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Design and Model Analysis of MEMS Respiratory Sensor

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Abstract

In this paper a MEMS based pressure sensor is proposed for detection of respiratory rate of human being. The difference in respiratory rates of male to female is compared and analysed that the probability of disease rate in male is more when compared to female. The maximum and minimum values of inhalation force in male is 9.80X10-7Newtonsand the minimum value is 7.27 X10-7Newtons. The maximum and minimum values of inhalation force in female is 8.21X10-7Newtons and the minimum value is 7.08 X10-7Newtons. The maximum and minimum values of exhalation force in male is 6.05X10-6Newtons and the minimum value is 1.93 X10-6Newtons. The maximum and minimum values of exhalation force in female is 4.02X10-6Newtons and the minimum value is 8.66 X10-7Newtons. The proposed resonator is designed with Sio2-poly crystalline Quartz. The material and dimension optimization has been done and selected the structure. The Eigen frequency and displacement analysis has been done and sensitivity is calculated and itsits value is 4.399X10-4. With respect to force the variation in capacitance is calculated. The maximum value of capacitance is 2.17-38X10-38 for male during inhalation and minimum value is for female during inhalation.

I. INTRODUCTION

Respiration:

Respiration refers to a person's breathing and the movement of air in and out of the lungs. The respiratory system provides oxygen to body tissues for cellular respiration, removes the waste product carbon dioxide. Inspiration is the process that causes air to enter the lungs, and expiration is the process that causes air to leave the lungs[1]. A respiratory cycle is one sequence of inspiration and expiration.Breath rate sensors can be separated into contact and noncontact strategies[2]. In noncontact strategies the techniques used are change of the chest area is observed by an infra-red, optical, or radar imaging framework. Noncontact techniques have the upside of not requiring the connection of any hardware to the patient. In contact techniques the equipment is attached to the patient which is not flexible to the patient.

Mems technology:

The condensing of MEMS is Micro Electro Mechanical System. Any architect in the framework that performs electrical and mechanical capacities with segments in micrometers is a MEMS(1 µm).There are Four sorts of MEMS segments it comprises of Micro sensors, Micro actuators, Micro gadgets, Microstructures.

Resonators:

Resonator is characterized as a framework shows particular reactions at explicit frequencies. The swaying in a resonator can be in electrical field or magnetic field. Resonators having various spaces like Mechanical electrical, electromagnetic, optical,

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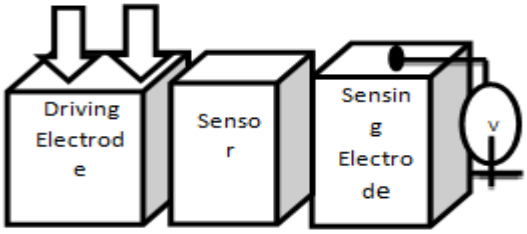
acoustic.

FORCE



Advantages of mems resonator:

1. Contrasted and gems, earthenware resonators cost just half as much as precious stones and are littler in size.
2. Quasi-Digital output.
3. Simple mechanical design
4. High frequency resolution

Disadvantage of mems resonator:

1. Contrasted and precious stones, the absence of recurrence and temperature dependability.
2. Its exactness is poor, extending from 1% to 0.1%.
3. Lower affectability
4. Sensitive to ambient changes.

Applications:

The MEMS resonators are minimal electromechanical structure that generally vibrate at high frequency. The application that are utilized for resonators it comprises of biological sensing, mass sensing ,timing references, oscillators, signal filtering, bio-chemical, force, accelerometer and other distinctive application.

II. STATE OF THE ART

1. This research is done by Chia-lingwei, Chien-fu-liu and I-Ta-tseng[3].This paper is about designing a flow sensor for respiration rate where the velocity of air in exhaled breath hits the surface of sensor and there exits deformation of sensor. The equations that are P=considered. Due to the applied pressure there is change in resistance which is changed voltage. The failure of this model is need two sensors facing in opposite directions for detecting the flow with both inspiration and expiration. The results conclude that sensor is sensitive enough to detect the flow rate of respiration.
2. This research is done by Gitesh Mishra, NehaParas, ArtiAvova. Thispaper is about simulation of MEMS based capacitive pressure sensorusing COMSOL multipysics[4]. The equation of this capacitive sensor isC=(A∈∈_°)/Dare considered. The failure of this model is the attractive attention of that capacitive sensor have to be in high sensitivity compared to other sensor. The paper explores designed parameters are on FEM(finite element modelling).The material is taken as single crystal silicon. The results areapplied pressure there is change in capacitance as well as it changes the displacement and also voltage.
3. This research is done by ‘SinaMoradian’ , ‘Reza Abdolrand’. This paperis about MEMS based passive wireless respiration profile sensor[5].The problem that the author identified the breathing problems like snoring sounds of human respiratory system and also the bulk sensor in the respiration rate. The equation that are F = P.A considered. There is afrequency shift keying process to respond air flow and wireless detection to translate the respiration process. The solution of thisproblem is in the respiration rate the TPOS and resonator die is having the top of the substrate layer it consisting piezoelectric layer, it means electrodes on resonator body and there is no need of any bias. Theresults measured respiration rate while the inhale the air or force through the different temperature is used to measured from thin filmpiezoelectric on substrate resonator.
4. This research is done by Toshiharu Mukai1, Kazuya Matsuo andYo Kato. This paper is going to build up a framework for unconstrained estimation of the lying posture, breath and heartbeat of an individual on a delicate elastic based material sensor sheet[6]. The software MATLAB.2018 is utilized

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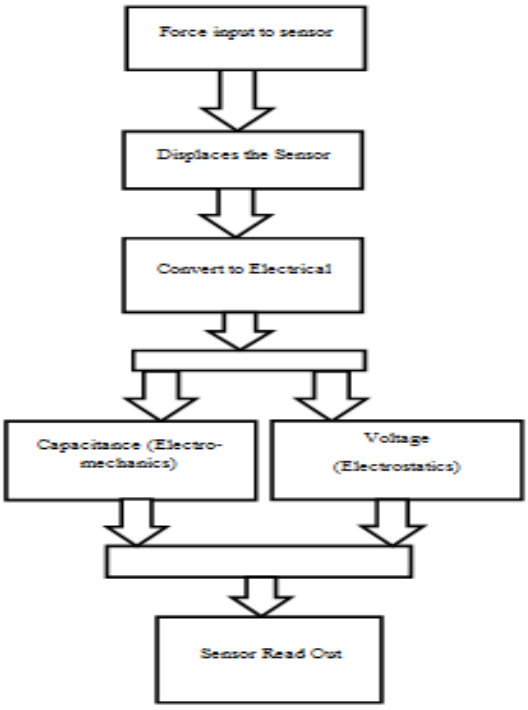
in this paper. The solution of this problem is used to measured with pressure for the four postures in respiration magnitude and phase. The soft-rubber sensor is connected to controller and pressure distribute by scanning. In the current program, measuring one cell takes 184 micro second which means 47 millisecond for the whole soft rubber sensor sheet. The pressure distribution is transfer to a PC, where the lying posture, the respiration rate, and the heart rate detected by pattern recognition and signal processing. The results conclude that respiration has a frequency range of approximately 0.1–0.5 Hz and the heartbeat has a frequency range of approximately 0.9–1.5 Hz.

5. This research is done by Christopher G Lausted, William H Scott, Arthur T Johnson. This paper is about maximum static inspiratory and expiratory pressure with different lung volumes[8]. Maximum inspiratory and expiratory pressure is measured over a range of lung volume in male and female. The result concluded maximum inspiratory pressure decreased with volume

III. METHODOLOGY



The force of air particles is the input parameter to the sensor.

$$P=F/A \quad (1)$$

where P is the pressure of the air

F is the force of air particles

A is the area of resonator

To design the sensor the tool used is COMSOL MULTIPHYSICS. The sensor displaces due to the applied force in the z direction. As there is displacement change in sensor there is change in capacitance i.e

$$C=(A\in\in\_°)/D \quad (2)$$

and voltage. The capacitance variations are analysed in ElectroMechanics physics and voltage variations are analysed in ElectroStatics physics.

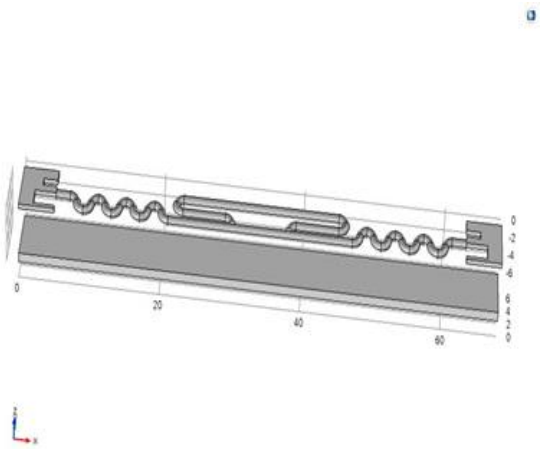


Fig.a: Sensor.

The resonator of Q factor is recommended by most extreme recurrence and least frequency. The contrast among greatest and least recurrence at 3DB recurrence. The Q factor value of the resonator is 1.000000018.

$$Q = (f\neg 0)/\Delta f \quad (3)$$

where f¬0is denoted as maximum frequency.

Δfis difference between maximum and minimum frequency.

F_{max}	Pressure	Displacement	Capacitance	Voltage

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Exhalation Male	6.05E-06	4.71	$-1.36*10^{-38}$	8.1
Inhalation Male	9.80E-07	3.34	$-2.17*10^{-38}$	8.19
Exhalation Female	4.02E-06	3.2	$-1.78*10^{-39}$	8.21
Inhalation Female	8.21E-07	1.04	$-1.28*10^{-38}$	8.21

F_{min}	Pressure	Displacement	Capacitance	Voltage
Exhalation Male	1.93E-06	0.55	$8.32*10^{-39}$	8.12
Inhalation Male	7.27E-07	2.89	$-1.71*10^{-38}$	8.22
Exhalation Female	8.66E-07	3.16	$-1.78*10^{-38}$	8.2
InhalationFemale	7.08E-07	2.84	$-1.71*10^{-38}$	8.13

In the start of investigation we have taken a few materials like SiO2,GaAs,Aluminium,SiO2(Insulator),Silver,SiC, Al2O3.The Eigen Frequency analysis is done to check the sensitivity of the materials

SiO_2(Polycrsytalline)		GaAs		Aluminium	
Eigen frequency	Displacement	Eigen frequency	Displacement	Eigen frequency	Displacement
193.79	5.63e-06	1.46E+02	5.63E+06	1.79E+02	5.63E+06
6.60E+05	3.60e-06	5.30E+05	3.59E+06	6.72E+05	3.59E+06
8.68E+05	2.91e-06	7.05E+05	2.90E+06	8.97E+05	2.90E+06
1.37E+06	3.50e-06	1.09E+06	3.49E+06	1.38E+06	3.49E+06
1.69E+06	3.96e-06	1.37E+06	3.96E+06	1.74E+06	3.96E+06
3.57E+06	3.36E+06	2.84E+06	3.44E+06	3.60E+06	3.48E+06

SiO_2 (Insulator)		Silver	
Eigen frequency	Displacement	Eigen frequency	Displacement
2.16E+02	3.37e-06	1.01E+02	5.63E+06
7.44E+05	3.60e-06	3.72E+05	6.59E+06
9.79E+05	2.90E+06	4.96E+05	2.90E+06
1.55E+06	3.49E+06	7.64E+05	3.49E+06
1.91E+06	3.96E+06	9.65E+05	3.95E+06
4.02E+06	3.37E+06	1.99E+05	3.50E+06

SiC		Al_2O_3	
Eigen frequency	Displacement	Eigen frequency	Displacement
5.34E+02	5.63E+06	3.78E+02	5.63E+06
2.05E+06	3.58E+06	1.32E+06	3.60E+06
2.74E+06	2.90E+06	1.75E+06	2.90E+06
4.19E+06	3.49E+06	2.74E+06	3.49E+06
5.32E+06	3.94E+06	3.41E+06	3.96E+06
1.09E+07	3.84E+06	7.13E+06	3.39E+06

The values that are obtained after the Eigen analysis are addressed in the form of graph. The graph represents which material has high sensitivity.

Sensitivity =(d2-d1)/(e2-e1)

whered is displacement of sensor

e is the Eigen frequency

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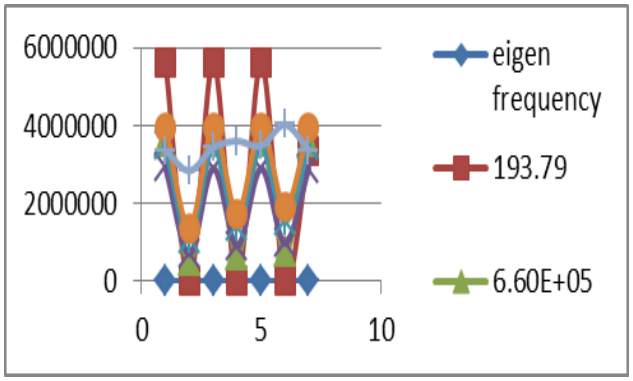
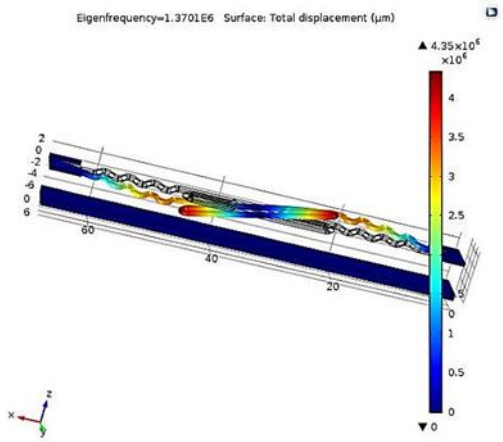


Fig.b: Eigen frequency versus Displacement of all materials.

Silicon dioxide polycrystalline is considered on the grounds that the affectability is more contrasted with different materials which are done in the examination.

IV. RESULTS

The Eigen recurrence is utilized to contrast and one after other there is variety appeared through the detecting element. Then the all out relocation is confirmed in maximum to minimum qualities spoke to in micro-meters. Every Eigen recurrence is having its own shapes and displacement in greatest to least values. Along these lines, SiO2 polycrystalline material is considered in light of the fact that affectability is more which are done in the outcomes. In the sensing element of resonator and single silicon substrate between them having the area as 6 micro-meter to getting the Eigen frequency versus displacement over the outcomes.



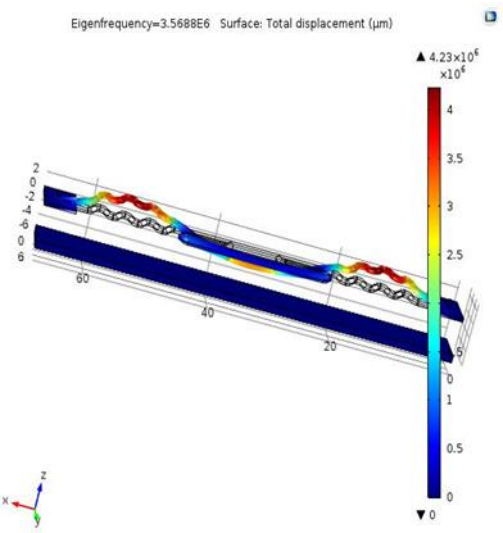


Fig.c: Displacement of sensor at Eigen frequency= 3.5688e6Fig.d: Displacement of sensor at Eigen frequency=1.37e6

The force values that applied in the range of 7.08E-07 to 6.05E-06 where the displacement

variation are from 4.71 to 1.04. The highest variation in the displacement is for male exhalation value and lowest variation in the displacement is for female inhalation. The capacitance variations are from 1.78E-39 to 2.17E-38. The highest variation in the capacitance is for male inhalation value and lowest variation in the capacitance is for exhalation female.

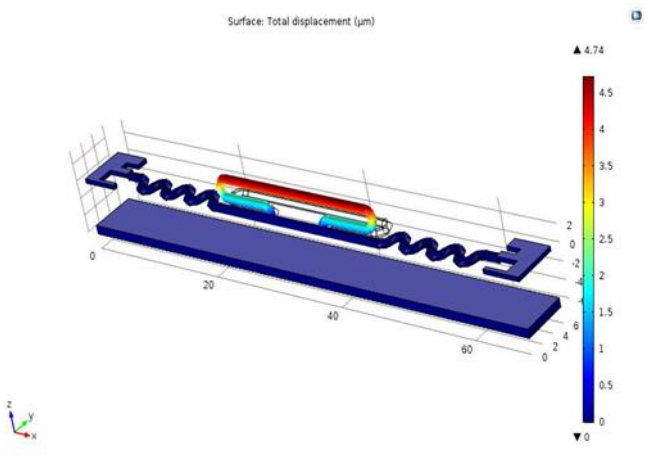


Fig.e: Displacement of Sensor at the force value 6.05e-6

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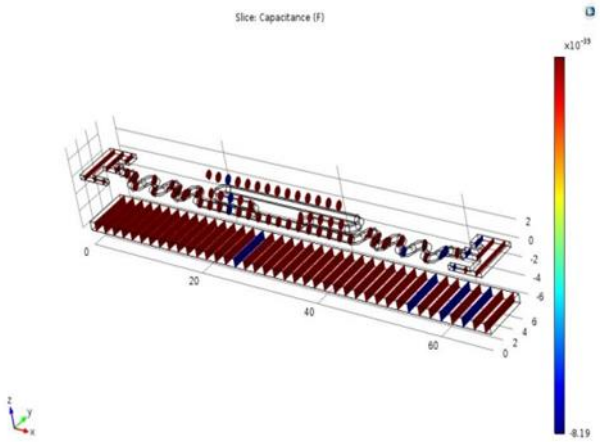

Fig.f: Capacitance of Sensor at the force value 6.05e-6

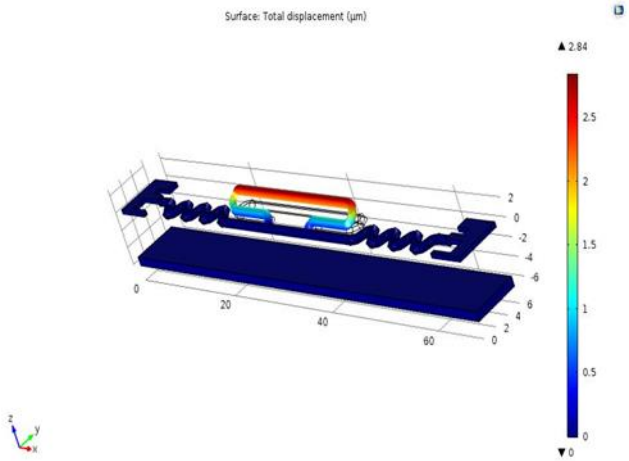

Fig.g: Total Displacement of Sensor at force value

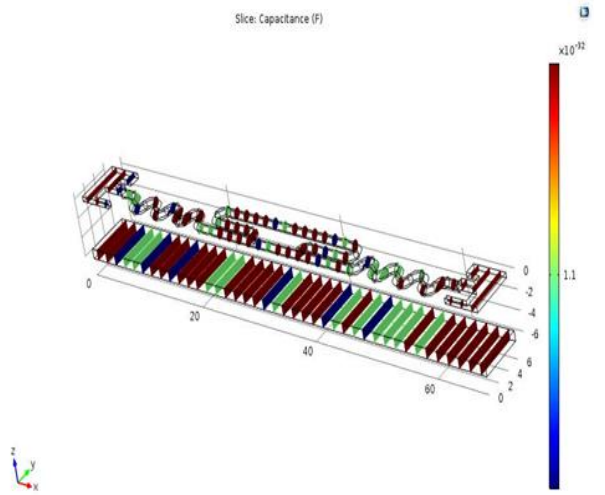

Fig.h: Capacitance of Sensor

The mix of electro statics and solid mechanics is utilized to get electric potential in nearness of volts. In solid mechanics the force value that applied in the scope of 7.08E-07 to 6.05E-06. The multi-slice electric potential in nearness of voltage there is no variety from most extreme to least qualities. It shows similar qualities from 8.1 to 8.21 approximate ranges for exhalation and inhaled breath in human respiratory profile.

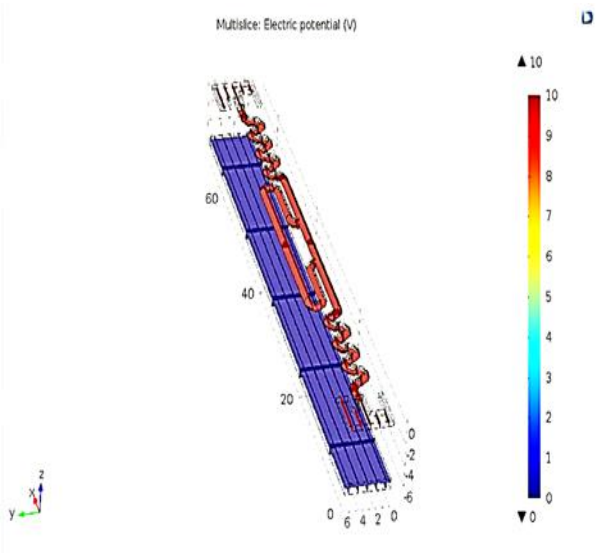

Fig.j:Displays max to min value Electric potential(volts) of sensor

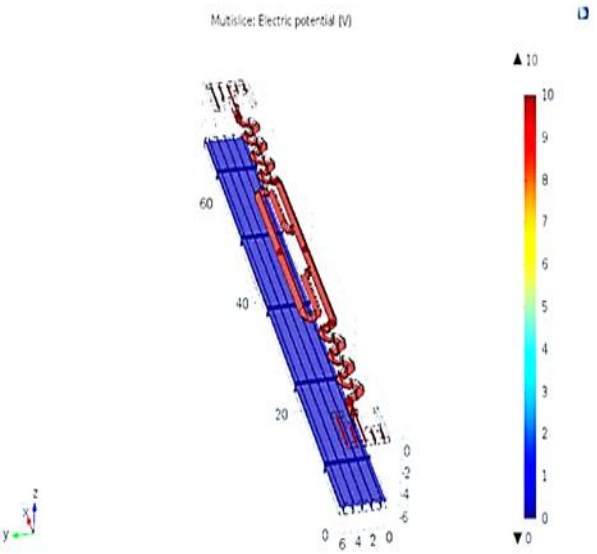

Fig.i: Electric potential(volts) of Sensor.

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V. CONCLUSION

In this paper the proposed work that applied certain forces based on eigen frequency and displacement analysis has been done and sensitivity is calculated and its value is 4.399X10-4 with respect to force the variation in capacitance is calculated. The minimum value of capacitance is 1.28X10-38 for female during inhalation

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