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Shape Modification of Microcantilever Beam for Biosensing Applications.

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ABSTRACT

An modification in the design of microcantilever beam is inevitable to increase the sensitivity of the device. The project involves an investigation in the sensitivity of the microcantilever biosensor to increase the deflection of the microcantilever beam by considering various parameters like length of the beam, thickness of the beam and some shape modification of the microcantilever beam. The deflection can be increased by increasing the length of the microcantilever beam or by decreasing the thickness of the microcantilever beam. The deflection value is obtained for two shapes of microcantilever beam having same length, thickness and materials are noted and concluded that shape modification will increase the deflection of the microcantilever beam. The modified design I is 16% more than rectangular cantilever beam and the modified design II is 22% more than the rectangular cantilever beam.
Keywords : MEMS, Biosensor, MicrocantileverBeam, Stoney'sequation, Deflection, sensitivity

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INTRODUCTION

The MEMS technology has created enormous possibilities in creation of high sensitivity and high throughput miniature sensor. The biological and chemical fields are area that greatly benefited from this development of miniaturized sensor. The biosensor can be used to detect, measure, analyse and monitor low concentration of chemical and biological agents. Biosensor has two main elements, bio receptors and transducer [1]. Bio receptors are known bio molecules that combine with target molecule, generate a unique signal during the reaction. The most common type of bio receptors used in biosensing is based on protein, antibody/antigen or nucleic acid. The transducer element of biosensor converts biomolecular interaction between target and probe molecules into a measurable signal. These signals can be measured using appropriate detection techniques like optical, capacitive and piezoresistive detection technique.

MICROCANTILEVER BIOSENSOR

Microcantilever beams are most ubiquitous structures in the field of micro electro mechanical systems (MEMS).Earlier it is used for atomic force microscopy(AFM)and in the recent years it is employed for physical, chemical and biological sensing. In biosensing application, it have wide application in the field of medicine, specifically for screening of diseases, blood glucose monitoring and detection of chemical and biological agents. These sensors are low cost, high sensitivity and low analyte requirements [2]. The advantage of microcantilever based biosensor compared to conventional biosensor is extensive packaging is not required, simple electronic interfacing and regular maintenance is not required.

The popularity of microcantilever as transducers in biosensing can be attributed by following reasons they render mechanical response immediately and sensitivity of these cantilever is superior to that of many **other** transducer[4].

The one face of the cantilever is coated with a functionalizing layer which is highly specific to a particular analyte. This layer acts as the sensing element. When the cantilever is brought into contact with the corresponding analyte, the interaction between the functionalizing layer and the analyte causes a change of free energy, which results in a change of surface stress[5]. The difference between the stresses of the functionalised and non-functionalised layers causes the cantilever to deflect. Thus the cantilever transduces a chemical reaction into a mechanical response. The induced surface stress between the lower and upper surface of cantilever cause the deflection of the beam. The deflection of the microcantilever depends on the distribution and number of target molecules adsorbed on the surface[7].

This in turn depends on the concentration of target molecules in the sample solution. Hence, the deflection of the cantilever represents the concentration of the molecules in the sample solution[11**].** Overall, microcantilevers have a number of advantages over other mass sensitive sensors (e.g. surface acoustic wave (SAW), quartz crystal microbalance (QCM), and flexural plate wave devices (FPW)). Micro cantilevers have a lower cost of fabrication and a smaller size that makes it portable for in- field applications. Compared to SAW, QCM, and FPW, microcantilevers's sensitivity are greater than other biosensors.

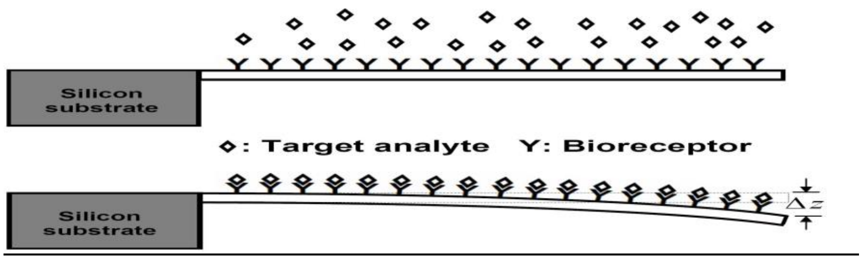

Fig 1: Working principle of microcantilever biosensor

MODELLING OF MICROCANTILEVER BEAM

The different shape of microcantilever beam is drawn using pro-e wildfire software. The dimensions choosen for modelling of rectangular microcantilever beam are400x100x1.

RECTANGULAR CANTILEVER BEAM

Fig 2: Rectangular cantilever beam

The rectangular cantilever beam is modelled using Pro-engineer wildfire software and it is imported to Comsol Multiphysics software and the deflection is calculated for the different length and thickness of the cantilever beam. The analysis is done using Comsol Multiphysics software. Sensitivity of a microcantilever sensor is dependent on its geometrical dimensions. The FEM modelling and simulation approach is employed to investigate the influence of various parameters on deflection of microcantilever beam such as

1. Influence of length.
2. Influence of thickness.
3. Influence of young's modulus of material.

INFLUENCE OF LENGTH

The width and thickness of the microcantilever beam is fixed at 100 µm and 1 µm, respectively, while the length of the beam is varied from 100-500 µm.

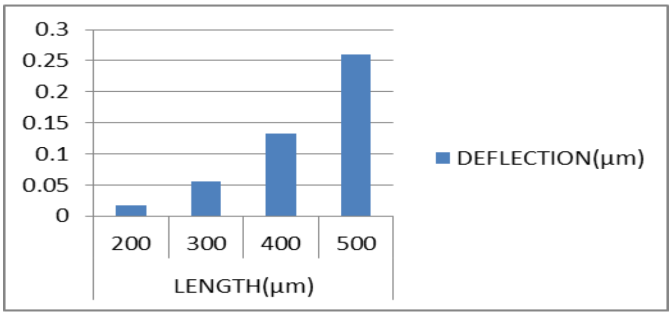

Fig 3: Effect of length on deflection of cantilever beam

The graph showing that the length of the cantilever beam increases, the deflection of the beam also increases.

INFLUENCE OF THICKNESS

The length and width of the beam is fixed at 400µm and 100µm and the thickness are varied from 1 µm to 3 µm.

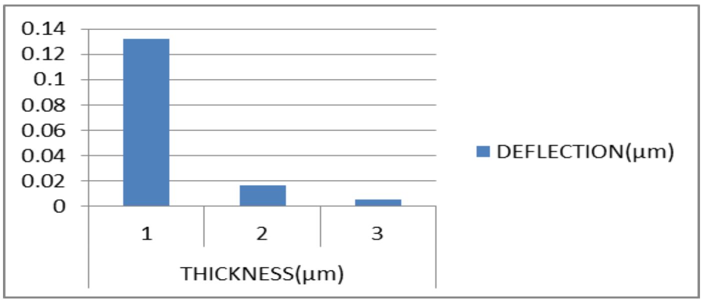

Fig 4: Effect of thickness on deflection of cantilever beam

It is observed that the thickness of beam decreases, the deflection of the beam increases.

INFLUENCE OF MATERIAL

The cantilever dimension of 400x100x1 μm^3 are choosen and three materials silicon, poly sillicon and polymer material (PMMA) are selected for analysis.

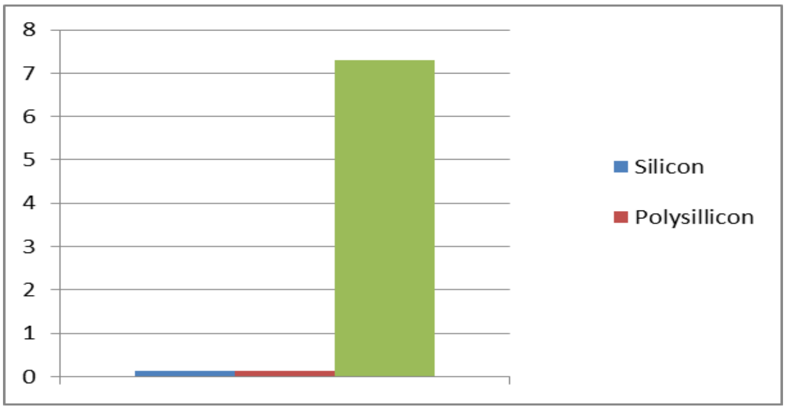

Fig 5: Effect of material on deflection of cantilever beam

It is observed that young's modulus of material decreases, the deflection of cantilever beam increased.

STONEY'S EQUATION

The stoney equation is used to calculate the deflection of rectangular microcantilever beam numerically

$$Z=\frac{3(1-v)\,\Delta\sigma}{E}(l/t)^2$$

Z- Deflection of cantilever beam (µm).
E-Young's moduus of material (Pa).
v- Poisson ratio.
l- Length of cantilever beam (µm).
t- Thickness of cantilever beam (µm).
Δσ-surface stress (N/m).
Dimensions of rectangular cantilever beam 400x100x1μm^3

The young's modulus and poisson ratio of material are 170 Gpa and 0.28 respectively.

$$\Delta\sigma=0.05 \text{ N/m.}$$

Substitute all the value in the stoney's equation

$$Z = \frac{3(1-0.28)0.05*10^{-6}}{170*10^{-3}}(400)^2$$

= 0.1016 µm.

COMPARISON OF ANALYTICAL AND SIMULATED RESULTS

Table 1: Comparison of numerical and simulated result

Surface stress(N/m)	Deflection(µm).	
	Analytical result	Simulation result
0.05	0.1016	0.1324

The analytical result obtained from stoney's equation is compared with simulation result. The variation in analytical and simulated result is 0.0308(μm).The simulated result shows good accord with analytical result.

MODELLING OF MODIFIED DESIGN OF MICROCANTILEVER

The influence of shape modification in deflection of microcantilever beam is studied by considering the two modified shape of microcantilever.

The same step followed in modelling rectangular cantilever beam is done to model the modified cantilever beam. While meshing, no of elements for modified design I is 4998 elements and no of elements for modified design II is 5051 elements.

Table 2: Deflection value for different structure

Structure	Deflection(μm).
Rectangular cantilever	0.1324
Modified design I	0.155
Modified design II	0.1612

The modified design I and II shows higher deflection when compared to standard rectangular cantilever beam.

Modified design

The two modified design are analysed in Comsol Multiphysics software to calculate the deflection of microcantilever beam.

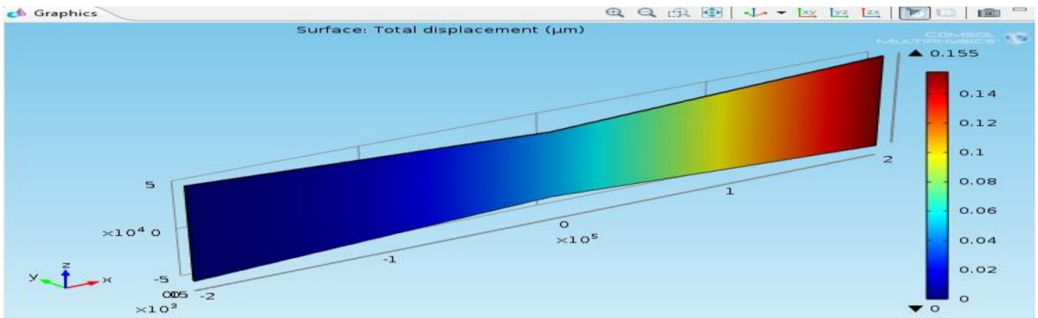

Fig 6: Deflection value for modified design I

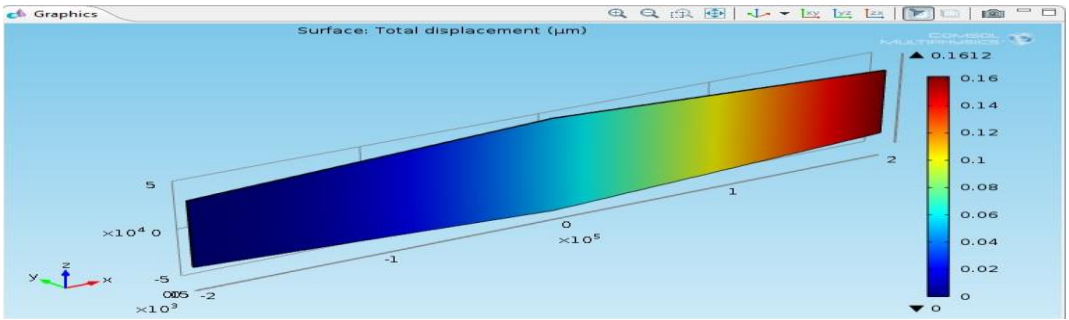

Fig 7: Deflection value for modified design II

CONCLUSION

The influence of various parameters like length, thickness and material on deflection of microcantilever beam is identified. The rectangular cantilever beam of dimension 400x100x1 μm^3 are selected. The structural variation are provided on rectangular cantilever beam. The deflection value is obtained for two shapes of microcantilever beam having same length, thickness and materials are noted and concluded that shape modification will increase the deflection of the microcantilever beam. The modified design I is 16% more than rectangular cantilever beam and the modified design II is 22% more than the rectangular cantilever beam.

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