Available online at www.elixirpublishers.com (Elixir International Journal)

Advanced Engineering Informatics

Elixir Adv. Engg. Info. 40 (2011) 5292-5294

ISSN: 2229-712X

MEMS based humidity sensor with integrated temperature sensor using Si cantilever beam for harsh environmental conditions

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ARTICLE INFO

Article history:

Received: 17 August 2011;

Received in revised form: 18 October 2011;

Accepted: 28 October 2011;

Keywords

MEMS,

RTD,

TEM.

ABSTRACT

Sensing and controlling of humidity and temperature is a major issue in various industries. This paper presents the design, fabrication and complete characterization of a Micro Cantilever based Humidity sensor integrated with a temperature sensor. A Si Cantilever based Humidity Sensor on capacitive principle is designed and various analyses were performed on the sensor. Platinum heater used in the humidity sensor is used for the vaporization of the moisture absorbed. The heater along with two gold electrodes can act as a temperature sensor so that the temperature variations can be easily detected. The temperature sensor was designed using Platinum and is of Resistance Temperature Detector {RTD} type. The temperature sensor is provided with two gold electrodes on each side. One of the electrodes is maintained at 5V DC and the other at 0V DC, enabling a current flow through the Platinum layer. When the temperature changes, the resistivity of the Platinum changes accordingly. This causes a change in the current flow through the temperature sensor. The sensor is designed in a structure that can tolerate the harsh environmental variations like pressure, temperature.

Introduction

Micro-Electro-Mechanical systems (MEMS) technology encompasses an enormous variety of applications, including sensors of almost any kind, imagers, ink jets, micropositioners, Optical beam steering and filtering, microphones, RF tunable components and switches. The MEMS is an advancement of the VLSI technology enabling the design of motors, actuators, sensors etc., in the Micrometer scale.

Micro cantilevers are one of these structures in the field of MEMS.MEMS cantilevers are commonly fabricated from silicon (Si), silicon nitride (SiN), or polymers (Dokmeci and Najafi 2001a, b).

Various sensors and sensing structures are made out of the cantilever structure. The cantilever structure with capacitive principle is used in many areas of MEMS (Maier 2001).

The MEMS based Humidity Sensor is used for the monitoring and measurement of moisture in the industrial environment.

The Humidity Sensor employs a platinum heater for the vaporization of the moisture absorbed. But this platinum heater can also be used as a temperature sensor by encorporating two gold electrodes at the ends. This provides more accurate output in the industrial environmental conditions since temperature variations has also been considered.

Sensor Design

The temperature sensor was designed using Platinum and is of Resistance Temperature Detector {RTD} type. The temperature sensor is provided with two gold electrodes on each side.

One of the electrodes is maintained at 5V DC and the other at 0V DC, enabling a current flow through the Platinum layer. When the temperature changes, the resistivity of the Platinum changes accordingly. This causes a change in the current flow through the temperature sensor.

The cantilever beam based humidity sensor gives a measurement of humidity in terms of capacitance variation at set intervals or in samples.

The Platinum RTD based temperature sensor gives the measurement of temperature as a variation of its internal resistance with temperature. The Platinum based heater is made to function between the sample times of humidity sensor for regenerating it.

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The Platinum RTD based temperature sensor gives the measurement of temperature as a variation of its internal resistance with temperature.

The Platinum based heater is made to function between the sample times of humidity sensor for regenerating it (Laville and Pellet 2002). They are shown in Fig 1 and 2.

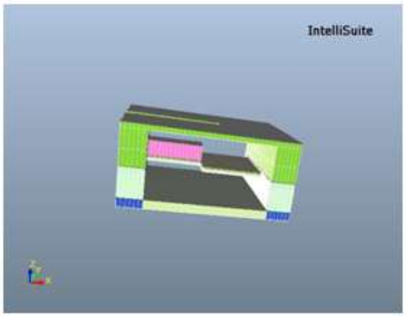

Fig1: 3-D design of MEMS Humidity sensor in Intellisuite.

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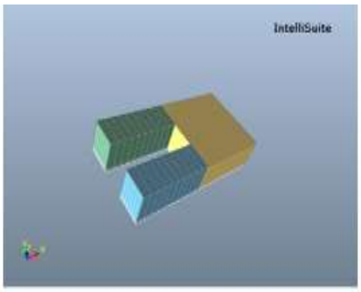

Fig2: Platinum based Heater

Sensor fabrication

The fabrication of the cantilever based MEMS humidity sensor along with Platinum RTD based temperature sensor and a heater involves a whole sequence of deposition, photo masking etching and the cycle continues for each material to be deposited to form the final structure.

The fabrication part involved is the design of Platinum, RTD based temperature sensor. The Platinum is coated on the Silicon Nitride base, to form an RTD temperature sensor. Leads are provided by depositing gold over the Platinum at suitable places.

The next step involved is the design of Platinum based heater. The heater is formed by depositing Platinum, with close and wide contact with Polyimide without compromising the design of Cantilever beams. It can be provided with potential to operate by allowing separate leads.

Sensor analysis

The sensor analysis was carried out using the Thermo Electro Mechanical (TEM) module of the Intellisuite.

The static displacement analysis was done on the cantilever beam. The result shows the displacement of the beam structure at various areas.

When the beam is loaded it moves in the Z-Direction. So, the displacement analysis of the beam is done in the Z-Direction. The beam showed a maximum displacement of 1µm. The result of analysis is as shown in the fig.3.

The theoretical Capacitance can be found out using the formula given below,

$C = \varepsilon o * \varepsilon r * A / d$ Farads

We have taken air as the medium between the fixed and movable electrodes, so $\varepsilon r = 1$ and the corresponding capacitance is found and the results are shown

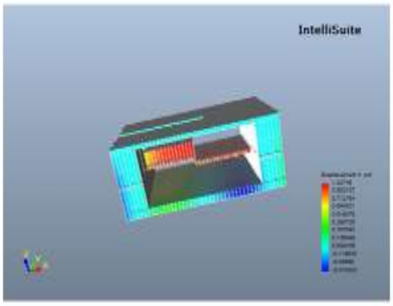

Fig.3 Resultofdisplacementanalysis

The temperature analyses provided the heat flux and corresponding charge density distribution patterns when the temperature is applied over the Platinum layer. It is shown in Fig 4, 5 and 6.

The gold electrodes are provided with 5v at one electrode and 0v at the other electrode and hence the current starts flowing through the platinum surface. Whenever there is a change in the temperature the resistivity changes. Due to change in the resistivity the current density varies and hence the output is plotted and the dynamic output is shown below

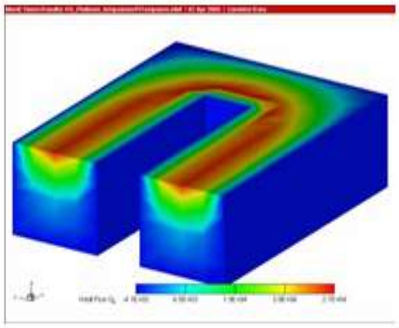

Fig 4 Heat Flux Distribution (Top)

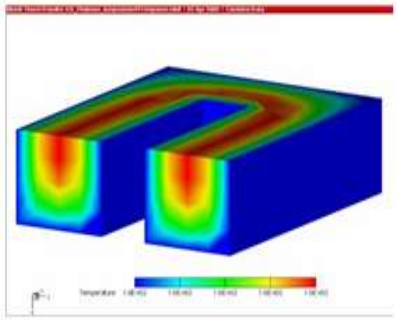

Fig 5 Temperature Distribution

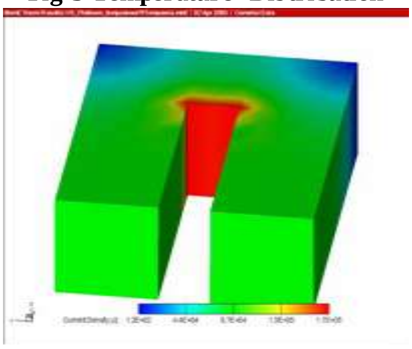

Fig 6 Current Density Distribution

In the temperature analysis when the temperature is increased the resistance value decreases and the current increases due to negative temperature coefficient. The formula to calculate the current density is shown below.

$R = A.e^{(B/T)}$

For various temperatures the corresponding current density is calculated. The dynamic output for temperature analysis is shown in Fig 7

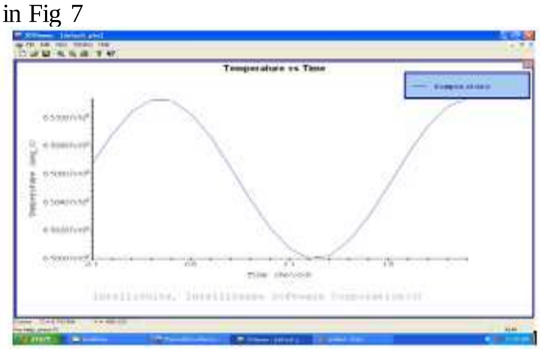

Fig 7 Dynamic output for temperature analysis

Conclusion

The MEMS based Humidity sensor with integrated temperature sensor was designed and analyzed using the various modules in Intellisuite. The temperature sensor also showed promising results, in terms of temperature, heat flux and charge distribution. The results of different sensors were correlated to provide the final integrated result. The Sensor had an option for regeneration using Platinum heater. The sensing structure can be regenerated in the time interval between the samples. The sensor has also good protective options to protect it from harsh environmental conditions.

References

Chatzandroulis S (2002) Fabrication of single Si cantilevers using a dry release process and application in a capacitive-type humidity sensor, Microelectronics Engineering 61-62 pp. 955-961.

Cheng H,Lin L,Nguyen CT, Najafi K(2001) Vacuum packaging technology using localized aluminum/silicon-to-glass bonding.14th IEEE International conference on MEMS 10(2):197-204

Chin-Yen Lee and Gwo-Bin Lee., et al., (2003) Micro machine-Based Humidity Sensors with Integrated Temperature Sensors for Signal Drift Compensation", Journal Of Micromechanics and Micro Engineering, 13 pp.620–627.

Dokmeci M, Najafi K (2001a) A high resistivity polyimide capacitive Relative humidity sensor for monitoring anodically bonded hermetic micropackages.J MEMS10(2):197- 204

Dokmeci M, Najafi K (2001b) A High resistivity polyimide capacitive Relative humidity sensor for monitoring anodically bonded hermetic packages. IEEE J Microelectromech Syst10:197- 204.

Govardhan K and .Alex ZC (2005) Mems Based Humidity Sensor, Department of Electronics and Instrumentation, Vellore Institute of Technology, Vellore, INDIA.

Laville C, Pellet C (2002) Comparison of three humidity sensors for a pulmonary function diagnosis Microsystems.IEEE Sens J 2:96-101.

Maier G (2001) Low dielectric constant polymers for microelectronics.Prog polym sci 26:3-65.

Muniraj N.J.R (2010) Mems based humidity sensor using Si cantilever beam for harsh environmental conditions, Department of Electronics and communication Karpagam College of engineering, microsyst technol, pp-27-29.

Tetens.O, Uber Einige MeterologischeBegriffe, Zeitschrift fur Geophysik, (1930) Vol, 6:297.

Celine Laville and Claude Pellet., et al., "Comparison of Three Humidity Sensors for a Pulmonary Function Diagnosis Microsystems", IEEE Sensors Journal, April 2002.

Table 1 Theoretical Capacitance values

Distance(µm)	Capacitance(pF)
24	276.678
24.1	275.781
24.2	274.559
24.3	273.445
24.4	272.341
24.5	271.246
24.6	270.159
24.7	269.082
24.8	268.013
24.9	267.953
25	266.901

Table 2 Theoretical Capacitance values

Temperature (^{0}C)	Current(mA)
25	4.803
50	4.901
100	4.950
200	4.975
300	4.983
500	4.990
600	4.991
700	4.992
800	4.993