BIOMED ARMOUR

Breath Analyzer for Detection of Biomarkers from Breath

Hyunji Ahn, Soosung Byun, Surush Ghulom Hazrat, Ethan Noh, Mohammed Al Rawahi, Hongjae Yoon
Schulich School of Engineering, University of Calgary

Introduction / Problem

About 50% of lung cancer patients are diagnosed at stage IV. Biomed Armour has developed a technology that analyzes frequency changes to detect specific biomarkers from the breath with biomarker specific sensing materials coated on a QCM. Our team translated this technology into a physical device. This breath analyzer has a wide range of potential usage such as for lung cancer or cannabis detection.

Technical Requirements

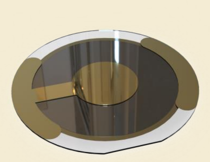
- 100 ccm of breath flow rate
- Minimum 200 ml breath volume
- Laminar boundary layer surrounding QCM
- Vertical constant flow to the QCM
- Compact design

Method

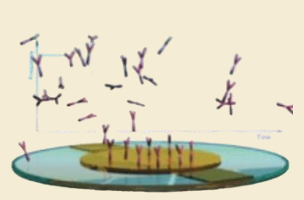
What is QCM?

QCM stands for quartz crystal microbalance. It is highly sensitive sensor that measures changes in mass on the surface of a quartz crystal using piezoelectric effect.

What is Working Principle?



An electric signal is applied to the quartz crystal.
↓
The crystal vibrates at a specific resonant frequency due to piezoelectric effect.
↓
Biomarkers are captured by its specific sensing material coated on the crystal surface.

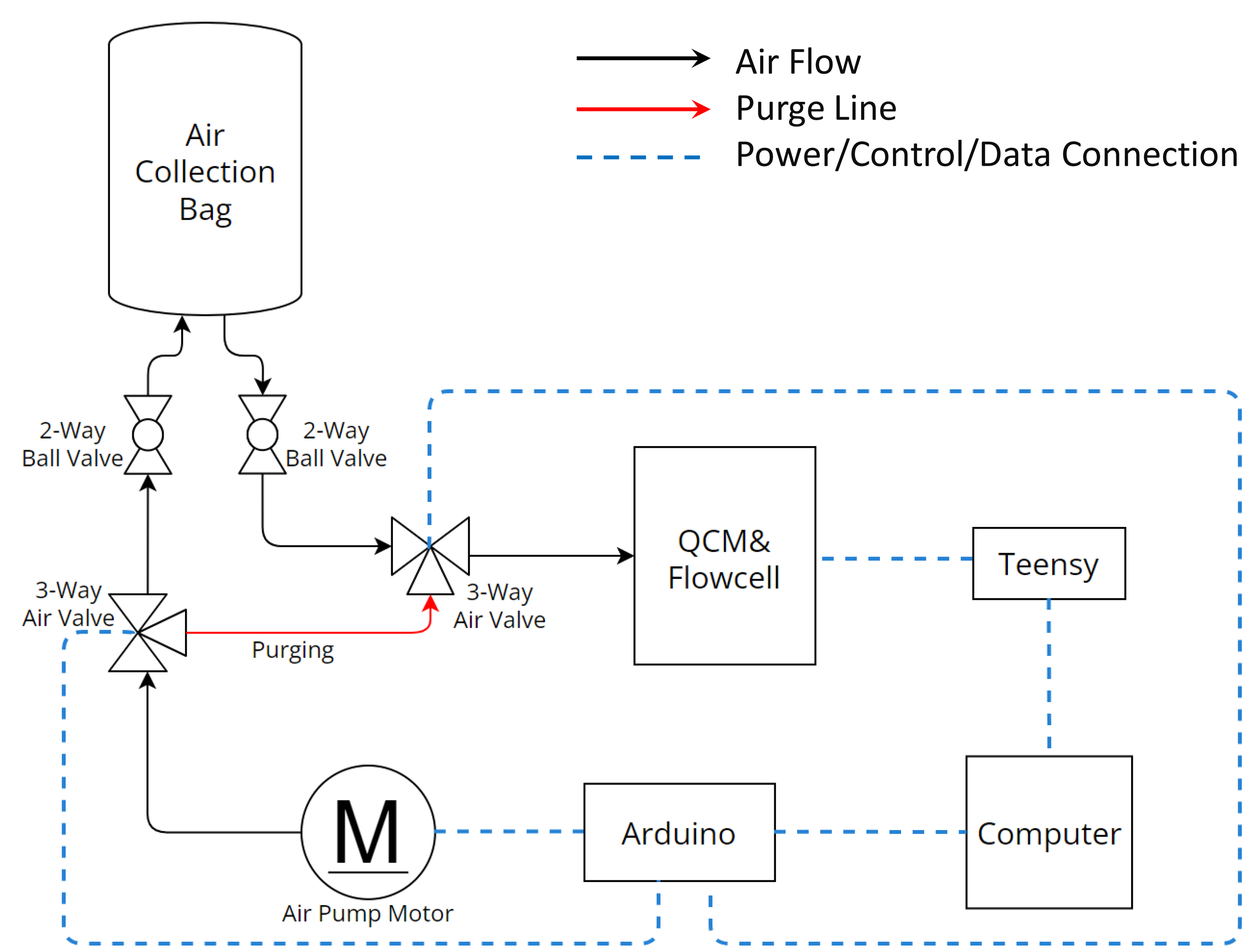


↓
The biomarkers adds mass to the crystal, and the change in mass results in frequency change.
↓
The frequency shift is analyzed to determine the concentration of the biomarkers to detect.

Impact

- Early detection of diseases for early treatment can significantly improve the chances of survival
- Cheap and accessible devices can provide immediate access to testing for individuals
- Wider range of testing capabilities compared to breathalyzers on the market

Flow Schematic Diagram



Laminarity of the Flow

$$\delta = \sqrt{\frac{2\nu}{\omega}}$$

$$\delta = \sqrt{\frac{2 \times 1.57 \times 10^{-5}}{2\pi \times 5 \times 10^{6}}} = 1\mu m$$

- ν is kinematic viscosity, $\nu = 1.57 \times 10^{-5}\, m^2/s \ at\ 25℃$
- ω is the angular frequency

Reynold Number Inside of the Flow Cell

$$Re = \frac{v\iota}{\nu}$$

$$Re = \frac{0.04 \times 1.5 \times 10^{-2}}{1.57 \times 10^{-5}} = 37.9299 < 2000$$

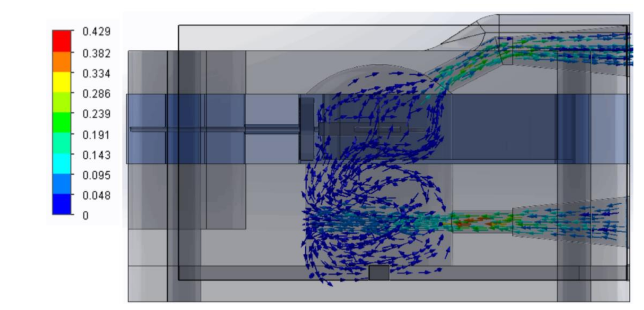
$$\therefore Laminar$$

- v is velocity of the flow
- ι is characteristic length, diameter of QCM (m)
- ν is kinematic viscosity, $\nu = 1.57 \times 10^{-5}\, m^2/s \ at\ 25℃$

Flow Cell Designs and Simulations

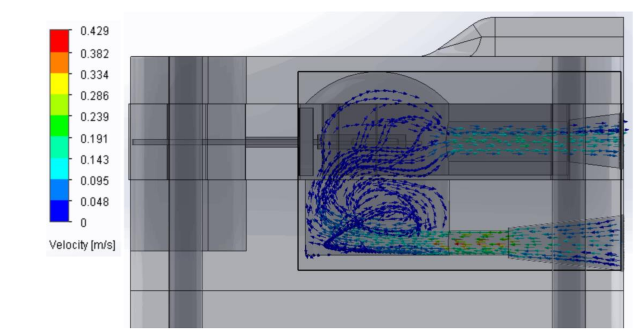
Prototype 1 - Original Flow Cell Design

- Unnecessary non-uniform flow trajectories



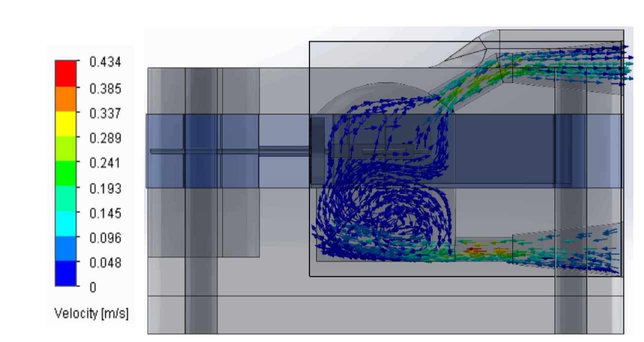
Prototype 2 - Flow Cell Without Bottom

- Turbulence near end of the QCM
- Inaccuracies in QCM measurements



Prototype 3 - Flow Cell with Lower Outlet

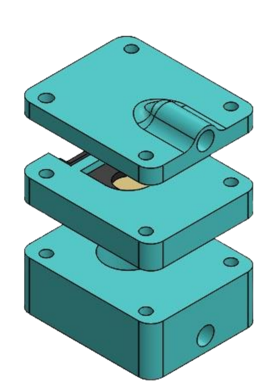
- Increased flow exposure to QCM
- Laminarity across the QCM
- Minimized stagnation points



Mechanical Design

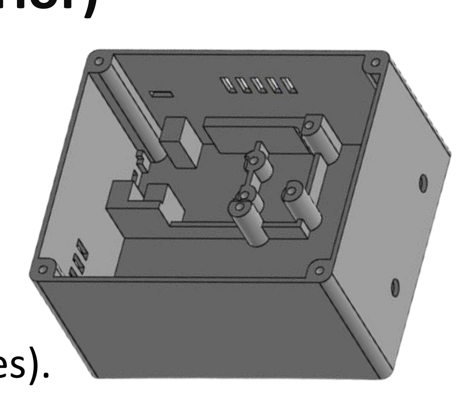
Flow Cell

The flow cell design allows laminar flow surrounding the QCM for biomarker capture.



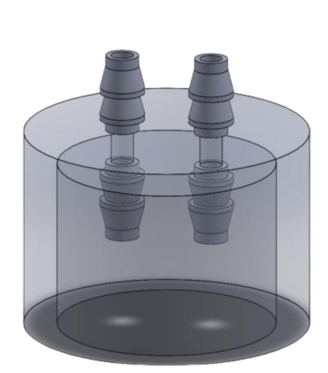
Housing (Interior)

Enclose every components that need to be inside (printed circuit boards, flow cell, motor, and air valves).



Air Bag Cap

The connector between air collection bag and tubes. One of tubes is coming from motor, another is toward to flow cell.



Electronic Design

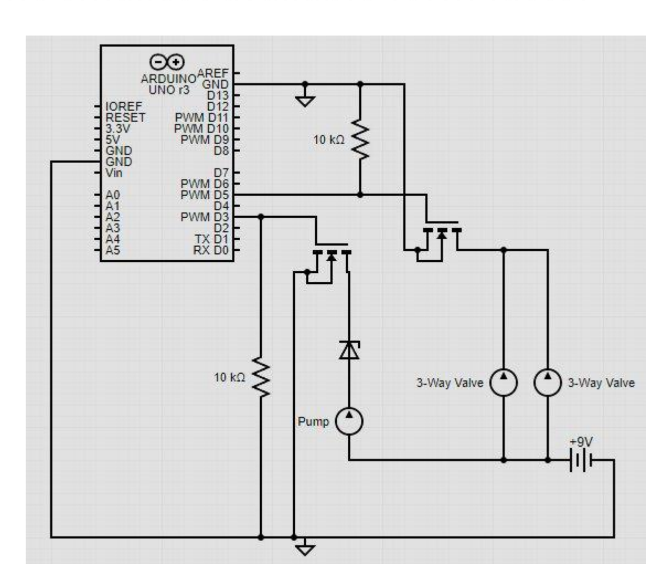
What hardware is used?

Teensy 4.0

- For frequency reading from QCM
- High processing speed for real-time monitoring and analysis

Arduino Nano Every

- For air pump and 3-way air valve control
- The smallest available form factor



- Mosfets used to control power to the motor and 3-way valves
- Diodes used to direct current in one direction

Analysis/Testing/Results 2