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MICRO ELECTRO MECHANICAL SYSTEM BASED SENSOR FOR EARLY DETECTION OF PARKINSON'S DISEASE – DESIGN AND SIMULATION

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ABSTRACT

In this paper, a novel structure is proposed at Micro Level to detect the symptoms of Parkinson's desease at an early stage. We have designed the proposed structure using Finite Element Method (FEM) tool, Comsol multi physics by utilizing capacitive actuation technique. The simulations are done on capacitive based micro structure by changing the material of proof mass and the force applied on proof mass. Also we have calculated and simulated the thermal variations and stress by thermal change on the legs of proposed structure. It is observed that Poly Tetra Fluro Ethylene material of the proof mass with silicon legs by giving specific dimensions are showing best optimized results. This result shows high sensitivity, high reliability and cost effectiveness of the proposed Parkinson's Disease Sensor.

KEY WORDS: **Parkinson's disease, FEM, PTFE, Sensitivity.**

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INTRODUCTION

The movement related analysis is one of the important criteria to assess the quality of Human Life. The Inertial (Measurement Units) IMU is the accurate measurements for human movement. Parkinson's disease (PD) is one of the most common movement disorder which denotes degenerative and progressive disorder of the central nervous system. The patients may suffer with a variety of symptoms, such as tremor, bradykinesia, rigidity, and postural instability. Tremor is the most well-known and apparent symptom for PD[1]. The current standard for evaluating parkinsonian Brady kinesia is the Unified Parkinson's Disease Rating Scale (UPDRS), a qualitative assessment that is completed by the subjective judgment of neurologists[2]. Tremor is observable and easily detectable symptom of neurological disorders due to its alternating character. This is true especially for the rest tremor or postural tremor, where the body segment does no other marked motions except the tremor. Moreover, if a specific tremor type is searched for, only limited frequency band can be investigated (e. g. 3 - 8 Hz for the tremor in Parkinson's disease)[3]. pill rolling tremor is best suited tremor to detect Parkinson's disease. It is still an mystery which causes PD, but tremosome works proposed, the low production of dopamine[4]

Clinical features of Parkinson's Disease

The clinical symptoms of Parkinson's disease are tremor or shivering, small hand writing, loss of smell, trouble in sleeping, trouble moving, constipation, soft of low voice , masked face, dazing or fainting and stooping or hunching over[5]. A Micro Electro Mechanical system accelerometer is designed and simulated. As per the studies of Parkinson's disease the basic identification criteria is resting tremor or pill rolling tremor[6]. Here in this paper a novel model of accelerometer with capacitive actuation technique. The frequency of an accelerometer is calculated with a spring mass arrangement (Figure1) and the frequency is calculated using the following equation.

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}} \quad Hz$$

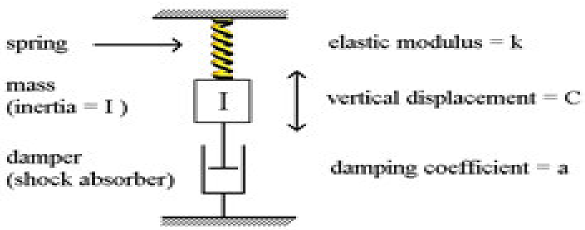

Figure 1
Spring mass arrangement

Micro Electro Mechanical system (MEMS) Sensors are used to sense the physical changes in the devices and the corresponding output in the form of electric signal. Numerous types of prototypes have been fabricated and tested for variety of bio applications. The major sensing elements in Micro Electro Mechanical system (MEMS) sensors are cantilevers, diaphragms and membranes. Those parts are incorporated in designs with some supporting fragments, eventually making a structure that can produce measurable output for a particular input problem. Micro Electro Mechanical system(MEMS) sensors are designed for a particular problem or we can say acts on specifically one stream[7]. We can't just say that an Micro Electro Mechanical system MEMS device as an electronic circuit, as it is having more than it. Of course the electric action is carried out, but it is having movable mechanical parts. This paper mainly concentrate on designing an accelerometer which is having proof mass movement methodology. The proof mass is suspended between 4 fixed supports, whereas all the four fixed arms are perfectly on other ends so as to produce vibrations. The design schema is chosen so that when a force is applied on the surface of the proof-mass, there will be variation in displacement, in-turn changes the Eigen frequency. The application of accelerometer is to measure the vibrations and force. There are some types in calculating the vibrations produced[8], piezo electric, piezo resistive and capacitive. Piezo electric technique is preferred for its easy response calculation but the bottleneck of this is the response is very slow. Looking into piezo resistive, the change in the resistance is to be calculated for that it need some external excitation resulting increasing overall device cost and complexity[9].The main aim of my work is to detect the severity of resting tremor for Parkinson's disease at an early stage. The proposed model consists of a wearable device to finger with accelerometer sensor[10]. As the main parameter for detection is the resting tremor[11], the displacement of proof mass of the accelerometer sensor varies with the tremor frequency which in turn varies the output voltage of the sensor. The capacitive technique, the two plates are separated by a distance[12]. The variation of capacitance with the change in distance between the plates.

$$C = \frac{\varepsilon 0 \ A}{D}$$

A= Area of plates
D= Distance between plates

One of the two plates (electrode) of the capacitor is fixed and another is moving proof mass[13], when a force is applied, the proof mass moves in a direction which causes variation in capacitance[14]. If no force is applied the output voltage is zero[15].

DESIGN PROCEDURE

Accelerometer sensor consists of a proof mass with a polymer Poly Tetra Fluro Ethylene. The legs or limbs with a torus which holds the proof mass with silicon material as shown in fig-2.

Dimensions

The poof mass is a square of side 2500μm. The Legs are of cylindrical rod with radius 100 μm and length 550 μm. The torus is of major radius 300 μm and minor radius 100 μm. The Legs and torus are arranged on four sides of the proof mass. The designs are tested with different materials of proof mass

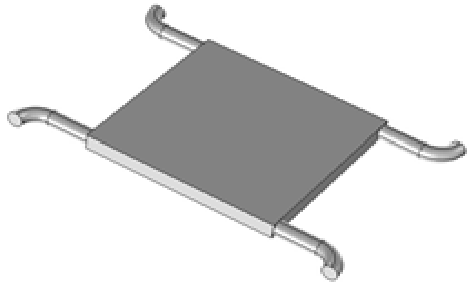

Figure 2
Proof mass Structure

Simulation Designs

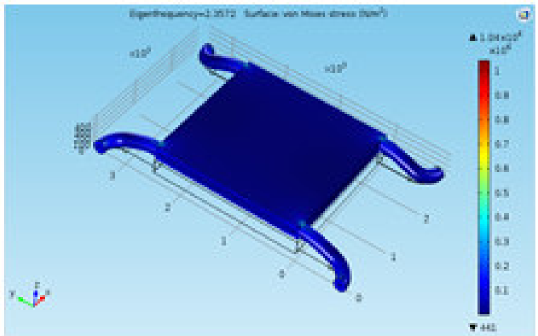

Figure 3
Minimum Eigen Frequency (2.3572Hz)

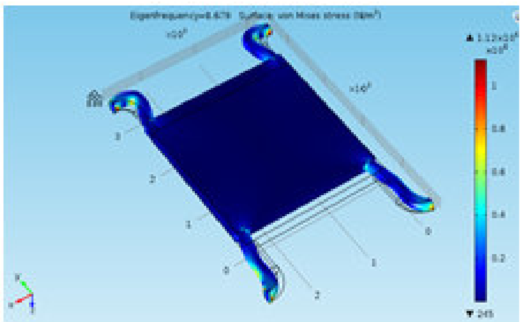

Figure 4
Maximum Eigen Frequency(8.676Hz)

Simulation Results

Table 1
Material Properties

Property / Material	**PTFE**	**Silicon**
Young's modulus	410	179
Poission's Ratio	0.46	0.26
Density (kg/m3)	2150	2330

Table 2
The Eigen Frequencies Observed for different proof mass materials

MATERIAL	EIGEN FREQUENCY					
Nylon	3.2046	4.4963	5.0855	7.2343	10.082	11.64
POLYIMIDE	3.0265	4.2432	4.8281	6.8952	9.6328	11.028
PMMA	3.154	4.4244	5.0129	7.1391	9.9563	11.467
PVC	2.6299	3.6715	4.2299	6.0918	8.5556	9.6202
POLYETHELENE	3.534	4.966	5.5508	7.8361	10.871	12.754
PTFE	2.3572	3.2966	3.8258	5.5377	7.803	8.679

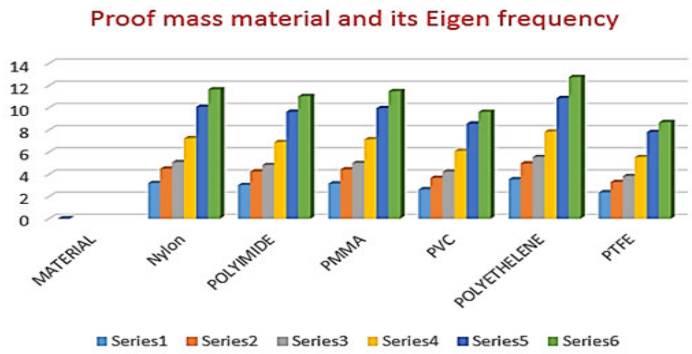

Figure 5
Graph of Eigen frequency for different materials

Table 3
Body load in Positive Z direction and its Eigen Frequencies

Eigen Frequency	With no load	5N/m3	10 N/m3	15 N/m3	20 N/m3
2.3572	1.04 X 10^{6}	3.44 X 10^{10}	5.31 X 10^{10}	4.44 X 10^{10}	4.37 X 10^{10}
3.2966	3.11 X 10^{10}	7.75 X 10^{10}	3.98 X 10^{10}	3.599 X 10^{10}	3.63 X 10^{10}
3.8258	4.25 X 10^{10}	4.23 X 10^{10}	3.33 X 10^{10}	3.13 X 10^{11}	7.51 X 10^{10}
5.5377	9.95 X 10^{10}	3.15 X 10^{10}	5.18 X 10^{10}	3.73 X 10^{10}	7.64 X 10^{10}
7.803	3.39 X 10^{10}	4.0 X 10^{10}	2.09 X 10^{11}	1.19 X 10^{11}	4.84 X 10^{10}
8.679	2.74 X 10^{10}	4.84 X 10^{10}	6.67 X 10^{10}	3.76 X 10^{10}	3.38 X 10^{11}

Table 4
Body load in Negative Z direction and its Eigen Frequencies

Eigen Frequency	With no load	- 5N/m3	-10 N/m3	-15 N/m3	-20 N/m3
2.3572	1.04 X 10^{6}	2.65 X 10^{11}	7.44 X 10^{10}	5.17 X 10^{10}	4.08 X 10^{10}
3.2966	3.11 X 10^{10}	7.4 X 10^{10}	4.15 X 10^{10}	2.7 X 10^{10}	8.36 X 10^{10}
3.8258	4.25 X 10^{10}	1.44 X 10^{10}	5.11 X 10^{10}	4.47 X 10^{10}	3.75 X 10^{10}
5.5377	9.95 X 10^{10}	5.29 X 10^{10}	2.46 X 10^{11}	8.82 X 10^{10}	5.02 X 10^{10}
7.803	3.39 X 10^{10}	7.11 X 10^{10}	4.05 X 10^{10}	6.25 X 10^{10}	6.54 X 10^{10}
8.679	2.74 X 10^{10}	8.29 X 10^{10}	5.06 X 10^{10}	3.97 X 10^{10}	7.45 X 10^{10}

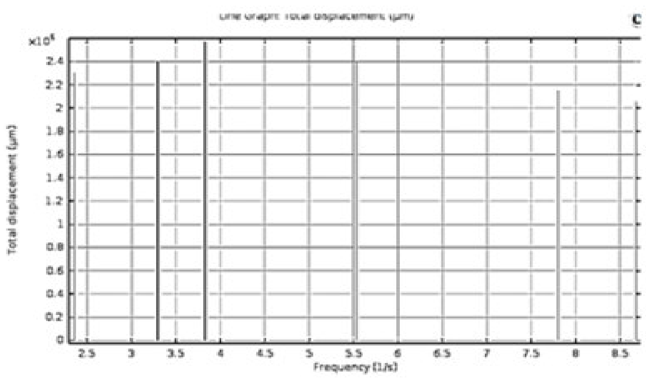

Figure 6
Graph of Eigen frequency Vs Displacement

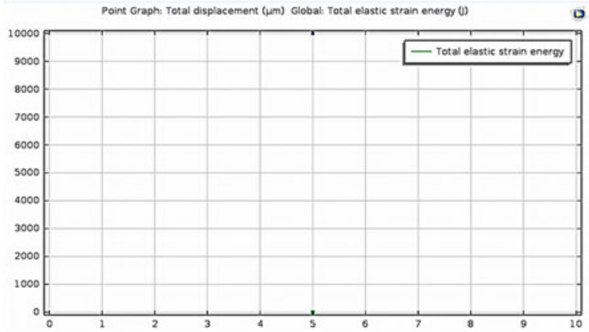

Figure 7
Total Elastic Stress on Limbs

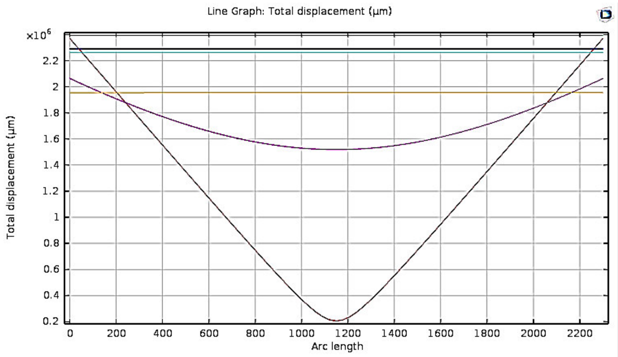

Figure 8
Arc Length Vs Total Displacement of Proof mass

RESULTS ANALYSIS

The Proposed Sensor is placed to the finger of the patient who is suffering from Parkinson's Disease. The different materials are assigned to proof mass and simulated using COMSOL Multi physics. From the simulation results we have observed the PTFE material is suitable for the specified range of required frequency i.e 2Hz – 8Hz, which is the tremor frequency of PD and is shown in table 2 and graph 5. Later on proof mass a force is applied to observe the deformation in the structure. Even for a large amount of force the deformation in the structure is less and it is shown in tables 3 and 4. The elastic stress was observed on limbs of the structure on application of force on proof mass and it is shown in figure7. Figure 8 represents the variation in displacement of the proof mass with respect to the arc length.

CONFLICT OF INTEREST

Conflict of interest declared none.

CONCLUSION

In this paper we have proposed and simulated a micro structure which detects a low frequency of 2Hz – 8Hz, which is the tremor frequency of the Parkinson's disease. It is evident that the materials for proof mass is PTFE and for limbs is Silicon. The actuation technique we want to adopt is capacitive actuation. The relative force was applied on proof mass of dimensions 2500um in width and depth.

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REFERENCES

1. Dai H, Lin H, Lueth TC. Quantitative assessment of parkinsonian bradykinesia based on an inertial measurement unit. Biomedical Engineering Online. 2015 Jul 12;14(1):1.
2. Ramaker C, Marinus J, Stiggelbout AM, van Hilten BJ. Systematic evaluation of rating scales for impairment and disability in Parkinson's disease. Movement Disorders. 2002 Sep 1;17(5):867-76.
3. Patel S, Lorincz K, Hughes R, Huggins N, Growdon J, Standaert D, Akay M, Dy J, Welsh M, Bonato P. Monitoring motor fluctuations in patients with Parkinson's disease using wearable sensors. IEEE Transactions On Information Technology In Biomedicine. 2009 Nov;13(6):864-73.
4. GRK Prasad et.al. A Review on Techniques for Diagnosing and Monitoring Patients with Parkinson's Disease Journal of Biosensors & Bioelectronics, 2016,Vol:7(2).

5. Liu K, Chen C, Jafari R, Kehtarnavaz N. Fusion of inertial and depth sensor data for robust hand gesture recognition. IEEE Sensors Journal. 2014 Jun;14(6):1898-903.
6. Grimaldi G, Manto M. Neurological tremor: sensors, signal processing and emerging applications. Sensors. 2010 Feb 24;10(2):1399-422.
7. S.Bag, et.al Review on Bioactive Ceramic coating, International Journal of Pharma and Bio-Sciences,2016,April,7(2):117-158.
8. N Siddaiah N, koti Reddy DR, Prasad GR, Pakdast H, Babu PS. optical and dielectric force gradient actuation schemes for excitation of triple coupled micro cantilever sensor in mass sensing applications,ARPN journal of Engineering and Applied Sciences,2015,May,10(8),3275-3279.
9. Hossein Pakdast,Triple coupled cantilever systems for mass detection and localization, Sensors and Actuators A:2012March 31,175: Pages 127–131
10. Jasti Sateesh et.al Design of MEMS bio sensor for Glucose Measurement, Journal of MEMS and Mechanics,2015,April 10(5):83-89.
11. Murthy K.S.N. et,al Design and simulation of MEMS bio sensor for the detection of Tuberculosis, International Journal of Science and Technology,2015,April, 9(31):1-5.
12. Thundat T, Oden PI, Warmack RJ.Microcantilever sensors. Microscale Thermophysical Engineering. 1997 Jul 1;1(3):185-99.
13. Napoli M, Zhang W, Turner K, Bamieh B.Characterization of electrostatically coupled microcantilevers. Journal of Microelectromechanical Systems. 2005,April;14(2):295-304
14. Rodríguez-Martín D, Pérez-López C, Samà A, Cabestany J, Català A. A wearable inertial measurement unit for long-term monitoring in the dependency care area. Sensors. 2013 Oct 18;13(10):14079-104.
15. Siddaiah N, Koti DR, Sankar YB, Kumar RA, Pakdast H. Modeling and Simulation of Triple Coupled Cantilever Sensor for Mass Sensing Applications. International Journal of Electrical and Computer Engineering. 2015 Jun 1;5(3):403.