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

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Presentation Overview

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- Project Constraints
- Designs
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- Prototype Scaling / Fresh Directive
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Presenter: Jason Carvalho

Project Scope

- The goal of this project is to design and implement a compact pressure sensor that is easily embedded between layers of Multi-Layer Insulation (MLI).
  - Rapid Response Time
  - The ability to measure a large pressure range
  - Noninvasive to the MLI

- This interstitial pressure is measured to quantify the heat transfer through the system

- Heat transfer is critical to cryogenic storage and applications in space

Project Objectives

- Develop a pressure sensor with minimal parts
- Minimize the wiring and power consumption of the device
- Minimize the 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

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

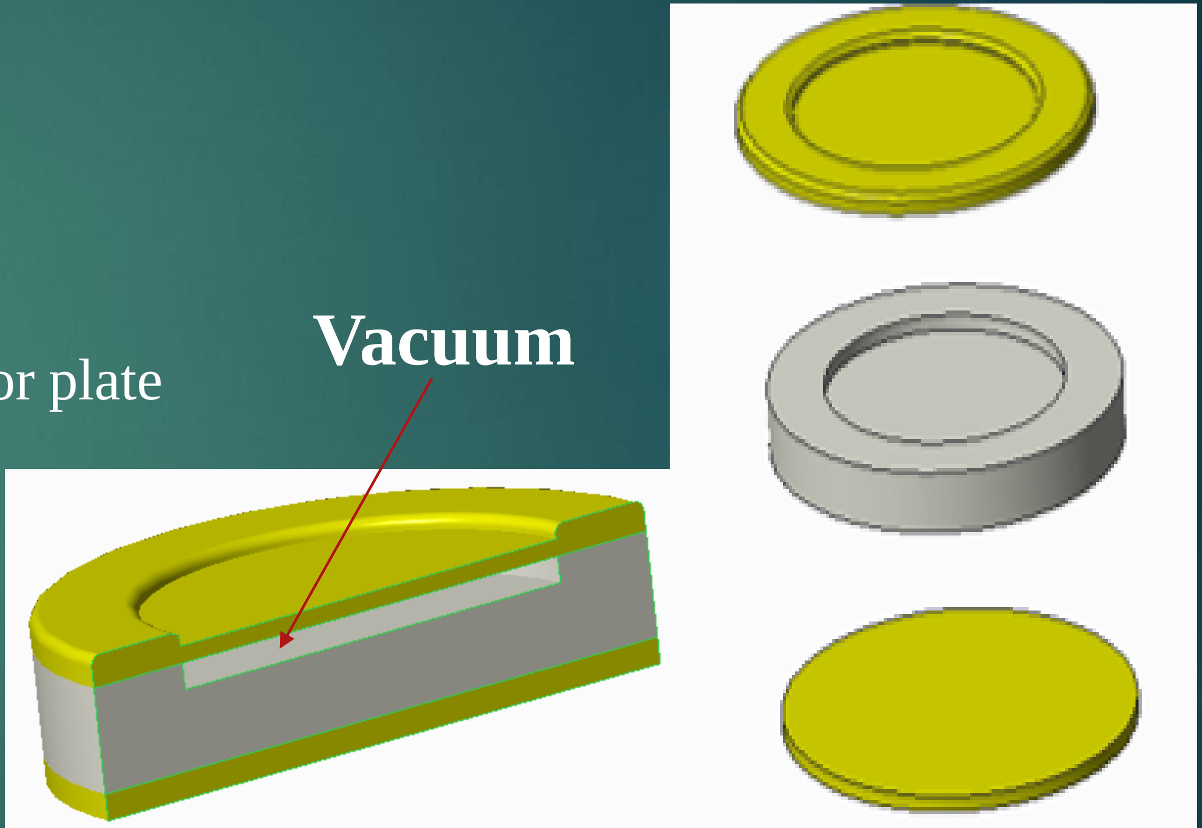

Figure 1: Cross section view of capacitor (left), and exploded view (right)

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

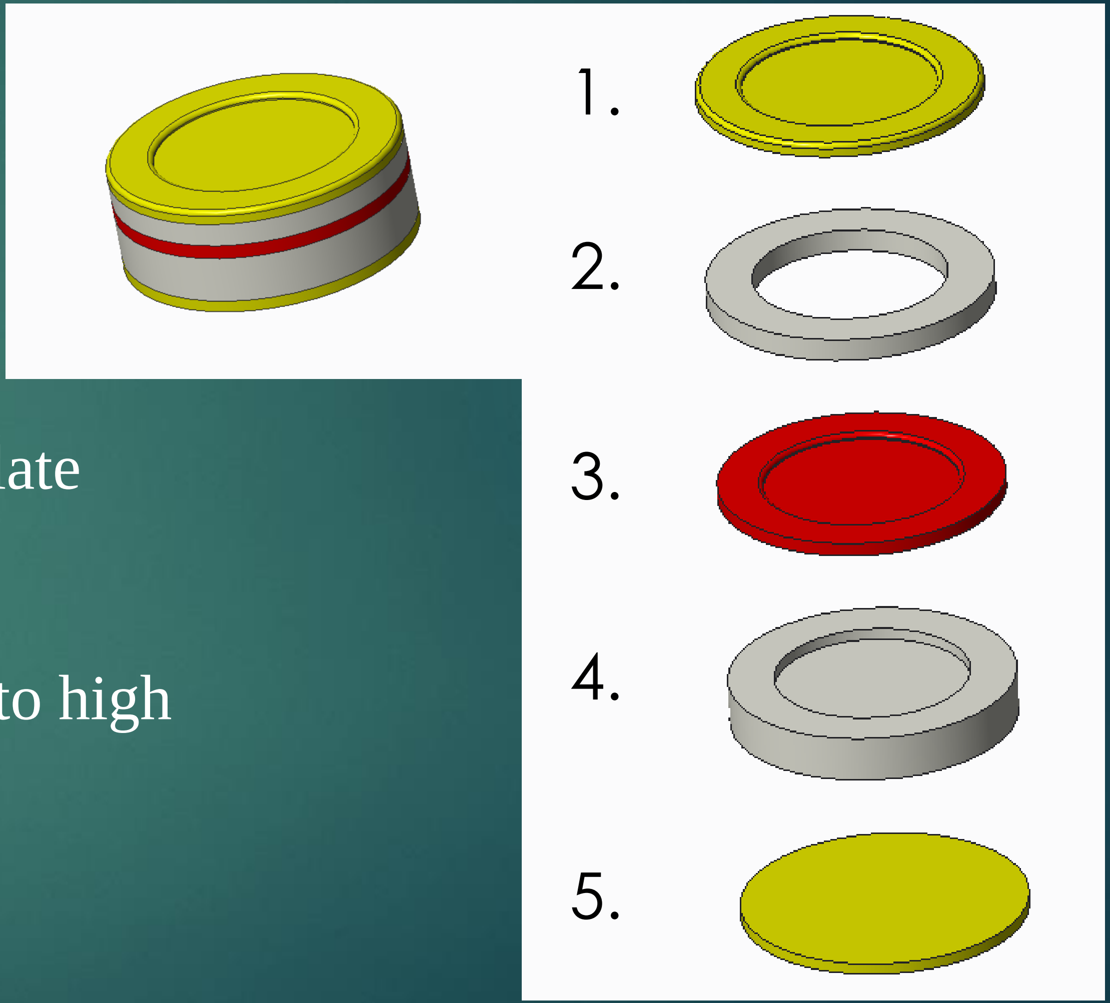

Figure 2: Displays the exploded view of the multi stage capacitor

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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

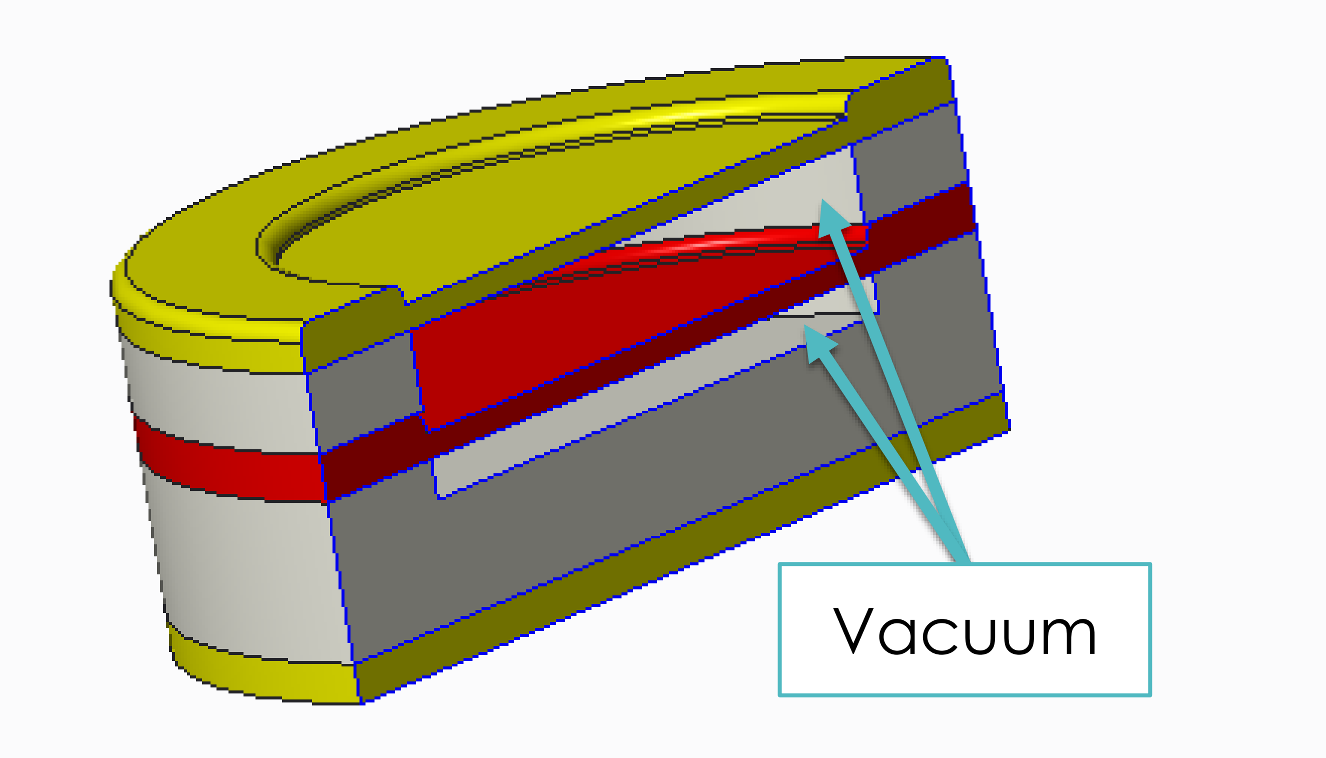

Figure 3: Multi stage capacitor cross sectional view

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
  - Assembly requires special equipment
    - Increased cost

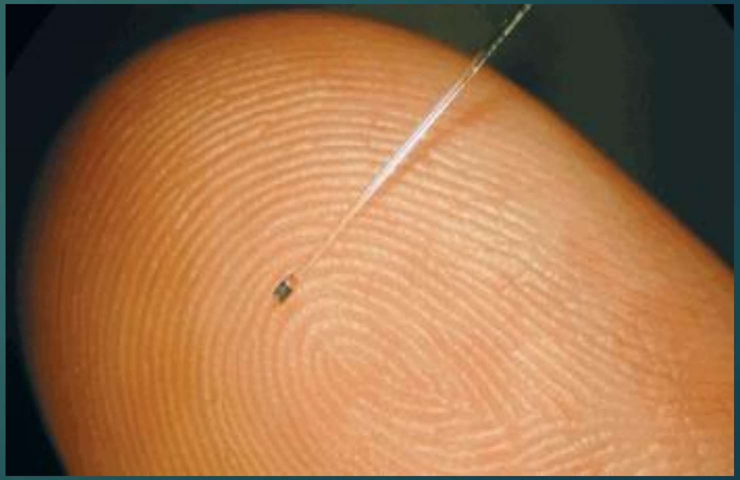

Figure 4: Displays the size of a fiber optics pressure sensor

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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

*note: this sensor is commercially available

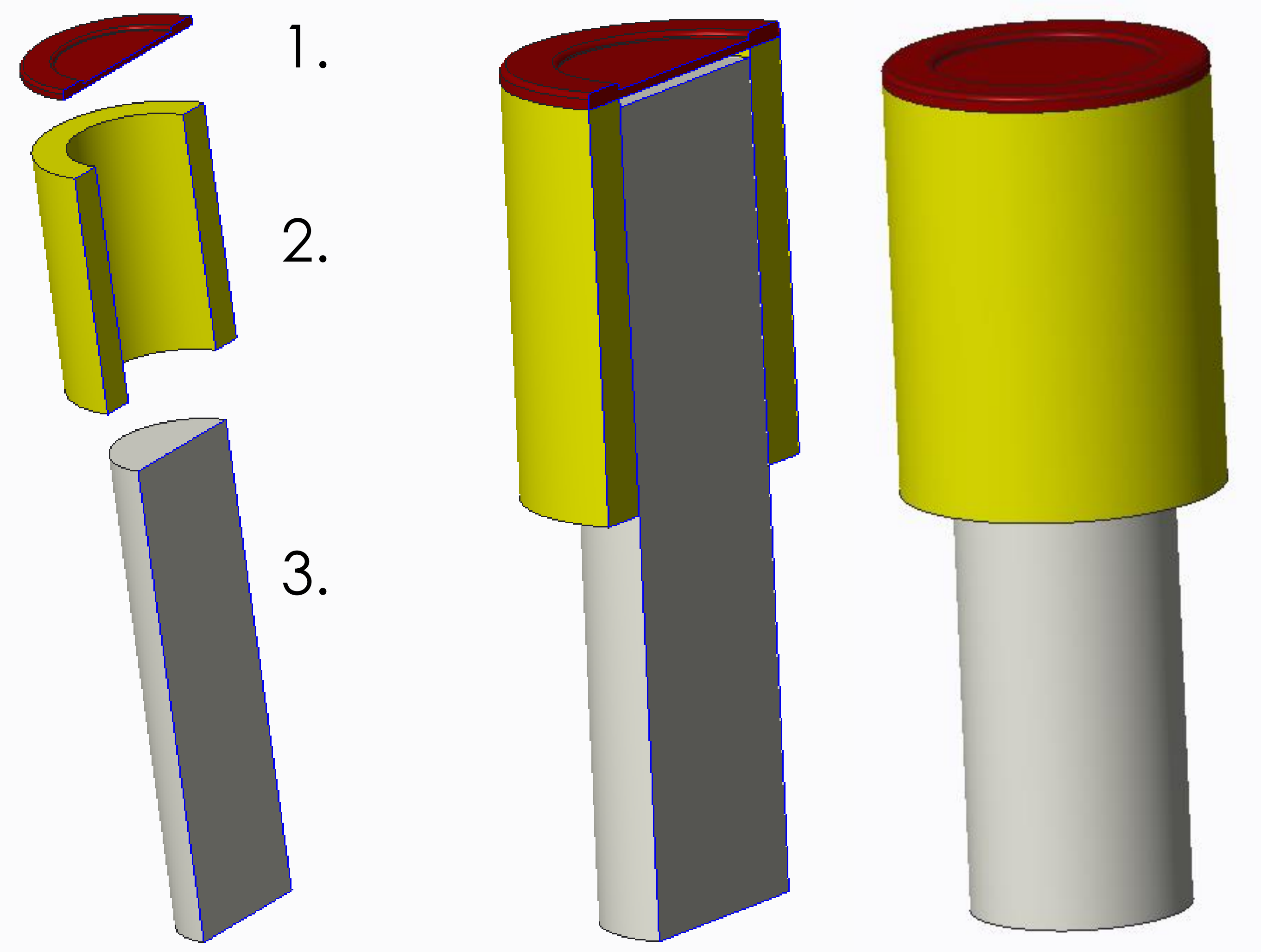

Figure 5: Cross section view and fully assembled view of Fiber optics sensor

Research on Efficient Production

- UV polymer cavitation creation technique used to increase sensor batch success rates
  - Technique could be implemented in nano-capacitor design to decrease cost

- “The sensor fabrication follows simple, repeatable processes and safe procedures, and uses less expensive materials and equipment. ”

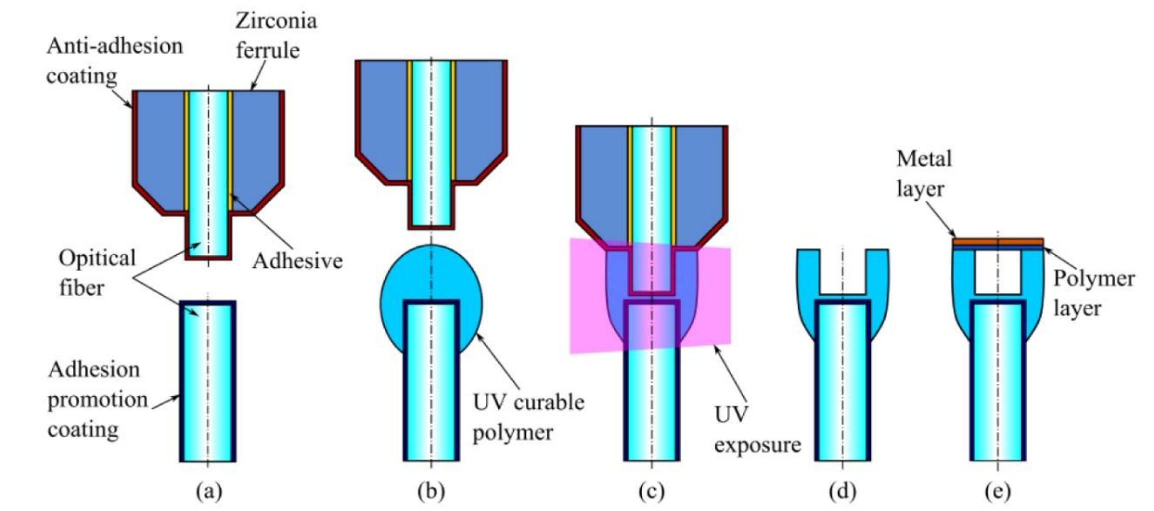

Figure 6: Shows UV polymer adhesion of a miniature Fabry-Perot fiber optic pressure sensor

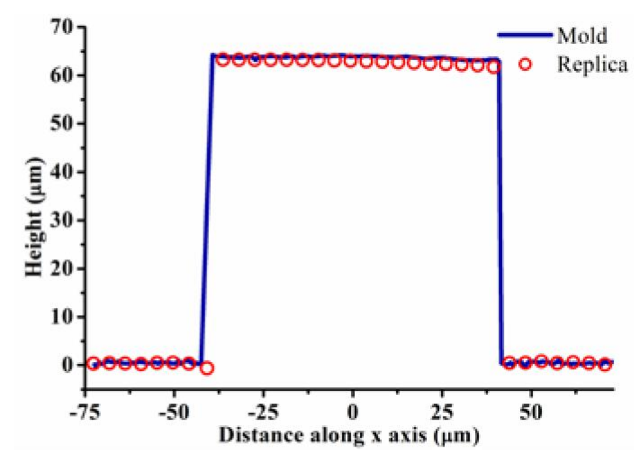

Figure 7: Shows cavity creation accuracy (RED) against the starting mold shape (BLUE).

H. Bae and M. Yu, "Miniature Fabry-Perot pressure sensor created by using UV-molding process with an optical fiber based mold," Opt. Express 20, 14573-14583 (2012)

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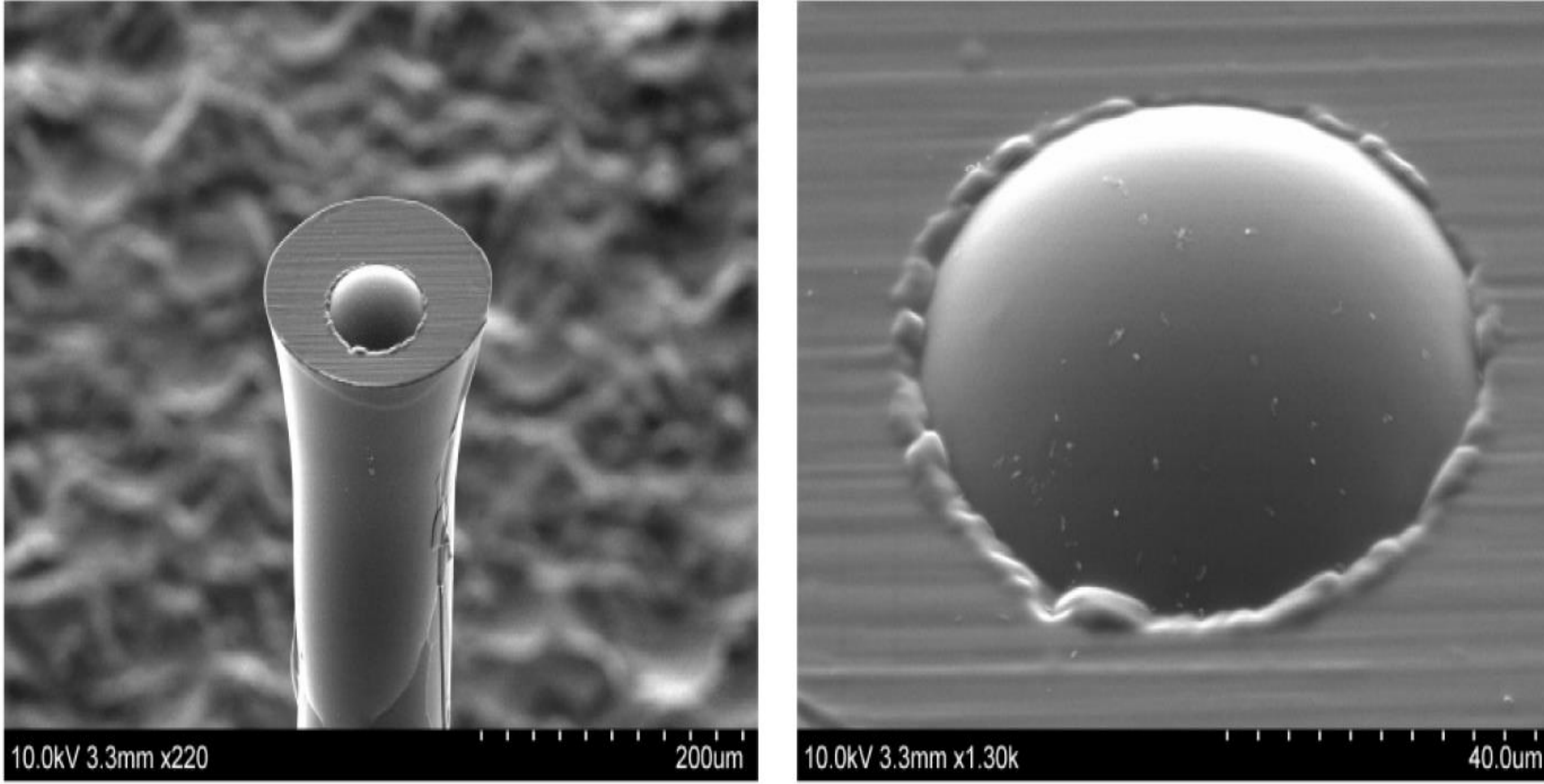

Figure 8: (left) Sensor base manufactured, (right) sensor diaphragm manufactured

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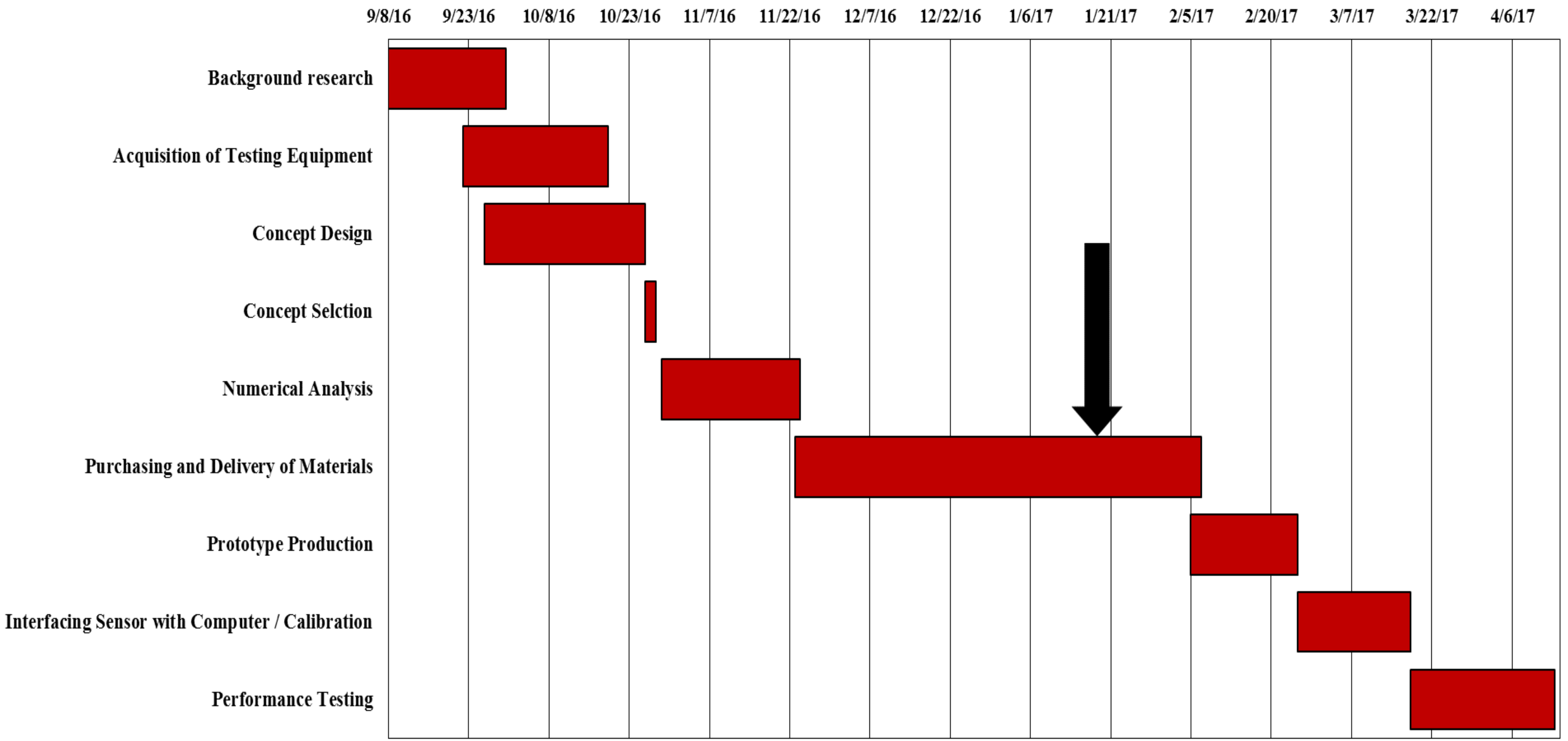
- Creating the nano capacitance prototype falls outside of the time restraint and budget
- To progress with a prototype and testing, scaling must occur
- Wish to scale from 125 μm OD to a more pragmatic 12.5 – 25 mm (100 – 200x)
  - Enables the experimentation of capacitance pressure sensors in the previously shown design
  - Easier implementation with ongoing sensor research directed at temperature detection

Fresh Directive

- Breaking free of the size constraint allows for new insight into cost effective materials for the prototype
- Realistic prototype design will be consulted with faculty who have means to help production
  - Hope to mimic aspects of known research into prototype
    - UV polymer cavity mold
    - Polymer adhesion of diaphragms
- Hope to have prototype finished by the end of February

Modified Gantt Chart



Future Steps

- Finalized prototype design with consultation from professors
- Purchasing of material
- Prototype production
- Interfacing sensors with system and computer
- Calibration
- Performance testing

Presenter: Jason Carvalho

References

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