Design of a Compact Pressure Sensor for Multi-Layer Insulation in a Vacuum

Team 15

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Presentation Overview

- Project Scope
- Project Objectives
- Project Constraints
- House of Quality
- Iteration of Designs
    1. Capacitor
    2. Multi-Stage Capacitor
    3. Fiber Optics Sensor
- Gantt Chart
- Future Work

Project Scope

- The aim of this project is to design and implement a compact pressure sensor that can fit between the layers of Multi-Layer Insulation (MLI).
  - Fast Response Time
  - Ability to measure small pressure changes
  - Noninvasive to the MLI
- This interstitial pressure is measured to quantify the heat transfer through the system.

Project Objectives

- Develop a pressure sensing concept with minimal parts
- Minimize the wiring and power consumption of the device
- Minimize heat produced by the sensor

Project Constraints

- Pressure Sensor
  - Be able to measure a pressure as low as 10^{-2} Pa
  - Have a minimum response rate of 1 sample per second

- Multi-Layer Insulation
  - Sensor dimensions shouldn't exceed interlayer spacing
  - 12 layers is roughly 5 mm

- Working environment
  - Temperature conditions range from 293 K to 77 K
  - Out gassing
  - Vacuum

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House of Quality

Table 1 - House of Quality for Pressure Sensor Design

Customer Requirements \ Engineering Characteristics	Customer Importance	Materials	Power Consumption	Geometry	Cost
Minimal Invasiveness	5	3	6	9	
Accuracy	5		6		6
Minimal Heat Produced	4	3	6		
Reading Range	4				6
Reading Speed	3		6		6
Total Weight		27	102	45	72

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Capacitor Design

1. Capacitor top diaphragm:
   - High sensitivity – reads low pressures
   - 125 µm OD, 85 µm ID diaphragm
   - Nano-metallic coating to create capacitor plate

2. Silica Base plate

3. Capacitor bottom plate:
   - Rigid metallic plate

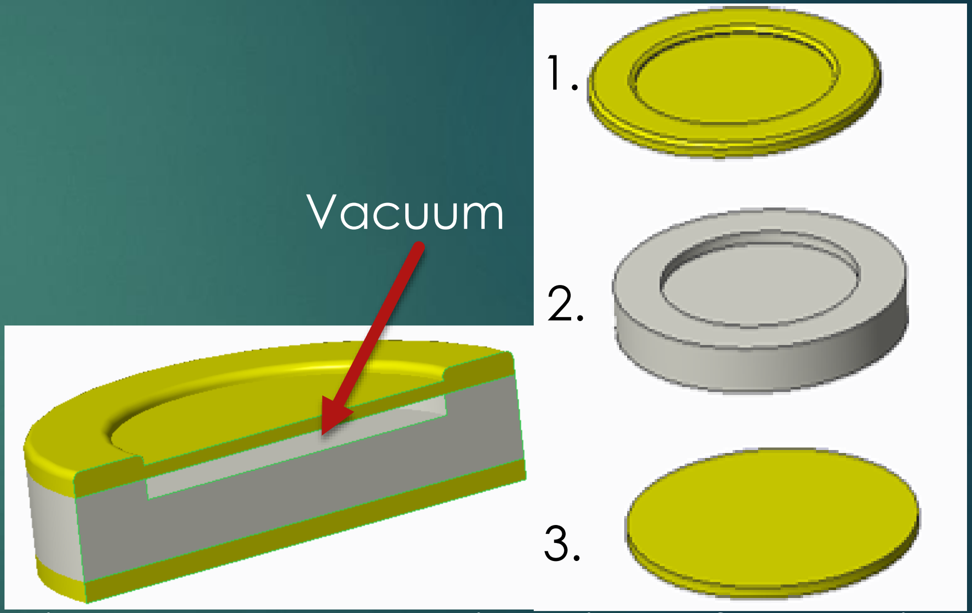

Figure 1A cross section view of capacitor (left), and exploded view (right)

Multi-Stage Capacitor Design

1. Capacitor top diaphragm:
   - High sensitivity – reads low pressures
   - 125 µm OD, 85 µm ID diaphragm
   - Nano-metallic coating to create capacitor plate
2. Silica spacer
3. Intermediate diaphragm:
   - Medium to low sensitivity – reads medium to high pressure ranges.
4. Silica Base plate
5. Capacitor bottom plate:
   - Rigid metallic plate

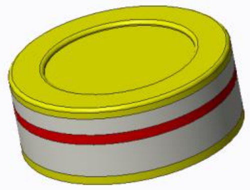

Figure 1 Multi stage capacitor assembled

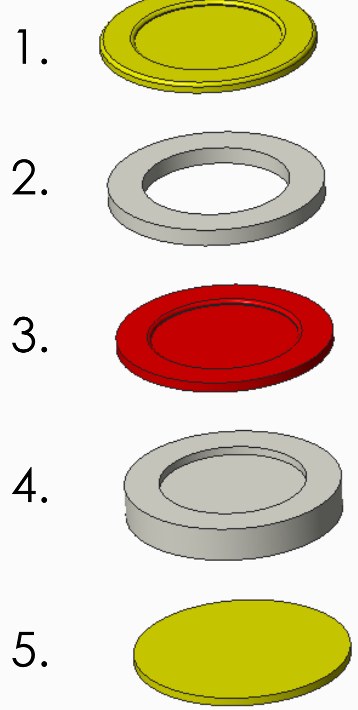

Figure 2 Displays the exploded view of the multi stage capacitor

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Multi-Stage Capacitor Design

- Cavities formed in the silica base by germanium doped etching
- Capacitor assembled in a vacuum
- Parts either fused together, or set with a UV-reactive polymer

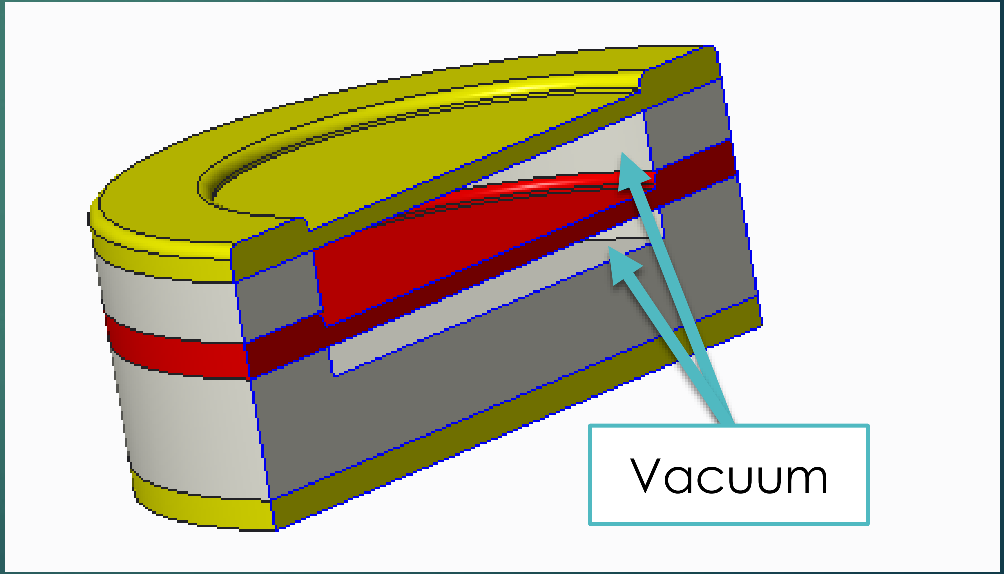

Figure 3 Multi stage capacitor cross sectional view

Fiber Optics

- Observes change in phase, polarization, transmit time, or wavelength to measure pressure
- Pros
  - Good in high vibrational, wet, noisy, corrosive, and extreme heat environments
  - Immune to electromagnetic interference
  - Ability to measure a large range of pressures
  - High Sensitivity and Bandwidth
  - Size (125 micrometers)
- Cons
  - Relatively difficult design
  - Cost
  - Assembly requires special equipment

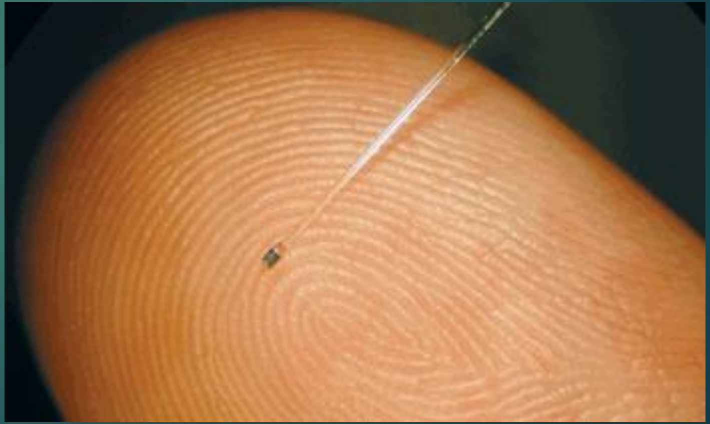

Figure 4 Displays the size of a fiber optics pressure sensor

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Fiber Optic Design

- 1: Silica diaphragm
  - 125 µm OD
  - 85 µm ID diaphragm
- 2: Silica core
- 3: Lead-in optical fiber
  - Multimodal or single modal

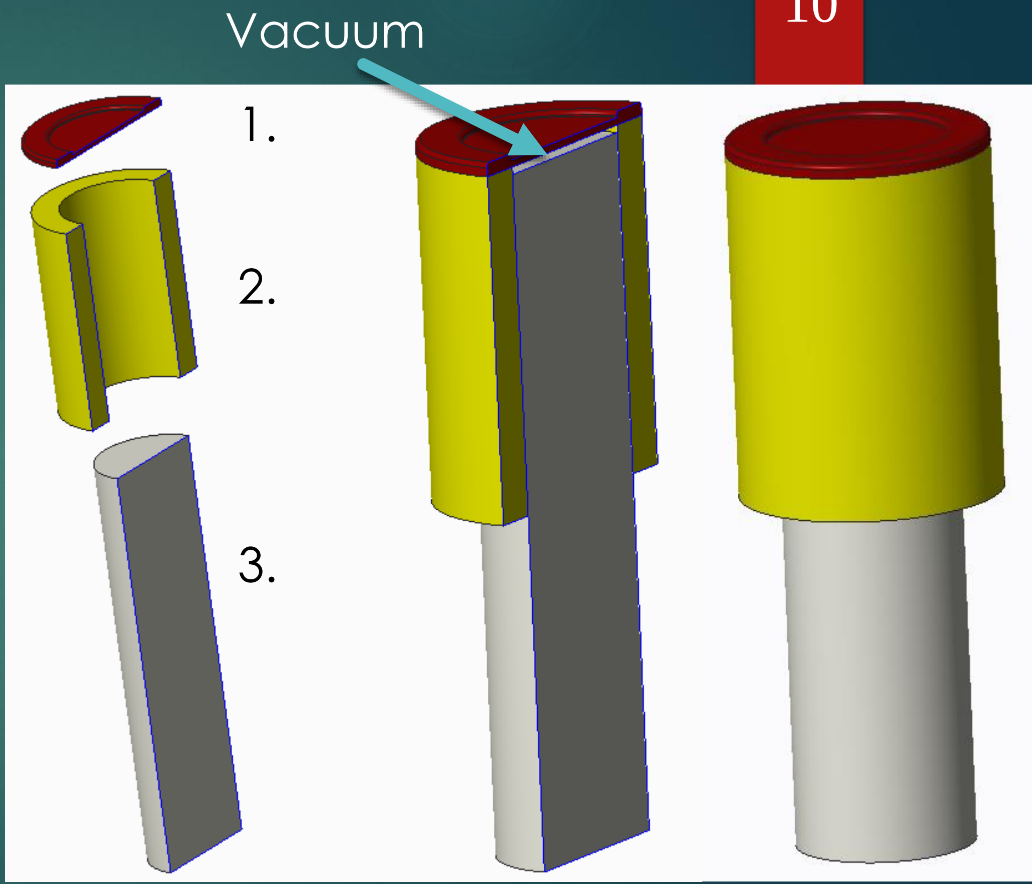

Figure 5 Cross section view and fully assembled view of Fiber optics sensor

Decision Matrix

Table 2 - Pugh Decision Matrix for pressure sensor concepts

	Capacitor	Fiber Optics	Multi-Stage Capacitor
Accuracy	0	1	0
Minimal Invasiveness	0	0	0
Heat Production	0	-1	0
Reading Range	0	2	1
Reading Speed	0	0	0
Total	0	2	1

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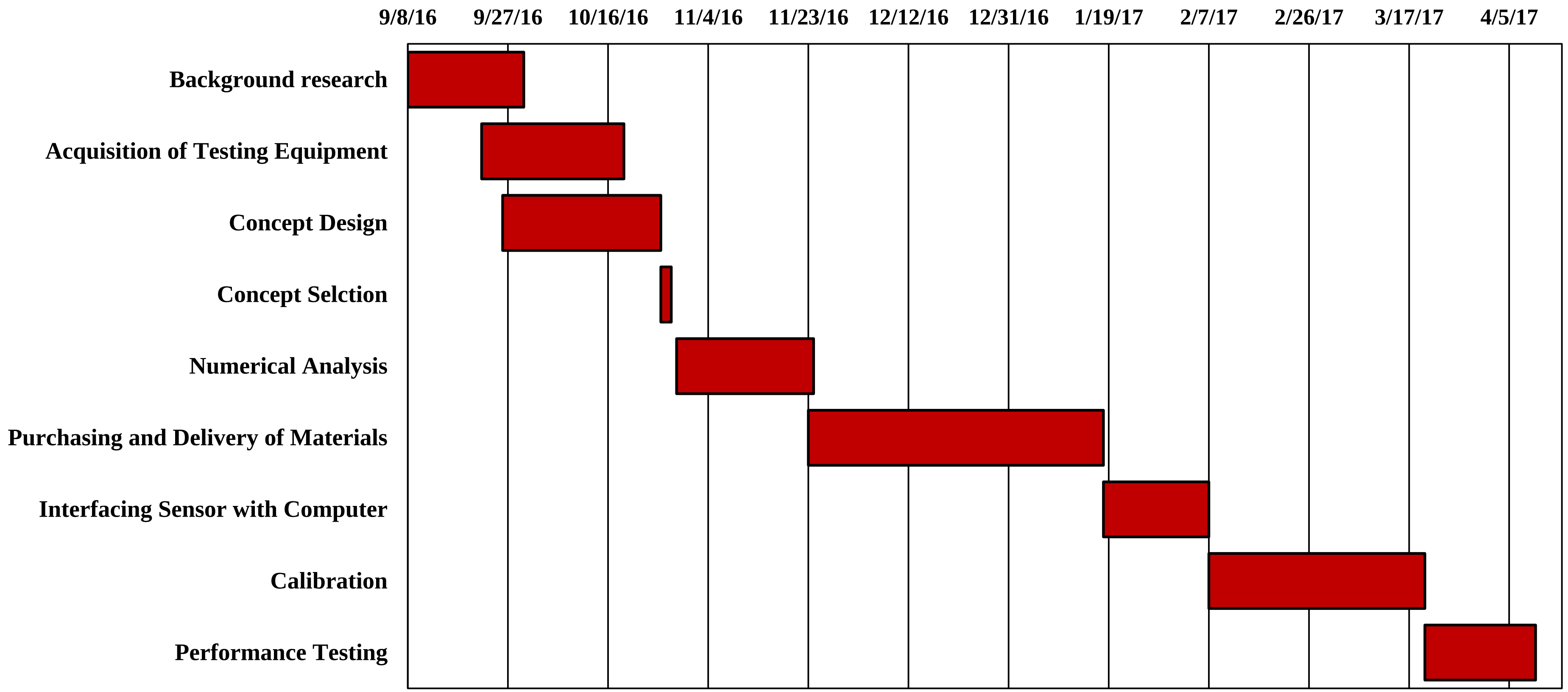
Gantt Chart


9/8/16
9/27/16
10/16/16
11/4/16
11/23/16
12/12/16
12/31/16
1/19/17
2/7/17
2/26/17
3/17/17
4/5/17
Background research
Acquisition of Testing Equipment
Concept Design
Concept Selction
Numerical Analysis
Purchasing and Delivery of Materials
Interfacing Sensor with Computer
Calibration
Performance Testing

Future Steps

- Purchasing of material
- Interfacing sensors with system and computer
- Calibration
- Performance testing
- Comparison of both designs for final selection

Conclusion

- Revisited the conceptual design phase
  - Capacitor pressure sensor
  - Multi-stage capacitor pressure sensor
- Two designs selected for experimentation
  - Fiber Optics
  - Multi-stage capacitor
- The next step is to contact multiple suppliers in the fields of:
  - Fiber optics
  - Nano-manufacturers

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Questions?