Studies of Lead Free Piezo-Electric Materials Based Ultrasonic MEMS Model for Bio Sensor

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Introduction and Motivation .....

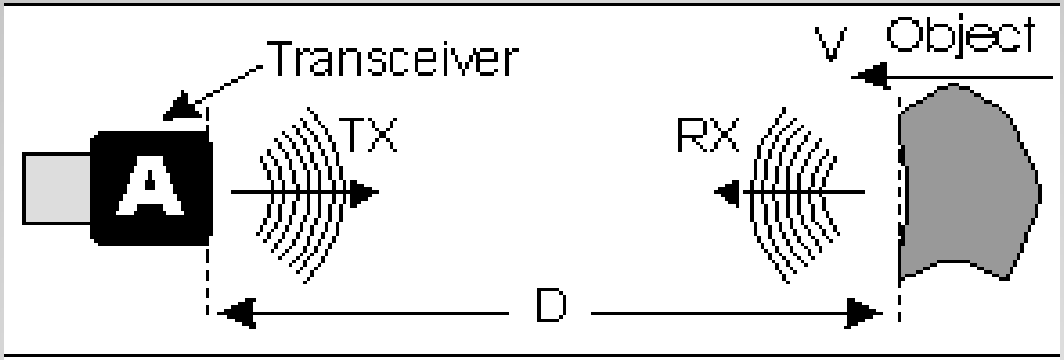
- To prevent complications in diabetes, accurate monitoring and timely management of blood glucose levels is essential.
- Regular monitoring of sugar level in patient can alarm any unwanted rise in the level and necessary precautions can be taken at the right time .
- Glucometers are supposed to be a solution for continuous monitoring of sugar level.
- The cost of the test strips used in commercially available glucometers are high
- To avoid the pricking fingers or other area of the skin, a non-invasive method for monitoring blood glucose levels is desired .

Ultrasonic Transducer Model for Bio Sensor

- Ultrasonic transducer method can be used to determine the glucose levels of human blood by studying the variation of amplitude with density of blood sample with glucose and it can be calibrated and compared to determine the sugar level.

Ultrasonic

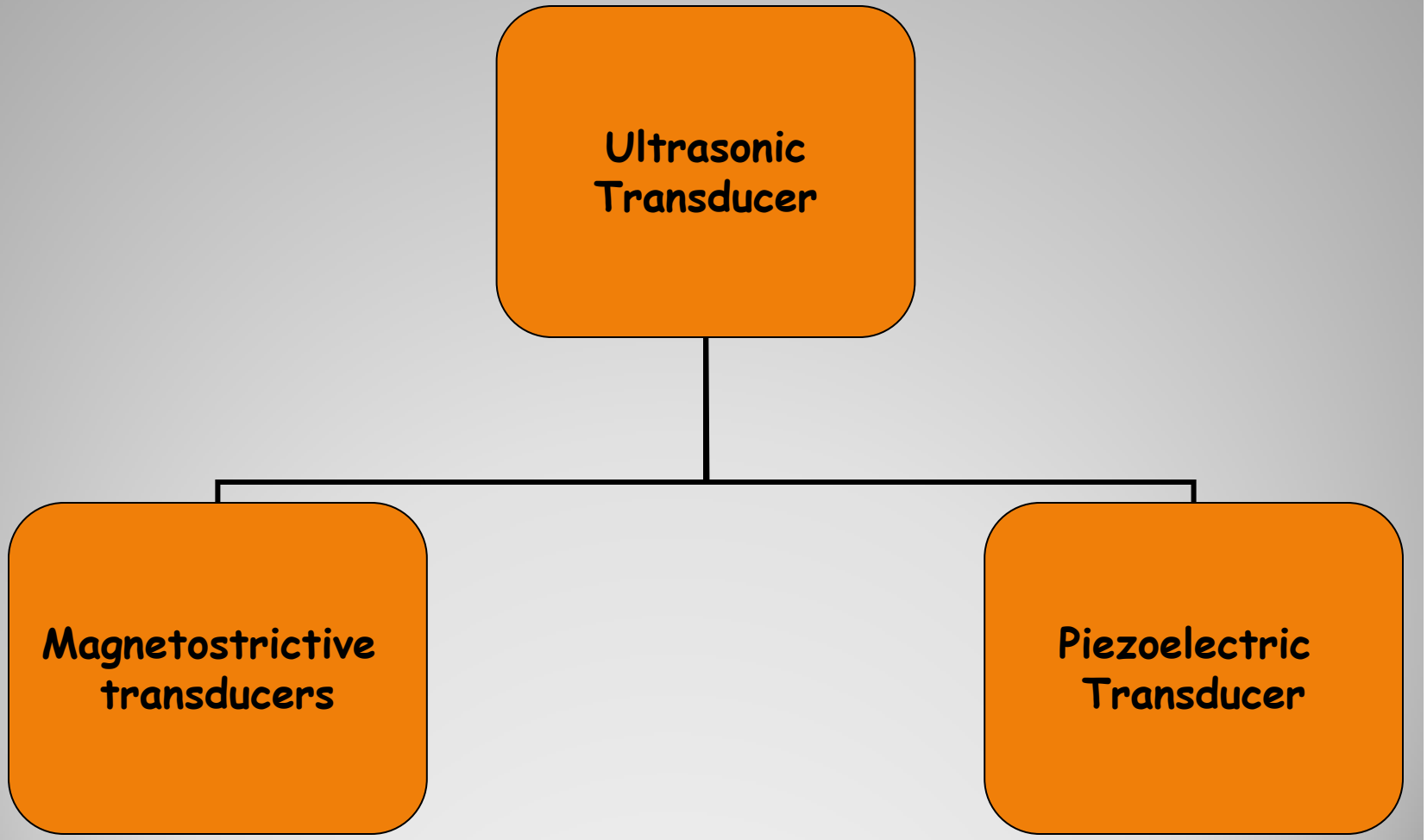
- It is a phenomenon that has the frequency above the hearing capability of human ear.



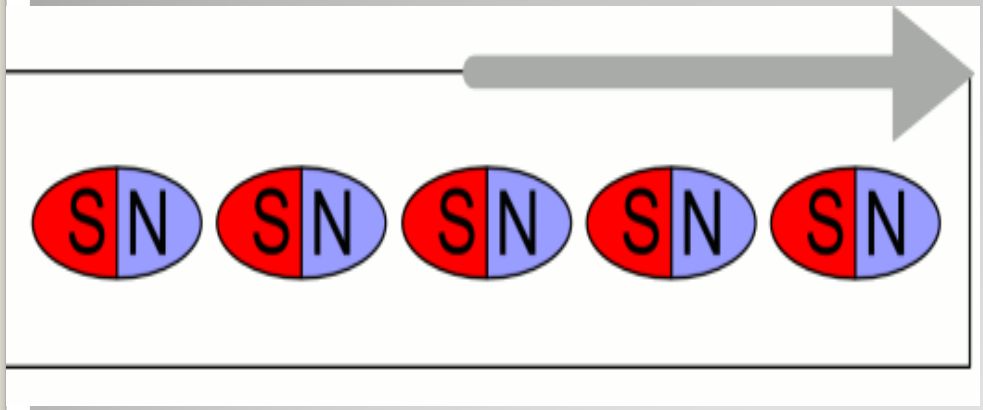
Ultrasonic transducer

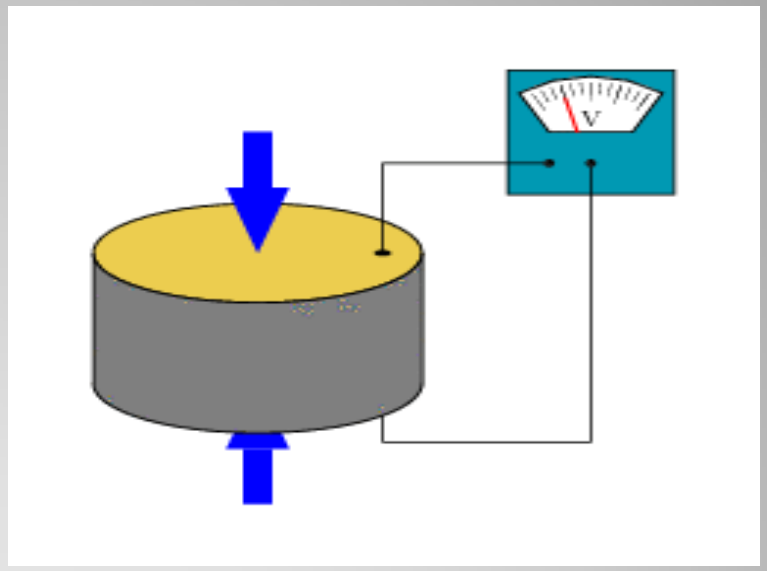
- It is a device that converts energy into ultrasonic waveform and vice versa

Types of Ultrasonic Transducer



Ultrasonic Transducer Principle





Magnetostrictive Transducer

Piezoelectric Transducer

Micro-electro mechanical system (MEMS)

- Conventional ultrasonic transducer 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.

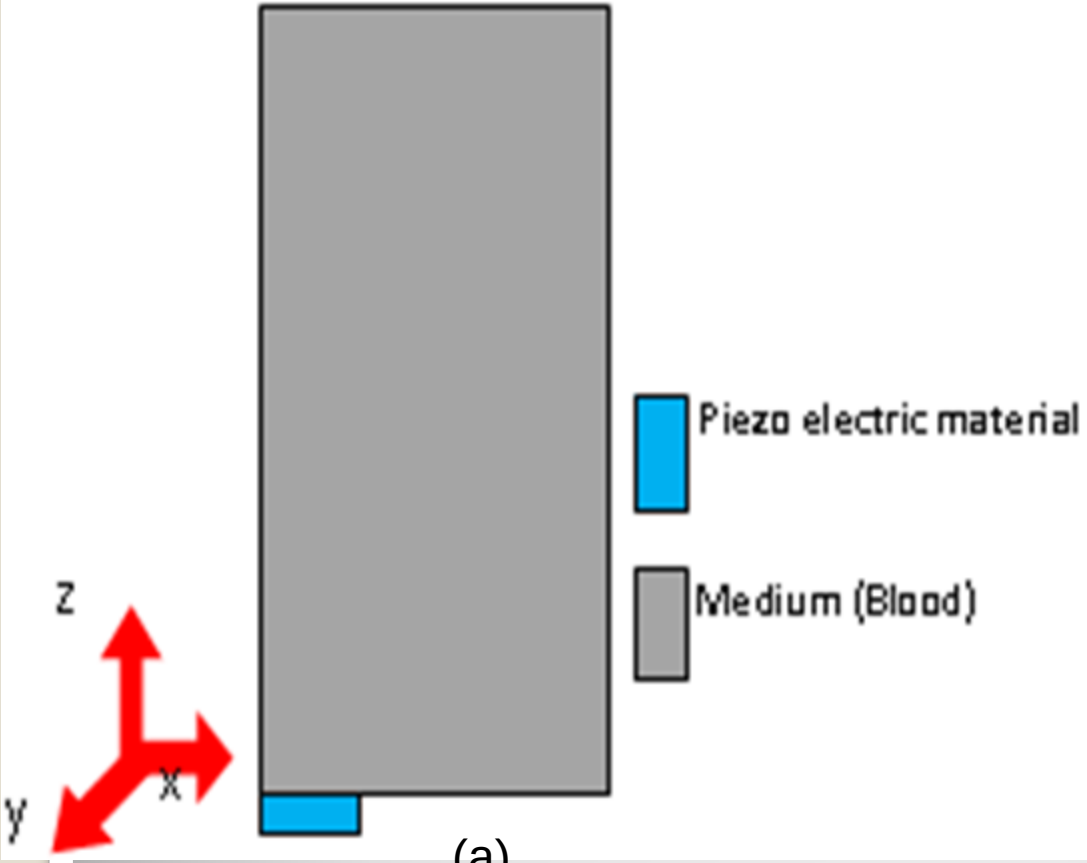
Why piezo materials?

- 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 transducers 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.

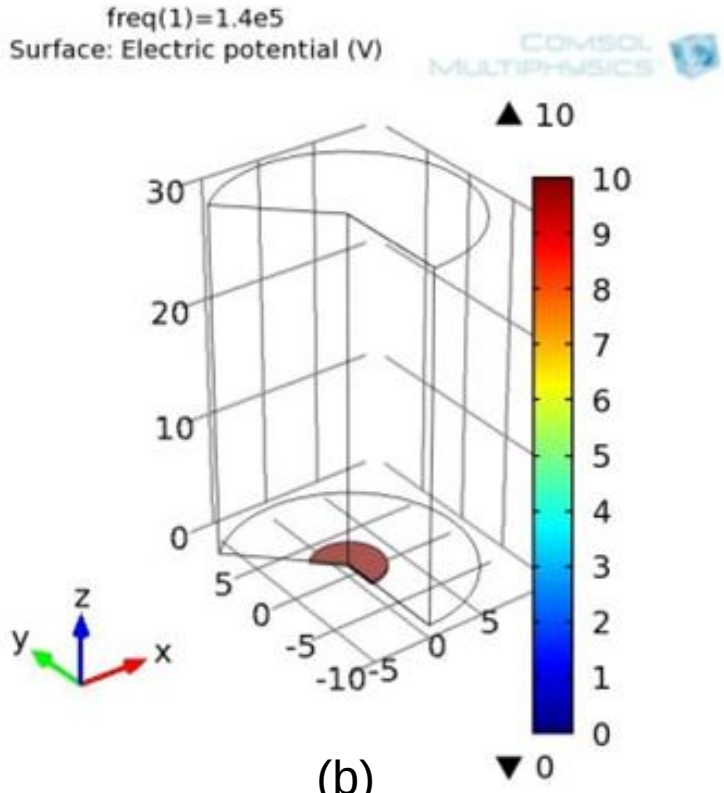
LEAD free Piezo Materials

- 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)

Model geometry and boundary conditions of ultrasonic transducer



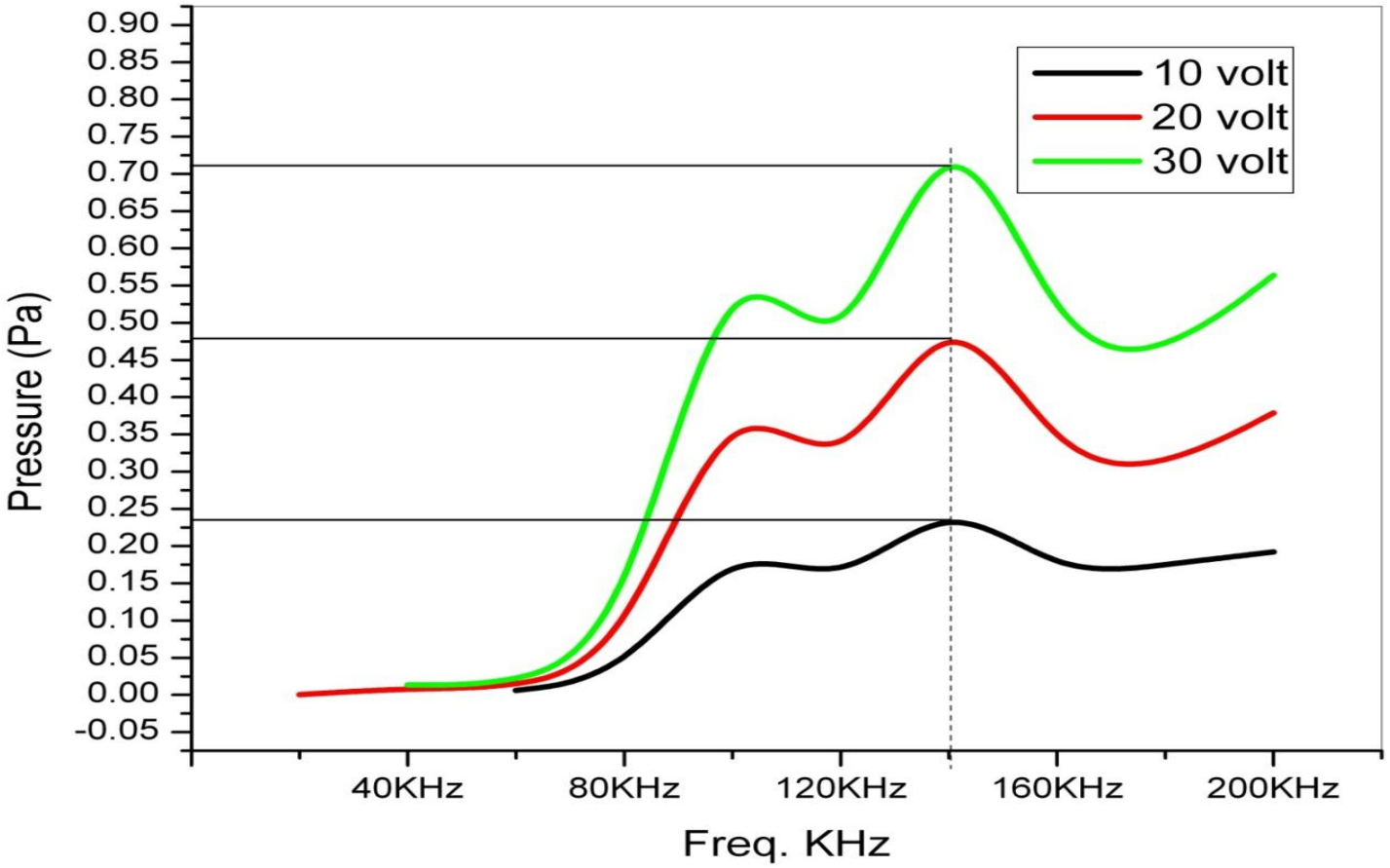
(a)



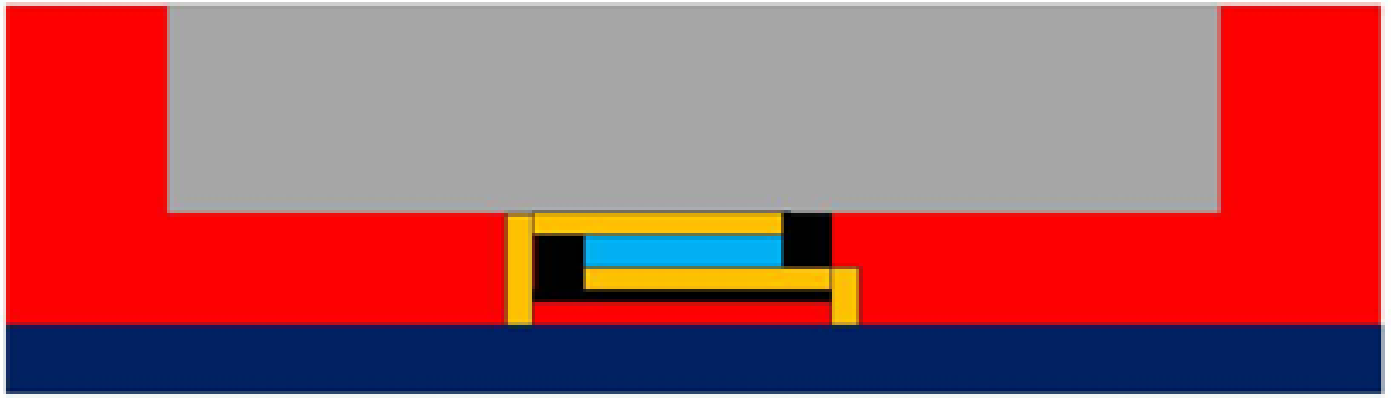
(b)

Figure 1 (a) Schematic model, (b) 2D axis- symmetric model geometry of the piezoelectric based ultrasonic transducer.

Frequency vs Pressure Graph for optimized frequency and voltage.



Schematic diagrams of layer structure of the MEMS



Silicon Substrate

Gold electrodes

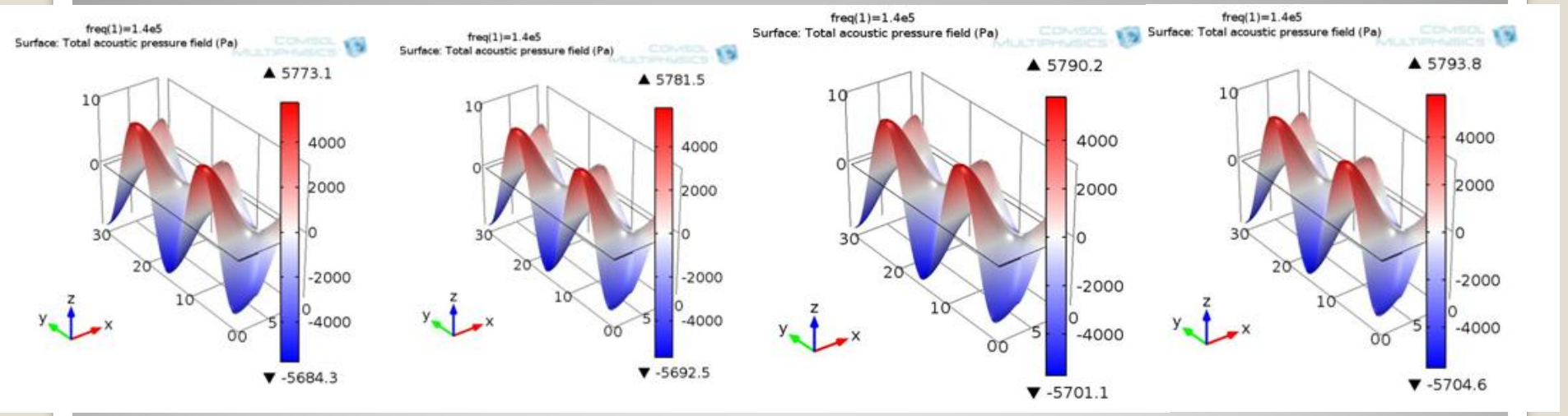
Oxide layer

Piezo Electric Material

Medium (Blood/glucose blood)

Micro Electronic Circuit

Results and discussion



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

Figure 3(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).

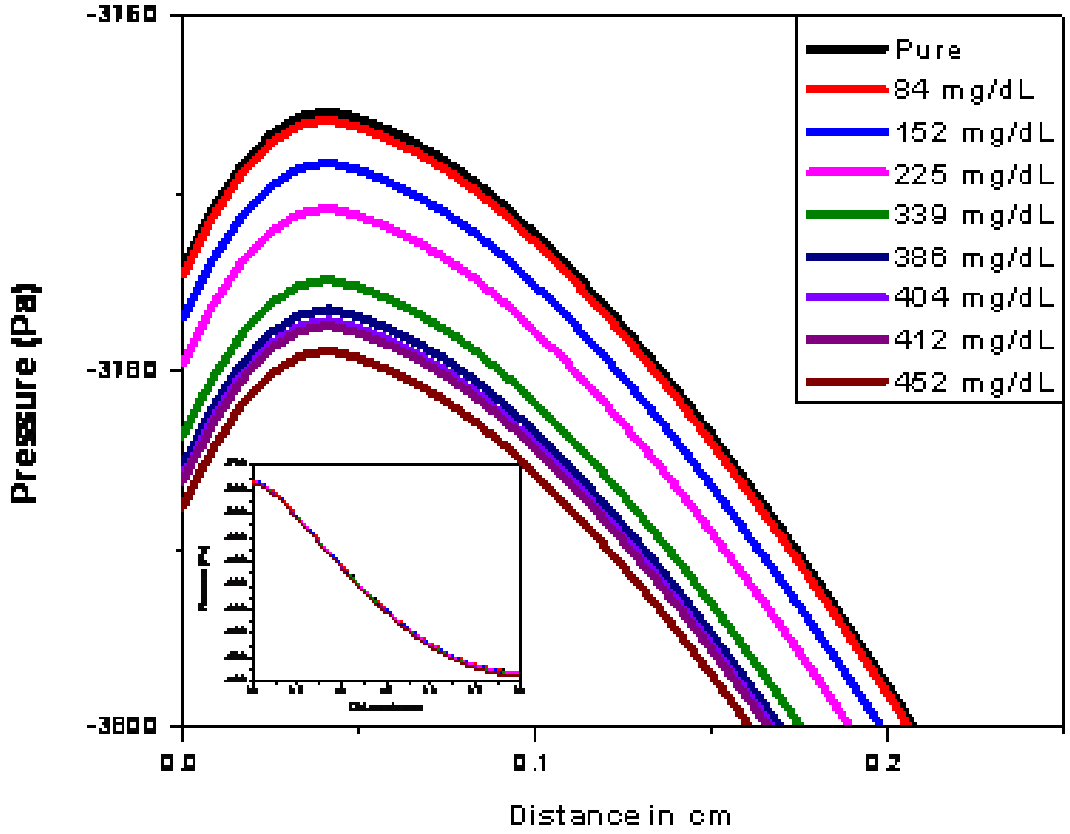


Figure 4 Acoustic pressure verses distance of the medium for different gluclose concentrations of blood sample.

Table 1 Comparison results of Electronic glucometer Pressure data and pressure generated by BT 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)	Pressure generated by BT (Pa)
1	0	1050	70	-3765.337914
2	14	1050.14	87	-3765.832407
3	82	1050.82	155	-3768.234204
4	155	1051.55	227	-3770.812553
5	269	1052.69	340	-3774.838906
6	316	1053.16	390	-3776.498856
7	334	1053.34	408	-3777.134575
8	342	1053.42	415	-3777.417116
9	382	1053.82	449	-3778.829811

Comparison results of different lead free piezoelectric materials based devices.

Blood sample	Pressure generated by LIN (Pa)	Pressure generated by BNN (Pa)	Pressure generated by BT (Pa)
1	-255.2156377	-1564.508718	-3765.337914
2	-255.2495062	-1564.715697	-3765.832407
3	-255.4140098	-1565.721021	-3768.234204
4	-255.590608	-1566.800254	-3770.812553
5	-255.8663893	-1568.485608	-3774.838906
6	-255.9800878	-1569.180438	-3776.498856
7	-256.0236318	-1569.446543	-3777.134575
8	-256.0429846	-1569.564811	-3777.417116
9	-256.139748	-1570.15615	-3778.829811

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 4.2a.
- 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.

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THANK YOU