutectic bonding, polymer layer, thermo compression bonding and solders
- Fusion bonding /direct bonding : Contact substrates and thermal annealing
- Anodic bonding which is very important and highly promising in case of the wafer bonding technology of MEMS. And here you need an electric field as well as temperature

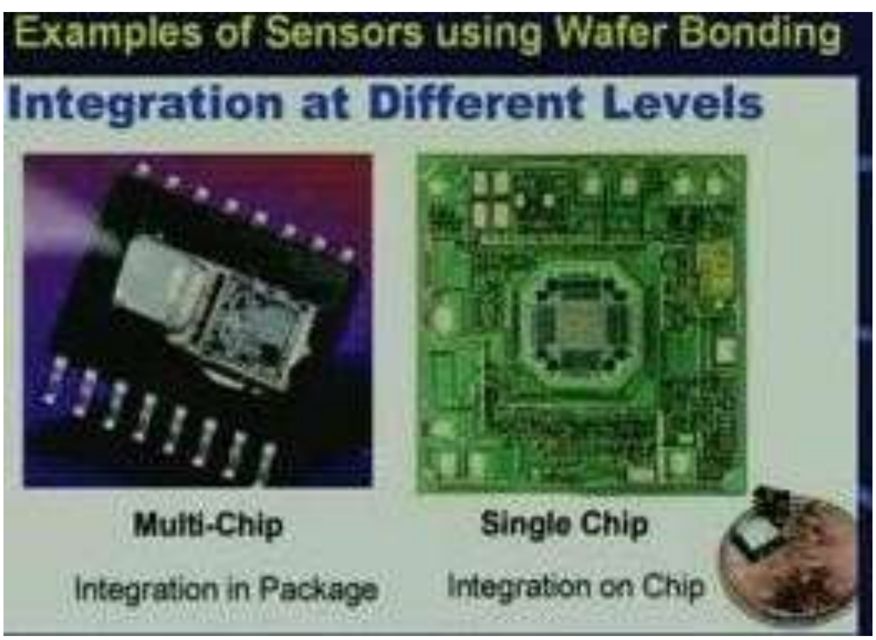
- So micro fluidic has got tremendous application in case of fluidic sensor as well as in biological sensor.



- So flow channels have been created over a small area with some nozzles that is the micro fluidic.
- So channel is made in silicon first you make some group and a top is the glass plate were you make some hole.
- Here is one hole and in the right side there is another hole. So in one hole is used for input flow in flow of the liquid and other is the out flow of the liquid exit.
- So now and in the bottom with the channel, so in this way just you make you etch or delineate the silicon wafer.
- And then in glass you make some small holes and now you bond the top glass and bottom silicon together.
- This very simple micro fluidic structure.

HYDROPHOBIC WAFER BONDING:

- So here basically to hydrophobic silicon wafer if you keep one after another and if you press gently and leave it the wafer of sometime it will be bonded.



- And that means you are not going to use a special kind of gadgets or machine to have bonding between the 2 silicon wafers. Just hydrophobic silicon wafers you are taking and putting one after another.
- So the wafer will be bonded but the problem is this kind of bonding is very weak bonding.
- Now in case of the hydrophobic wafer bonding the bonding energy is nearly 26 mill joule per meter square.
- Now if it has been observed that the hydrophobic bonding temperature, if you go on increasing so bonding strength also increases.
- So for example if you increase the temperature from 400 degree C to 600 degree C.
- That the bonding strength or bonding energy will increase 26 mill joules per meter square to 2.5 joule per meter square if you raise the temperature from 400 to 600 degree C.

SILICON FUSION BONDING:

- The fusion bonding is a direct bonding and it is possible only on certain conditions. What are those conditions?
- The surface micro roughness or smoothness should be very small in case of fusion bonding.
- Other than a hydrophobic wafer bonding is a basically extension of hydrophobic with certain precautions and certain modifications. That is the fusion bonding.
- So here the smoothness or micro roughness of the surface should be less than 10 angstrom RMS value.
- Then the wafer bonding will be very good and at the same time radius of curvature of the wafer should be very large.
- Thermal annealing is followed at a temperature between 700 to 1100 degree C.

- And in this case of fusion bonding you can get silicon bonding, silicon oxide bonding, and silicon nitrate bonding oxide, oxide bonding and nitrate bonding. So all kinds of bondings are possible in fusion bondings.

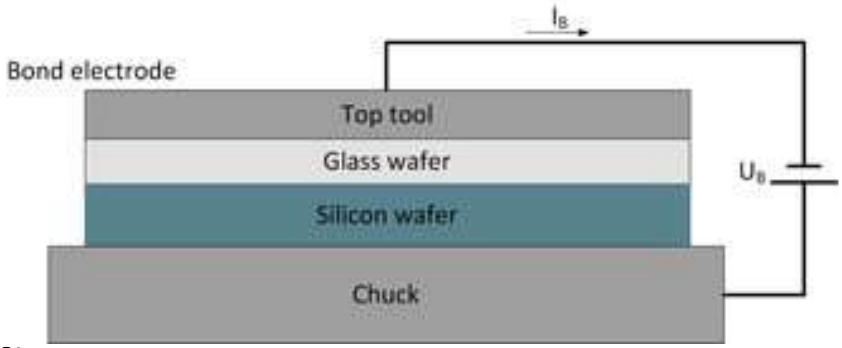
ANODIC BONDING:

- This particular technique is assisted by an electric field till anodic bonding.
- Silicon is anode and glass is cathode
- Wafers are kept on a heater whose temperature is raised within 300 to 400 degree c and voltage is applied.
- Silicon is a positive and glass is negative. So positive sodium ions in the glass is drifted away from the interface. As a result of which a negative charge will be left at the interface.
- The parameters of the or quality of controlling the anodic bonding techniques are time, temperature and voltage.

ADVANTAGES:

- Low temperature process means temperature is nearly 450 degree c.
- Low residual stress obvious if the temperature is low, the stress formation will be less
- Less stringent requirements on the surface quality of the wafers as compared to fusion bonding.

- Well developed technology with a high yield if care is taken to achieve a good cleaning procedure and a dust free environment.



Requirements:

- Surface roughness of the wafers must be smaller than 1 micron rms. So there in case of fusion bonding it was 10 angstrom.
- Surface must be clean and dust free.
- The native oxide layer on the silicon must be thinner than 200 nanometer.
- Thermal expansion coefficients of the bonded materials must match in the range of temperatures.

INTRODUCTION TO BIOMEMS:

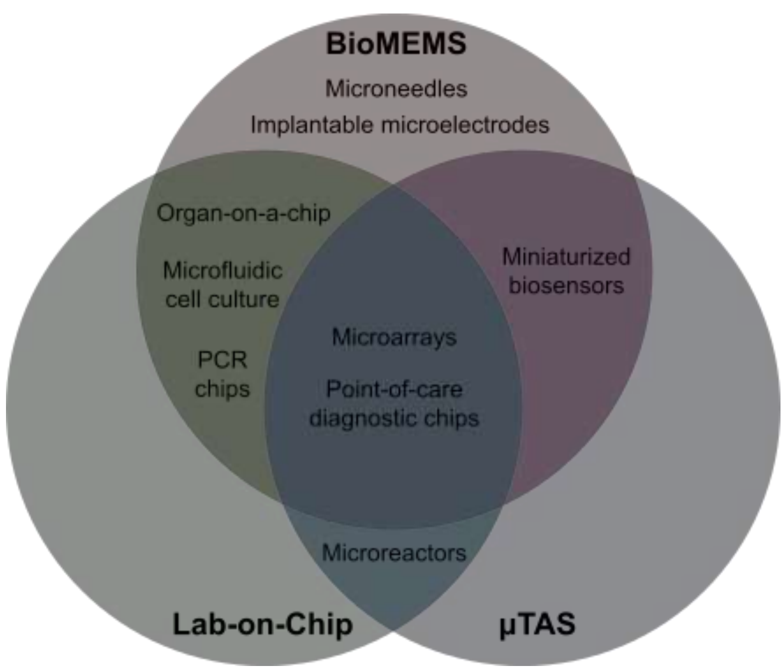
- Bio-MEMS is an abbreviation for biomedical (or biological) microelectromechanical systems.
- Bio-MEMS have considerable overlap, and is sometimes considered synonymous, with lab-on-a-chip (LOC) and micro total analysis systems (µTAS).
- Bio-MEMS is typically more focused on mechanical parts and Microfabrication technologies made suitable for biological applications.
- On the other hand, lab-on-a-chip is concerned with miniaturization and integration of laboratory processes and experiments into single (often micro fluidic) chips.
- In this definition, lab-on-a-chip devices do not strictly have biological applications, although most do or are amendable to be adapted for biological purposes.

- A broad definition for bio-MEMS can be used to refer to the science and technology of operating at the micro scale for biological and biomedical applications, which may or may not include any electronic or mechanical functions.
- The interdisciplinary nature of bio-MEMS combines material sciences, clinical sciences, medicine, surgery, electrical engineering, mechanical engineering, optical engineering, chemical engineering, and biomedical engineering.
- Some of its major applications include genomics, proteomics, molecular diagnostics, point-of-care diagnostics, tissue engineering, single cell analysis and implantable micro devices.

HISTORY:

Researchers started to use photolithography equipment for micro fabrication of microelectromechanical as inherited from the microelectronics industry.

At the time, the application of MEMS to biology was limited because this technology was optimized for silicon or glass wafers and used solvent-based photoresist that were not compatible with biological material. In 1993, George M. Whiteside's, a Harvard chemist, introduced inexpensive PDMS-based



Microfabrication and this revolutionized the bio-MEMS field. Since then, the field of bio-MEMS has exploded. Selected major technical achievements during bio-MEMS development of the 1990s include:

- In 1991, the first oligonucleotide chip was developed
- In 1998, the first solid microneedles were developed for drug delivery
- In 1998, the first continuous-flow polymerase chain reaction chip was developed
- In 1999, the first demonstration of heterogeneous laminar flows for selective treatment of cells in microchannels

MATERIALS:

- Silicon and glass
- Plastics and Polymers
- Biological materials
- Paper
- Micro fluidics

BIOMEDICAL MICROSENSORS:

- The majority of MEMS used in biomedical applications act as sensors.
- Examples include critical sensors used during surgery (i.e., measuring intravascular blood pressure), long-term sensors for prosthetic devices, and highly sophisticated sensor arrays for rapid lab-quality diagnosis at home.
- Microsensors for Biomechanics Studies of the forces created by and imposed on the body benefit from increasing the sensitivity of mechanical stress and strain sensors while also reducing their size and cost.
- The following are examples of microsensors used to study biomechanics.

Strain Gauges:

- Strain gauges are used to characterize the forces in the body.
- Since silicon is known to be an excellent piezoresistive material (i.e., it's resistance changes as a function of applied force), it can be easily micromachined to form sub-millimeter multi-axis strain gauges.
- Applications of such miniaturized strain gauges include orthopedic research and the study of muscles.
- Although the understanding of muscle function and structure is well understood at the whole-muscle and cellular levels, muscles have not been well characterized in the region in between.
- An improved understanding at this level would allow for the development of improved locomotion therapies and prosthetic devices.

Accelerometers:

- One class of microsensors that MEMS technology has had the most positive impact on are inertial sensors (i.e., accelerometers and gyros).
- Since inertial devices typically consist of a proof mass, mechanical flexure, and displacement sensor, MEMS technology is well suited to integrate each of these sensor elements into a single chip.
- In fact, it is also possible to integrate ICs with the micromechanical elements to add signal amplification and filtration capability to the chip-scale sensor .
- Inertial microsensors are useful to determine impact level and patient posture.

Microsensors for Pneumatic Bio systems:

- Since much of the human body is a complex system of pumps, valves, vessels, and interconnects, pressure in many parts of the body is an important parameter to indicate the health and well being of a patient. Pressure sensors are used in medicine in many applications: blood pressure, bladder pressure, and cerebral spinal fluid pressure to name a few.

- In addition to performance requirements, the size of pressure sensors, particularly those inserted into the body must be small and ideally disposable.
- MEMS technology is well positioned to deliver solutions to this opportunity.
- In fact, a good example is the commercially successful low-cost disposable medical pressure sensor developed by Lucas Nova Sensor NPC-107.

Microsensors for Chemical Bio systems:

- Since living organisms are extremely sophisticated chemical processing systems, there are many biomedical applications for chemical sensors (e.g., medical diagnostic instruments, drug screening, implantable sensors for prostheses, and environment monitoring).
- Although the micromachining of chemical sensors is typically simple, other components sometimes used in a complete chemical sensor system (i.e., sample preparation and delivery, reaction control, and waste disposal) are more difficult to integrate together.

Polymer-Based Gas Sensors:

- Many polymers will geometrically swell reversibly when exposed to certain gases.
- Conductive polymers, such as polypyrrole, can be used directly as a viable chemiresistor.
- To use insulating polymers, they are doped with conductive particles to reduce their impedance (e.g., carbon black).
- When doped, the overall resistance of the doped polymer will change as a function of the chemically specific and concentration-dependent swelling.
- One difficulty is that the polymers will swell to a greater or lesser extent when exposed to a variety of gases.

- To identify specific gases, the response pattern of many different polymers is needed. In addition to resistive measurements of geometric swelling, configurations that capacitive detect swelling have also been used.
- In these sensors the insulating polymers are not doped.
- Since it is known that certain diseases cause the body to generate specific gases that are not normally present, gas sensors have been used to help diagnose patient health.

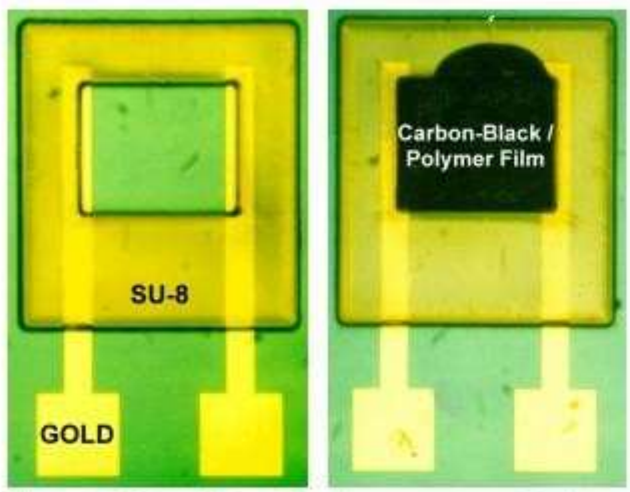


Figure 5: Microfabricated polymer carbon-black gas sensor with SU-8 microwell for solvent containment

- In order to micro fabricate arrays of sensors with unique polymers, the integration process must contend with the large volume of solvent that is typically present during polymer deposition.
- Furthermore, the Microfabrication technique must not damage previously deposited polymers.
- One strategy is to use a removable mask to selectively deposit each polymer into a specific area.
- This technique has difficulty forming sub-millimeter sensors due to poor adhesion to the substrate when the mask is removed (i.e., the polymers adhere more strongly to the mask than to the substrate). Another strategy is to use a permanent micro well structure to contain the polymer-solvent solution in a well-defined sub-millimeter area

without disturbing previously deposited polymers. An example of a polymeric impedance-based gas sensor that uses an SU-8 microwell structure is given in Figure 5.

Electrochemical Sensors:

- The oxidation and reduction of chemical species on a conducting electrode can be observed by measuring the movement of charge.
- There are two primary methods of sensing electrochemical reactions: potentiometric and amperometric.
- Potentiometric sensors can be used to measure the equilibrium potential established between the electrode material and the solution, a potential that is dependent on the chemistry involved.
- Amperometric sensors measure the current generated by a reaction and thus give a measure of reaction rates.
- By controlling the potential of the electrode relative to the solution and measuring the charge flow induced, the presence of specific ions can be determined by observing the potential at which they undergo oxidation or reduction.
- This is a process known as voltammetry

Molecular-Specific Sensors :

- Chemical sensors that respond only to certain ions or molecules can be extremely selective.
- Among the most selective are the interactions between complex organic molecules, such as antigens and antibodies.
- One caveat is that often very selective sensors are also less reversible and thus may require special packaging to protect the sensors until they are needed.
- A prominent example of a molecularly sensitive amperometric sensor is one that uses a glucose oxidize enzyme to detect glucose.

- The enzyme, which is typically immobilized on or near electrodes, reacts with glucose and alters the local pH, oxygen concentration, and hydrogen peroxide concentration – events that can be electrochemically.

MICROSENSORS FOR ELECTRICAL BIOSYSTEMS:

- The central and peripheral nervous systems are the primary electrical Biosystems of interest.
- Many sensors and probes have been used to measure the electrical signals generated by neural tissue.
- Example includes electrocardiogram (ECG), electroencephalogram (EEG), electroneurogram (ENG), electromyogram (EMG), and electroretino gram (ERG).
- These bioelectrical signals are typically transduced with either external or internal electrodes.
- With MEMS technology, many electrodes can be co fabricated onto a single substrate so that both precise temporal and spatial information can be obtained.
- MEMS technology can also be used to shape the substrate into either arrays of microprobes capable of penetrating neural tissue (Figure 7) or into a perforated membrane through which regenerating neural tissue can grow and then be monitored
- In the U.S. the University of Michigan [22], Stanford University [23], and the University of Utah have spent years developing and improving various MEMS-based neural electronic interfaces.

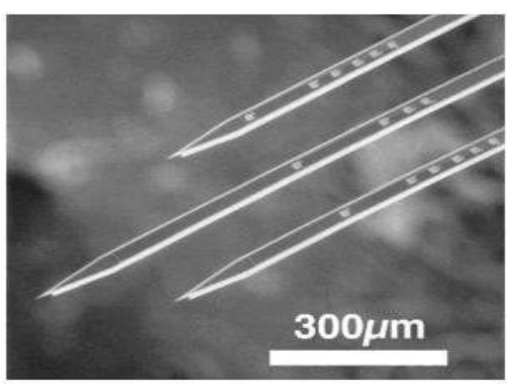


Figure 7: Microfabricated silicon neural probe arrays.
Top: Close-up of the probes and electrodes [19].

BIOMEDICAL MICROACTUATORS

- Micro actuators are useful in biomedical applications when biological objects or their environment need to be controlled on the microscopic scale.
- Furthermore, the ability to integrate many micro actuators as easily as only one makes it feasible to produce complex microsystems capable of controlling many parameters.

Micromanipulators

- To manipulate cells, tissues, and other biological objects, micromanipulators must be driven by a micro actuation mechanism capable of operating in a conductive solution.
- Good candidates include magnetic, pneumatic, thermal, and shape-memory alloy actuation.
- The magnetic micro actuator shown in Figure 8 has been used to manipulate single-cell protozoa in saline.
- The shape memory alloy micro actuator shown in Figure 9 is capable of grasping tissues during endoscopic surgical procedures.
- A second-generation device constructed with polymers is being commercialized by Micrus, Inc. and is presently in human trials.

Figure 8: Magnetic microactuator manipulating a single-cell protozoa (from [25]).

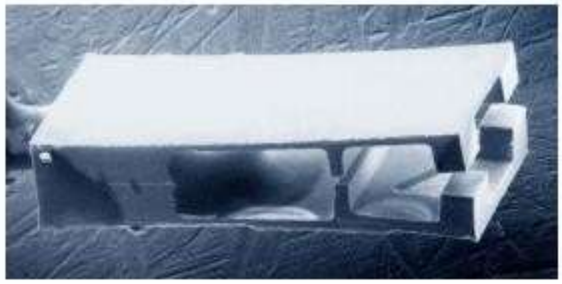


Figure 9: Surgical microgripper actuated by shape-memory-alloy forces (from [26]).

Surgical Micro instruments:

- The capability of most micro actuators to surgically interact with biological tissues is hindered by their inability to withstand forces on the scale of ~1 mN.
- The most successful uses of micro actuation in surgical devices employ high-force small displacement stepper motors or resonant microstructures.
- MEMS technology can be used to add a variety of capabilities to surgical micro instruments (e.g., micro heaters, microsensors, fluid delivery, fluid extraction, feedback and control).
- A scalpel driven by a piezoelectric micro actuator is an innovative example of using MEMS technology in surgical tools (Figure 10)
- The piezoelectric stepper motor allows the position the scalpel to be precisely controlled.
- By integrating an ability to measure the stresses experienced by the scalpel during cutting, the actual cutting force can be quantified and controlled.

Figure 10: Piezoelectrically driven force sensitive scalpel (see [27]).

- An ultrasonic cutting tool fabricated by bulk micromachining is another good example of using MEMS technology in surgical devices.
- Again, piezoelectric material is attached to the cutter to resonante the tip of the tool at ultrasonic frequencies.
- Only when activated will the device easily and rapidly cut through even tough tissues (e.g., the hardened lenses of patients with cataracts) .
- The devices shown in Figure 11, includes a imbedded microchannels through which fluid and surgical debris can be extracted while cutting.

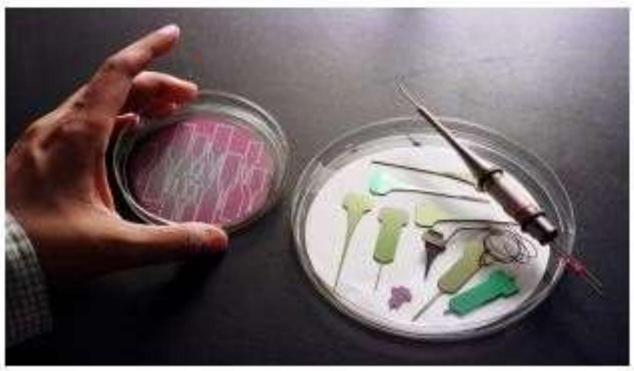


Figure 11: Micromachined ultrasonic cutting tool [28].

BIOMEDICAL MICROSYSTEMS:

- The ability to miniaturize entire biomedical systems, such as DNA analysis, chemical analysis, drug development, and neural prosthetics, has the potential to reduce the cost of health-care management.
- For example, reducing the cost and complexity of performing DNA screening and chemical analysis to the point that tests can be performed rapidly on the desktop, would reduce the infrastructure required for the test without compromising capability.
- This would enable remote or small-scale clinics to offer fast high-quality tests.

Micro fluidic Systems

- Chemical, pharmaceutical, and genetic analysis systems require the precise handling of fluids (i.e., sampling, mixing, heating, cooling, reacting, and separating).
- Conventional fluidic analyses are typically performed with relatively macroscopic fluidic systems (>25 µL).
- Miniaturization and integration of fluidic systems offers the following advantages:

  (1) Smaller typical operating fluid volume,

  (2) Precise control of sample volumes,

  (3) Ability to perform massively parallel tests,

  (4) Take advantage of the effect of scaling on fluidic, electrical, and thermal behavior,

  (5)Possible reduction in system size, and

  (6) Possible reduction in system cost.
- One important caveat with miniaturizing fluidic analysis systems is the fact that reducing the sample size requires a corresponding increase in sensor sensitivity.
- In addition, micro-scale fluid flow is almost completely laminar (i.e., there is very little turbulence and thus mixing can be problematic).

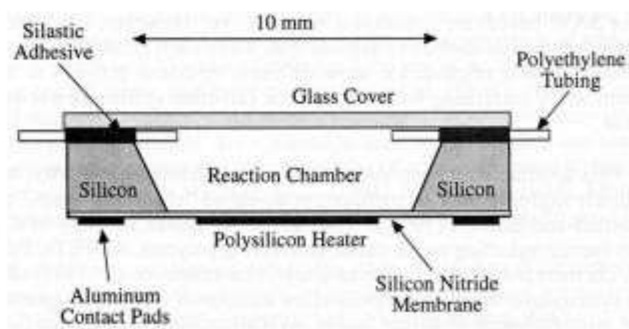


Figure Micromachined PCR chamber (from [36]).

INTERFACE ELECTRONICS FOR MEMS

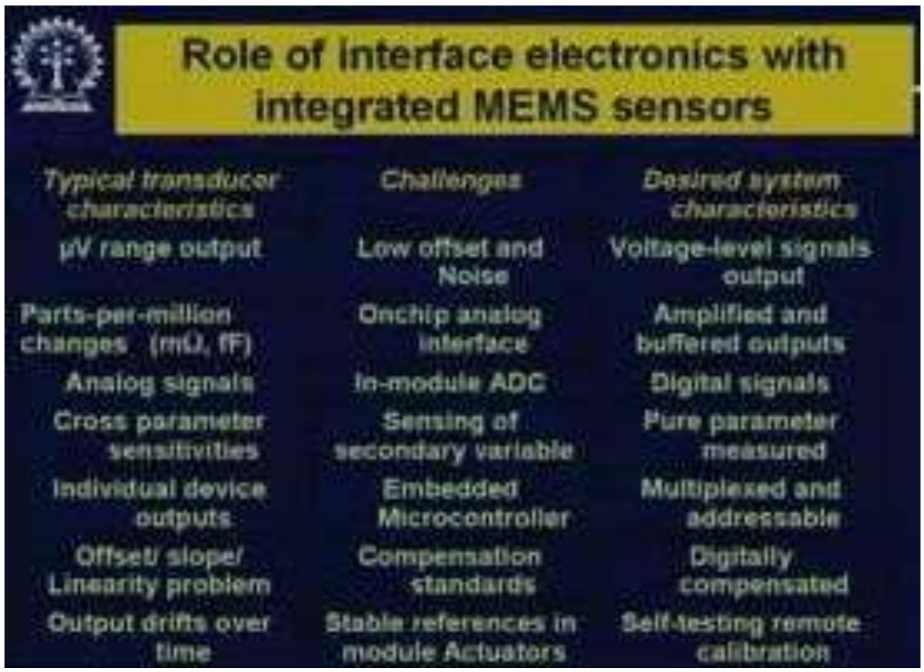
TRENDS IN SENSOR ELECTRONICS:

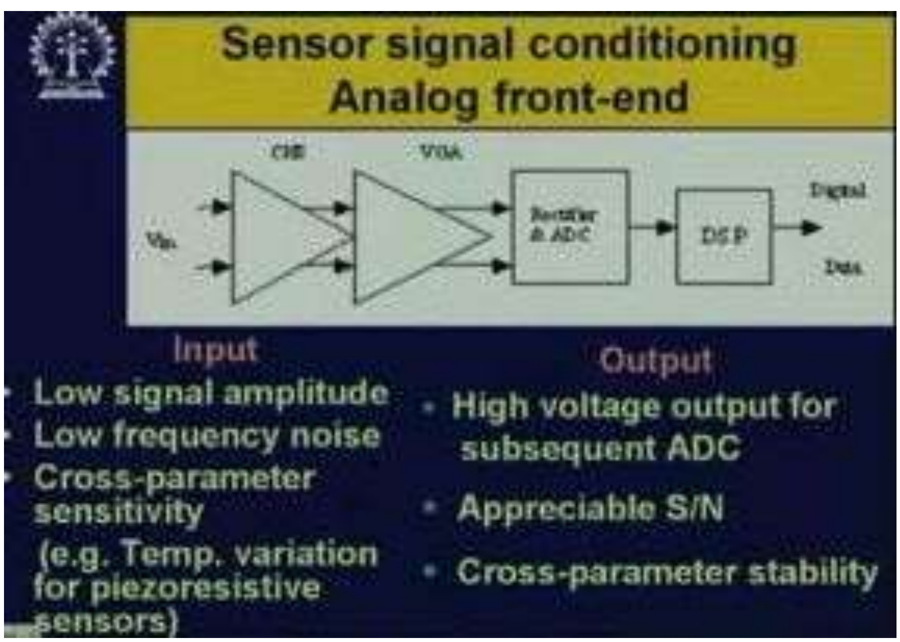
- The sensing element means microsensors are miniaturized day by day and at present due to the micro miniaturization the sensor signal output level is very small.
- It is in the range of micro volt or mini volt or if its output is current, then some cases microampere, nanoampere any in some cases pico ampere also.
- If it is a capacity the changes in the range of the picofarads, so since the change is negligibly small.
- So obviously there is a problem of the sensitivity. Because if this signal output from the microsensors are extremely low, so it is very difficult to the person to distinguish between which is the signal and which is the noise.
- Because any of this system will have noise fluctuations and those noises coming from different reasons.
- Demand for increased functionality:
    1. A/D conversion
    2. Self test
    3. Sensor Addressing
- Sensor and Circuit Merging(SoC)
    1. Hybrid SoC
    2. Monolithic SoC

HYBRID SoC:

- MEMS sensor built on one chip
- Electronics part you built on the second chip and
- MEMS sensor you built on the separate chip.
- Both the chips the MEMS sensors and electronics, both you can integrate together. That is known as the multiple modules or MCM or it is also some kind of SoC mounted and packaged in multichip module which is known as MCM or separately on PCB.


Accelerometer prototype with ASIC /
Sensors in a single package


Role of interface electronics with integrated MEMS sensors
Typical transducer characteristics
Challenges
Desired system characteristics
µV range output
Low offset and Noise
Voltage-level signals output
Parts-per-million changes (mΩ, fF)
Onchip analog interface
Amplified and buffered outputs
Analog signals
In-module ADC
Digital signals
Cross parameter sensitivities
Sensing of secondary variable
Pure parameter measured
Individual device outputs
Embedded Microcontroller
Multiplexed and addressable
Offset/ slope/ Linearity problem
Compensation standards
Digitally compensated
Output drifts over time
Stable references in module Actuators
Self-testing remote calibration


Sensor signal conditioning
Analog front-end
VGA
Vin
Rectifier & ADC
DSP
Digital
Data
Input
• Low signal amplitude
• Low frequency noise
• Cross-parameter sensitivity
(e.g. Temp. variation for piezoresistive sensors)
Output
• High voltage output for subsequent ADC
• Appreciable S/N
• Cross-parameter stability