Micro machined Silicon Accelerometer with Piezoresistive SCR implementation for Glucolysis

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Abstract
Micro-Electro-Mechanical Systems (MEMS) note as Micro generation has grown in advance greater than decades. This venture reports approximately the silicon based piezo resistive Micro cantilever for glucose sensing. Elevated sensitivity, highest operation collection, extensive frequency reaction, excessive resolution, proper linearity are the the majority preferred residences of the sensor. The displacement, strain at specific limits, sensitivity and deformation is analyze by by means of finite element method (FEM) for two exclusive structures. 3D structural modeling of three layers in micromechanical sensors may be achieve at ANSYS.14.5. In bio-medical request, adsorption of glucose on a functionalized exterior of the micro fabricated cantilever will gathering a exterior strain and therefore meandering the cantilever beam. The cantilever meandering enhance the sensitivity of the micro cantilevers sensor.

Instead of capacitive accelerometer which produces changes in the seismic mass, the best method is PZR-Piezo resistive accelerometer that takes advantage of change in resistance and produces electrical output signal. The argument of the resolution problem in the study out system for piezo resistive detection technique with requirement of devices like Low pressure chemical vapor deposition (LPCVD)etc. is easily done by introducing SCR-Stress Concentrated Region considered as slot in the structure so that it enhances sensitivity of the device further higher. This technique is for sample, detect and monitor glucose level and produces simulation wrapping up in the micro cantilever beam are twist, pressure, injure and displacement.

Keywords: MEMS, Glucose sensing, PZR-piezoresistive accelerometer, SCR-Stress Concentrated Region, ANSYS 14.5 software.

Introduction

MEMS is defined Micro Electro Mechanical System. The generation of incredibly tiny devices that's micro meters in length. Benefit of MEMS sensors are of tiny length, mild load, stumpy price and low strength and their capacity to monolithically formulate indicator habituation circuitry at the identical die, ensuing in stepped forward sensor overall presentation and determined sensor rate. Many programs like gyroscopes, MEMS microphones, silicon pressure sensors, presentations, ocular switch generation, Bio MEMS. MEMS micro cantilever sensor is predicated at the mechanical buckle of the shape. Polysilicon is a substance that includes tiny silicon crystal on the thing stage. This tool can urbanized for the software of sensing via absorption of glycolysis as human frame measurement tool. Biosensor is use for reasonably-priced size and it gives promising evaluation to touchy and rapid, monotonous [1].

MEMS primarily based micro cantilever has been analyze as an influential display place for extremely responsive chemical and genetic sensors. The micro cantilevers have turn into so famous owed to its soaring warmth and selectivity. It also thrilling because of the ease in calibration, conveniently deployable into the electro mechanical machine and it does now not necessitate any peripheral recognition gadgets [8]. This work focus on the design of a micro cantilever piezo resistive Silicon covered micro cantilever beam for the application of high glucose sensing element by absorption of molecules as force on the entire sensational of surface stress from inertial applied force and consequently bends the cantilever beam. Piezoresistive accelerometer was the first silicon accelerometer using micro machined technology.

Miniature silicon piezoresister are embedded at maximum stress location in a suspended beam to sense the input acceleration. A MEMS cantilever based totally sensor incorporated with piezo resistive examine out is generally used to degree the exterior stress modify [9]. In the preceding decade micro cantilevers end up extra famous as it's towering sensitivity selectivity, clean for manufacture and supple for chip in the circuit [10].

This task evidence about the micro cantilever beam is model the use of ANSYS 14.5. A industrial restricted element analysis on the premise of Silicon piezo resistive cantilever and designed especially for MEMS - Micro Electro Mechanical System application. Winding of micro cantilever beam investigation is achieved to incline deflection of the sunbeam. The structural version in the piezo resistor proposition on the cantilever sunbeam is investigated to augment sensitivity of the micro cantilever sensor in view of the fact that the forces generate is very small. The strain allocation and the plumb disarticulation of the piezo resistive micro cantilever may be studied through the design and simulation.

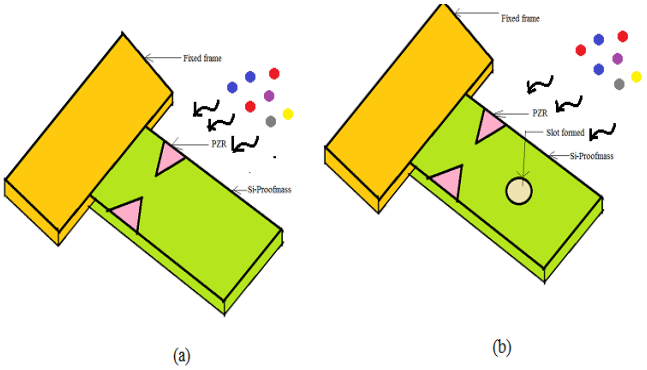


Figure 1: (a)Simple PZR-Piezoresistive Micro Cantilever
(b) SCR-Slotted PZR- Piezoresistive Micro Cantilever

Design consideration and analysis

Structural Analysis: The simple accelerometer device consists of proof mass and its outer fixed frame - micro cantilever. The piezo resister is placed above the surface of the proof mass at 10 um depth. Figure 1 Shows the T-Sectional Cantilever structure. The parameters are measured in um w.r.t. Length X Breadth X Depth such as Silicon Proof mass with dimension as (2500x1200x100) um and Silicon Outer fixed frame is (4000x1500x300) um. Initially the simple accelerometer beam with no SCR slotted PZR-Piezo resister is simulated and analyzed in order to find the sensitivity of the structure. But to reduce the complexity of the result the slotted PZR is taken to achieve the best sensitivity. The sensing mechanism utilizes the change of resistivity of the piezo resistive accelerometers and structural simplicity. Required damping of a piezo resistive accelerometer can be obtained by changing the gap between the moving proof mass and the fixed plates by squeeze film effect [18]. No complex process steps are required in achieving the required damping, since changing the gap between moving and fixed cover plates does not affect the device sensitivity. But the main drawbacks of the piezo resistive sensing method are large temperature sensitivity and low overall sensitivity. So Stress Concentrated region of Slotted PZR-piezo resister with dimension of 600 um along with the Piezo resister with dimension of (1500x600x10) um is taken above the surface of the proof mass. The parameters like prime axis sensitivity and displacement of the structure are analyzed for different acceleration inputs. But the structure shows some variations along the X and Y axis of DC offset voltage with Off axis sensitivity.

Define Material Properties: Silicon with piezo resistive fabric are used in this design for glycolysis size but micro cantilever will acquire bend after apply the pressure on it. This layout geometry is relying on the measurement lengthwise, breadth and width. The absolute facade of the micro cantilever is deliberate with peizo resistive objects to change the strain on the facade and this is the approach for conniving micro cantilever piezo resistive accelerometer. Deformation of micro cantilever because of trade in anxiety will generate strain to the piezo resistor [3]. This strain-in will transform its confrontation of the piezo resistor. It is able to document and measure the all ethics electronically. This technique uses unique properties like Young Modulus, Poisson's ratio and density, wherein those values of micro cantilever might be capable of alternate the placement, stress, displacement and deformation.

Construct Geometry Polysilicon Piezoresistive Microcantilever: Extrude gathering in pro/E (pro/ENGINEER), to produce a square version of 3 layer microcantilever after that import in ANSYS 14.5, wherein it is accomplished of recreation effortlessly, but it may layout in ANSYS itself but for greater console the representation strained with its dimension in pro/E and import as in the ANSYS then carried out all parameters which is necessary. The given silicon microcantilever is a hard and fast one. The Silicon with evidence mass paintings as a helping of Silicon Piezoresistive accelerometer. This acts as frame structure so one can get bend while pressure practical. Piezoresistive impact describe the converting the location of Body structure due to the submission of mechanical pressure. The geometry alternate consequences in vertical exchange in its arrangement after determining the entire parameter.

This impact used for semiconductor base completely sensor inclusive of germanium, silicon and polysilicon. Silicon offer enormous Piezoresistive achieve and it has capacity to maneuver digital circuits. Semiconductor silicon is the further essential and universal resources inside the MEMS micro generation. The electric and mechanical property of the silicon is of notable hobby which differ from some performer like metals in addition to insulator similar to rubbers. It have a conductivity which lies among insulator and idyllic conductor [2]. When the cantilever is weighed down, its pressured essentials bend, then microcantilever may be proficient to bend. As this buckle occur, the structure change form, on nook aspect that's free cease at the facade of structure then displace up and down. The conception of the deflection takes place when a commotion or loading is applied to the cantilever that is loose end or along the MEMS micro cantilever floor.

The vibrate to the wide variety of annotations of microcantilever is very responsive to the property of the microcantilever floor. Altering in the facade houses of the microcantilever via the preserving via converting the general cantilever accumulation and the breadth of the every one of three layer [8]. The piezoresistive microcantilever model analysis is carried out with the aid of the usage of finite detail analysis. The evaluation is accomplished to analyze and appreciate the pressure and deflection of the piezoresistive micro cantilever. When outer anxiety or load is apply on the gratis end corner elevation of the cantilever

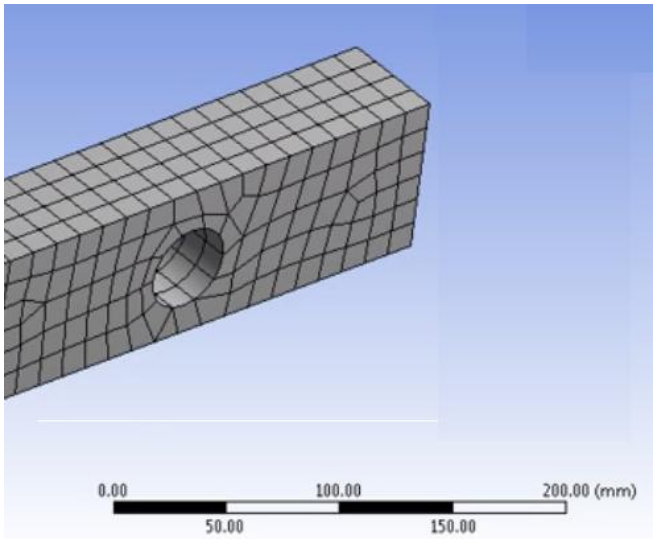


Figure 2: 3D meshed structure of the PZR cantilever SCR-slotted structure

it has be distort as agreed restraint, conversely it is have some confines which may competent to stick the cantilever deflection of the piezo resistive micro cantilever.

Ansys meshed modelling of Slotted PZR: Meshing is the process of converting a solid model into a FEA model for the analysis purpose. There are two types of meshing as free meshing and mapped meshing. In free meshing the meshing volumes size is larger to mesh. In mapped meshing the small size control input is assigned to make the nodes and element nets get closer with each other. In FEA modelling as the number of elements increases accuracy also increases. That is, the solution gets closer to the true solution. However the solution time taken and the computer resources required will be more. A fine meshing does not omit any geometrical details. ANSYS provides us with an option to give the global element size option that specifies the element edge length and the number of element divisions. The good resolution of the material can be obtained by this tupe of meshing. [3]. 3D closed slotted meshed structure of proof mass with micro cantilever is shown in figure 2 above.

Mathematical calculation of analytical model

The structure experiences structural molecules, the mass tend to stay at rest until the spring being stretched enough energy on the mass to make it move. With the addition of an electric pickup signal, a generated signal that is proportional to the relative motion between the mass and the frame can be used. In this there are two components, while store energy, mass and the spring. The piezo resistive achieve cause a change in resistivity, ρ, when a conductive material is subjected to stress. For the piezo resistors the resistance is agreed by:

$$R = \rho L / A \tag{1}$$

Where length= *L; A*= is cross sectional area. The change in resistivity is thus proportional to the stress which is given by:

$$\{dR\} = [\pi]\{\sigma\} \tag{2}$$

Where *R* is the original resistance; π is the longitudinal piezo resistive coefficient and σ is the longitudinal stress. The facade strain for the micro cantilever surface can be calculated from the observed micro cantilever deflection using Stoney's equation (3):

$$\Delta\sigma_s = 6Fl/bh^2 \tag{3}$$

where Ds s is the disparity surface stresses on the surface of the micro cantilever, M, Moment=F, Force X l, length of the cantilever, b and h are breadth and height of the cantilever. Greatest deflection during power applied or the beam can be calculated using the equation as:

$$\Delta\delta_s = Fl^3/3El \tag{4}$$

where δ_s is the maximum deflection, F is the force applied, l is the cantilever length, E is the young's modulus o the silicon cantilever, I is the moment of the inertia of the cantilever.

FEM analysis and optimization

The MEMS micro cantilever piezo resister module in Pro-ENGINEER compute the transform in resistivity of a piezo resistive fabric situation to mechanical deformations via restricted element approach. The piezo resistive phenomenon in semi-conductors is associated to a modify in resistivity of the silicon substances in rejoinder to an useful stress and pressure. When a pressure and injure pasture are implemented by means of absorption of molecules, the resistivity is changed and turns into anisotropic. Submission of discrepancy facade strain to a square plate is equivalent to load of the unfastened edges by moments in keeping with unit period of importance σs. Piezoresistive silicon with evidence mass and blanketed micro cantilever beam for utility in individual pressure measurement, which incorporates theoretical and almost layout, simulation have a look at in finite detail evaluation. The given systems having houses as shown in table I. Given homes is well-designed for given magnitude if it is untouched then imitation result might be misrepresented after which it'll consequence on micro cantilever buckle.

Table I
Material properties of structure

Structural materials	Values
Young's modulus	0.3 G Pa
Poisson ratio	0.11
Density	830 kg/m^3

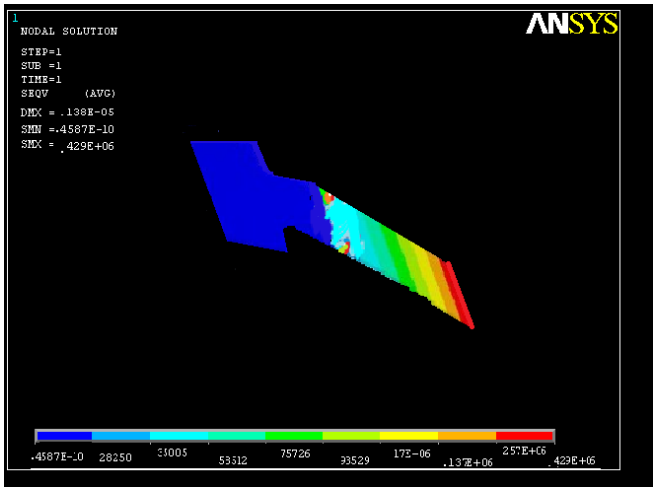


Figure 3:Simple PZR-Piezoresistive cantilever with stress and displacement simulation

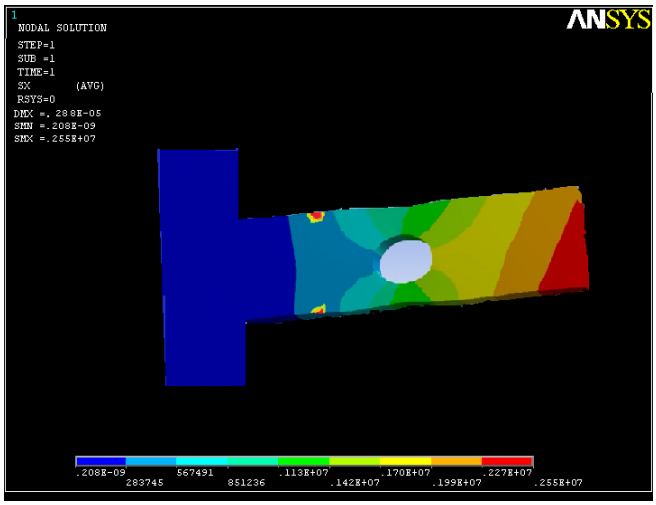


Figure 4: Slotted with diameter of 600um PZR-Piezoresistive cantilever with stress and displacement simulation

Microcantilever sensor analysis

Stress and displacement Simulation result: Microcantilever stress obtained effectively on silicon with piezoresister structure. Propose anxiety is the ceiling facade underneath effortless loading circumstances for strain in compound loading circumstances. It is regularly premeditated using Stoney's which basically relate an induced substrate bending to a surface stress. Regrettably, control of the surface stress using Stoney's formula require Young's modulus of the cantilever material to be known [7]. This is challenging in the container of frequently used fixed free end micro cantilevers.

In addition, the superfluous force or further application for sensor device assumed by absorption of molecules on the cantilever surface so it can considerably alter the cantilever's elastic properties to produce deformation upwards and downwards. Although Figures in the simulation work using ANSYS 14.5 have made improvement on surface properties, they at a standstill involve acquaintance of Young's modulus, which introduce outsized uncertainty for premeditated surface pressure.

Figure 3 and 4 shows the result of stress obtained by the structure. The cantilever sense the stress during the force of 20N is applied to the top surface of the Microcantilever structure. This assumption is taken based upon the absorption of molecules on the peak facade of the cantilever while one end is fixed one and other end is tending to move upwards and downwards from the original position which creates maximum and minimum stress with deformation of the material. There are two types of stress. One is compressive and other is tensile stress.

The structure here experiences the tensile type by absorption of molecules on peak facade of the cantilever. It is undoubtedly exposed that microcantilever Piezoresistive provide privileged displacement larger than silicon proof mass for the identical useful load formation Piezoresistive extra appropriate for used as a extremely sensitive Microcantilever sensor. Cantilever is worn right through the simulation progression where privileged displacement and surface stress sensitivity are predictable [9] for accurate measurement. Its offer a complete resolution for scheming, modifying, and verifying complex system designs rapidly and expenditure effective [12].

Piezoresistive geometrical model: Fixed unfastened end microcantilever are ever more life form used as a proposal to appraise the surface stress connected with molecular adsorption. We have proven in this approach to analyze the floor strain from the cantilever deflection the usage of effortlessly able to be gauged cantilever residences, such as its geometry, spring steady, and Poisson's ratio for constant size. Deflection dimension with the aid of touching on the optical beam deflection dimension to a direct degree of the deflection acquired the use of a strain size. These strategies allow to appropriately decide the floor stress related to the deflection of a microcantilever to higher overall performance. Figure 5 show the clear details of the piezoresister with dimension of (1500X600X10) um is implanted with above the surface of the microcantilever structure. Once the surface load is applied by absorption of molecules then the resistance changes with respect to the original resistance.

The obtained sensitivity is directly proportion to the change in the resistance. The position of the piezoresister is further enhances the sensitive of the device. Here the PZR is located at near the fixed end of the structure. Figure 5 shows that the piezo resistors are highly concentrated at the end of the corners. In biosensor micro cantilever beam structure, the force of 20 N is applied on the top surface of the cantilever. Here the force contact is made at three different layers which placed one above the other. The one end cantilever is fixed and other end is free to move with slower motion makes electrostatic contact and integrated device contact in biosensor for the detection of glycolysis.

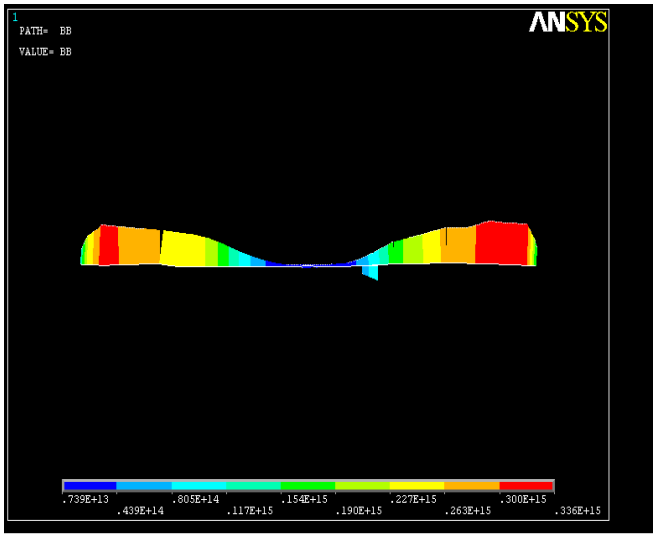
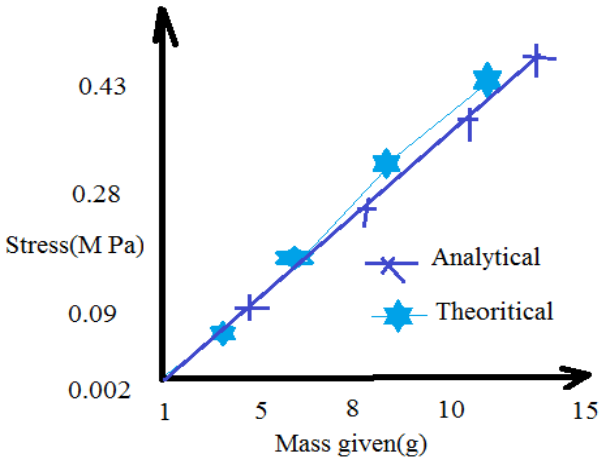


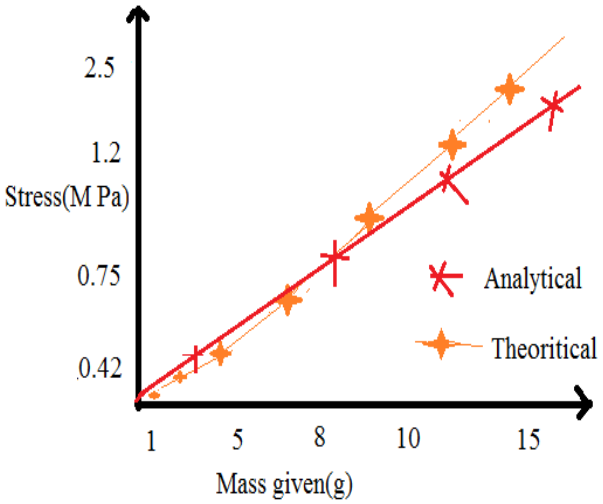
Figure 5: Piezoresister two ends at 10 um thickness

Force contact surface: In biosensor micro cantilever beam structure, the force of 20 N is applied on the top surface of the cantilever. Here the force contact is made at three different layers which placed one above the other. The one end cantilever is fixed and other end is free to move with slower motion makes electrostatic contact and integrated device contact in biosensor for the detection of glycolysis. Graph 1 show the result of the simple PZR –Piezoresister cantilever structure with no slotted surface on proofmass.

The surface stress experiences 0.43 M Pa at 15 g at the force of 20N. To make the structure in real time application with higher sensitivity and to improve the performance of the device much higher the slotted piezoresister type sensor PZR accelerometer is taken on the surface of the micro cantilever at 2.5 M pa which shows the sensitivity more than 5 times higher and it's easy to pick up the sensor signals. Figure 6 show the rectangular paddle type Piezoresistive accelerometer with and without slotted structure from paper [5].



Graph 1: Mems Simple PZR-Piezoresister without slot graph for Stress Vs Mass applied



Graph 2: Mems Slotted PZR-Piezoresister structure with diameter of 600 um.

Conclusion with result

The Piezoresistive microcantilever structure is implemented in this paper. This makes us to easily read the sensitivity of the structure. The performance of the device depends upon the Cantilever length, breadth, depth of the entire structure. The finite element model using ANSYS14.5 simulated the mechanical behavior of the result for detecting the glucoses in biomedical application. The parameters like the maximum and minimum stress, strain, Deformation of the material, two end corners of the piezoresister are obtained. The prime axis sensitivity of the Slotted structure shows value of 4.5 um result which is more than thrice times of the simple PZR model. There is a slight deviation result of the analytical and theoretical model of the structures. The stress is directly proportional to the mass applied and displacement occurs from the original position to some other extend. The obtained deformation of the result are also directly proportional to the stress. This assures that the slotted design shows the more sensitive result as compared with simple piezoresister design. The deformation of the simple piezoresister model and slotted piezoresister model are 1.3 um and 2.88 um. The cross axis sensitivities of the device are reduced for better improvement of the device.

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