Design of Nanotube Based Sensor for Biomedical Application

J.DevaPrasannam, D.JackulineMoni

Abstract— In This Paper, A Nanotube Based Blood Pressure Monitoring Sensor Is Designed To Replace The Normal Blood Pressure Detector Which Is Used Externally. Main Aim Is To Design An Implantable Nanotube Sensor For Continuous Monitoring Of Blood Pressure. In This Design, Rectangular Topology Is Used For The Base And The Nanotube Is Placed On It. When The Pressure Is Increased It Gets Deflected From Its Original Position. It Is An Implantable Sensor So The Nanotube Is Placed In The Blood Vessels Of The Arteries In The Form Catheter To Monitor The Blood Pressure. Due To High Blood Flow The Nanotube Can Be Displaced And It Is Measured From Its Reference Value .It Varies In The Range of microscale or nanoscale to increase the sensitivity and the efficiency of the sensor. By using MEMS/NEMS technology, the design of the nanotube sensor has been done. For simulation, COMSOL Multiphysics is used to obtain better solution. The displacement of the nanotube increases as the pressure exerted on the boundaries.

***Index Terms*— *Biomedical applications, COMSOL Multiphysics, implantable sensor, , MEMS/NEMS, nanotube, sensitivity, biocompatible materials* .**

1 INTRODUCTION

TEMS application of miniaturized micromachined sensors are being increased in different areas of biomedical applications, communication systems, vibrations and motions systems etc. By using MEMS technology large number of small devices can be integrated or fabricated using integrated circuit (IC) technology and it has the combined properties of mechanical and electrical components. In biomedical application MEMS devices can be used in the form of sensors such as pressure sensor, flow sensor, temperature sensor etc and microfluidic devices, microvalve are actuators and it is implemented in drug delivery applications. MEMS devices analyze the pressure by measuring the deformation of the sensing plate.

Normally blood pressure is occurred due the high blood flow, which strikes the walls of the blood vessels. It is necessary to measure the blood pressure to treat critical conditions like hypertension and hypotension and it can cause stokes, heart attacks and failures, dizziness, shock. The most common device to measure the blood pressure is sphygmomanometer. Continuous monitoring of blood pressure is needed for critical cases like kidney failures, heart congestion and its related problems [1], [2]. Implantable sensors provide earlier detection of the problems, efficient treatment and the measurement of pressure value and it can be more accurate since it is obtained by the internal detection.

In this work, it describes the design and simulation process of nanotube based sensor for continuous monitoring of blood pressure. The requirements of the pressure sensor are related to flexibility of the structure (to be placed inside the catheter) and thickness of the device (should be very thin) [3]. All these requirements can be used to build highly flexible pressure

sensors. An appropriate range of measurement, signal, bandwidth can lead to achieve high resolution. In this system

resolution can be measured by the smallest change in the range or signal, which is distinguished by the sensor [4]. Conventionally, the blood pressure monitoring system employs an elastic cuff around the blood vessels. It detects only the vessel pressure and independent of the cuff pressure on the vessel. The vessel restriction is substantially reduced because soft of the cuff elasticity and it also minimizes the biological effects [5].

The properties of the material plays a very important role in the designing process of pressure sensor. Mainly electrical and mechanical properties of the material can be considered for bio-MEMS applications [6]. Since it is an implantable sensor biocompatible materials are used, because of its properties similar to the characteristics of human tissues. By considering the mechanical properties of nanotube, it is strongly based on its structure. Carbon, gold, titanium can be used to construct the nanotube. By analyzing the properties of above material carbon has the maximum tensile strength and young's modulus and low cost compared to other materials [7], [8]. By implementing MicroSystem Technologies (MST) in implantable applications, it offers better therapies and increased quality of life. The devices using MST can be implemented in all applications because of its small size and it can reach small places also.

2 Design Methodolgy

The design of nanotube structure is shown in Fig.1, based on the cantilever structure the nanotube is designed. One end of the nanotube is suspended free and the other end is placed on the base. The base is made with rectangular topology to support the nanotube at the one end. The dimensions used in this design can be in micrometer or nanometer to obtain better resolution. The pressure applied to the design causes deformation of the nanotube from its original position. The material used to design the nanotube is carbon. The selection of material for implantable sensor plays an important role. By functionalization, the nanotube made of carbon becomes the tube of biocompatible.

1. J.Deva Prasannam, M.E Research Scholar
Karunya University,
2. Dr.D. JackulineMoni, Professor
Karunya University

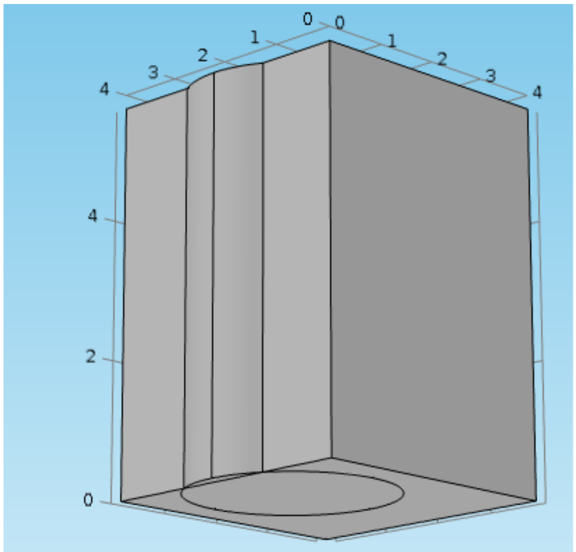

Fig. 1.Structure of a nanotube based sensor

The material used for the base is polyurethane and it the commonly used material for many sensor applications. The nanotube is made of carbon, because of its high tensile strength and elasticity property. For carbon the young's modulus is 1TPa and the tensile strength is 30GPa [2]. The original position of the nanotube is taken as the reference. After applying the pressure the sensing nanotube gets deformed. The deformation can be increased or decreased based on the range of pressure applied on the nanotube. Deformation of the structure is directly proportional to the pressure exerted on the nanotube.

3 Simulation Using ComsolMultiphysics

In general, the simulation process in ComsolMultiphysics can be done in two steps. One is structural analysis
and the other one is vibrational analysis. Structural analysis is used to define the effects of loads or pressure applied and the vibrational analysis is used to find the displacement due to the stress or strain on the design. ComsolMultiphysics is a Finite Element Analysis (FEA), and the solutions are significant when compared to the others. After designing the structure pressure is applied on the boundaries of the nanotube and fixed constraints are given to one end of the tube to make it fix. Initial step in the simulation process is to mesh the structure. The structure is exposed to extremely fine meshing to obtain equal sizing at all the boundaries after applying the pressure.

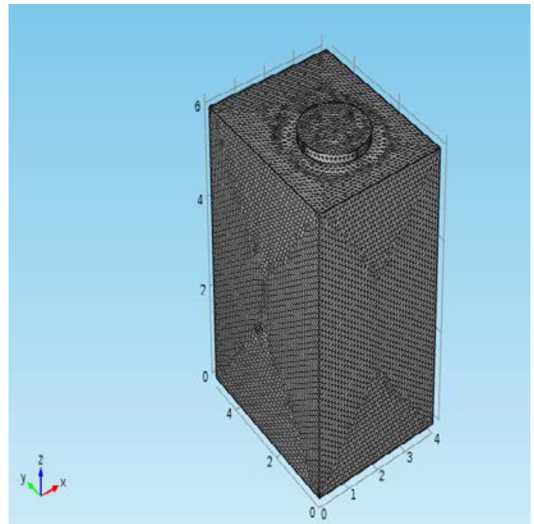

Fig. 2. Generation of mesh

Fig 2. shows the generation of mesh analysis of the carbon nanotube structure. The main aim of this paper is to find the displacement of the structure. The displacement can be increased or decreased based on the amount of pressure applied. In this nanotube design the displacement is directly proportional to the pressure. After meshing the structure, stress analysis can be done. The design on carbon nanotube is done in MEMS module and to find mechanical stress analysis solid mechanics and structural mechanics are introduced. The stress analysis of the carbon nanotube design is shown in the Fig 3.

The results of stress analysis explains that, when the pressure is applied in the nanotube the suspended end experience more stress than the other end. It increases the displacement of that particular end. By applying this same condition in monitoring of blood pressure , when the blood flow increases due to stress on the walls of the blood vessels increase the blood pressure and it can be measured by using the pressure sensor. Fig 3 (a). shows the simulation of stress on the design and in the Fig 3 (b). shows, the bottom layer of the nanotube experience more pressure than the top layer. It results in the displacement of the bottom layer.

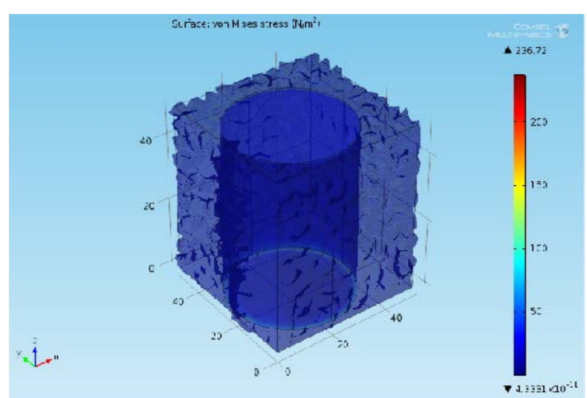

Fig. 3.a. Stress analysis at top layer

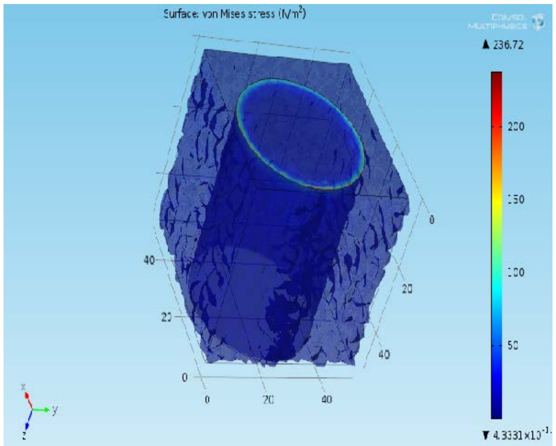

Fig . 3.b. Stress analysis at bottom layer

4 RESULTS

The Fig 4. Shows the graph for displacement and pressure. The results explain that by increasing the range of pressure, the displacement will be increased and it is measured in the range of 2 micrometers. The displacement of the nanotube can be measured from its reference position. The displacement can be higher or lower than the reference value, from this value it can be stated that the blood pressure is in abnormal condition. If it is high, the blood pressure will be high and if it is low then the pressure will be low.

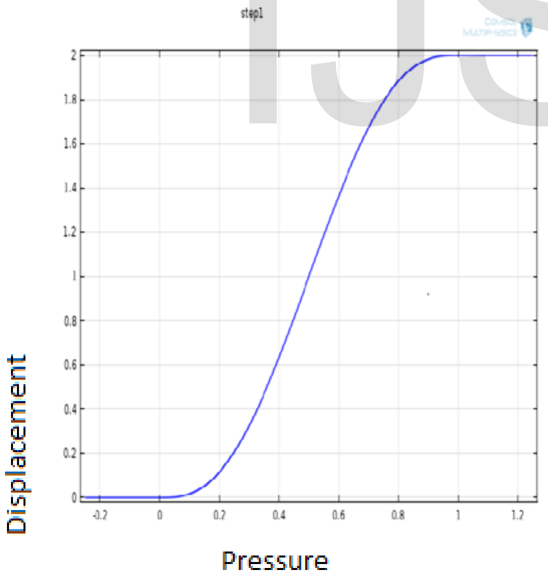

Fig . 4. graph for displacement after pressure applied

5 CONCLUSION

A nanotube based sensor is designed and analyzed for the application of implantable sensor for continuous monitoring of blood pressure. Carbon nanotube is converted to biocompatible by adding different functions to increase the sensitivity of the sensor. When compare to other materials carbon has high sensitivity and it can be used in all applications because of its low cost. The evaluation of this sensor shows the displacement is directly proportional to the pressure applied.

REFERENCES

[1] RaghavendraNagaralli, Kirankumar B. Balavad, B.G. Sheeparmatti, " Modeling of impalntable blood pressure sand protein sensor using comsolmultiphysics", International journal of innovative research & studies, vol 2 issue 9, 2013.

[2] M.Silambarasan, T.Prem Kumar, M. Alagappan, G. Anju," Design and analysis of implantable nanotube based sensor for continuous blood pressure monitoring" proccedings of the comsol conference in Bangalore, 2012.

[3] A.T Sepulveda, A. J. Pontes, J. C. Viana," Flexible sensor for blood pressure measurement", 33rd annual international conference of the IEEE EMBS, Boston, Massachusetts USA, August 30, September 3,2011.

[4] J.A. Potkay," Long term implantable blood pressure monitoring systems", Biomedical microdevices, vol 10, pp.379-392, 2008.

[5] P. Cong," Novel long term implantable blood pressure monitoring systems with reduced baseline drift", Conference proceeding IEEE, 1:1854-7, 2006.

[6] J.P. Salvetat, J. M. Bonard, N. H. Thomson, " Mechanical properties of carbon nanotubes", Applied Physics, A 69, 255-260, 1999.

[7] Niraj Sinha, " Carbon nanotubes for biomedical applications", IEEE transaction on nano bioscience, vol 4. no. 2, 2005.

[8] M. S. Dresselhaus, G. Dresselhaus, J. C. Charlier, E. Hernandez," Electronic, thermal and mechanical properties of carbon nanotubes", Chem. Phys. Lett. 354, 62–68, 2004.

[9] R. Rogier, A.M. Receveur, Fred W. Lindermans," Microsystem technologies for implantable applications ", J. Micromech. Microeng. 17, R50–R80, 2007.

[10] S.Bal, S,Samal," Carbon nanotube reinforced polymer composites–A state of the art ", Bull. Mater. science, vol30, no 4, pp. 379-386, 2007.

[11] Carolyn R. Bertozzi," Biocompatible carbon nanotubes generated by functionalization with glycodendrimers, angew", Chem.Int.Ed,vol 47, 5022-5025, 2008.

[12] R.Tugrul," Magic gold nanotubes", Turk J phys,vol.29, 269-276,2005.

[13] Y.Kong, D.cui, C.S.ozkan, H.Gao," Modeling carbon nanotube based bio-nano systems: a molecular dynamics study", in Proc.Material research Soc. Symp, vol.773,pp.111-116, 2003.

[14] R. Andrews, M.C.Weisenberger," Carbon nanotube polymer composite", Current opinion in solid state and materials science 8,pp.31-37, 2004.

[15] R. Shandas, C.Lanning," Development and validation of implantable sensors for monitoring function of prosthetic heart valves: in vitro studies", Med.Bio. Eng. Comp, vlo 41, no.4,pp.416-424, 2003.