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Cardiovascular pressure monitor using capacitive sensor in medical stent

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ABSTRACT

Capacitive pressure sensor have been fabricated over a titanium diaphragm of 2.5[mm] thickness for sensing pressure in order to prevent the heart failure. This capacitive pressure sensor is implantable in a heart in order to monitor the blood pressure with the help of medical stent

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Introduction

Heart failure is generally regarded as the inability of the heart to provide adequate blood flow to the body. Measurements of pulmonary arterial pressures are often used to diagnose and/or monitor heart failure. This pressure is measured with the help of capacitive pressure sensor. The main component of the sensor is diaphragm. This is placed in a medical stent which have a variety of application and are most widely used in treating the obstruction of blood flow in the cardiovascular system.

Device Design

The operating principle of a capacitive pressure sensor is to measure the change in capacitance between two electrodes when a change in pressure displaces one of the electrodes, located on a thin diaphragm. The diaphragm separates a reference compartment kept at vacuum pressure and a pressurized compartment. At the bottom of the pressurized compartment is a fixed base (with one electrode), while the diaphragm (with a counterelectrode) is located at its top. As the pressure changes,the diaphragm that separates the two compartments is displaced, and the change in separation between the two electrodes results in a corresponding change in the capacitance.

Although the deformation of the sensor is primarily caused by the applied pressure, any initial stress in the material also affect the deformation. Therefore, the manufacturing process and the selected materials directly influence sensor operation. The sensor in this measures static pressures of a magnitude from zero to atmospheric pressure. The model first computes the initial stresses from the manufacturing process; then it accounts for the structure's mechanical deformation resulting from an applied pressure. It finally calculates the sensor's capacitance for the deformed shape: the 2D model calculates the capacitance from a computed electric field,

Stress and Deformation

During manufacturing, the sensor is bonded together in a vacuum and at a high temperature before it is cooled down. Therefore, during this process no external forces act on the sensor's boundaries, but internal stresses appear because the two materials have different coefficients of thermal expansion. This process also produces a vacuum in the upper cavity that serves as the reference pressure. During regular operation, the sensor is fixed to a solid surface, and ambient pressure pushes on all outer boundaries. The temperature also changes, which produces extra stresses due to thermal expansion. For a linear elastic material, the stress-strain relationship—taking into account initial stress, σ_0, initial strain, ε_0, and thermal strain, ε_{th}—is

$$\sigma = D\varepsilon_{el} = D(\varepsilon - \varepsilon_{th} - \varepsilon_0) + \sigma_0$$

where D is the elasticity tensor, and the 6-dimensional vectors σ and ε give the normal and shear values of the stresses and strains.Initially only thermal expansion is active. It is given by

$$\varepsilon_{th} = \begin{bmatrix} \varepsilon_x \\ \varepsilon_y \\ \varepsilon_z \\ \gamma_{xy} \\ \gamma_{yz} \\ \gamma_{xz} \end{bmatrix} = \alpha_{vec}(T - T_{ref})$$

where α_{vec} are the coefficients of thermal expansion, T is the ambient temperature, and T_{ref} is the reference temperature. The manufacturing stage produces the initial stress for normal operation, where further thermal expansion takes place. This model assumes that the sensor is close to its initial geometry after manufacturing, so that the initial strain equals zero. Furthermore, you solve the first application mode using the small deformation assumption but allow large deformations for the second one.

Capacitance

To compute the sensor's capacitance, the 2D model solves for the electric field in the deformed geometry (or frame), which is defined by the Moving Mesh (ALE) application mode. Using a port boundary condition, the capacitance is obtained from the energy of the electric field from the equation

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$$C = \frac{2}{U^2}\int_{\Omega_d} W_e d\Omega_d$$

where U is the potential difference between the plates (U = 1 V for the port boundary condition) and We is the electric energy density. The area Ωd corresponds to the narrow air gap in the sensor.

Advantages of Titatium

Titanium is a safe, allergy free metal due to it's light, strong and rust-resistant characteristics. It also has the ability to regulate disrupted electric currents that run through the body because of its tendency to ionize. It used widely in the sports and medical fields Processed Metal. Titanium has exceptionally high corrosion resistance, inherent dampening qualities, and a high strength to weight ratio. Another benefit to titanium for use in medicine is its non-ferromagnetic property, which allows patients with titanium implants to be safely examined with MRIs and NMRIs. Another advantages are cost-efficient, non-toxic, Biocompatible (non-toxic and not rejected by the body),Long-lasting,Osseointegrated (the joining of bone with artificial implant)Long range availability Flexibility and elasticity rivals that of human bone.

Applications of Titanium

Titanium resists corrosion, is biocompatible and has an innate ability to join with human bone, it has become a staple of the medical field, as well. From surgical titanium instruments to titanium rods, pins and plates, medical and dental titanium has truly become the fundamental material used in medicine.

Simulation and Result

The capacitive pressure sensor was designed as glass Hoya with the thickness of 2.5[mm] and the middle layer we chosen as titanium also having the 2.5[mm].The capacitive pressure sensor designed with the help of comsol software.

We designed the capacitive pressure sensor to detect the blood pressure variation in the heart to detect the heart failure which can be find with the variation of capacitance.

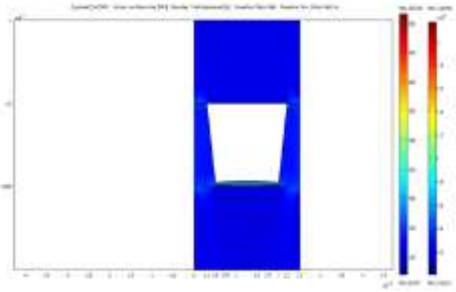

Fig 1: Variation of electric fields

The above figure shows the variation of the electric field in order to calculate the capacitance with respect to pressure

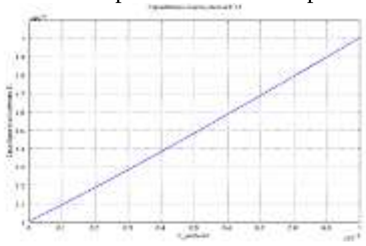

Fig 2: Variation of capacitance

The above figure shows the variation of capacitance with respect to pressure.

Conclusion

The design of MEMS based capacitve pressure sensor was carried out using comsol. The capacitive pressure sensor was designed after number of simulations in order to get the required output by changing the material.

References

Alfred.E.,"Design challenges of implantable pressure monitoring system'' doi: 10.3389/neuro.20.002.2010

Chiang,C.C., CLin, C. K., and Ju, M.S. (2007). ''An implantable capacitive pressure sensor for biomedical applications''. *Sens. Actuator A. Phys* 134,382–388.

Choi MG, Koh HS, Kluess D, O'Connor D, Mathur A, Truskey GA,RubinJ,ZhouDXSunKL.

''Effects of titanium particle size on osteoblast functions in vitro and in vivo''. Proc Natl Acad Sci U S A. 2005 Mar 22;102(12):4578-83. Epub 2005 Mar 8.

Puers, R. (1993),''Capacitive sensors: when and how to use them''. *Sens. Actuators A. Phys.* 37/38, 93–105.

Table 1: Comparision of various materials

Parameters	Titanium	Silicon	Poly-Si
Young's modulus	40e9[Pa]	131e9[Pa]	160e9[P]
Poisson's ratio	0.36	0.27	0.22
Density	21.9 [w/(m*k)]	163 [w/(m*k)]	34 [w/(m*k)]
Thermal expansion	8.60e-6[1/k]	4.15e-6 [1/k]	2.6e-6 [1/k]

Table 2: Materials and its dimensions

Property	Top and bottom layers	Middle layer
Shape	Rectangular	Rectangle with engraved cavities
Width/Length	2.5 mm	2.5 mm diaphr.: 1.5 mm
Height	0.5 mm	0.5 mm diaphr.: 20 µm
Material	Glass HOYA, SD-2	Titanium