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Microcantilever Based Integrated Temperature Sensor, Humidity Sensor and Moisture Sensor – Comparitive Analysis

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ABSTRACT

Microcantilever based integrtaed temperature sensor, humidity sensor and moisture sensor is proposed to reduce the cost of the device. This novel idea of integrating temperature, humidity and moisture sensor since they are inter dependent parameter in the environmental measurement. The proposed work investigates about the performance of the three sensor by placing them in a single silicon substrate. The structure which yields maximum deflection is the optimized method to fix the three sensors. The deflection analysis is carried out for temperature at 100ºC, relative humidity at 10% to 100% and the moisture range of 10 % to 100%.

Keywords: Temperture Cantilever, Humidity Cantilever, Moisture cantilever, Maximum Deflection.

I. INTRODUCTION

MEMS based cantilever sensor is simple to design and economical in manufacturing such devices using micro machining method. Now a days, more than two sensors are integrated in a single substrate to achieve the precision output with better compensation also. To achieve this MEMS technology is most widely used since the product is smaller in size, low in cost and low power consumption.

The output from the sensor has two uses. The first one is to display the data or to store the data, but it not result with automated output without any feedback. The second one is sensor are part of feedback loops to achieve the control over the measured parameter. The output of sensor is eventually used to function the actuator with or without modification. In both the cases the sensors are needed individually. However many practical functions require the concreted use of multiple sensor [1] located at different locations. One of the most prominent example is monitoring the weather conditions [2] and agricultural monitoring [11]. The integration of multiple sensors result in effective use of power supply, reduced size and computational time and increase the commercial availability of sensor with MEMS technology adopted [6, 7, 8, 9, 10].

The key idea of this proposed work is to integrate the three interdependent sensor such as temperature cantilever, humidity cantilever and moisture [3] cantilever using single silicon substrate with advancement of MEMS technology. The simple cantilever structure is proposed for each sensor to integrate them. The sensor is proposed for the temperature range of 100°C to 40.556°C ,Relative Humidity range of 10 % to 100 % at the temperature range of 25°C to 40°C and soil moisture range of 10% to 100%. The performance is studied based on placing the three microcantilever sensor on single silicon substrate in different directions. The structure with maximum deflection is the optimized integration of three sensor. The simulation is carried out using MEMS CAD INTELLISUITE Tool.

II. STRUCTURE OF INTEGRATED SENSOR

A. Basic structure

The basic structure of the temperature cantilever, humidity cantilever and moisture cantilever is shown in Figure 1, 2. The temperature cantilever with dimension 200µm x 100µm x 0.5µm and it is comprises of three layer such as substrate, dielectric layer and sensing layer. Similarily The temperature cantilever with dimension 200µm x 100µm x 0.5µm and it is comprises of four layer substrate, dielectric layer and sensing layer 1, sensing layer 2. The temperature and humidity sensor is constructed using INTELLISUITE MEMS CAD tool.

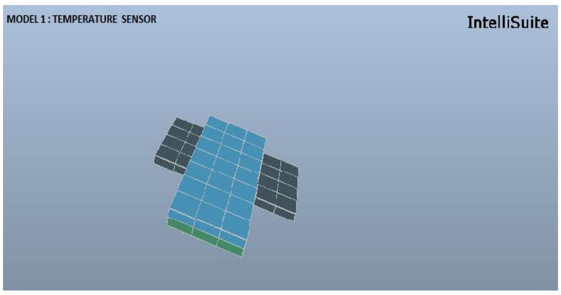

Figure 1: Temperature Sensor

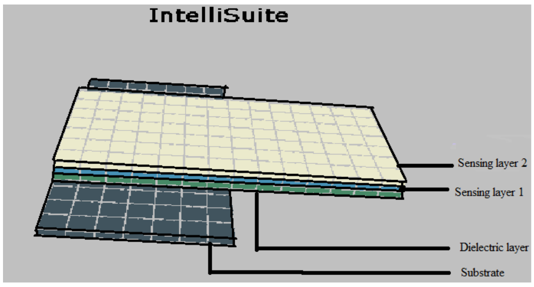

Figure 2. Humidity Sensor

B. Optimized Dimension

The maximum deflection for the dimension of temperature and humidity sensor shown in Table 1, Table 2, Table 3.

TABLE I

OPTIMIZED DIMENSION OF TEMPERATURE SENSOR

Structure Name	Dimension(µm)	Deflection(µm)
Corner perforation	**200x 100 x 0.5**	**54.9271**
Without perforation	200x 100 x 0.5	50.5893

TABLE II

OPTIMIZED DIMENSION OF HUMIDITY SENSOR

Humidity (100 %)	Dimension(µm)	Deflection(µm)	
	200x 100 x 0.5	Without ribs	With ribs
T= 25ºC	200x 100 x 0.5	28.0929	38.3051

C. Structure of Integrated sensor with respect to different placement

Silicon based Temperature sensor and humidity sensor [2, 4] is integrated in the single simple cantilever. Integrated sensor is constructed on the either side and also on the same side of the cantilever. Temeperature sensor comprises of Aluminum [5] deposited upon the dielectric layer Silicon dioxide. Aluminum is best temperature sensing element Humidity sensor is comprises of Platinum, temperature compensation layer upon the polymer based humidity sensor, Polysilicon with the constant dimensions of length 200µm , width 100µm , height 0.5µm. The various cases of the integrated cantilever structures are shown in below:

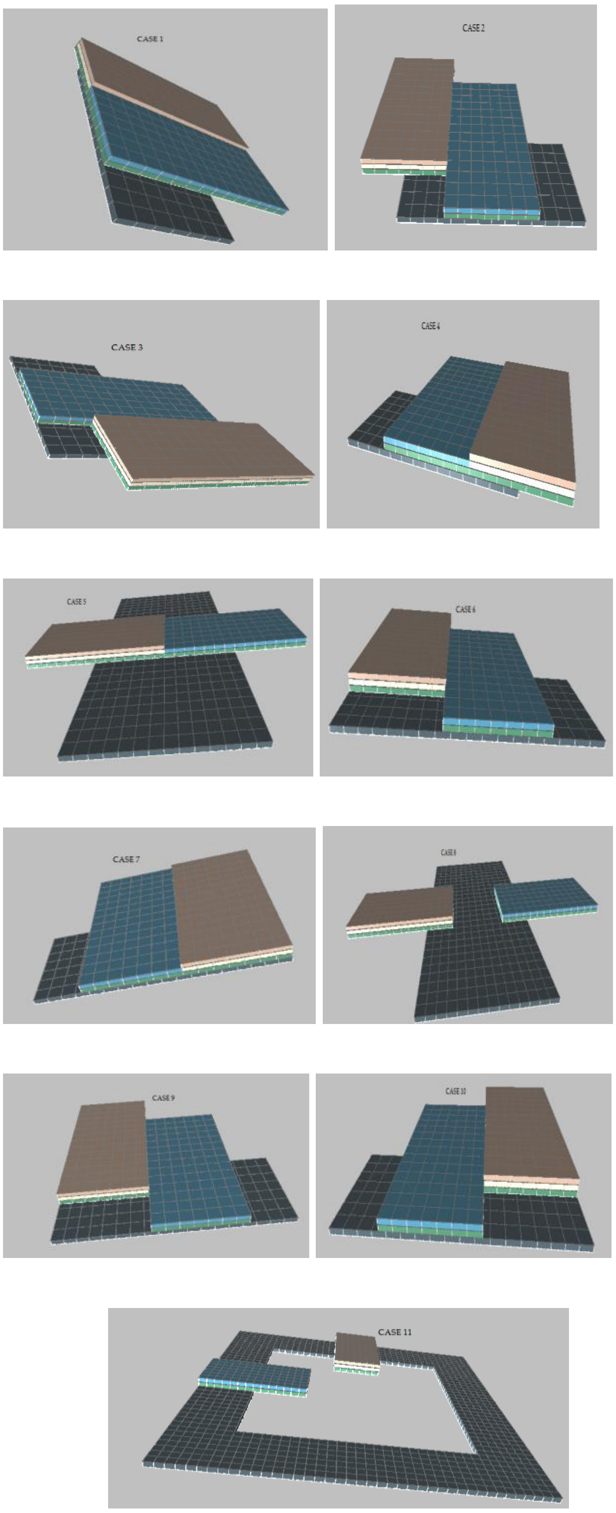

Figure 3. Varied Structure for the Integrated Temperature and Humidity Sensor

D. Deflection output

For the integrated temperature and humidity sensor, deflection analysis is carried out for the optimum temperature and humidity range for the various structure on the cantilever and it is tested and optimized The deflection analysis is shown in the Table 1.

TABLE III

DEFLECTION ANALYSIS OF VARIED STRUCTURES OF INTEGRATED SENSOR

CASE	DEFLECTION(µm)	
	TEMPERATURE FOR 100° C	**HUMIDITY for 100% at 25° C**
Case 1	46.9143	24.2056
Case 2	38.8155	29.066
Case 3	38.8155	29.066
Case 4	46.9143	24.2056
Case 5	52.6223	26.4591
Case 6	46.0789	21.5997
Case 7	46.0789	21.5997
Case 8	8.41255	3.5583
Case 9	38.7535	27.2908
Case 10	38.7535	27.2908
Case 11	47.5853	27.6799

E. Optimized Structure Of Integrated Sensor (Temperature And Humidity Sensor)

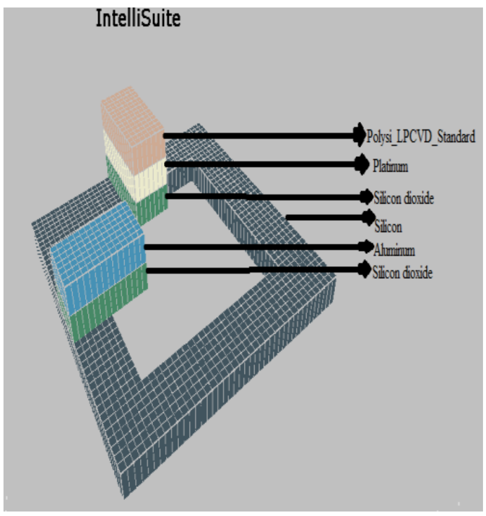

Figure 4. Optimized Integrated Temperature and Humidity Sensor

F. Structure of integrated sensor (temperature and soil moisture sensor)

The integrated sensor on silicon substrate of dimension 600µm x 600 µm x 5µm by using bulk micromachining. In order to form the cantilever, centre of the substrate is etched using mask of dimension 500µm x 500µmx 5µm. the temperature and soil moisture based cantilever is constructed on the substrate Each sensor dimension has been satisfied by significant design aspect ratio are:

(1) Ratio of length to width (l : w)
(2) Ratio of width to thickness (w: t)

The two constraints are shown in the Equations below:

$$l: w \geq 2:1 \quad (1)$$

$$w - 8t \leqslant 0 \quad (2)$$

The two-layered cantilever based temperature and soil moisture sensor is constructed with the dimension of 200µm x 50µm x 6.25µmis shown in Fig.5.

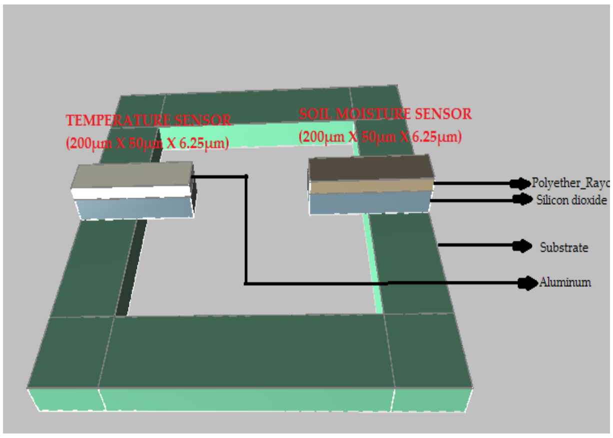

Figure 5. Optimized Integrated Temperature and Soil Moisture Sensor

TABLE IIV DIMENSION OPTIMIZATION OF INTEGRATED TEMPERATURE AND SOIL MOISTURE SENSOR

THICKNESS VARIATION (µm)		DEFLECTION (µm)	
Dielectric Layer	Sensing Layer 1	Temperature At 40.566°C	Soil Moisture At 100%
0.25	6	1.43338	177.08
1	5.25	1.72689	143.15
1.25	5	1.96608	124.511
2	4.25	2.2455	48.676
2.25	4	2.27906	24.7605
3	3.25	2.31226	0.00419557

G. Deflection output

Sensitivity analysis of integrated temperature and soil moisture sensor for the thickness variation of substrate of 5(µm) and dielectric layer of 0.25(µm) and sensing layer of 6(µm) for the dimension of [200 (µm) x 50(µm) x6.25 (µm)] is shown in Table 4, Table 5.

TABLE IIIV SENSITIVITY ANALYSIS OF INTEGRATED TEMPERATURE SENSOR

Temperature (°C)	Deflection (µm)
1.66667	0.0589055
4.44444	0.157081
7.22222	0.255256
10	0.353432
12.7778	0.451609
15.5556	0.549785
18.3333	0.647958
21.1111	0.746134
23.8889	0.844311
26.6667	0.942487
29.4444	1.04066
32.2222	1.13884
35	1.23701
37.7778	1.33519
40.556	1.43338

TABLE V SENSITIVITY ANALYSIS OF SOIL MOISTURE SENSOR

SOIL MOISTURE AT 100%	Deflection (µm)
10	17.7088
20	35.4176
30	53.1264
40	70.8353
50	88.5441
60	106.253
70	123.962
80	141.671
90	159.38
100	177.088

Sensitivity analysis of integrated temperature and soil moisture sensor for the thickness variation of substrate of 5(µm) and dielectric layer of 3(µm) and sensing layer of 3.25(µm) for the dimension of [200 (µm) x 50(µm) x6.25 (µm)] is shown in Table 6, Table 7.

TABLE VI SENSITIVITY ANALYSIS OF INTEGRATED TEMPERATURE SENSOR

Temperature (°C)	Deflection (µm)
1.66667	0.0951058
4.44444	0.253615
7.22222	0.412124
10	0.570634
12.7778	0.729144
15.5556	0.887655
18.3333	1.04616
21.1111	1.20467
23.8889	1.36318
26.6667	1.52169
29.4444	1.6802
32.2222	1.83871
35	1.99722
37.7778	2.15573
40.556	2.31426

TABLE VII SENSITIVITY ANALYSIS OF SOIL MOISTURE SENSOR

SOIL MOISTURE AT 100%	Deflection (µm)
10	0.0000041974
20	0.00389636
30	0.000584455
40	0.00167823
50	0.00209778
60	0.00251734
70	0.0029369
80	0.00335646
90	0.00377601
100	0.00419557

III. CONCLUSION

By using simple cantilever, MEMS based temperature and humidity sensing is integrated on the single free standing cantilever for the varied application. This integrated sensor will be in compact size and also can be used in the various applications as one among the other sensor. In the integrated sensor , temperature and humidity is placed on both sides also on the same side of the cantilever and the deflection analysis is carried out with respect to to temperature (°C) and relative humidity (%). Among the varied structure Case 11 has maximum deflection for the temperature sensor and humidity sensor. Even Case 5 has maximum deflection for temperature sensor but the structure is not as a typical cantilever structure. Hence case 10 has chosen as the optimized structure. Integrated temperature and soil moisture sensor has been designed in the dimension of 200µm x 50µm x 6.25µm based on the aspect ratio and the optimized thickness variation is achieved depend on the maximum deflection. For the thickness variation for substrate of 5(µm) and dielectric layer of 0.25(µm) and sensing layer of 6(µm) has maximum deflection of 177.08µm for the moisture senor . Where else , the thickness variation for substrate of 5(µm) and dielectric layer of 03(µm) and sensing layer of 3.25(µm) has maximum deflection of 2.31226 µm for the temperature senor This current study is further develops the optimized structure with perforation and ribs for the enhanced deflection in the microcantilever .

IV. REFERENCES

[1] David J.Nagel, "Microsensor Cluster", Microelectronics Journal, 33 (2002), 107-119. (Elsivier)

[2] Rong-Hua Ma, Chia-Yen Lee, Yu-Hsiang Wang, Hao-Jen Chen "Microcantilever-based weather station for temperature, humidity and flow rate measurement," Microsyst Technol, vol. 14, pp. 971-977, November 2007.

[3] Jie Liu, Mangilal Agarwal, Kody Varahramyan,Ernest S. Berney IV, Wayne D. Hodo "Polymer- based microsensor for soil moisture measuremnet," Sensors and Actuators, vol. B129, pp. 599-604, September 2007.

[4] Lung-Tai Chen, Chia – Yen Lee, and Wood-hi cheng, "MEMS-based humidity sensor with integrated temperature compensation mechanism," Sensors and Actuators, vol. A147, pp. 522-528, July 2008.

[5] Ashish, Kumari Nidhi Gupta, Dr. T.Shanmuganantham, "Design Of Temperature Sensors For Enviromental Applications", Int. Journal of Engineering Trends and Technology (IJETT) –Volume 4 Issue 10 - Oct 2013.

[6] B.Priyadarisshini, D.Sindhanaiselvi, T. shanmuganatham, "Design and dimension optimization of high sensitive microcantilever as humidity sensor," IEEE, Accepted.

[7] D.Sindhanaiselvi, T.Shanmuganantham, "Double Boss Sculptured Diaphragm Employed Piezoresistive Mems Pressure Sensor With Silicon-On-Insulator (SOI)" Journal of Engineering Science and Technology, School of Engineering, Taylor's University., Vol. 12, July 2017

[8] Marie Joan Syndhya, D.Sindhanaiselvi, T.Shanmuganantham, "Design and Analysis of Rectangular type Pizoresistive Microcantilever for Antigen Detection", International Journal of Control Theory and Application, International Science Press, Vol. 10, 2017.

[9] Marie Joan Syndhya, D.Sindhanaiselvi, T.Shanmuganantham, " Investigation on Piezoresistive Micro Cantilever Design for Blood Glucose Sensing", International Journal of Control Theory and Application, International Science Press , Vol. 10, 2017.

[10] D.Sindhanaiselvi, T.Shanmuganantham, "Investigation on Performance of Piezoelectric Beam Based Mems Actuator for Focussing of Micro Lens in Mobile Application", IEEE International Conference on circuits and systems, 2017.

[11] Rajul S. Patkar, Madhuri Vinchurkar, Mamta Ashwin, and V. Ramgopal Rao, "A Novel PET-Based Piezoresistive MEMS Sensor Platform for Agricultural Applications," Journal of Microelectromechanical Systems, Vol. 26, No. 4, Pp. 746-748, August 2017.