Design and Analysis of different microcantilevers for sensor Applications

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Abstract: In this report we present the design and analysis of micro cantilevers of various shapes and materials for different applications. Here we investigate the sensitivity i.e. amount of bending of the cantilever due to same amount of force applied to each of the shape and the respective material using a tool called COMSOL Multi physics. In this context we are restricted to the use of micro cantilevers in glucose sensing applications as an aid to the diabetic patients. Currently the use of micro cantilevers as sensors has been studied extensively in the areas like biomedical, consumer products, industrial needs etc. due to its flexibility, versatility and high sensitivity. Finally we analyse the best shape and material among the others in order to enhance the sensitivity of the cantilever using graphical/statistical methods. Here we have paid a prime attention on obtaining the suitable dimension, shape and most importantly the material of the cantilever for the glucose sensing application. We put forward a prototype of a blood glucose sensor which can in turn be employed in the blood glucose monitoring system.

Keywords: ***Cantilever, Biocompatible, Displacement, MEMS***

1. Introduction

A cantilever is type of beam which is supported and constrained at only one end and of course free at the other end. Since these cantilevers have their dimensions in micrometers therefore they are usually called as Microcantilevers. Micro cantilever is a widely used component in micro system devices. It finds wide range of applications in different fields such as biomedical, consumer products due to its flexibility and versatility.
In order to understand the behaviour of cantilever as a sensor it is required to know what are the processes taking place at the surface of the cantilever. As seen from the figure, firstly the cantilever surface is coated with a bio-receptor which binds only with the specific molecule in the sample. When the cantilever surface encounters the sample, the bio receptor molecules bind only to the specific molecule in sample. This results in increase in the weight over the cantilever which ultimately is a force in the downward direction due to the mass of the bonded molecule. As a result the cantilever deflects or bends and undergoes displacement at the free end. This amount of displacement is the factor which makes the cantilever to act as a sensor and is measured using various techniques like Position Sensitive Photo detector, Optical luminescence, Capacitive Sensing etc.
The commercial cantilevers are typically made of silicon, silicon nitride, or silicon oxide and are available in a wide variety of different shapes, dimensions, and force sensitivities. Recent developments combine the latest integrated circuit (IC) and complementary metal oxide semiconductor (CMOS) technologies to produce intelligent extremely small cantilevers in the form of an array. In this context we try to develop the cantilever based sensor using some bio-compatible materials like SU8 and Parylene such that they can be employed in implantable glucose sensing devices.

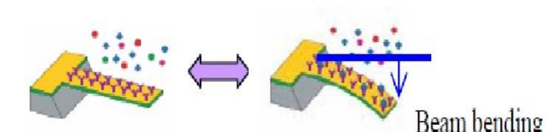

Figure 1. Steps involved in cantilever to behave as sensor

2. DESIGN OF MICRO CANTILEVERS

A. Overview:

In order to start with the design of cantilever we selected a rectangular plate of each material whose dimensions were 300um*50um*2um.
The reason for selection of this dimension was that it is regarded as the standard dimension for fabrication considering the strength and mechanical properties of all the three different materials.
The materials used for the design were:

- Silicon
- SU8 (A Photoresist by itself)
- Parylene

Four different shapes were considered for the analysis of sensitivity which were developed from 300um*50um*2um plate of each material

and the shapes are:
1. Rectangular
2. Triangular
3. Pi-Shaped
4. T-Shaped

B. Properties of the Materials

Silicon: It is a chemical element which is regarded as the eighth most common element in the universe by mass but rarely occurs as a pure free element. It finds its application in semiconductor industry and more on embedded applications.

SU8 Photoresist:_SU8 is commonly epoxy-based negative photoresist. Negative refers to a photoresist whereby the parts exposed to UV become cross-linked, while the remainder of the film remains soluble and can be washed away during development. SU8 was originally developed as a photoresist for microelectronics industry to provide a high resolution mask for fabrication of semiconductor devices. It is now often used in bio-MEMS.

Parylene:_It is a polymer which is often used as a moisture and dielectric barrier. It is self-initiated and un-terminated with no solvent or catalyst required. It has high temperature stability and a great bio-compatibility.

C.Force On Cantilever

The optimum level of glucose in human blood ranges between 82-110mg/dl. Since we are working in micro scale the optimum blood glucose level per microliter is82e-5 to 110e-5mg/uL.Weight of glucose molecules on cantilever is nothing but the force acting on cantilever and *Here we take lower limit into consideration so as to obtain sensitivity at smaller loads.*

3. ANALYSIS OF CANTILEVERS

In this section we will compare the results obtained due to various cantilever simulations to yield the best one out in terms of sensitivity.

S.No	Shape of Cantilever	Displacement due to 8.036nN Force (um)		
		Silicon	*SU8*	*Parylene*
1.	Rectangular	$7.0582*10^{-11}$	$3.7251*10^{-9}$	$4.1875*10^{-9}$
2.	Triangular	$2.3575*10^{-11}$	$1.2437*10^{-9}$	$1.4001*10^{-9}$
3.	Pi-Shaped	$7.4825*10^{-11}$	$3.9613*10^{-9}$	$4.4891*10^{-9}$
4.	T-Shaped	$7.746*10^{-11}$	$4.0887*10^{-9}$	$4.609*10^{-9}$

Table 4.1 Tabulation of displacements due to different cantilevers

A. Comparison for displacement:

Here we perform the statistical analysis to easily understand which shape of the cantilever is more sensitive when same amount of load is applied to all the shapes

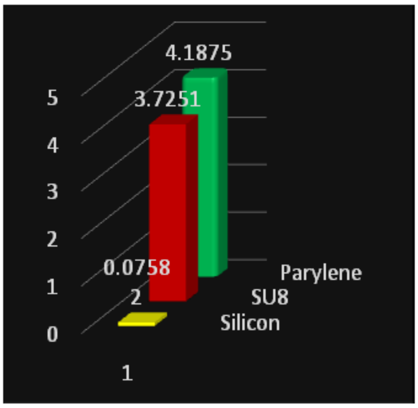

Fig ure 2: Rectangular-Shaped Cantilevers

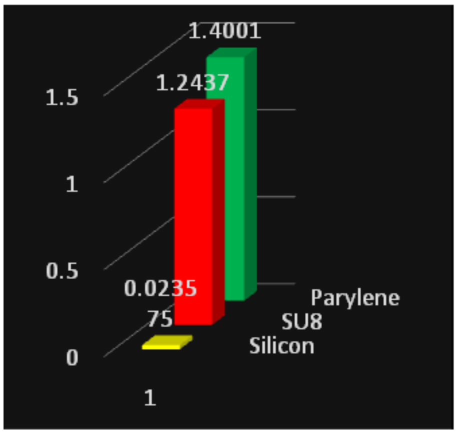

Fig ure 3: Triangular-Shaped Cantilevers

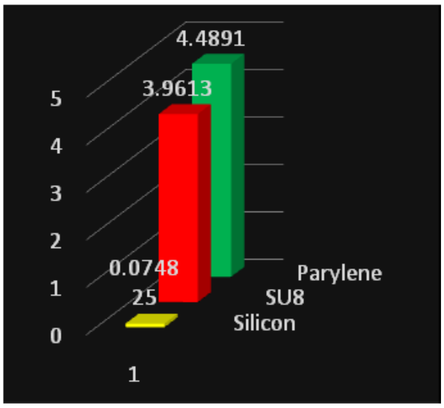

Fig ure 4: Pi-Shaped Cantilevers

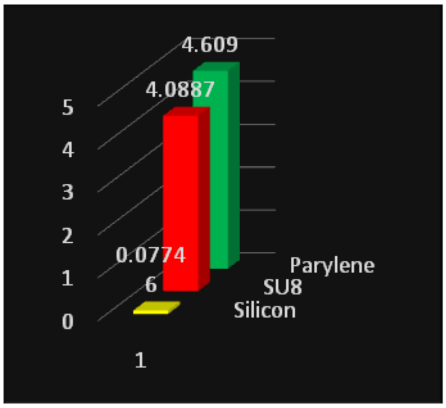

Fig ure 5: T-Shaped Cantilevers

4. Use of COMSOLE multiphysics:

The proposed structure for the micro Cantilever is very simple and was designed with greater ease. All the cantilevers are analyzed using the load of 8.036nN in Comsol tool.

No.	Name of the Material	Young's Modulus (Pa)	Poisson's Ratio	Density (Kg/m^3)
	Silicon	$170*10^9$	0.28	2329
	SU8 Photoresist	$2.1*10^9$	0.22	1190
	Parylene	$2.8*10^9$	0.4	1289

Table 2: List of Materials and their Properties

5. Simulation and result:

After all this analysis it is evident that out of all the shapes considered in the report T-Shaped Cantilever has the best sensitivity.Also out of all the materials used Parylene suits better for the application of glucose sensing. Apart from all this we also outsource that a Parylene T-Shaped Cantilever with head and tail of the length equal to half of the total length of the cantilever can be employed for sensing applications.
A rectangular strip of dimension 300um*40um*2um was extracted from given rectangular SU8 plate as shown below

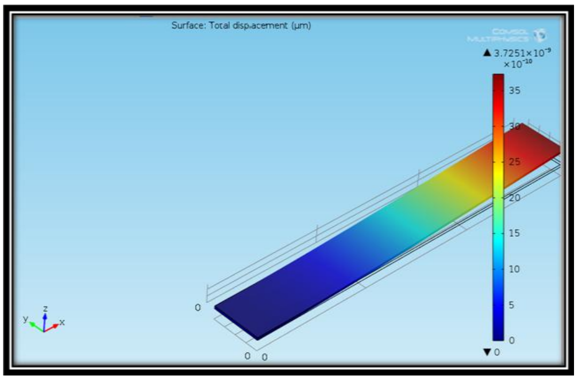

Figure 6: Stress vs Displacement of SU8 Rectangular Cantilever
Obtained Displacement=$3.7251*10^{-9}$um

A rectangular strip of dimension 300um*40um*2um was extracted from given rectangular silicon plate as shown below

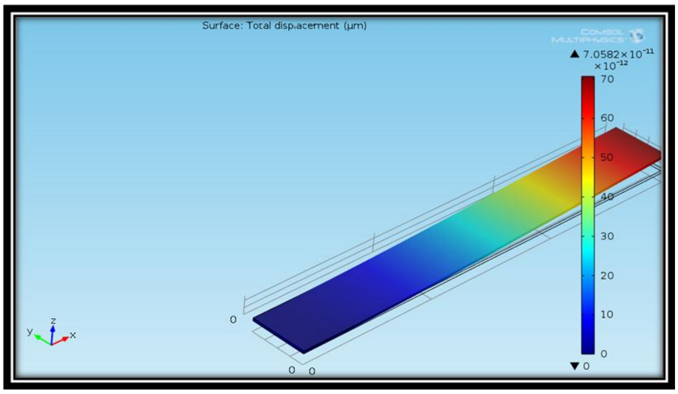

Figure 7: Stress vs Displacement of Silicon Rectangular Cantilever
Obtained Displacement=$7.0582*10^{-11}$um

A rectangular strip of dimension 300um*40um*2um was extracted from given rectangular Parylene plate as shown below

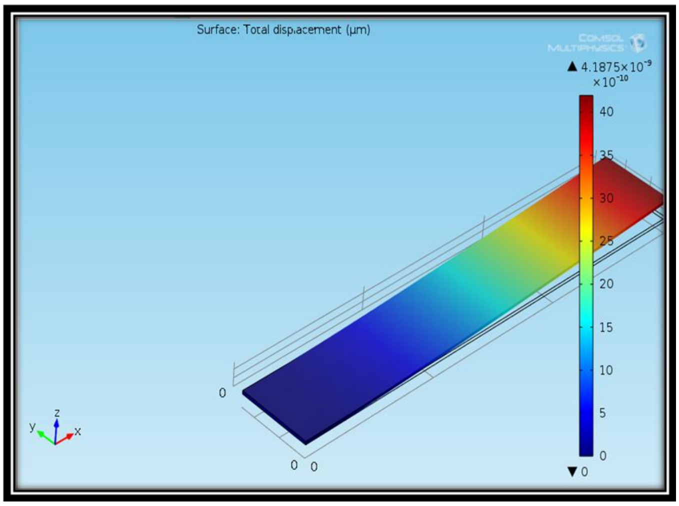

Figure 8: Stress vs Displacement of Parylene Rectangular Cantilever
Obtained Displacement=$4.1875*10^{-9}$um

6. Conclusion:

We finally conclude that for mass sensitive cantilever to act as a bio-sensor for glucose monitoring application the best structure to choose is Parylene T-Shaped with the dimension as mentioned in the result.
As we all know by now that the micro-cantilevers can be utilised as a bio-sensor but the future aspect of these cantilevers leads to the facts that they can be employed in variety of fields pertaining to industry, medical, defence etc. but keeping in mind the potential and drawbacks.
We have a great future leads in the areas pertaining to employment of audio devices such as microphones Using these cantilevers. MEMS enthusiasts have been able to study and employ cantilevers as ear diaphragms and could get lot of innovative ideas for developing a hearing device. Cantilevers

can prominently be applied not only on micro scale but also on a scale where it becomes useful in civil applications to detect undesirable bends or cracks in the buildings, bridges and so on.
Keeping all these on the note and many more things being investigated more and more application are likely to evolve in the years to come and hence future leads for the use of cantilevers is proliferating and emerging at a great pace.

7. Acknowledgement:

The authors would like to thank NPMASS for setting up the National MEMS Design Center at NMIT and professors at CeNSEIISc for giving technical guidance as and when required. Also the authors would like to thank the management of NMIT for setting up the Center for Nanomaterials and MEMS where this work was carried out.

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