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DESIGN OF MICRO SENSOR WITH CANTILEVER BEAM FOR TEMPERATURE MEASUREMENT

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Abstract

MEMS are systems of tiny devices, easy weight, enhanced performance and dependability detecting wider applications field of industrial, automotive and environment area, particularly in expressions of weather monitoring and estimate. In this work, design and simulation of MEMS sensor for temperature applications was proposed. An inherent platinum material for use temperature sensor can absolutely detect the sensor's working for temperature. The MEMS sensor is a single of the bimorph cantilever which deflections are felt by application of temperature. Basically, the cantilevers are thermally annealed to relax the thin film stresses. By changing the materials of bimorph, overall sensitivity can be changed. We use both platinum and titanium as the sensing material of temperature sensor to design process to integrate mechanical sensors into for example temperature for micro weather station. Finally, the proposed design can be used as a temperature sensor from 10°C to 60°C and also we obtained platinum as a good sensing material for detecting the temperature.

Keywords:

MEMS Sensor, Temperature, Cantilever, Displacement, Sensitivity

1. INTRODUCTION

Temperature is an essential parameter in all fields of atmospheric sciences, natural science, including physics, chemistry, geology, and biology. These also used to evaluate physical characteristics in measurement of science. Presently, then measure the temperature can be found with a substantial accuracy, while the measure the water vapour content in gaseous, atmosphere. A cantilever based MEMS sensor is one of the leading in the field of environmental applications. Jolly et al. [1] the performance and range are determined by the detail cantilever material properties, dimensions, and thickness of coating. By setting the functional coating layer and thickness, the range and sensitivity can be optimized. Lung-Tai Chen [2] noted the sensitivity of the humidity sensor decreases when the temperature as increases, but increases as the length of the pit resistor embedded in the cantilever structure is increased. L. -Y. Chen et al. [3] in future the sensor packaging for a high-temperature ceramic-based package with precious metal interconnects will be studied. J. G. Zhang et al. [4] humidity and temperature sensors can be classified in various principles, i.e. gravimetric, hygrometric, resistive, capacitive and optical techniques.

Daniel et al. [5] temperature sensors for temperature control used platinum (PT) resistors as heaters. Johari. H [6] was planned to place the strain gauges coordinate to the long edges in the area, which has a reliable maximum stress, one of the following two analysis equations to be performed in (1) linear, or (2) nonlinear, depending on the magnitude of the deformation. Chia-Yen Lee et al. [7] has designed and analyzed two different humidity sensor designs such as single and double micro cantilever. The empirical data analyzed a, high sensitivity, humidity, stability, low hysteresis and fast response time. G. Kowalaski [8] the temperature-compensation techniques have been reported as clever use of material properties.

MEMS sensors have lately a growing attention as encouraging and extremely sensitive devices for mechanical transducers with micron scale. This proposed work has been designed and verified the different parameters of achievement such as deflection and sensitivity. Here the atmospheric temperature can be analyzed using the change in an environmental position of temperature. An essential part of the micro sensor is constructed by using substrate and functional layer as a silicon with the two different heats absorbent thin coated sensing material are used, i.e. platinum and titanium.In model1, Silicon is used both substrate and structural layer, Silicon dioxide is used as sacrificial layer and platinum as sensing material. The model2 constructed by the same substrate, structural and sacrificial layer at the same time titanium as sensing material. The proposed temperature sensor is a first step to maintain an extensive output and high sensitivity for entire input ambient temperatures under the discussion. In this work, design and simulation of different cantilever structure, i.e. part of temperature sensor analyzed using FEM tool. Therefore, the proposed composition is being evaluated with two different sensing materials by using various cantilever structure such as trapezium, rectangular, slotted paddle, paddle and slotted triangular shaped. It facilitates us to obtain the cantilever beam of trapezium shaped with expects deflection and sensitivity.

2. THEORETICAL ANALYSIS

MEMS based temperature micro sensor is adapted with a cantilever which is designed by using as a sensing layer. The measured value of temperature is most important in different component as well as private environmental, industry and medicine. Here, the measurement of temperature coefficient of resistance is a thermal sensitivity of resistors and is determined as the ratio of temperature variation versus resistance change in resistance value. Theoretically, it is presented as,

$$R_t = R_{ref} \times (1 + \alpha \times \Delta T) \tag{1}$$

where, R is measured value of resistance at temperature T, R_{ref} is measured value of resistance of a reference value of temperature, α is temperature coefficient of resistance and ΔT is a change in temperature.

In present-day temperature gradient is a field to cantilever beam which resulted deflection. The cantilever pressure equivalent of temperature of the atmosphere is brought into consideration. The beam deflection is given by the relation as [9-10].

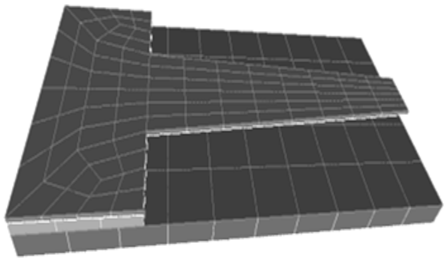
$$\delta = 3 \times \sigma s \times (1-v)/E \times (L/t)^2 \tag{2}$$

where, σ_s is surface stress/vapor, E is the Young's Modulus and v is the Poisson ratio, L is the length of the cantilever beam, and t is beam thickness.

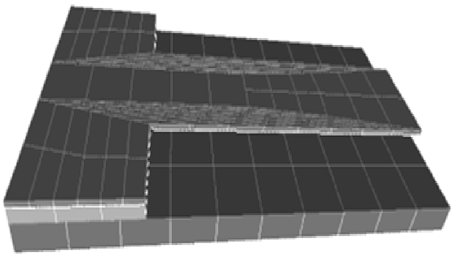
The deflection of cantilever depends upon the geometry of the cantilever beam associated as length, breadth and height in addition depends on designing cantilever using different mechanical properties of the material. Here, the over observed equations determine with the aim of the output deflection is similar to the accomplished pressure. Therefore the cantilever beam deflection and sensitivity changes with the development are realize the shape of the cantilever and material. So, that the study is concluded on the design of cantilever with the subsequent length, width and thickness shown in the Table.1.

3. DESIGN OF TEMPERATURE SENSOR

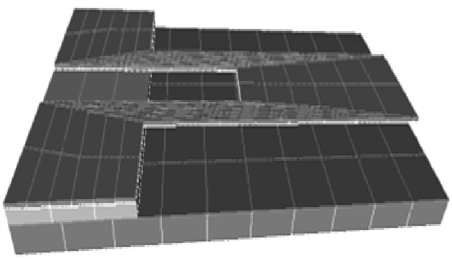
The two different temperature sensor models are designed using MEMS CAD tool as an Intellisuite 3D builder. Here, we talked about two special sensing materials of MEMS temperature sensors such as Platinum and Titanium. In model 1 is designed by platinum as a sensing material and SiO_2 used as a dielectric layer due to thermal inequality in the dispensation, the beams are normally deflected at the virtual temperature of the atmosphere. Therefore, it makes a change in surface stress and therefore modifies the deflection. The cantilever based temperature sensor sensitivity increases when increases the length of the cantilever. Then the geometry of thickness and their appropriate coefficient of thermal expansion will establish the sum of deflection on a particular temperature.



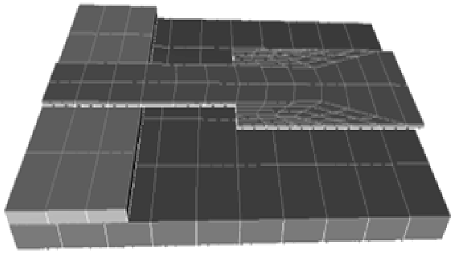
(a) Trapezium shaped cantilever



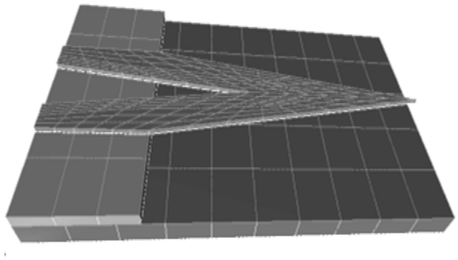
(b) Rectangular shaped cantilever



(c) Slotted paddle shaped cantilever



(d) Paddle shaped cantilever



(e) Slotted triangular shaped cantilever

Fig.1. Various type of cantilever for temperature measurements using 3D Builder

The model 2 has been designed by using sensing materials as titanium. The materials and dimensions of beam thickness should be selected because of cantilevers will be straight at the most deflection of preferred output. The Fig.1 shows the various micro cantilever structures designed by using 3D builder are as follows:

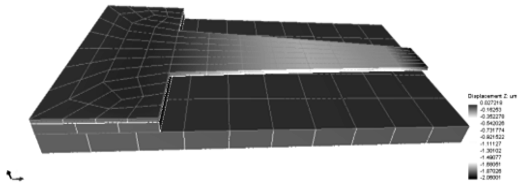
4. RESULTS AND DISCUSSION

MEMS sensor is adequate and modern tools for illumination and constructing sensor devices in arranging to reduce the size and the price of the devices. Hence, substrate as Silicon, Sacrificial layer as SiO_2, also structural layer as Silicon and two different sensing are used such as platinum and titanium. The cantilever beam has the adopting size and mechanical properties are as shown in Table.1.

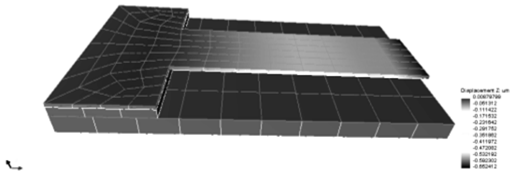
Table.1. Properties of Material and Dimensions

Layers [Material]	Dimension (μm)	Material Property		
		Young's Modulus (Gpa)	Poisson Ratio	Density (gm/cc)
Substrate [Silicon]	200×100×10	170	0.26	2.32
Sacrificial Layer [SiO_2]	50×100×5	64	0.25	2.2
Structural Layer [Silicon]	150×40×1	170	0.26	2.32
Model 1 Sensing Layer [Platinum]	150×40×0.5	146.9	0.35	21.45
Model 2 Sensing Layer [Titanium]	150×40×0.5	115	0.3	4.51

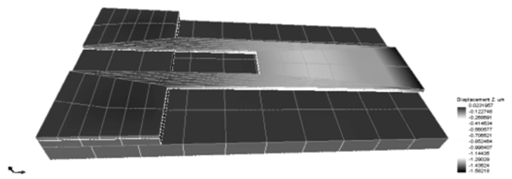
The simulation results for the various temperature sensor deflections are shown in Fig.2(a)-Fig.2(e). Hence, the temperature sensor outcomes are found the utmost deflection of the trapezium cantilever composition. The comparative results of displacement as model 1 has been used Platinum sensing material with various structures such as Trapezium, Rectangular, Slotted Paddle, Paddle and slotted triangular shaped cantilever shown in Fig.2. Then the model 2 sensors have been used Titanium sensing material with various structures. Therefore, the model 1 (i.e. Platinum as sensing material) results are found that the utmost displacement and sensitivity using the trapezium cantilever composition.



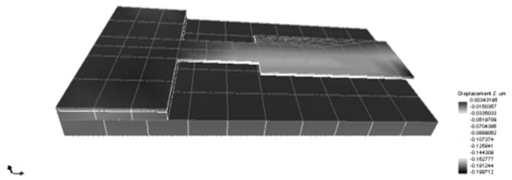
(a) Displacement Analysis of Trapezium Cantilever at10°C



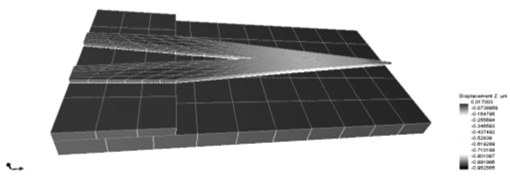
(b) Displacement Analysis of rectangular Cantilever at10°C



(c) Displacement analysis of slotted Cantilever at10°C



(d) Displacement analysis of paddle Cantilever at10°C



(e) Displacement analysis of triangular Cantilever at10°C

Fig.2. Simulation results various type of cantilever for temperature measurements using 3D Builder

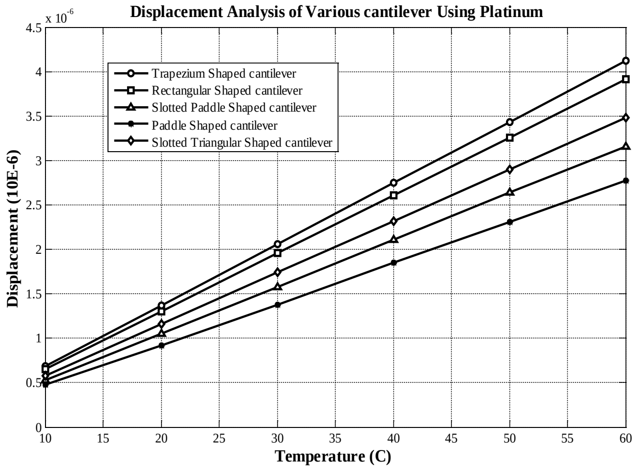
The simulation end results show that both the deflection and sensitivity are enhanced with the alterations in beam sensing material or else we can modify in the dimensions of length or thickness.

Therefore, the Table.2 shows the comparison between the analysis of different cantilever structure in terms of displacement and sensitivity and shows trapezium cantilever as the better response compared to all other shaped cantilever.

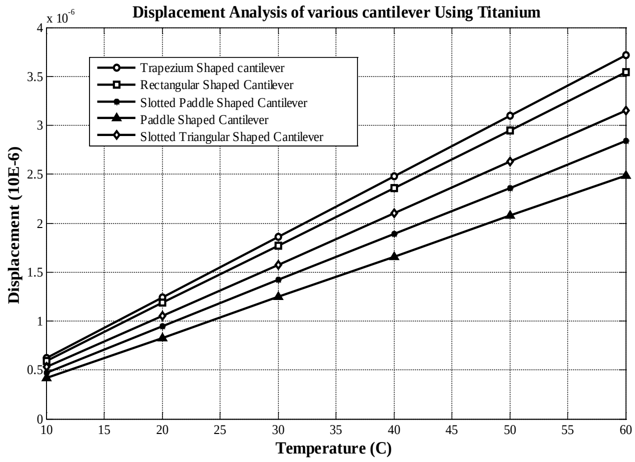
Table.2. Comparison response results of various cantilever structure at temperature as 30°C

Cantilever Structure	Displacement ($10E^{-6}$)		Sensitivity ($10E^{-6}$/C)	
	Platinum	Titanium	Platinum	Titanium
Trapezium	2.06e-6	1.86e-6	6.87e-8	6.2e-8
Rectangular	1.96e-6	1.77e-6	6.5e-8	5.9e-8
Slotted Paddle	1.58e-6	1.42e-6	5.3e-8	4.7e-8
Paddle	1.38e-6	1.25e-6	4.6e-8	4.15e-8
Slotted Triangular	1.74e-6	1.57e-6	5.8e-8	5.23e-8

The comparative results of displacement shown as Fig.3(a) and Fig.3(b) using two different sensing materials such as platinum and titanium. The trapezium cantilever sensor produces mores displacement than others. The Fig.3(a) has been used the sensing materials as Platinum and the same as Fig.3(b) used the sensing layer as titanium.



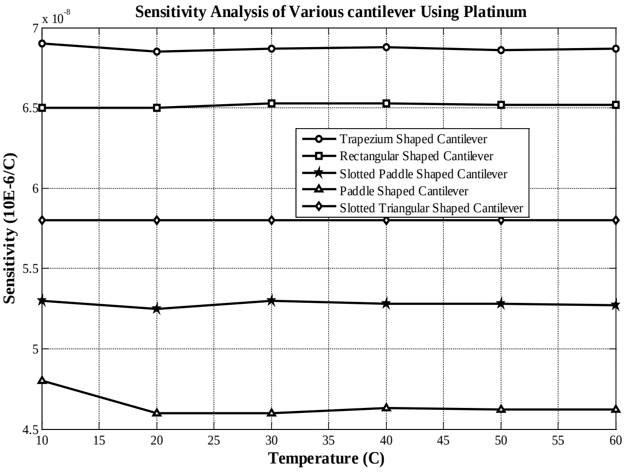
(a) Responses of the sensor at different temperature using Platinum



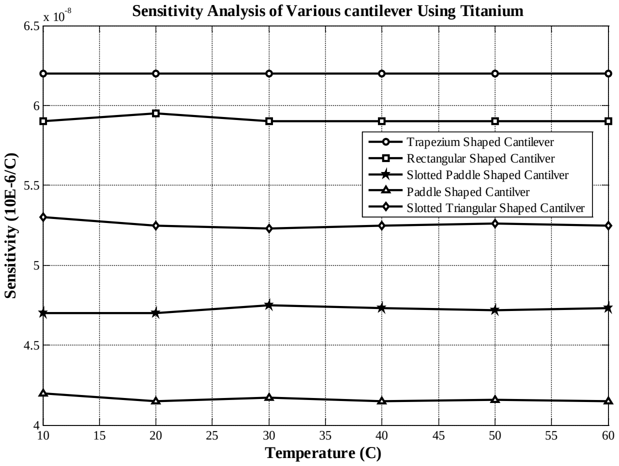
(b) Responses of the sensor at different temperature using Titanium

Fig.3. Caparisons of various cantilever displacements analysis

In Fig.4(a) and Fig.4(b) as shown sensitivity of both model 1 and model 2 temperature sensors are summarized. Here, the model 1 simulation effects are found the utmost sensitivity of the trapezium cantilever beam. Thus the results present that both the deflection and sensitivity are improved when modify in cantilever beam sensing material or else modify in that dimension.



(a) Sensitivity Analysis Using Platinum



(b) Sensitivity Analysis Using Titanium

Fig.4. Caparisons of various cantilever sensitivity analysis

5. CONCLUSION

The trapezium shaped cantilever using two different sensing materials has been planned and their sensitivity is studied with different stimulus atmospheric temperature. We could initiate that the cantilever based temperature sensor presents excellent performance and also platinum as good sensing material for measurement the temperature in the range between 10°C to 60°C. Hence, dimensions and materials on the sensitivity of a MEMS temperature sensor have been considered using FEM analysis MEMS CAD tool. Therefore, we resolve that the Trapezium shaped cantilever with a sensing material of Platinum is more desirable for temperature sensor.

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