A Micro Strain Gauge Sensor on Polydimethylsiloxane (PDMS) Substrate for Artificial Lateral Line

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***Abstract*— This work demonstrates flexible strain gauge pressure sensor for artificial lateral line; an alternative navigation mechanism for small autonomous system using pressure sensor array. We are developing MEMS pressure sensor on polydimethylsiloxane (PDMS) substrate. Arrays of this sensor system will enable an Underwater Autonomous Vehicle (UAV) to form a three dimensional pressure map of its surrounding environment like biological lateral line do for fish. Each sensors of the array is designed for low pressure detection and can easily be mounted on any conformal surface. A zigzag structure of Gold film of thickness 200nm is used as a strain sensor on 150µm thick elastomeric PDMS substrate.**

I. Introduction

Small autonomous vehicle demands fast, low powered navigation mechanism for increased situational awareness. Current UAV's utilize optical and sonar based navigation system but they faced severe problem in muddy, unsteady and cluttered environment. Fish can solve such types of complex environment by utilizing their pressure sensitive neuromas found on their body known as lateral line [1]. This line helps them to make a three dimensional pressure profile from which they can detect and identify nearby object [2]. Some species of cave fish solely depends on lateral line for swimming in complex environment. In this work we are demonstrating MEMS based pressure sensor for artificial lateral line. Each sensor of the array is developed on polydimethylsiloxane (PDMS) substrate as PDMS is chemically inert, flexible, and low young's modulus (850kPa-2.4MPa) MEMS material.

II. Sensor design for the Array

To enable lateral line applications of these sensors, their effective membrane size is kept 1.5mm in diameter and thickness of 150µm. The cavity enclosed by PDMS substrate and thin PDMS membrane has height of 300µm. A small tunnel is kept for pressure compensation. A gold thin film strain gauge of zigzag structure is designed on the PDMS membrane. This structure has long radial element and short tangential element and placed over maximum stress region. Young's moduli of gold and PDMS are E_{Au} = 79GPa, and E_{PDMS} = 2.4MPa, respectively. So, the thickness of the PDMS is kept quiet thick (i.e. 150µm) to avoid damage on the Au strain gauge.

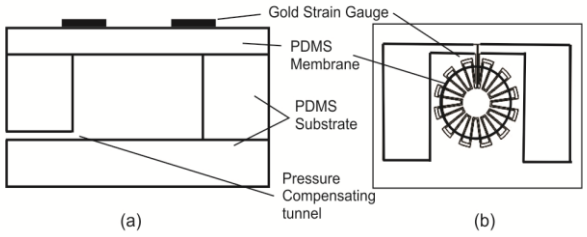

Figure 1. (a) Cross sectional view of the sensor, (b) Top view of the sensor

COMSOL based finite element analysis is done for maximum strain on the gold strip. PDMS is hyperplastic material so Moony–Rivlin stress–strain relationship is used for membrane deformation. Maximum stress is found not only at the edge of the diaphragm but also some distance beyond the circumference because of rubber like nature of PDMS. Low young's modulus PDMS gives larger deflection and hence provide larger strain on Au strain gauge. The pressure response is found linear up to 6KPa.

Conclusion

Lateral line application requires pressure range of operation to be 0-5KPa, so the designed sensor is suited for artificial lateral line. The sensitivity of this sensor is found high in pressure range upto 6KPa. Use of PDMS makes the sensing system flexible so that sensor system can be mounted in any streamline bodies. Array Fabrication and characterization for pressure mapping is currently under development.

References

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