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Design and Simulation of Capacitive pressure Sensor using Intellisuite

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Abstract: The design and modelling of a capacitive pressure sensor are presented in this work. High sensor sensitivities and resolutions have been accomplished using Micro Electro Mechanical Systems (MEMS) technology. Initial information on the simulation and design of such a sensor is provided in this report. The diaphragm deformation-induced capacitance change is used in capacitive sensing. A polycrystalline diaphragm that makes up the sensor deflects when pressure is applied to it. When pressure is applied, the 211m diaphragm deflects, altering the capacitance between the polysilicon diaphragm and silicon substrate. A high working pressure range and good linearity are achieved in the simulation of the MEMS capacitive pressure sensor in touch mode. To optimise the design, enhance the performance, and shorten the manufacturing process, Intellisuite software is used to model and simulate MEMS capacitive pressure sensors.

Keywords: Capacitive pressure sensor, MEMS, PolySilicon, Sensor

I. INTRODUCTION

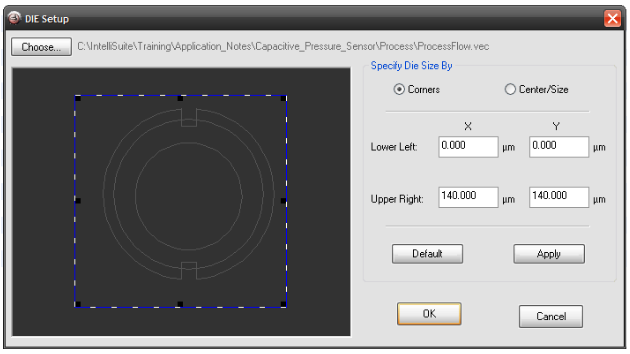
An example of a sensor is a capacitive pressure sensor, which gauges pressure by identifying variations in capacitance. A system of conductors and insulators has capacitance when it can store electrical charge. A membrane or diaphragm is sandwiched between two conductive plates to create a capacitor in a capacitive pressure sensor. The diaphragm slides towards one of the plates when pressure is applied, altering the distance between the plates and, consequently, the capacitance. The pressure being applied to the diaphragm can be measured and inferred from this change in capacitance. Automotive, aerospace, and medical device sectors all often use capacitive pressure sensors. They are renowned for their precision, consistency, and minimal hysteresis.

II. SOFTWARE USED

Using the software tools in Intellisuite, micro-electromechanical systems (MEMS) and other micro-systems are designed and simulated. The programme was made by and is updated by IntelliSense Corporation. Intellisuite is frequently used for MEMS research and development in both academia and business. It provides a comprehensive set of tools for designing, modelling, and simulating MEMS devices, which can help engineers and researchers make better designs and hasten the release of MEMS products.

III. SENSOR DESIGN

Intellisuite simulation software is used during the sensor design process. Utilising both Intellifab and 3D building tools, the sensor is created. The MEMS device masks were first imported using the fabrication process, and after that, a process table was constructed with all of the processes required to build the device from which the material properties were deduced. The imported mask set was connected to the process during process design, defining the x-y geometry of the structure. The device's 3D model may then be seen in the 3D Viewer and exported to an analysis module. The sensor is made up of a fixed silicon substrate that serves as the other half of the pressure-dependent capacitor and a circle polysilicon diaphragm with a 2 m thickness that deflects in response to pressure. The diaphragm is supported by beams to the substrate and suspended over it by a distance of 5 µm. An air gap and a thin layer of Si02 divide the diaphragm and substrate. Thermo Electro Mechanical Analysis (TEM) tool was used to import the constructed sensor for additional static and dynamic analysis. Figure 1 shows the layout of the capacitive sensor.



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Specify Die Size By

● Corners ○ Center/Size

	X		Y	
Lower Left:	0.000	µm	0.000	µm
Upper Right:	140.000	µm	140.000	µm

Figure 1. The layout of the capacitive sensor

IV. FABRICATION PROCESS

The following steps are included in the fabrication process:

1. The fabrication process includes the following steps:
2. Making Silicon (Si) wafers
3. Silicon dioxide (Si02) deposition during the heating procedure.
4. Partial silicon dioxide (Si02) wet etching
5. the deposition of phosphosilicate glass
6. In the standard technique, partial etching of phosphosilicate glass
7. Low-pressure chemical vapour deposition technique for Polysilicon deposition
8. Etching the silicon, phosphosilicate glass, and polysilicon sacrificial layer.

V. MESHING

The Intellisuite term "mesh structure" describes how a capacitive pressure sensor's 3D model is broken up into tiny, discrete parts for finite element analysis. A capacitive pressure sensor's mesh structure in Intellisuite is crucial for precisely simulating the sensor's response under various electrical and mechanical loading scenarios. To produce a precise and effective finite element analysis simulation, care should be taken while selecting the mesh density, element type, and boundary conditions. Figure 2 shows the meshed model of the capacitive pressure sensor.

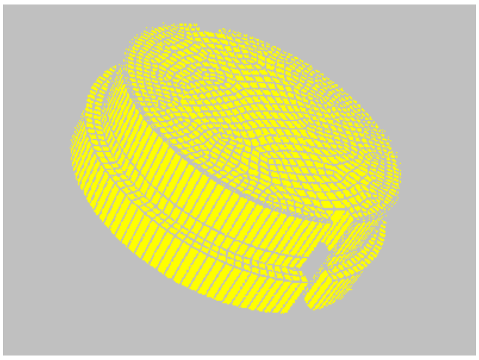


Figure 2. Meshed model in intellisuite

VI. THERMO-ELECTRO-MECHANICAL (TEM) ANALYSIS

A. Boundary fixing:

The boundary conditions are specified before any analysis is performed. All four of the sensor's sides and the bottom face are fixed. This study carries out investigations on frequency, static, and electrical phenomena. Figure 3 shows the boundary conditions are fixed in the capacitive sensor.

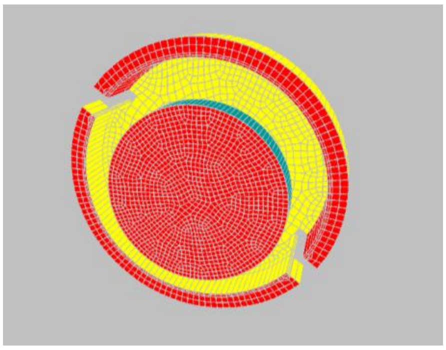
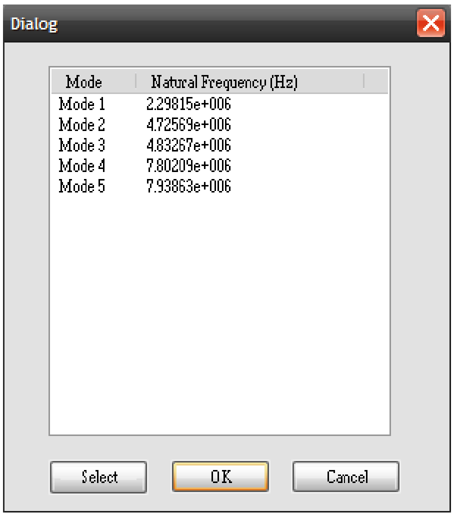


Figure 3. Boundary conditions are fixed in the capacitive sensor

B. Natural Frequency:

This part uses the device's five modes to evaluate the capacitive pressure sensor's inherent frequency. The frequency analysis is started using the simulation frequency setting. Next, the number of modes is decided. It is possible, depending on the circumstances. Here, after choosing five modes, the natural frequency is discovered. The system oscillates at its inherent frequency in the absence of any external forces. If the system is used outside of its native frequency, it could suffer long-term damage. The design of the capacitive sensor involves testing five different frequency modes. Figure 4 shows the natural frequency value and Figure 5 shows the first mode of animation of the capacitive pressure sensor.



Mode	Natural Frequency (Hz)
Mode 1	2.29815e+006
Mode 2	4.72569e+006
Mode 3	4.83267e+006
Mode 4	7.80209e+006
Mode 5	7.93863e+006

Figure 4. Natural Frequency

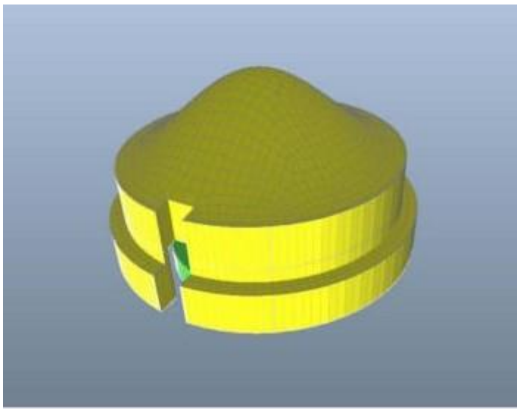


Figure 5. The first mode of animation

C. Static behaviour:

The idea behind how a capacitive pressure sensor works is that when a force is applied, the capacitance between two conductive plates changes. The capacitance between the two plates changes when pressure is applied to the sensor, which in turn affects the distance between the two plates. It is possible to detect and connect this capacitance change with the applied pressure. A capacitive pressure sensor's static behaviour is how it reacts to a steady pressure that doesn't change over time. The capacitance between the two plates will stabilise at a specific value, which corresponds to the applied pressure when constant pressure is applied to the sensor. As long as the pressure stays steady, the capacitance value will be stable. A calibration curve, which is established during the sensor's manufacturing process, typically describes the relationship between the capacitance of the sensor and the applied pressure. The sensor's output can be transformed into a pressure reading using the calibration curve.

It's important to keep in mind that variables like temperature, humidity, and the sensor's age might have an impact on the static behaviour of a capacitive pressure sensor. These elements may modify the capacitance of the sensor and the capacitance-to-pressure relationship. As a result, it's crucial to consider these aspects when creating and utilising a capacitive pressure sensor. A capacitive pressure sensor's response to a constant or gradually varying pressure input is referred to as its static behaviour. A capacitive pressure sensor's capacitance is typically proportional to the distance between its two electrodes, which is proportional to the diaphragm's deflection in reaction to pressure. The distance between the electrodes contracts as the pressure on the diaphragm rises, increasing capacitance. The sensitivity, linearity, and hysteresis of a capacitive pressure sensor can all be used to describe its static response. Figure 6 shows the static behaviour of the capacitive pressure sensor.

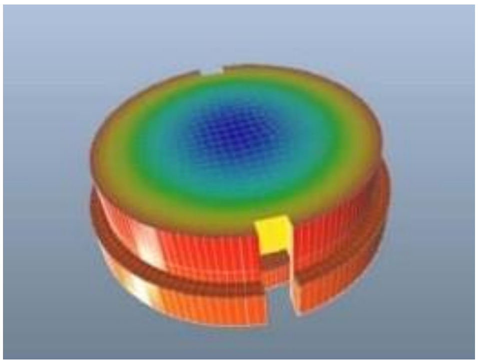


Figure 6. Static behaviour

VII. STATIC RESPONSE

The following steps are included in the static response:

1. Sensitivity: The degree to which a change in pressure causes a sensor's capacitance to alter is known as sensitivity. In applications where the pressure range of interest is narrow, more sensitivity means that the sensor is more responsive to changes in pressure.

2. Linearity: The degree to which the capacitance of the sensor changes linearly with pressure is known as linearity. A sensor should, in theory, respond linearly across the entire range of its functioning. Errors in the measurement of pressure can be caused by nonlinearities in the sensor response.

3. Hysteresis: The variation in sensor response to inputs of increasing and decreasing pressure is referred to as hysteresis. If not adequately taken into account, hysteresis, which can be brought on by mechanical and electrical causes, can result in pressure measurement mistakes.

4. Temperature sensitivity: A capacitive pressure sensor's capacitance may be sensitive to temperature variations, which could result in inaccurate pressure readings. These impacts can be reduced by employing temperature compensation techniques, such as adjusting the sensor output using a temperature sensor.

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5. Parasitic capacitance: Parasitic capacitance is a capacitance that isn't meant to be a component of the sensor construction but is there because it's close to other conductive materials or structures. Particularly at high frequencies, parasitic capacitance can have a considerable effect on sensor performance.

6. Packaging and handling: If a capacitive pressure sensor is sensitive to mechanical stress or electromagnetic interference, packaging and handling could have an impact on the sensor's static behaviour. The sensor can work as intended if shipping and handling are done carefully.

VIII. RESULT

Under increased external pressure, the diaphragm moves closer to the substrate, increasing the capacitance of the device. Since the distance between the two plates is smaller than the thickness of the diaphragm, the stretching of the plate has been disregarded. Since the substrate and diaphragm are made of the same material, residual stress in the plate has been disregarded. In the range of 0.1 MPa to 1 MPa, the pressure sensor offers a linear change in capacitance versus pressure. Figure 7 shows the input/output graph for pressure Vs capacitance.

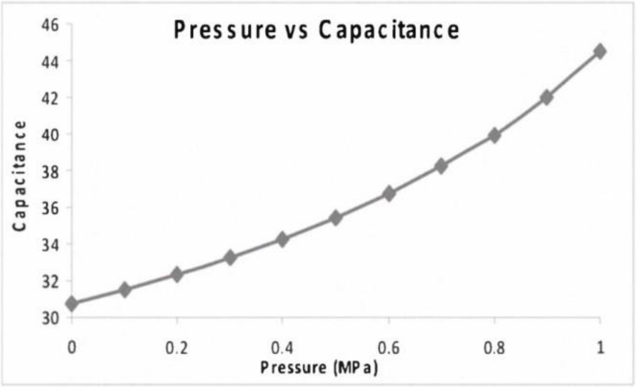

Figure 7. Pressure Vs Capacitance

IX. CONCLUSION

The modelling, creation, and testing of the sensor led to the following conclusions. The sensor model was initially created with the Intellisuite software. Both the static and thermal electromechanical analyses were carried out. Results from modelling and simulating data were produced. According to the link between the plate spacing and the capacitive response of the sensor, things went as planned. Future studies will require extracting the system model from the sensor in order to build analytical models for each of the system's energy domains and identify all forces as energy gradients.

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