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Design and Analysis of Implantable Nanotube Based Sensor for Continuous Blood Pressure Monitoring

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Abstract: This paper presents the design and simulation of a blood pressure sensor using MEMS/NEMS technology. A normal blood pressure detector is used externally, but this work aims for designing an implantable nanotube based sensor for continuous monitoring of blood pressure. In this study, a base has been designed on which the nanotube is placed such that it gets displaced when the pressure is exerted due to the blood flow. The material properties vary at the nanoscale enhancing the sensitivity and efficiency of the sensor. The use of COMSOL Multiphysics acts as a good platform to develop a nanotube sensor by using the MEMS module. The displacement obtained in the nanotube is directly proportional to the pressure exerted on the boundaries. The effects of various parameters such as length, thickness and material of the nanotube on the sensor performance are analyzed.

Keywords: Micro/Nano Electro-Mechanical Systems, Systolic, Diastolic.

1. Introduction

Blood pressure is the force which is exerted by the blood on the walls of the blood vessels. An average adult's blood pressure can be expressed in terms of systolic pressure over diastolic pressure (mmHg) as 120/80. There are many devices through which the blood pressure can be measured. Among these devices the most common is sphygmomanometer [7]. There are some cases like kidney failure and stroke affected person in which the continuous monitoring of blood pressure is needed. This paper describes a system for continuous monitoring of blood pressure using a nanotube based design and also its analysis by using various parameters.

2. Structural Design

A conceptual view of this system is shown in Fig 1.In this design, a nanotube sensor is based on the model of cantilever sensor. Here the nanotube is placed like cantilever which is supported by the base .The base is made as rectangular topologies for the support of nanotube. Nanotube has been designed in such a way that one end of the tube is attached to the base and the other end is suspended free. In this design the dimension of the base are in micrometer. The nanotube is also designed in units of micrometer except the thickness which is in nanometer for high sensitivity. The suspended end gets displaced when the pressure is exerted due to the blood flow. Since it is an implantable sensor the material chosen plays a vital role. Nanotubes can be made using gold, titanium , carbon etc [2].These tubes are biocompatible either in nature or can be made by functionalization [1]. The material for the base which acts as the support can be of polyurethane which is most common material for such applications. Carbon nanotube has the young's modulus of 1TPa [4] and the maximum tensile strength of 30GPa [3]. These properties of nanotube act as greatest advantage since this structure having the highest young's modulus and tensile strength.

3. COMSOL Multiphysics

The MEMS/NEMS Nanotube sensor was designed and simulated using COMSOL Multiphysics simulation software. MEMS module was used to design the sensor. Solid mechanics physics was applied in order to exert a pressure over the nanotube and provide the fixed constraint on nanotube at the fixed end. When the pressure is exerted due to blood flow, the free end of the nanotube which is suspended shows a displacement.

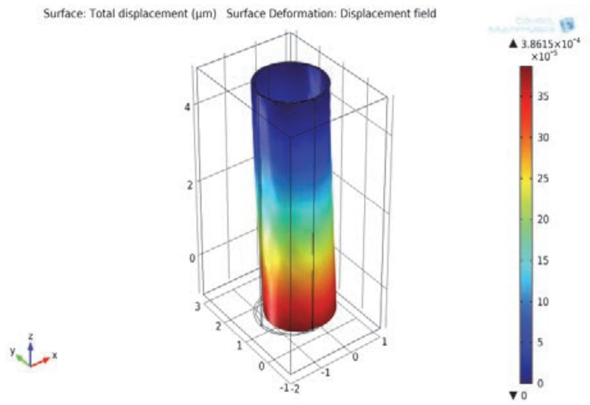

Figure 1. Design and simulation of nanotube sensor

For a normal blood pressure values of 120/80(mmHg) [6] there will be displacement of nanotube within a certain range. If the displacement of the nanotube is greater or less than that of the displacement occurring due to the normal blood pressure, it can be stated that the blood pressure is abnormal. Here the displacement due to normal blood pressure acts as reference.

4. Simulation and Analysis

The design was simulated with the help of COMSOL multiphysics and analyzed for various parameters such as length, thickness and material of the nanotube in order to improve the performance of the sensor.

4.1 Effects of change in length

Length of the nanotube has been analyzed to see the effect on sensor performance.

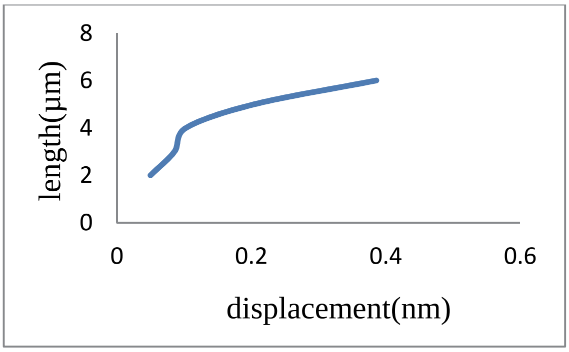

Figure 2. Effects of change in length on sensor performance

Length of the nanotube is varied between 2 μm to 6μm. The result for a sensor with nanotube thickness of 50nm and material carbon experiencing a pressure of 16KPa are plotted in Fig 2.It is observed that as the length increases the displacement increases. This shows the increase in the sensitivity as there is increase in length.

4.2 Effects of change in thickness

Here, the thickness of the nanotube has been analyzed to see the sensor performance. The thickness of the nanotube is varied between 20nm to 50nm.

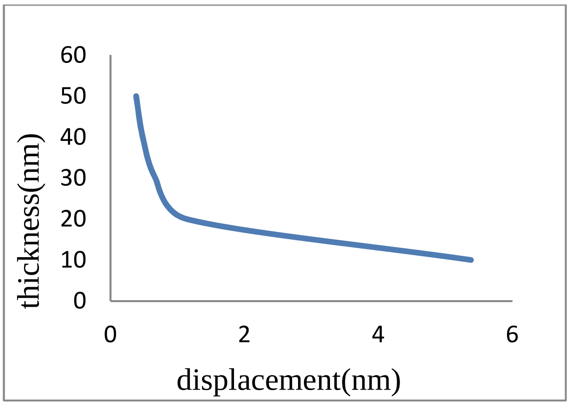

Figure 3. Effects of change in thickness on sensor performance

The result, for a sensor experiencing a pressure of 16KPa, length of 6μm and material carbon are plotted in Fig 3. It is observed that as the thickness increases the displacement decreases. This shows the decrease in the sensitivity as there is increase in thickness

4.3 Effects of change in material

Though the properties of the material are enhanced at the nanoscale, each material has its own effect on properties at the nanoscale.

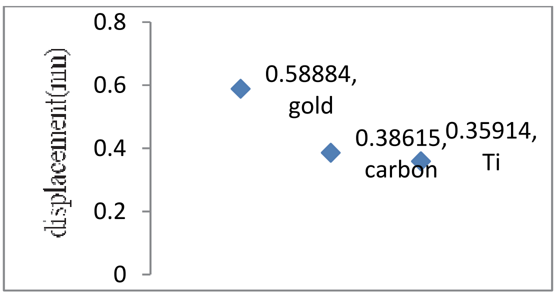

Figure4. Effects of change in material on sensor performance

Here the nanotube is designed with three different material such gold, carbon and titanium. The result is shown in Fig 4, with pressure of 16KPa, nanotube thickness of 50nm and length of 6μm. From Fig 4, it is observed that the sensor made up of gold nanotube has high displacement. This shows that the sensitivity of sensor also depends on the material used.

5. Result & Discussions

The analysis of nanotube sensor shows that the displacement increases as there is increase in pressure with length of 6μm, thickness of 50nm and material of carbon. Thus by making the displacement due to the normal blood pressure values (120/80 mmHg) as reference point, the systolic and diastolic pressure can be monitored.

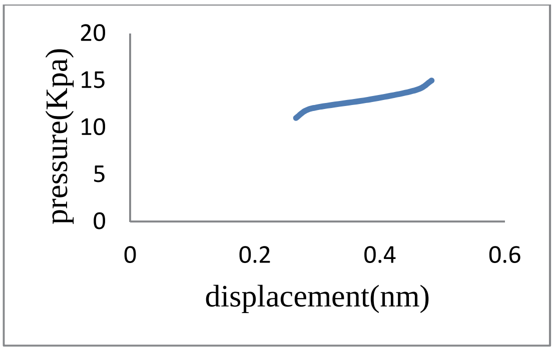

Figure 5. Results of displacement for applied pressure

From the Fig 5, it is observed that there is increase in displacement as there is increase in pressure. The sensitivity of the pressure sensor can be increased by optimizing the design parameters.

The blood pressure values of humans and the corresponding displacements obtained of the nanotube are shown in the following table 1.

pressure (mmHg)	Pressure (KPa)	Displacement (nm)
80	11	0.26547
90	12	0.28961
120	16	0.38615
140	19	0.45855
150	20	0.48268

Table 1. Results of displacement for applied pressure

6. Conclusion

A Nanotube based sensor is designed, simulated and analyzed by varying the parameters to be used as an implantable sensor for continuous blood pressure monitoring. Titanium nanotube can be used as implantable sensor as such due to its biocompatibility [8], but the gold and carbon nanotube also made as biocompatible by functionalizing. The evaluation of sensor in MEMS/NEMS recommends that the sensor made up of gold shows greater sensitivity when compared with other materials.

7. References

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