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Investigation Study of Three In One Multiple Agricultural MEMS Sensor Using Microcantilever

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ABSTRACT

MEMS based three- in- one multiple sensor with soil Temperature, soil moisture and humidity sensor proposed using simple cantilever for the agricultural applications. These parameters are the most important parameters for agricultural monitoring to control the usage of water supply to the plants. The study is to find the optimized dimension of the three- in- one multiple MEMS sensor with respect to maximum deflection for the temperature range of 0°C to 40.556°C, relative humidity and the soil moisture range of 10 % to 100%. The dimension is optimized with respect to aspect ratio parameters such as length, width and thickness of different layers.

Keywords: Microcantilever, Temperature, Humidity, Soil Moisture, Deflection.

I. INTRODUCTION

Agriculture field is influenced by chemical products into the soil, natural hazard and improper irrigation that affects the growth of the crop. Monitoring soil nutrients, soil moisture, soil temperature, humidity and soil pH gives thorough knowledge of the field condition that enriches the crop by understanding the soil health. MEMS technology acts as economical platform in designing the sensor in the diverse fields especially in the research work of agricultural sector [10]. This is an emerging technology in designing the multiple sensor in compact size, cheaper cost, and low power consumption benefits to the farmers. These advantages indicates the multiple sensor are affordable and they are highly recommended for the poor farmers for their boon.

MEMS is most broadly used technology in microscopic device with electrical and mechanical elements in it used in wide applications [6, 7, 8, 9]. Depending upon the ranges of the parameters, farmers can monitor and collect data of soil water availability, temperature that gives better understanding to perform smart irrigation system, which gives high profit in harvesting the crop.

The novelty of this project to measure the three different influential parameters using three –in- one multiple sensor such as temperature, humidity and soil moisture with advancement of MEMS technology for the. The exact soil moisture and soil temperature,

humidity gives wide knowledge about usage of water in the field and intake of nutrients from the soil for the critical growth stages of the crop. The simple cantilever is proposed to design the three in one multiple sensor. The sensor is proposed for the temperature range of 0°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 investigation study is carried out too find the optimized dimension for three multiple sensor in the single substrate with respect to aspect ratio such as length in (μm) , width in (μm) and thickness in (μm) and its performance is analysed. The cantilever based temperature sensor is tend to deflect when exposed to the temperature layer with higher thermal coefficient. Similarily humidity and soil moisture sensor [2] tends to deflect more when exposed to the polymer based material since it had good absorbtion of water content in the soil and in air.

II. STRUCTURE OF THREE –IN – ONE INTEGRATED SENSOR

A. Basic structure

The three in one multiple 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, humidity, soil moisture based cantilever is added on the surface of the substrate by surface micromachining method. Each sensor dimension has been satisfied by

Significant design aspect ratio [5] 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:

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

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

The length, width and thickness are considered to be the key factors to optimize the structure of the cantilever without any breakage of the beam and also to obtain the maximum deflection. In the temperature cantilever sensor consists of two layers such as dielectric layer and sensing layer. The humidity cantilever sensor is of three layers such as dielectric layer and sensing layer with the temperature compensation layer. Soil moisture cantilever sensor comprises of two layers such as dielectric layer and a sensing layer. The dimension of three sensors is followed with respect to Equations (1) and (2). is given in Table 1.

TABLE I

DIMENSION OF THREE- IN-ONE MULTIPLE SENSOR

PARAMETER	DIMENSION (μm)						
	L:w	*Length*	*Width*	*Thickness*			
				Substra	*Dielect ric*	*Sensing layer1*	*Sensing layer1*
Temperature	4:1	200	50	5	6.25		-
Humidity	2:1	200	100	5	12.5		
Soil Moisture	4: 1	200	50	5	6.25		-

Multiple sensor is designed by applying the first aspect ratio of the micro cantilever given in Equation (1). So the length and width is fixed in the ratio of 4:1 for the three layered sensor such as Soil Temperature and soil moisture sensor and for four layered humidity sensor [1,3] , the length and width is fixed in the ratio of 2:1. The dimension of two layered temperature and soil moisture sensor of 200μm x 50μm and the dimension of three layered humidity sensor is of 200μm x 100 μm. . Based on the width of the sensor, the thickness of the overall layer has been obtained by obeying the second aspect ratio.

Due to the mutual split up of the thickness for each layer of the sensors. Henceforth, thickness of the soil

temperature and soil moisture sensor is 6.25 µm. While thickness of the humidity sensor is 12.5µm. The three- in- one multiple sensor is shown below Fig 1:

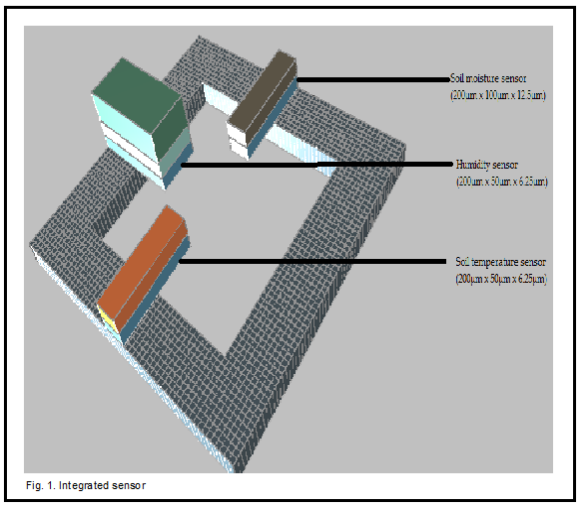

Figure 1. Structure of three- in- one multiple sensor

The soil temperature sensor and soil moisture sensor comprises of three layers such as silicon based substrate, silicon dioxide as dielectric layer and the sensing layer as in Fig. 1. Aluminium [4] as temperature sensing element and poly ether as soil moisture sensing element. Whereas humidity sensor has four layer with temperature compensation layer beneath the polymer based humidity sensing element, Polysilicon.

III. DEFLECTION ANALYSIS

Three in one multiple sensor ' s thickness has been varied in the different cases are carried out for the deflection analysis at the maximum temperature (105 °F / 40.556°C) and humidity range of 100% for 25°C and soil moisture for 100% for the optimized structure on the cantilever and it is tested . The deflection analysis is shown below in the Table II, Table III and Table IV with the thickness variation for each layer such as sensing layer1, sensing layer 2 and dielectric layer. But the silicon based substrate is kept constant with the thickness of 5µm. The optimized thickness with maximum deflection of the three in one multiple sensor is given in Table V.

TABLE III DEFLECTION ANALYSIS OF TEMPERATURE SENSOR

THICKNESS VARIATION (µM)		DEFLECTION (µm)
DIELECTRIC LAYER	SENSING LAYER 1	TEMPERATURE AT 40.566°C
0.25	6	1.35148
1	5.25	1.83464
1.25	5	1.96629
2	4.25	2.2459
2.25	4	2.29681
3	**3.25**	**2.31463**
3.125	3.125	2.24369
3.25	3	2.27488
4	2.25	2.01712
4.25	2	1.88435
5	1.25	1.10779
5.25	1	1.10018
6	0.25	0.18809

TABLE III DEFLECTION ANALYSIS OF HUMIDITY SENSOR

THICKNESS VARIATION (µm)			DEFLECTION (µm)
DIELECTRIC LAYER	SENSING LAYER 1	SENSING LAYER 2	HUMIDITY AT 100°C FOR 25°C
0.25	6	6.25	3.23499
1	5.25	6.25	3.29117
1.25	5	6.25	3.30135
2	4.25	6.25	3.30902
2.25	4	6.25	3.30473
3	3.25	6.25	3.27468
3.125	3.125	6.25	3.0259
3.25	3	6.25	3.2598
4	2.25	6.25	3.20476
4.25	2	6.25	3.18409
5	1.25	6.25	1.20281
5.25	1	6.25	3.10039
6	0.25	6.25	3.04945

TABLE IV DEFLECTION ANALYSIS OF SOIL MOISTURE SENSOR

THICKNESS VARIATION (µm)		DEFLECTION (µm)
DIELECTRIC LAYER	SENSING LAYER 1	SOIL MOISTURE AT 100%
0.25	**6**	**177.152**
1	5.25	143.26
1.25	5	124.908
2	4.25	49.0729
2.25	4	24.7669
3	3.25	0.208663
3.125	3.125	0.0146309
3.25	3	0.203307
4	2.25	0.187437
4.25	2	0.184115
5	1.25	1.14275
5.25	1	1.60853
6	0.25	0.145377

TABLE V OPTIMIZED THICKNESS VARIATION OF INTEGRATED SENSOR

THICKNESS VARIATION (µm)			DEFLECTION (µm)		
DIELECTRIC LAYER	SENSING LAYER 1	SENSING LAYER 2	TEMPERATURE AT 40.566° C	HUMIDITY AT 100°C FOR 25°C	SOIL MOISTURE AT 100%
0.25	6	-	-	-	177.152
2	4.25	6.25	-	3.30902	-
3	3.25	-	2.31463	-	-

IV. CONCLUSION

MEMS based three in one agriculture sensor is proposed as compact sensor designed using cantilever for the agricultural application. The dimension of the sensor is fixed based on the aspect ratio for 200 µm x 100 µm x 12.5 µm for cantilever based humidity sensor and 200µm x 50 µm x 6.25 µm for temperature and moisture sensor. The investigation study is carried out for maximum deflection for analysis by mutual split up of thickness among the dielectric layer and sensing layer it is found that the temperature sensor yields deflection of 2.31463µm, humidity sensor yields the deflection of 3.30902 µm and soil moisture sensor yields the deflection of 177.152 µm. further the sensitivity can be enhanced by adding of ribs and perforation.

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