IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 13, Issue 2 Ver. I (Mar. - Apr. 2016), PP 40-43
www.iosrjournals.org

Design Analysis and Fabrication Steps of MEMS Humidity Sensor for Automobile Applications

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Abstract: *Humidity measurement plays a major role in various industries and energy applications. Monitoring and controlling the humidity is of great importance for the reliable operation of various systems. One of the techniques for measuring humidity is the use of absorption capabilities of polymers. Humidity variations change the electrical permittivity of polymers. Therefore, if the polymer is placed between the two plates of a capacitor, the value of the capacitance which can be practically measured becomes a measure for humidity. In micro electromechanical systems (MEMS) the fabrication of two capacitor plates with a polymer material between the plates is feasible. Furthermore, the packaging of such a measuring device including electrical wiring is possible. In this paper, a MEMS polymer capacitor based humidity sensor is designed and its fabrication sequence is laid out. The developed MEMS humidity sensor has fast response and low cost due to its small size. In addition, the humidity sensor power consumption is low and its performance is insensitive to temperature variations which is a great advantage.*

I. Introduction

Sensors play a critical role in protecting the public and environment from chemical threats. Micro-electromechanical systems (MEMS) are useful as sensors because they are capable of converting different types of changes (chemical, optical, mechanical) into electrical responses. Small electrical responses can be precisely detected. MEMS sensors, have fast response times, and consume little power. Polymer-based MEMS sensors are popular because polymers react in measurable ways when exposed to small concentrations of target chemicals. This paper presents the fabrication two capacitor plates with a polymer material between them. The following sections discuss the sensor design, and the fabrication steps. While only the sensor is discussed in this paper, the ultimate goal is to detect the humidity via the capacity.

Polyimide is well suited for the application due to a high water uptake and a high diffusion rate resulting in high sensitivity and short response time. Polyimide experiences a linear change in dielectric constant (ε) from ε = 3.0 at 0% RH to ε = 4.2 at 100% RH [9].

In case of the humidity sensor, the polymer, which functions as a dielectric between the electrodes, absorbs or releases moisture and its dielectric properties (permittivity) change as a function of the relative ambient humidity, thus the capacitance changes.

Design

The working principle of the sensor begins with a carefully chosen polymer that will absorb humidity. The polymer is sandwiched between two electrodes to form a parallel-plate capacitor, as shown in the Fig. For a parallel-plate capacitor, the metric relating the voltage to current, and thus describing its electrical behaviour, is given by:

$$C = 0.0885 \frac{\varepsilon_{\circ} A}{d} \qquad (1)$$

where C is the capacitance, ε is the effective relative dielectric permittivity, A is effective area of the electrode in mm^2, and d is the distance between the electrodes in mm. the Equation above shows that the capacitance is proportional to the dielectric permittivity and inversely proportional to the distance between the electrodes

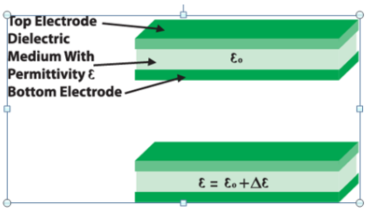

Figure (1): the capacitor formed from the polymer sandwiched between two electrodes

The data in Fig (2) shows the behavior of Polyimide's relative permittivity with respect to the relative humidity (RH) that is the polymer's relative permittivity increases linearly when the relative humidity(RH) increases.

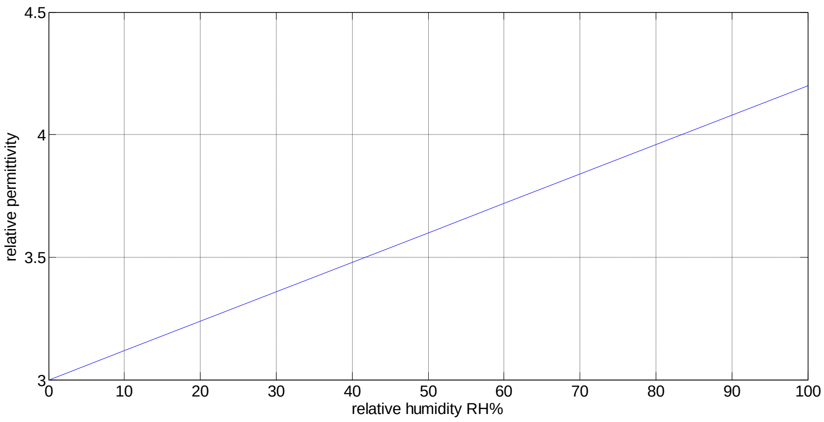

Figure (2): polyimide's relative permittivity versus the relative humidity (RH)

Fabrication

In this section, the steps of fabrication of the humidity sensors will be discussed. To start, a 500nm thermal oxide is grown on a (100) silicon wafer, ensuring sufficient electrical isolation of the sensor from the substrate. High-quality amorphous silicon dioxide is obtained by oxidizing silicon in either dry oxygen or in steam at elevated temperatures (850º–1,150ºC). Then, 250nm of aluminium is sputtered and patterned, serving as the bottom electrode. In this process, a target made of a material to be deposited is physically bombarded by a flux of inert-gas ions (usually argon) in a vacuum chamber at a pressure of 0.1–10 Pa. Atoms or molecules from the target are ejected and deposited onto the wafer.Next, the polymer (Polyimide) is applied using a spin coater to yield a uniform, 1μm thick film. Finally, the top electrode (250nm of aluminium) is sputtered and patterned.

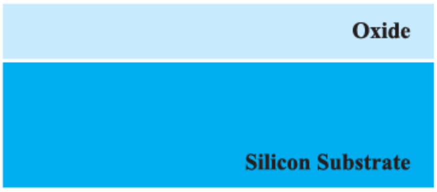

Figure (3): Thermal Oxide grown on Silicon substrate

II. Results

The data in Fig (4) verifies that the capacitance increases linearly with the increasing of permittivity which is stated in equation (1).

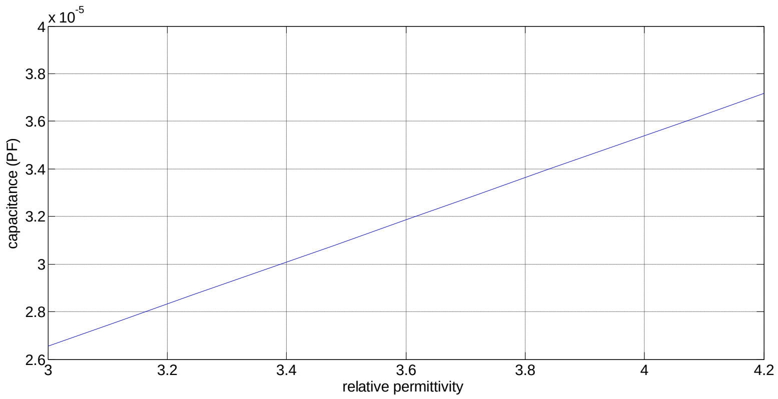

Figure (4): capacitance change with respect to polyimide's relative permittivity change

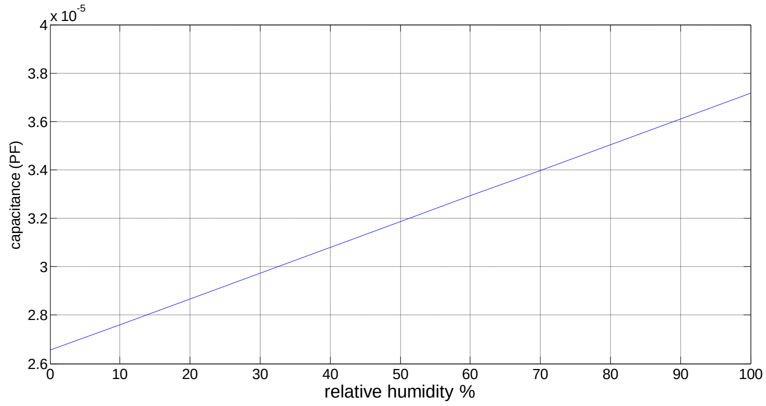

Figure (5): capacitance response due to change in relative humidity (RH)

On the other hand, increasing the relative humidity (RH) in the environment, increases the relative permittivity of Polyimide as mentioned before, hence increasing the capacitance as shown in Fig. (5).

Finally it is recommended to take into account the Ratio A/d for the analysis of the sensor since it plays a major role in increasing the capacitance. Fig (6) shows the relation between the magnitude of the capacitance and the ratio A/d. It is clearly seen that it is directly proportional to the capacitance of the sensor.

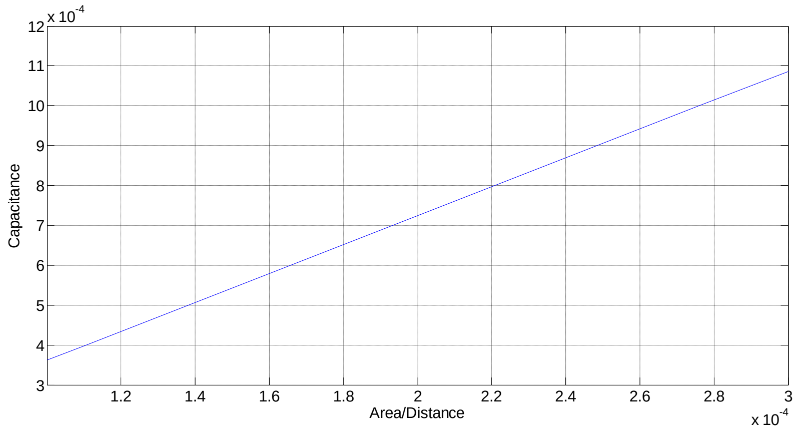

Figure (6): Relation between Capacitance (C) and the Ratio A/d

III. Conclusion

This paper studies the Design and Fabrication of MEMS Humidity Sensor. This work investigated the behavior of the relative permittivity of the Polyimide with respect to the relative humidity change. Hence, the capacity of the capacitor. Also this paper studies the effect of the area and the electrodes distance on its capacitance. This capacitor is formed from a polymer (Polyimide) sandwiched between two aluminum electrodes. Once the polymer absorbs the moisture in the air, its permittivity increases linearly with humidity increase, consequently the capacitance increases. Many automobiles use a humidity sensor as part their defrosting and defogging systems to automatically adjust the temperature and source of air used for heating and air conditioning. Humidity sensors also have industrial applications for production of materials that are sensitive to moisture such as food and agricultural industries. The developed MEMS humidity sensor has fast response and low cost due to its small size. In addition, the humidity sensor power consumption is low and its performance is insensitive to temperature variations which is a great advantage.

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