Design and Simulation of MEMS Based Sensor for Continuous Glucose Monitoring

[1]Shivaraj hebballi, [2]Dr. Prassannakumar S.C

[1]PG Student, [2]Professor
Department Of Electronics and Instrumentation Engineering,
R. V. College Engineering, Bangalore.
Bangalore, India.

***ABSTRACT*— As the technology has attracted a lot of attention the capacitive sensors based on the cantilever of the microelectromechanical system (MEMS) are promising devices with good performance. They are also able to observe the temporal effects of the environment and calibrate the values to provide information about the physical parameters by studying the deviation of the cantilevered structure. In this work, a capacitive sensor based on MEMS is designed, which while bending provides a movement of the cantilever when subjected to applied pressure by means of external factors. To estimate the cantilever performance and obtain a specific application design of the parameters, simulations of finite element analysis were carried out using COMSOL Multiphysics.**

***Index Terms*: MEMS, Cantilever, Capacitive sensor, Comsol, Displacement.**

I INTRODUCTION

DIABETES mellitus is a metabolic disease characterized by persistent hyperglycemia (high blood sugar levels). Close monitoring of daily blood sugar levels reduces the risk of diabetes-related complications by allowing timely identification and correction of hyperglycemia as well as hypoglycaemia (low blood sugar levels), a condition that typically results from excessive insulin uptake or inadequate glucose intake. This can be most effectively achieved by continuous glucose monitoring (CGM), which involves constantly repetitive measurements of physiological glucose levels. Microelectromechanical systems (MEMS) have attracted many researchers for two decades, especially in micro sensors and actuators. Pressure sensors are one sensors have been based on various physical properties, such as piezoresistive, piezoelectric, capacitive, magnetic and electrostatic. But compared to other MEMS technologies, piezoelectric MEMS recommend. biocompatible polymer that binds specifically and reversibly with glucose, and is equipped with a cellulose acetate semi permeable membrane, which allows glucose to permeate in and out of the chamber while maintaining glucose sensitivity polymer to escape. The diaphragm is embedded with a Mobile gold electrode, this forms a capacitor with a Gold electrode on the substrate below. Separating the electrodes it is a sealed air space.
A set of Permalloy thin film strips is also integrated in the diaphragm. Permalloy strips and movement the electrode is passive to avoid direct contact with the polymer solution. The dimensions of these components are shown in Fig.1.

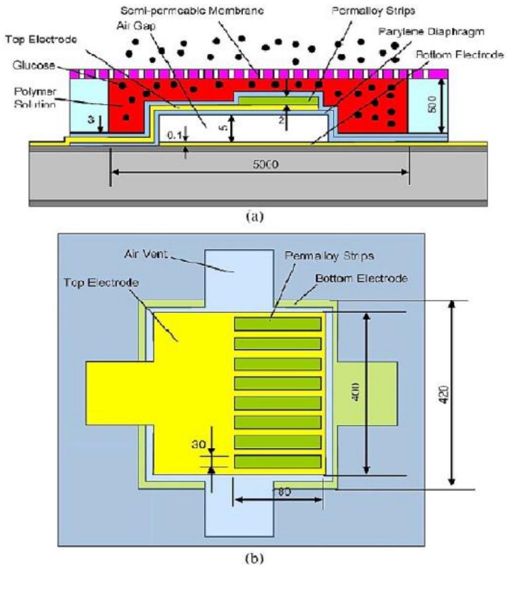


Figure 1: Schematic of the MEMS capacitive glucose
Sensor: (a) Side view of the capacitive glucose sensor and (b) top view of the capacitive glucose sensor (dimensions are given in micrometers).

2.1 Capacitive

Capacitive sensors can be used to detect different variables such as pressure and conductivity. Any parameter that affects the value of the capacitance can be measured with capacitive sensors. In general, the capacitance is equal to the division of the load by the voltage applied between two conductive plates, and can also be defined by equation

$$C= \varepsilon_r \varepsilon_0 \frac{A}{d} \text{........... (1)}$$

Where ε_o and ε_r are the dielectric constant and relative permittivity of the material between the plates respectively, A is the effective area and d is the distance between two plates. Different applications of capacitive sensors are based on changes of one of these parameters. one of the main methods that is often used in capacitive cantilever sensors is to exploit the variation of the space between two electrodes. In this case, the beam will act as an electrode and the second electrode will be a fixed plate, which is placed under the beam. Since this variation has a direct effect on the capacitance, cantilevers can detect very small forces that can make minimum deflections.

3 FABRICATION PROCESS

As shown in Fig. 2, the manufacturing process of the device began with the deposition and the chromium pattern (5 nm) and gold (100 nm) to form the fixed electrode (420 420 0.1 m3) in the SiO2 layer thermally grown on a silicon wafer. A sacrifice photoresistive layer (5 m) was coated by centrifugation and modelled to define the air space of the electrode [Fig. 3 (a)], followed by the deposition of a layer of Parylene (3 m). A second layer of chrome (5 nm) and gold (100 nm) were deposited for movement electrode (400 400 0.1 m3) and Permalloy seed layer [FIG. 2 (b)]. Subsequently, with Permalloy strips defined by a photoresist mold (5 m), Permalloy (2 m) was electrodeposited. This was followed by the removal of the photoresist mold, modeling of the moving gold electrode and deposition of a Additional layer of Parylene
(3 m) for passivation [Fig. 2 C)]. Two engraving holes (500 500 m2) were opened through the Two layers of Parylene by oxygen plasma to expose the sacrifice Photoresist layer [Fig. 2 (d)], which was subsequently removed by acetone (80 C) to release the diaphragm. (Devcon) [Fig. 2 (e)]. After cutting of wafers and joining wires, a chip was attached to a polycarbonate sheet (thickness: 500 m), in which the holes of sizes were drilled to define themicrochamber as well as the input and exit (every 10 L) for the manipulation of the polymer solution. the the polycarbonate, in turn, joined a regenerated cellulose acetate semi-permeable membrane (Fisher) with a Cutting weight of 3500 Da and thickness of 20 m with epoxy [FIG. 2 (f)].

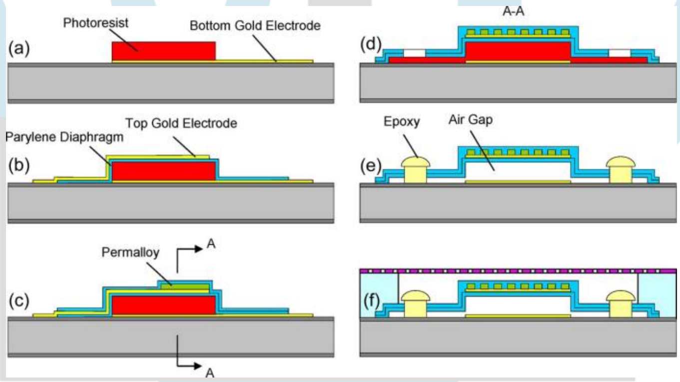


Figure 2: Fabrication process. (a) Bottom gold electrode deposition and sacri_cial layer patterning. (b) Parylene deposition and top gold electrode deposition. (c) Permalloy electroplating and additional Parylene layer deposition. (d) Photoresist etching hole patterning. (e) Sacrificial layer removal and diaphragm releasing. (f) Membrane bonding and device packaging.

3.1 Geometry

The E-shaped cantilever is a beam anchored at a single end with a length greater than that which is compared with its width and thickness. Very sensitive optical and capacitive methods have been used to Measure the static deflection in the cantilever beam. The cantilever movement is effected its length, width, thickness and various properties used to make the structure. The cantilever Final deflection can be calculated
as:

$$\partial = \frac{3\sigma(1-V)L^2}{Et^2} \text{........... (2)}$$

Where '' is the Poisson relation, 'E' is the Young's modulus, 'L' is the beam length and’t’ is the Cantilever thickness. The Cantilever Constant 'k' pier refers to the cantilevered dimensions and the material constants are given by [2]:

3.2 Material properties.

Table 1. Properties of materials used

Material Properties	PZT-5H	Silicon
Youngs modulus(GPa)	**63**	**165**
Density(kg/m3)	**7500**	**2330**
Poisson Ratio	**0.31**	**0.3**

Table 2 Device Specifications

Layer	PZT-5H	Silicon
Length (um)	60	60
Width (um)	10	10
Thickness(um)	0.31	0.3

4 RESULTS AND DISCUSSION

We may be wondering what is COMSOL Multiphysics? In short, COMSOL Multiphysics is a comprehensive simulation software environment for a wide array of applications, but structured and user-friendly for all to use.

Figure 3: Displacement with increasing arc length of Cantilever, for Structure.

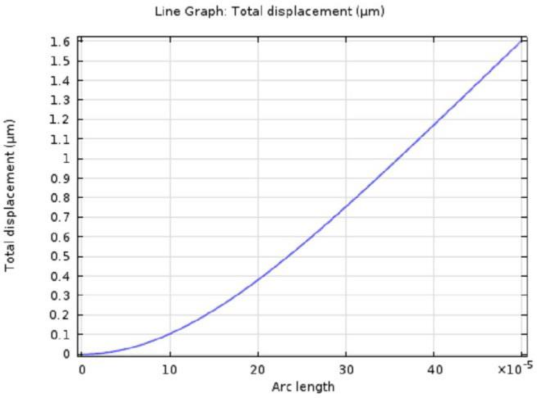
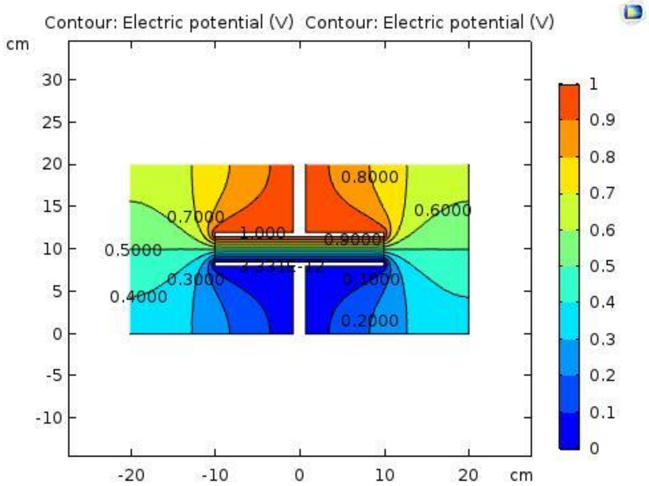


Figure 4: contours of the voltage field at a slice through the center of the capacitor.



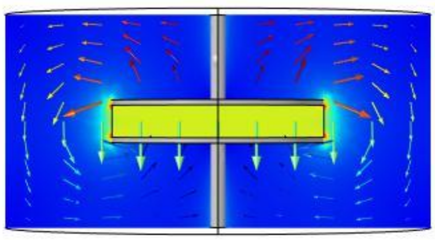


Figure 5: The electric field strength in the dielectric and air domain surrounding the capacitor.

CONCLUSION

The MEMS Micro-Cantilever capacitive glucose sensor designed exhibits selectivity and sensitivity properties that play a role in Glucose level detection. This can be used effectively for the continuous glucose monitoring sensor for the drug-drug system. Also SiO2 was showing the high sensitivity that other material. Even changed the dimensions to alter the performance of sensor.

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