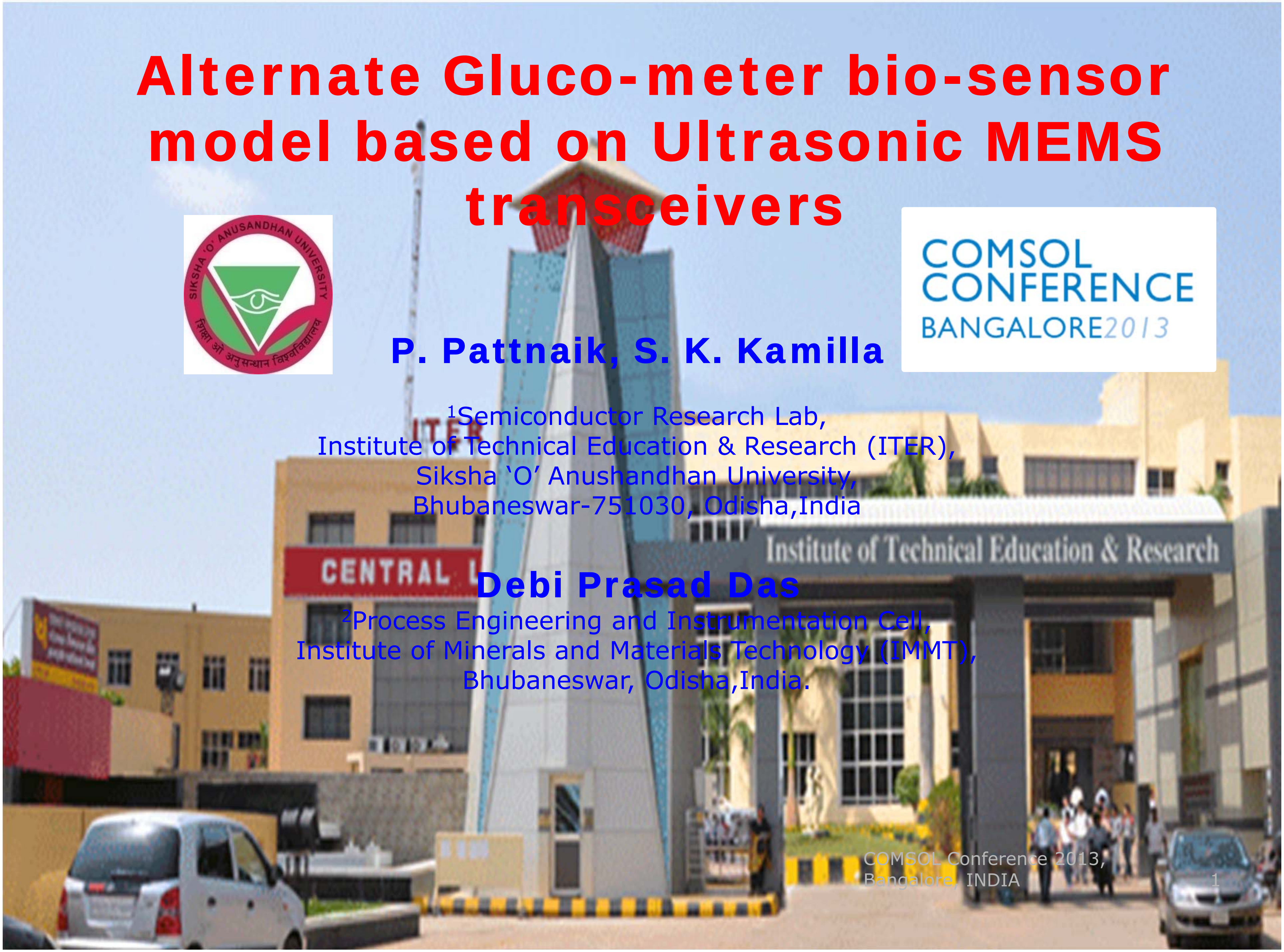

Alternate Gluco-meter bio-sensor model based on Ultrasonic MEMS transceivers

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Introduction and Motivation ……

- To prevent complications in diabetes, accurate monitoring and timely management of blood glucose levels is essential.

- Regular monitoring of sugar level in patient can alarm any unwanted rise in the level and necessary precautions can be taken at the right time .

- Glucometers are supposed to be a solution for continuous monitoring of sugar level.

Present technique of monitoring blood glucose

Either invasive or minimally invasive

Being off-line methods-

- **Time consuming**
- **Labour intensive**
- **May not reflect real-time status of the glucose can cause cell contamination**

Shortcomings of invasive method by using commercial glucometer

- Painful
- High recurring cost (test strips are very high)
- Potential source of spread of diseases like
  Hepatitis,
- HIV through contact with bodily fluids
- Continuous monitoring not possible

To avoid these difficulties a non-invasive method for monitoring blood glucose levels is desired .

It can be said that most of the non-invasive technologies are still in their early stages of development.

Potential non-invasive methods

- Infrared and Near-infrared absorption spectroscopy
- Near-infrared scattering technique
- Photo acoustic spectroscpy
- Bioimpedance spectroscopy

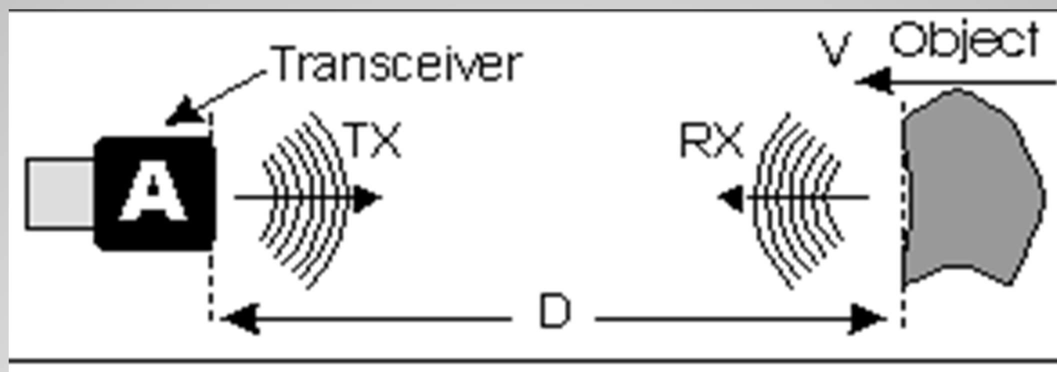
Ultrasonic transceivers Model for Bio Sensor

- Ultrasonic wave which penetrates the skin for blood glucose monitoring
- By using transceivers (both transmit and receive) the this can be determined.

- Ultrasonic sensors generate high frequency sound waves and evaluate the echo which is received back by the sensor.

Ultrasonic

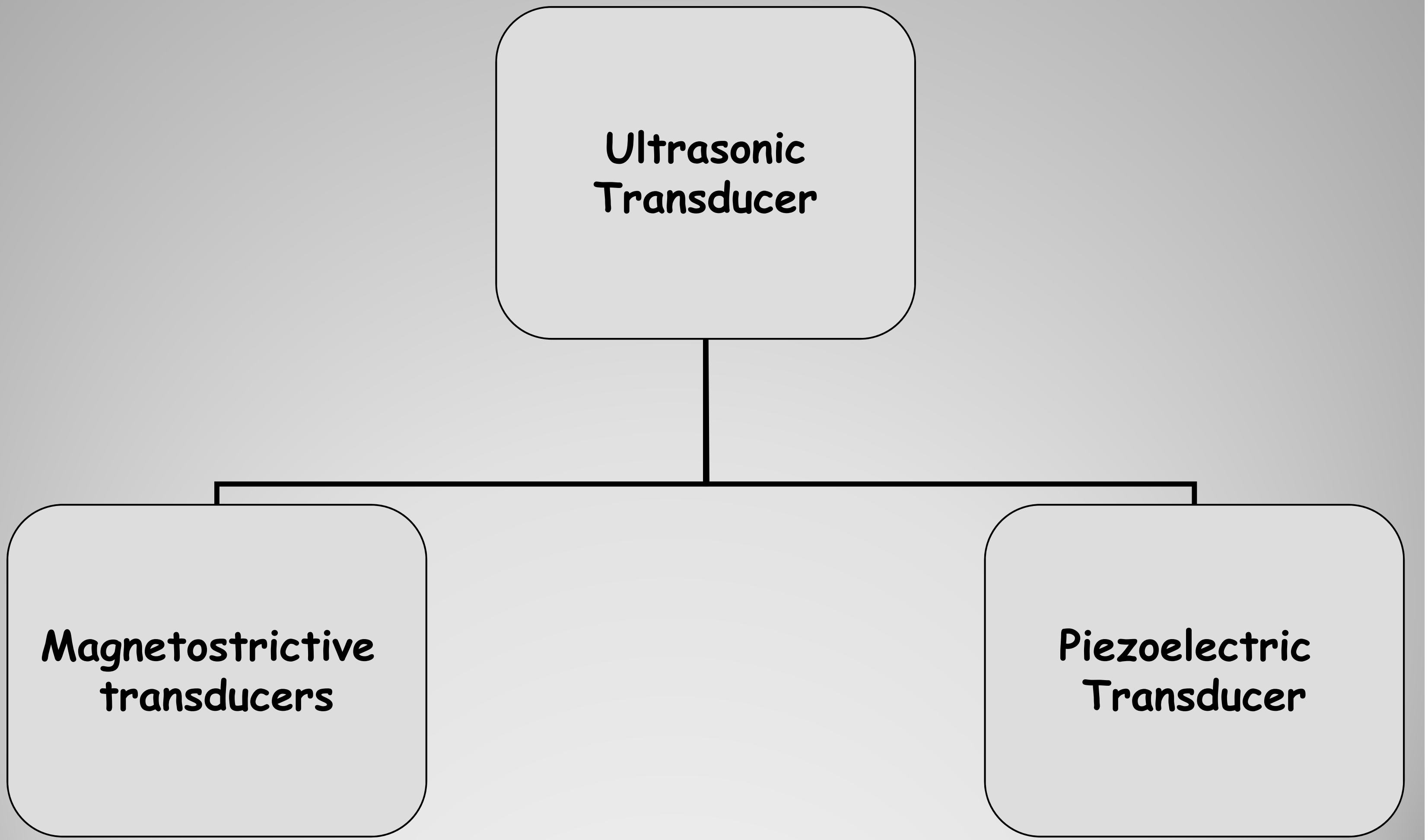
- It is a phenomenon that has the frequency above the hearing capability of human ear.



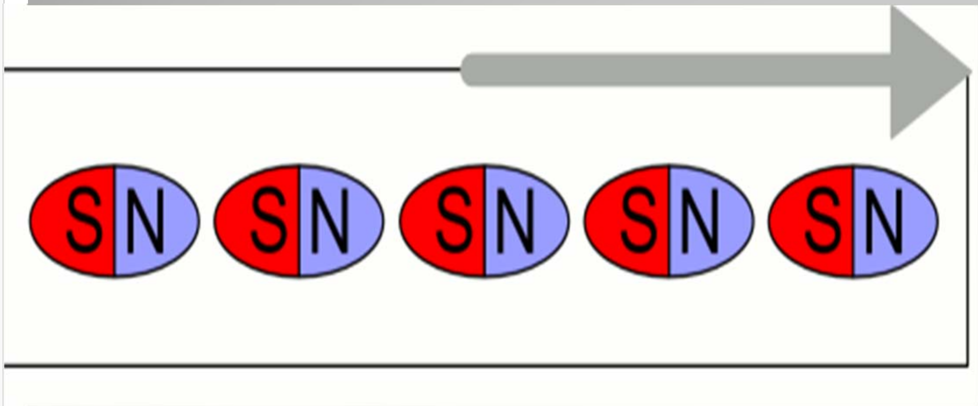
Ultrasonic transducer

- It is a device that converts energy into ultrasonic waveform and vice versa

Types of Ultrasonic Transducer



Ultrasonic Transducer Principle



Magnetostrictive Transducer

Piezoelectric Transducer

Micro-electro mechanical system (MEMS)

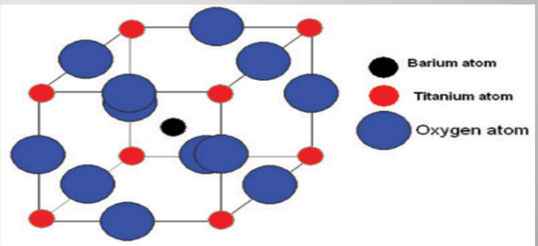
- Conventional ultrasonic transceivers systems became very bulky and power hungry.
- Hence we switched over to Micro-electro mechanical system (MEMS)
- MEMS based acoustic biosensing transducer is based on the piezoelectric technology which exploits the nature and properties of the propagating ultrasonic wave in blood medium of various densities.

Why piezo materials?

- Piezoelectric materials are :-
  - offer a high pressure per density ratio for the actuator,
  - high stability in hostile environment,
  - chemically they are very stable.
- For making ultrasonic transceivers and piezoelectric actuators, it is desirable to have
  - high electromechanical coupling coefficients
  - relatively large dielectric constant
  - large piezoelectric coefficient.
- For this reason,
  - Lead Zirconate Titanate ($Pb[Zr_xTi_{1-x}]O_3$), or PZT ceramics become the dominant material in the ultrasonic transducer industry in the past 40 years.

LEAD free Piezo Materials

- Lead Zirconate Titanate (PZT) has been recognized as an environmentally non-friendly material which contains more than 60% lead by weight .
- Unfortunately, among the existing lead-free ferroelectric crystals, some have weak piezoelectricity and some are very expensive to fabricate.
- Different lead free piezoelectric materials like
  - Barium Sodium Niobate ($Ba_2NaNb_5O_{15}$)(BNN),
  - **Barium Titanate (BaTiO3)(BT)**
  - and Lithium Niobate (LiNbO3) (LN)

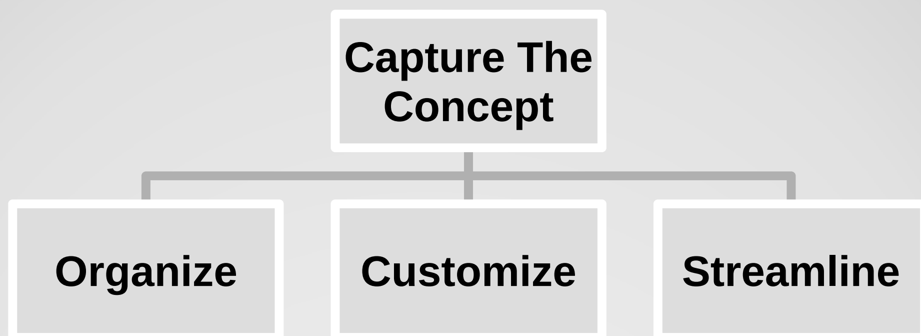


Prior to fabrication of ultrasonic Micro-Electronics Mechanical Systems (MEMS) device, design and simulation are extensively needed to avoid expensive time and cost.

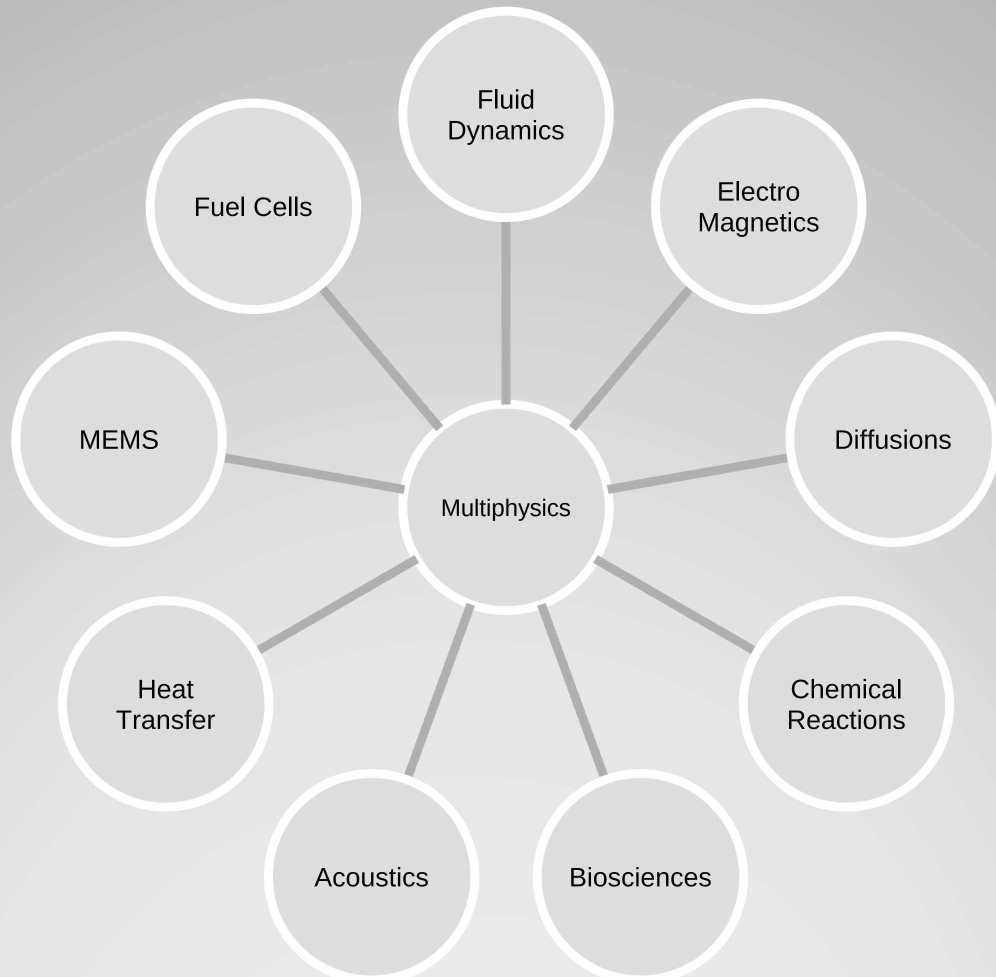
Comsol Multiphysics

COMSOL Multiphysics is a powerful interactive environment for modeling and solving scientific and engineering problems

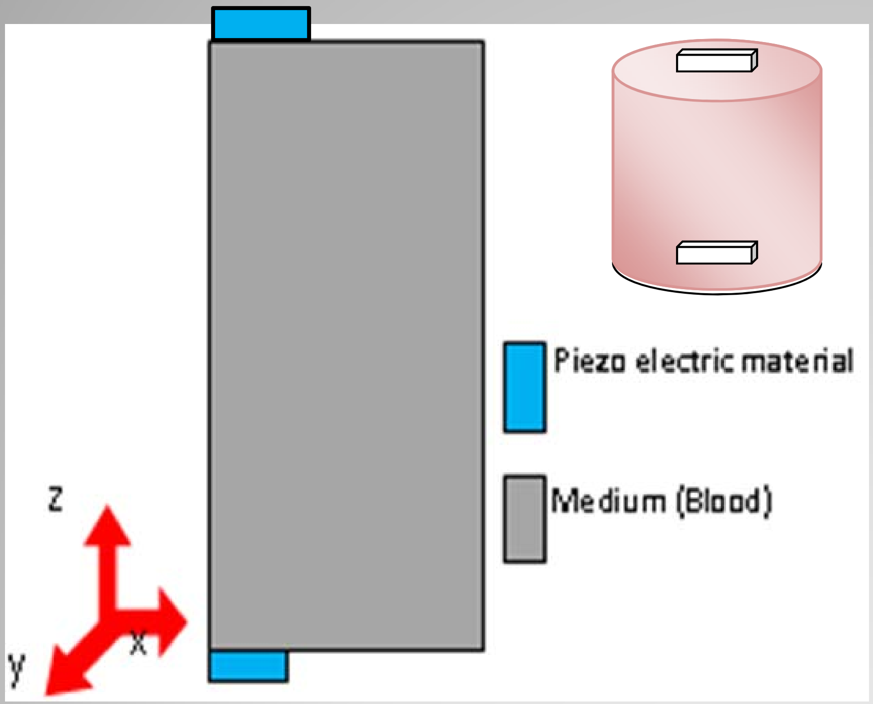
It provides a powerful integrated desktop environment with a Model Builder where we get full overview of the model and access to all functionality



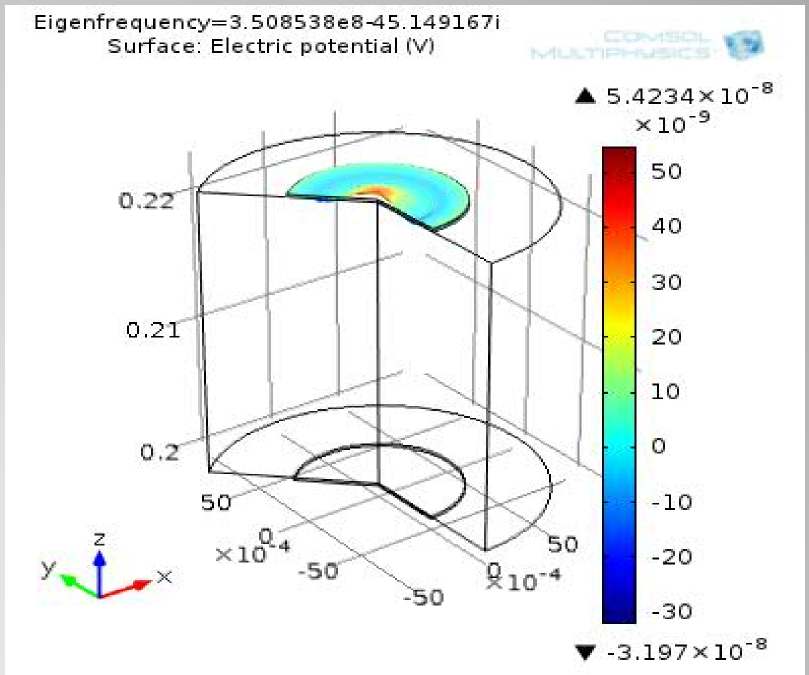
Application Of COMSOL Multiphysics 4.3



Model geometry and boundary conditions of ultrasonic transceiver



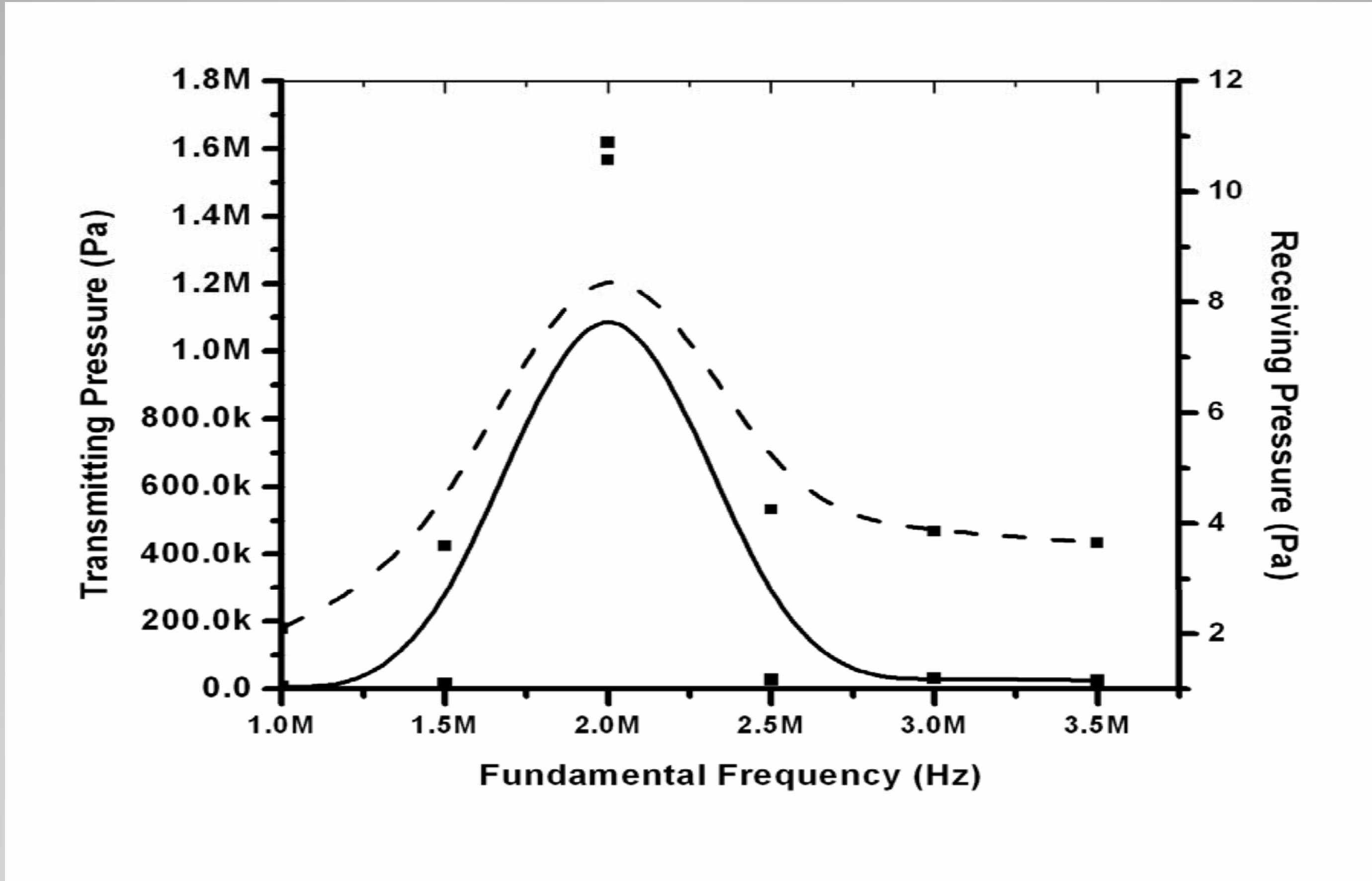
(a)



(b)

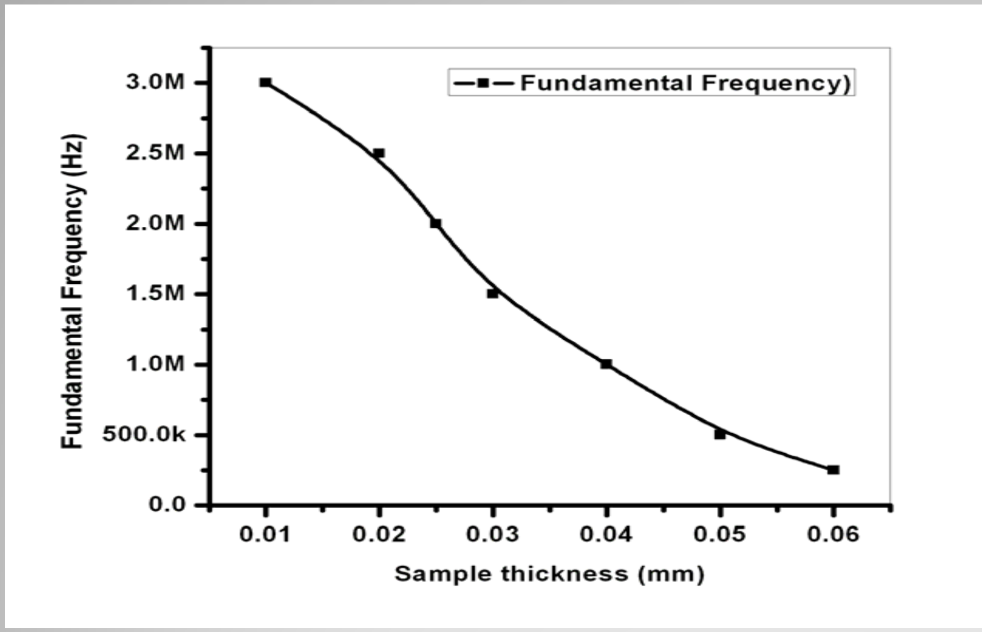
2D axis- symmetric model geometry of the piezoelectric based ultrasonic transducer using COMSOL Multiphysics.

Effect of frequency on pressure in both transmitting and receiving ends



The optimize fundamental frequency was found 2MHz

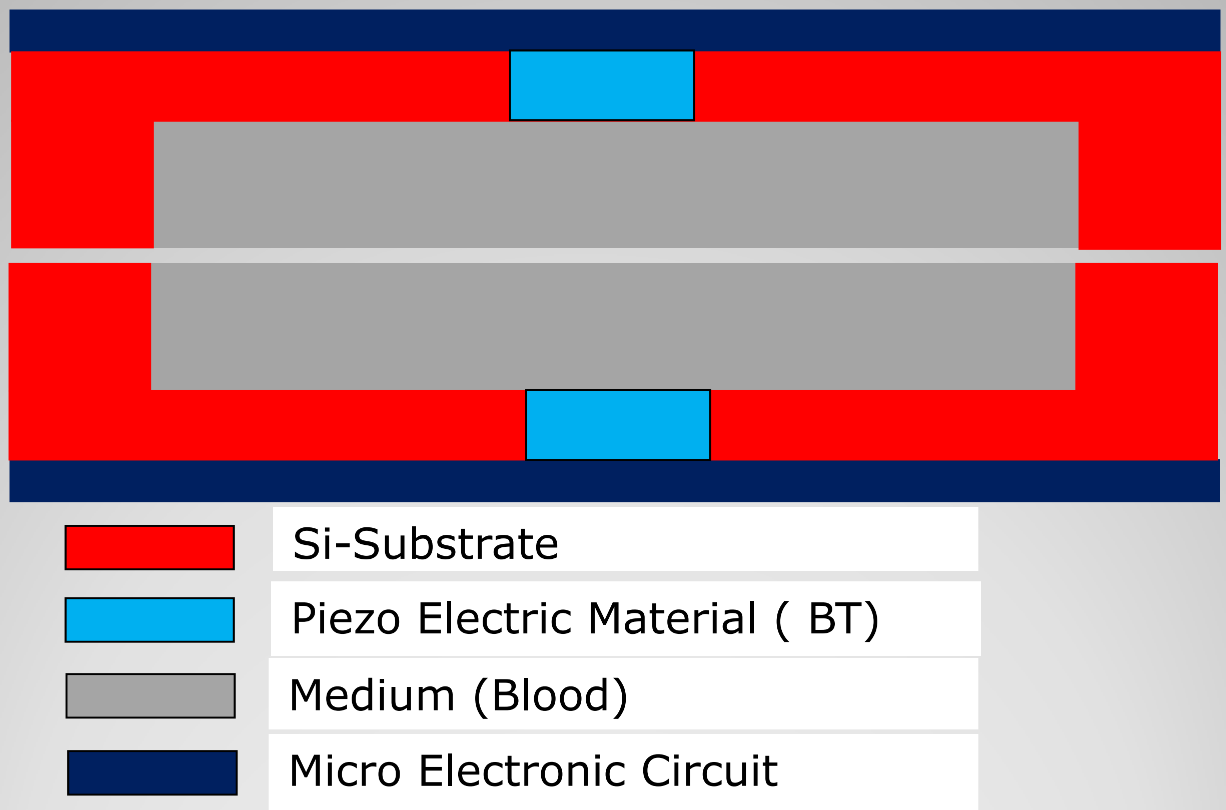
Effect of sample thickness on fundamental frequency



$$f = \frac{c}{\lambda} = \frac{c}{2t}$$

Thickness of piezoelectric sample (BT) was 0.025 mm at 2 MHz fundamental frequency.

Schematic diagrams of layer structure of the MEMS

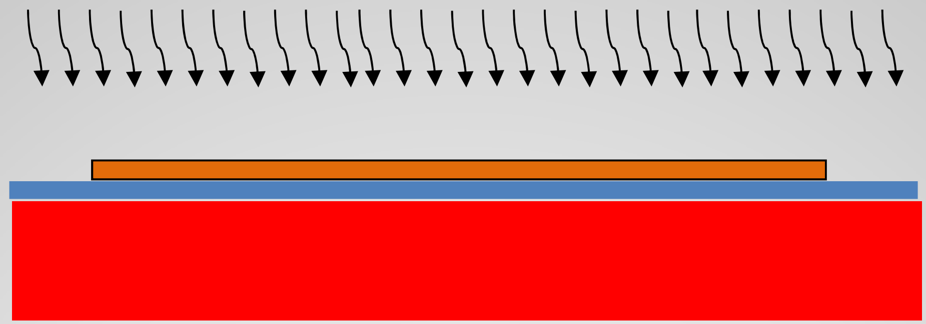


Process flow of Fabrication of ultrasonic MEMS transducer

Step 1. Silicon Wafer was taken Degreased thoroughly.

Step 2. A film of silicon Nitride is grown to create an insulating medium

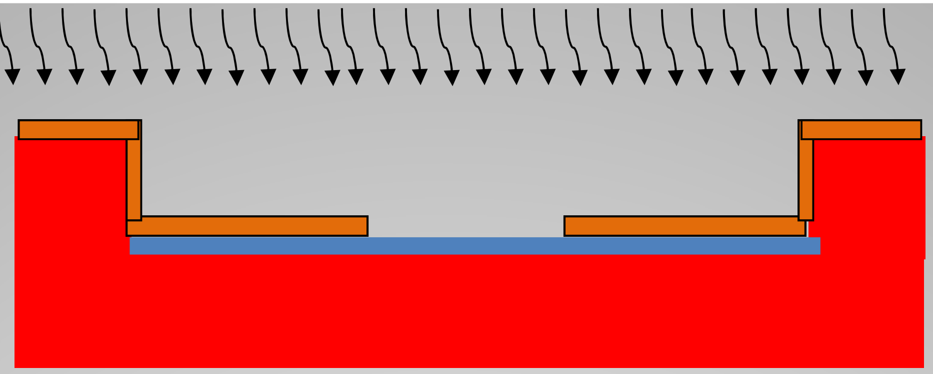
Step 3. Uniform coat of photo resist is applied and dried thoroughly.



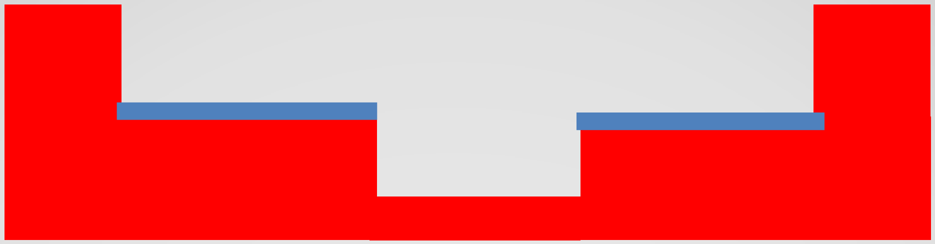
Step 4. The wafer is now subjected to UV light to make the photo resist soluble for cleaning. So that the nitride layer can be etched out where it's unwanted

Step 5. The nitride layer is etched out from the unwanted areas

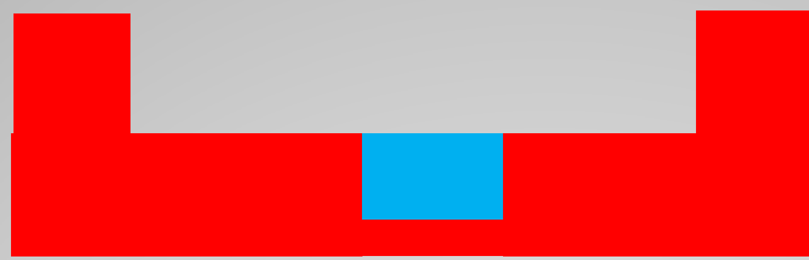
Step 6. The silicon is grown at the exposed area as shown



Step 7. Again a coating of photo resist is applied so as to open the layer.



Step 8. Now the device was ready for the piezo electric material layer which acts as a transducer



Step 8. finally the transducer for transmitting part looks as in the diagram

Similarly We can fabricated the transducer of receiving part. And also microelectronic circuit for both transmitting as well as receiving side.

Procedure for calibration of Glucometer

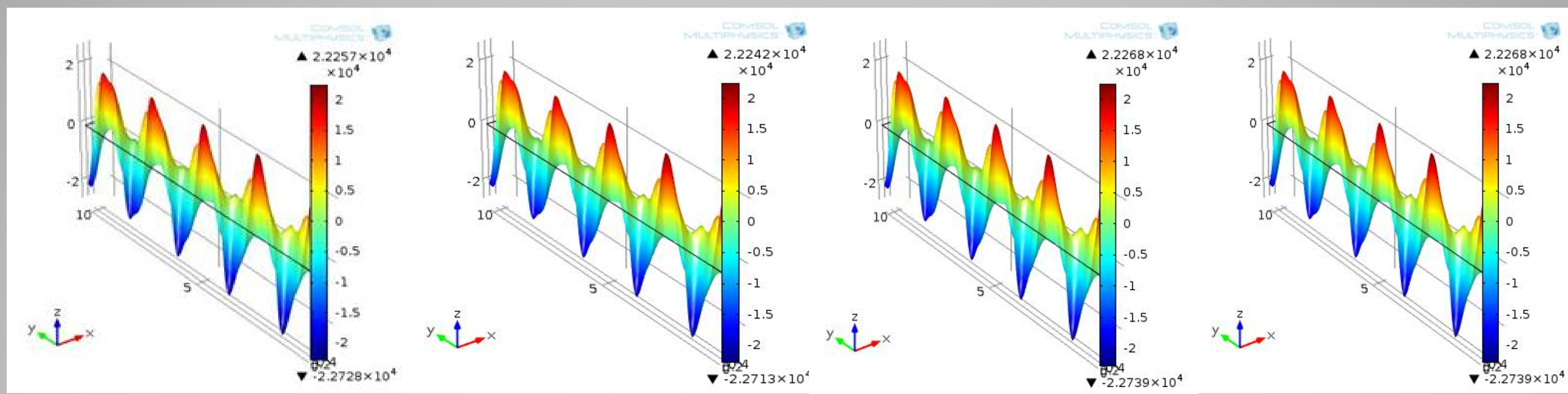
0.5 ml of blood was taken and EDTA anticoagulant was added to prevent coagulation of blood

Then very small amount of weighted glucose was added to the blood to increase the glucose level

The glucose level of this sample was then measured with the help of electronic glucometer

The density of blood were calculated with respected to the amount of glucose added in samples.

Results and discussion



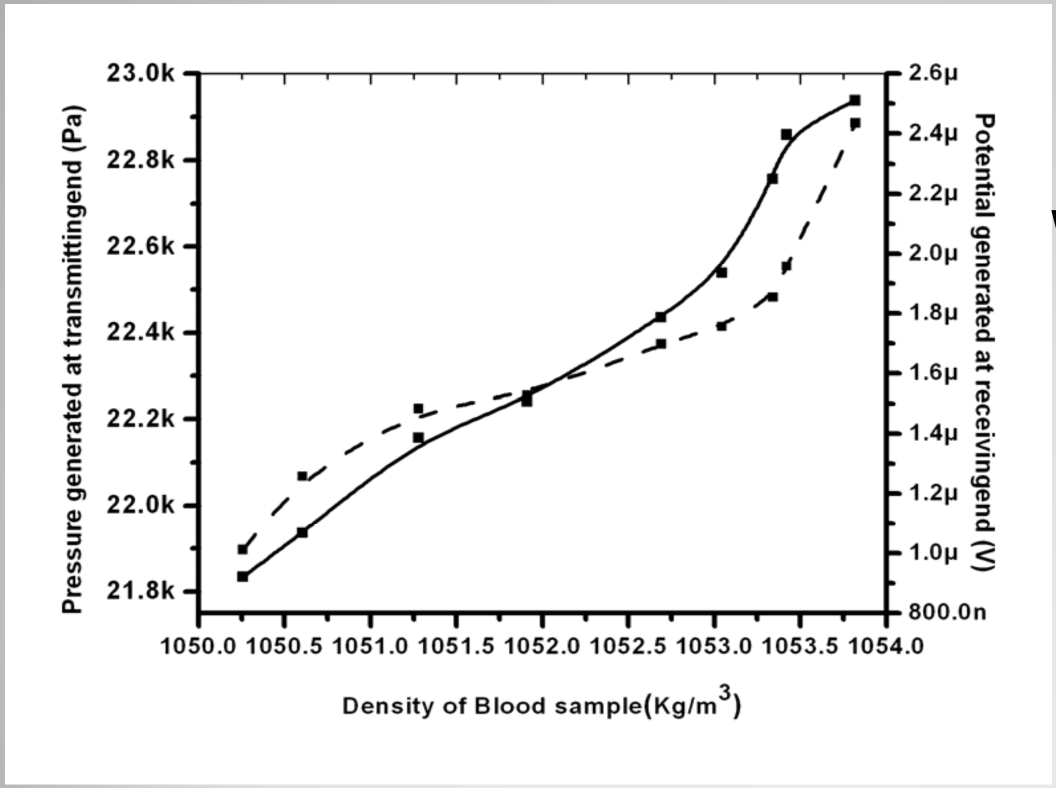
(a) **(b)** **(c)** **(d)**

(a) Acoustic pressure plot for pure blood sample, **(b)** Acoustic pressure plot for blood sample (155mg/dL), **(c)** Acoustic pressure plot for blood sample (316 mg/dL), **(d)** Acoustic pressure plot for blood sample, (382 mg/dL).

Table 1 Comparison results of Electronic glucometer data with different concentration of glucose.

Blood sample	Glucose added in blood sample (mg/dL)	Density of Blood sample (Kg/m^3)	Electronic glucometer (mg/dL)
1	0	1050	70
2	14	1050.14	87
3	82	1050.82	155
4	155	1051.55	227
5	269	1052.69	340
6	316	1053.16	390
7	334	1053.34	408
8	342	1053.42	415
9	382	1053.82	449

Effect of acoustic wave propagation on the density of blood



$$V = S_V P t$$

Where V = Piezoelectric generated voltage (Volts)

S_V = Voltage sensitivity of the material (Volt*meters/Newton)

P = Pressure (N/m²)

t = thickness of material (meters)

Conclusion

- From the property of different lead free piezoelectric materials with different glucose concentrations of blood sample medium displacement and pressure are simulated using software COMSOL Multiphysics 4.3.

- It was found that BT has shown better performance compare to others.

- It has an edge over PZT as it is free from lead contain which are bio compatible.

Acknowledgment

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THANK YOU