Design of a Compact Pressure Sensor for Multi-Layer Insulation

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Project Scope

The goal of this project is to design and implement a compact pressure sensor that can fit between the layers of Multi-Layer Insulation (MLI) and measure minute changes in pressure.

Background

- Multi-Layer Insulation is a thermal insulation system used to protect cryogenic fluids and spacecraft
- The unwanted interstitial pressure within the MLI allows for additional energy transfer between layers via conduction and convection
- Working Conditions
  - Cold Welding
  - Out gassing

Objectives

- Design a pressure sensor with minimal moving parts
- Minimize wiring and power consumption of the pressure sensor
- Minimize heat produced by the sensor

Constraints

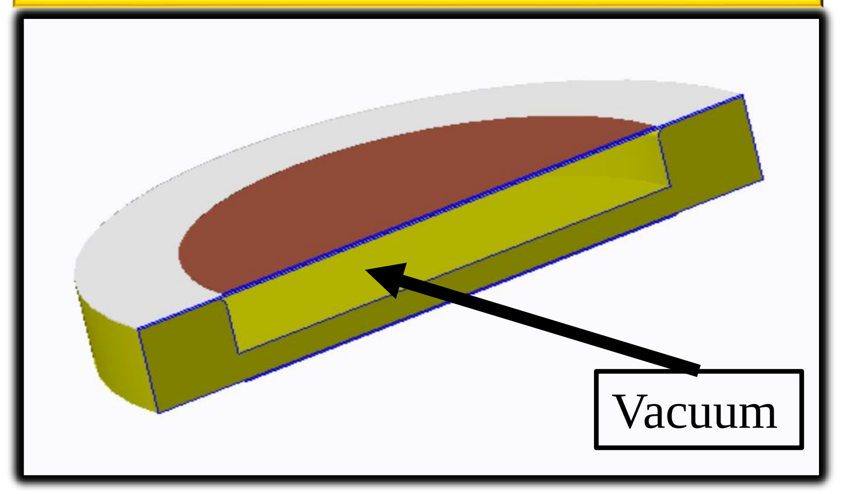
- Must read a minimum of 10^{-2} Pa
- Must read one sample per second
- Minimally invasive to the MLI

Challenges

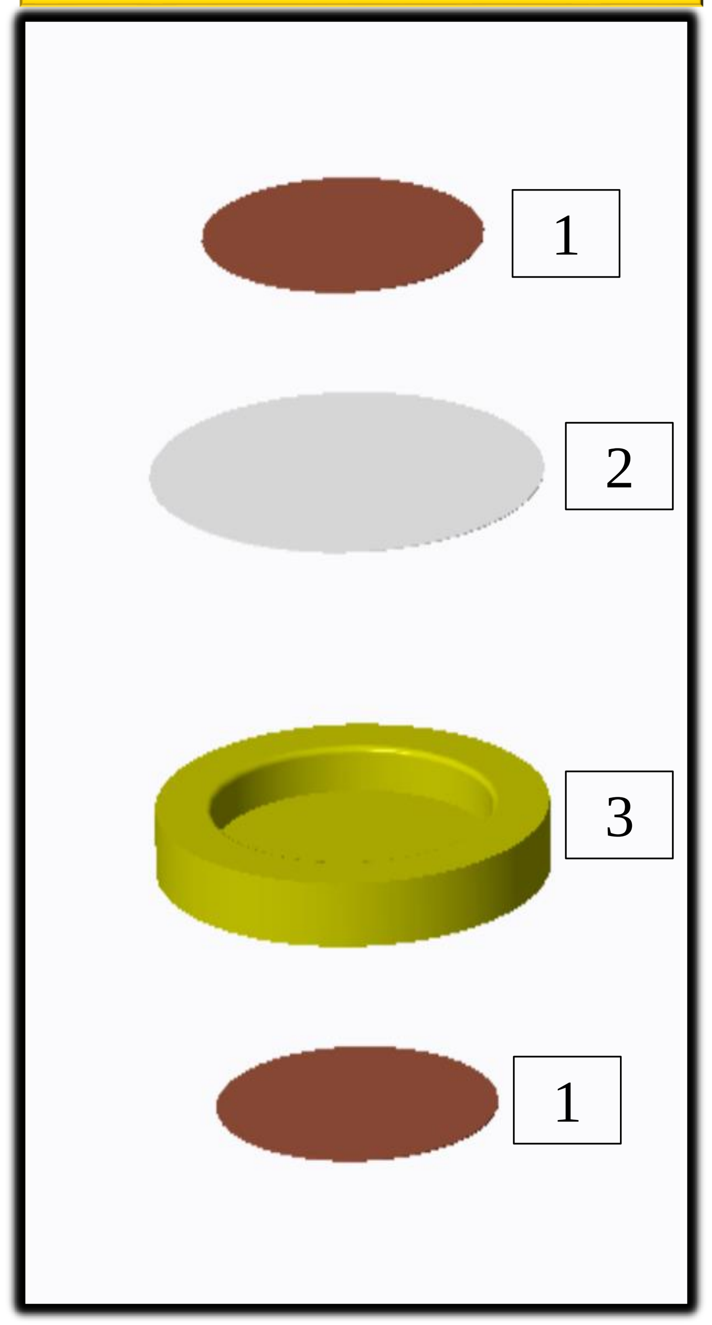
- Achieving a viable price point for a UV silicone adhesive
- Determining a suitable diaphragm substitute
- Manufacturing sensor in vacuum chamber

Sample of MLI

Capacitor Design

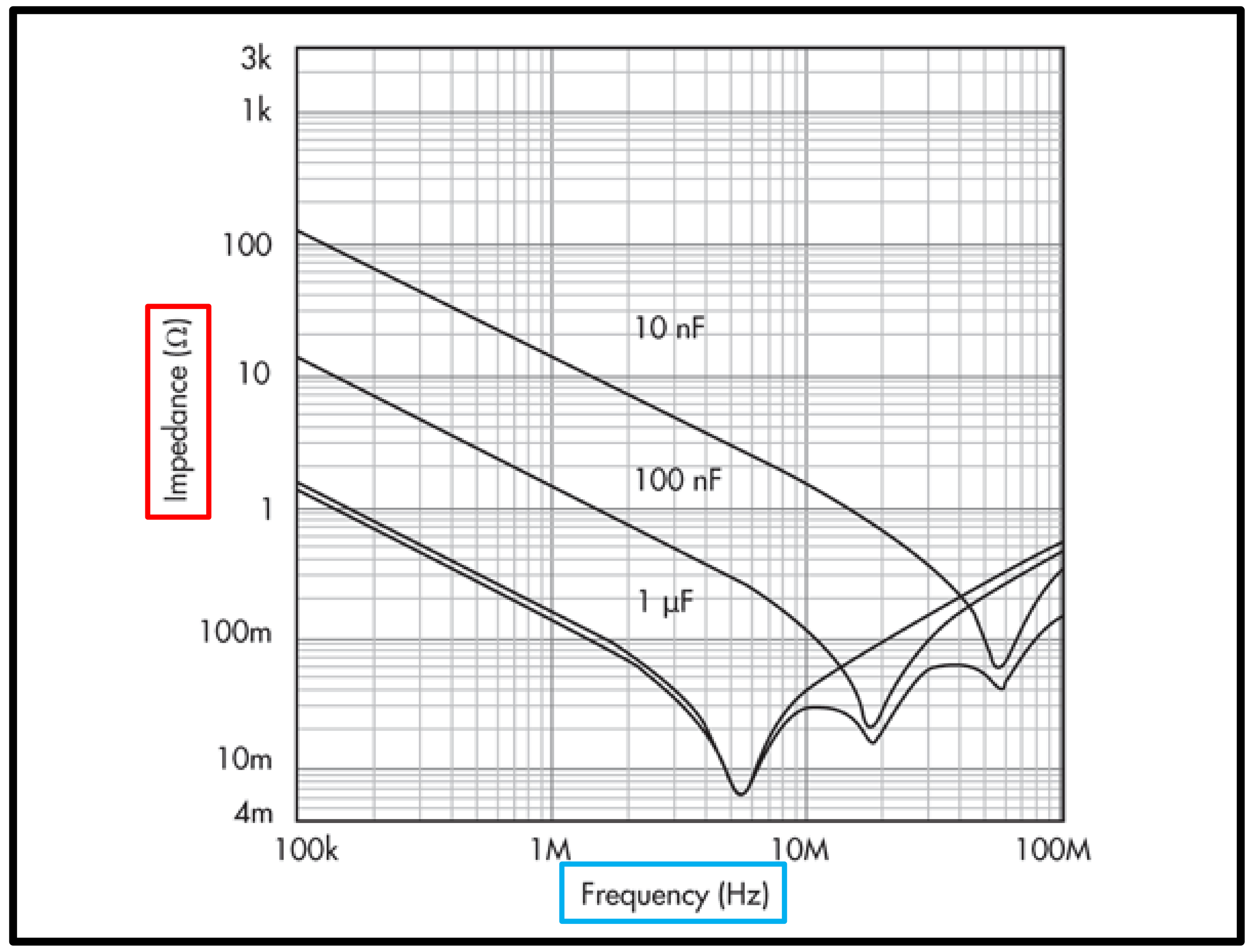


Capacitor Design Exploded View



This plot demonstrates how the natural frequency relates to the impedance of the capacitor

$$V = I * R$$
$$Voltage = f(frequency)$$
$$Frequency_R = f(deflection)$$
$$Pressure = f(deflection)$$
$$Pressure = f(frequency_R)$$



Capacitor Design

1. Palladium-Gold sputtered capacitance tract
2. Silicone diaphragm
3. Silica capacitor base

Future Work

- Purchase Masterbond UV10 epoxy
- Finish sensor assembly
- Test and calibrate sensor

$$h = \sqrt{\frac{3\pi r^2 * P}{4\pi\sigma_y}}$$

$$w_{max} = -\frac{3\pi r^2 P\left(\left(\frac{1}{\mu}\right)^2 - 1\right) r^2}{16\pi E h\left(\frac{1}{\mu}\right)^2}$$

$$p = \frac{0.855}{(1-\mu^2)^{\frac{3}{4}}} * \frac{E\sqrt{\gamma}}{\left(\frac{r}{t}\right)^{\frac{5}{2}} * \frac{l}{r}}$$

$$\gamma = 1 - 0.901(1 - e^{-\phi})$$

$$\phi = \frac{1}{16}\sqrt{\frac{r}{t}}$$

μ = Poisson's Ratio
E = Young's Modulus
r = diaphragm radius
l = sensor length
t = shell thickness

Diaphragm Thickness (ID)	Critical Diaphragm Thickness	Critical Diaphragm Pressure	Maximum Pressure Exerted (Takeoff)	Maximum Deflection @ 150 kPa	Shell Thickness	Critical Body Pressure
125μm	0.50μm	600 kPa	150 kPa	28μm	20μm	400 MPa

Acknowledgements

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Reference

- Ashrafi, Ashkan. *Research Gate*. Research Gate, Aug. 1999. Web.
- "Multi layer insulation, multilayer films for MLI insulation - Dunmore corporation