# Piezoelectric Paper: Characterization and Sensor Application

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# Outline

- Background – Piezoelectric materials
- Research on fiber content and fines effect on material properties
  - Introduction
  - Materials – Two type of piezoelectric papers
  - Method – Dynamic mechanical analysis (DMA)
  - Results – Fiber content effect on modulus
- Applications – Accelerometer
- Future Research Plan — Characterize electromechanical properties

# Background
# Piezoelectric Materials

# Piezoelectric Materials

## Piezoelectric Effect Principle

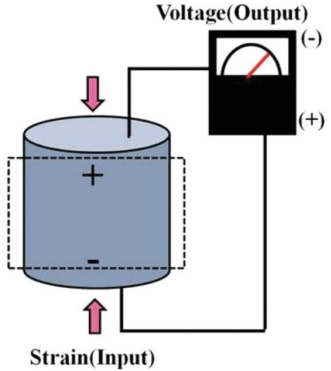
- Positive and negative charges at different centers
- Dipole moments under loading
- Electro-mechanical Coupling
- Reverse piezoelectric effect

## Piezoelectric Coefficient

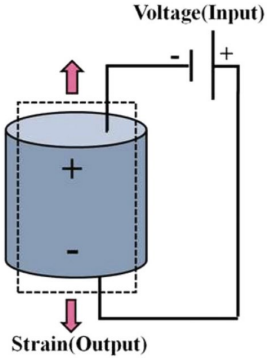
- Strength of piezoelectric response
- Induced charge / Applied force

## Applications

- Piezoelectric Effect – force and acceleration sensors
- Reverse piezoelectric effect – actuators and speakers




Piezoelectric effect




Reverse Piezoelectric effect

# Research on Fiber Content and Fines Effect

# Introduction

## Piezoelectric papers

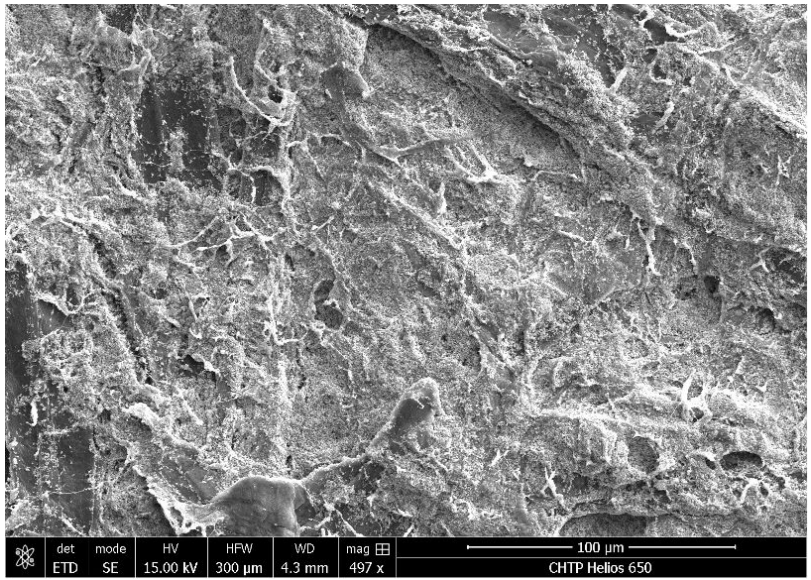
- Flexible and sustainable piezoelectric materials (Mahadeva et al., 2016)
- Research gaps on piezoelectric papers

## Our Research

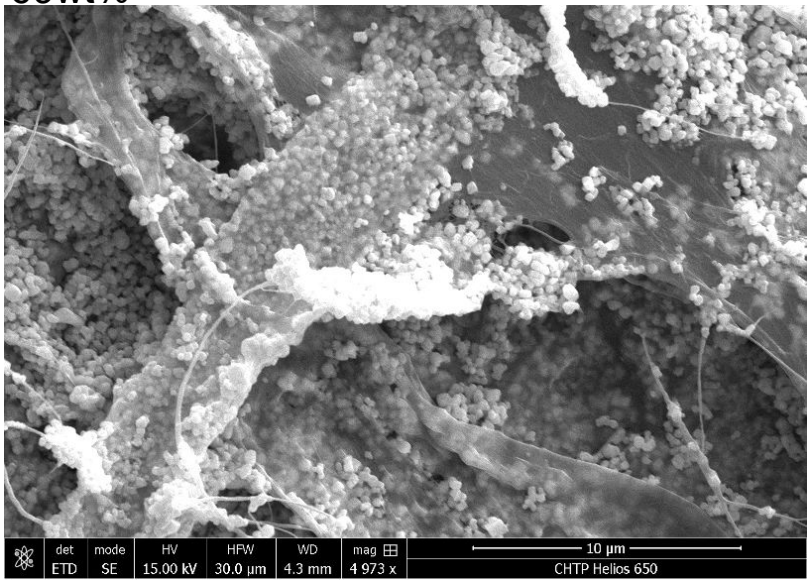
- Study fiber content and fines' effect on material properties

# Materials

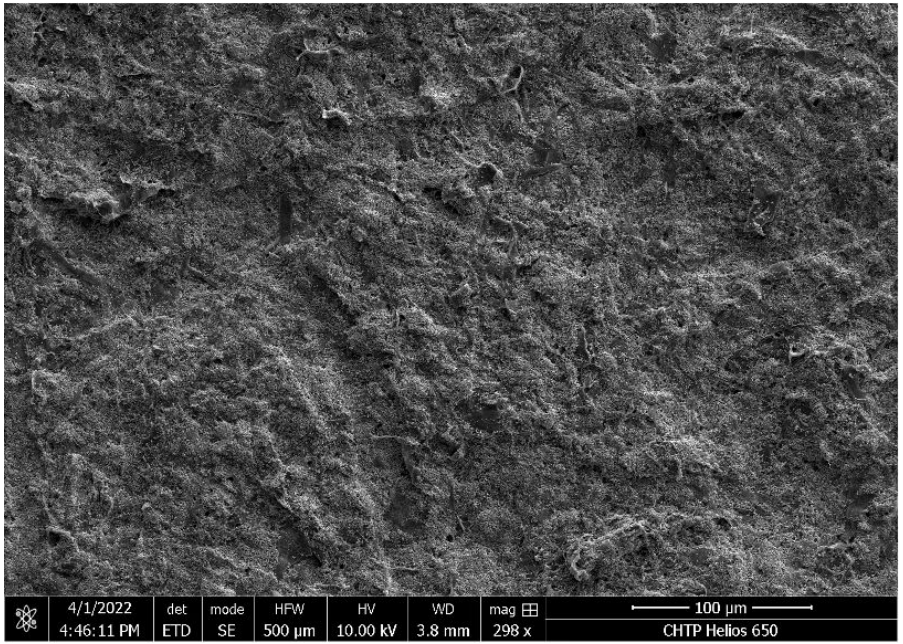
- Paper substrate with:
  A. Pulp
  B. Pulp and Fines, enhance strength
- 300nm $BaTiO_3$ particles loaded on the papers, 69wt%



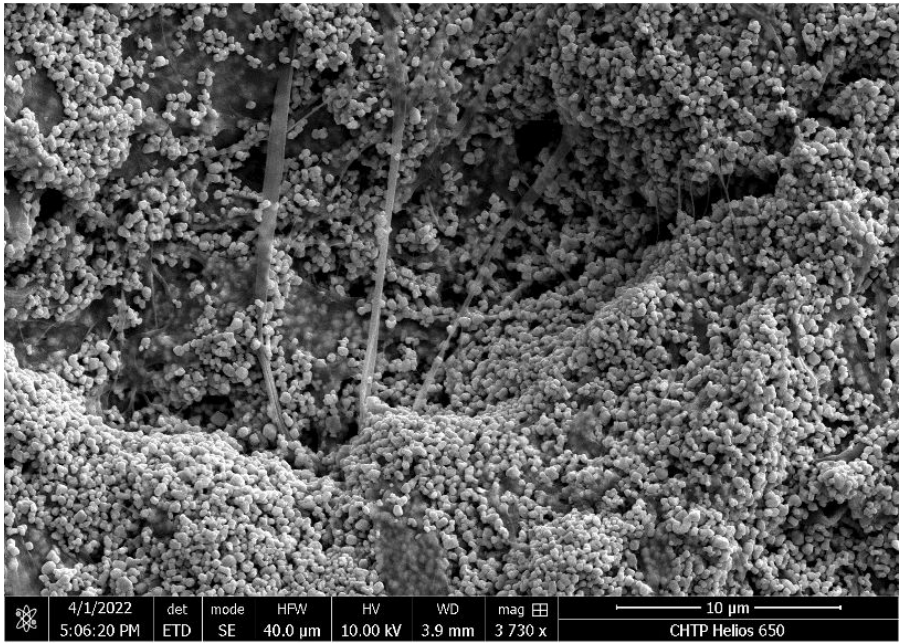

Paper with Pulp in 100 µm scale




Paper with Pulp in 10 µm scale



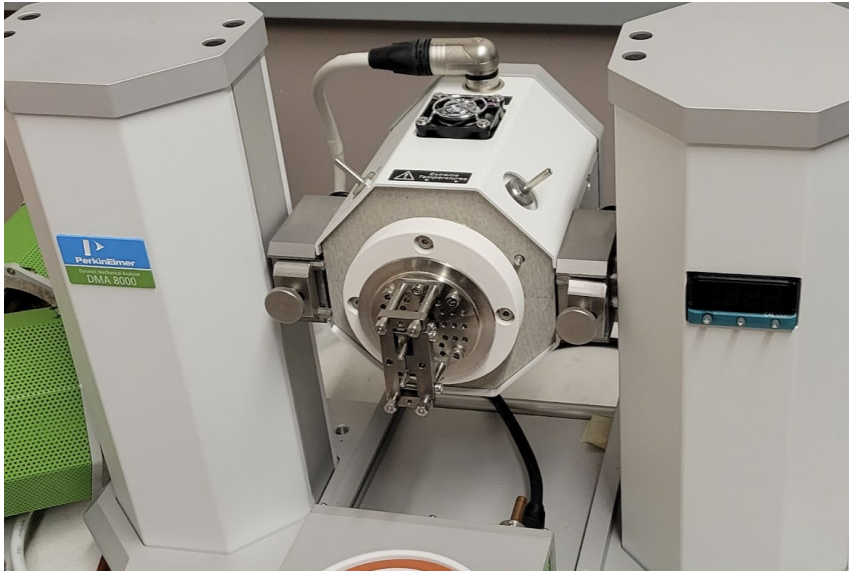

Paper with Pulp and Fines in 100 µm Scale




Paper with Pulp and Fines in 10 µm Scale

# Equipment and Method

- **Dynamic Mechanical Analysis**
  - What is that?
    - A technology to analyze materials' kinetic properties by applying stress or strain.
  - How it works in our experiment?
    - Applying sinusoidal force
    - Measure the sample displacement
  - Applications in measuring:
    - Modulus
    - Viscosity



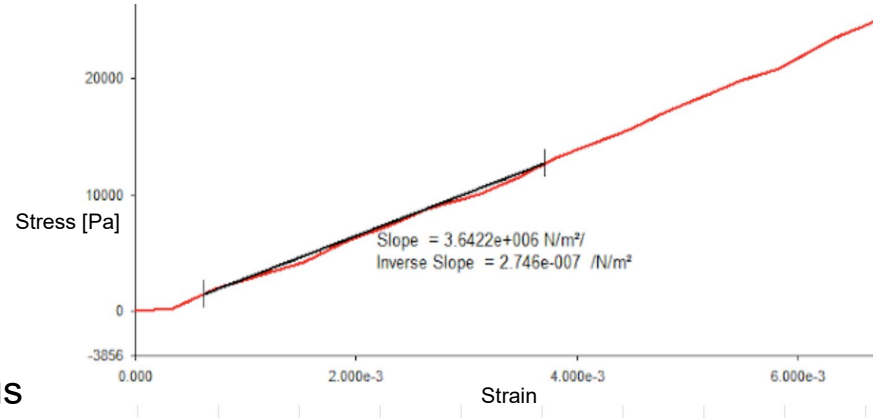

DMA Machine, DMA 8000

# Equipment and Method

- **Test Method**
  - 5mm by 5mm paper sample
  - Appling loading at:
    A. 2 to 4 N (tensile)
    B. 2 to 10 N (compressive)

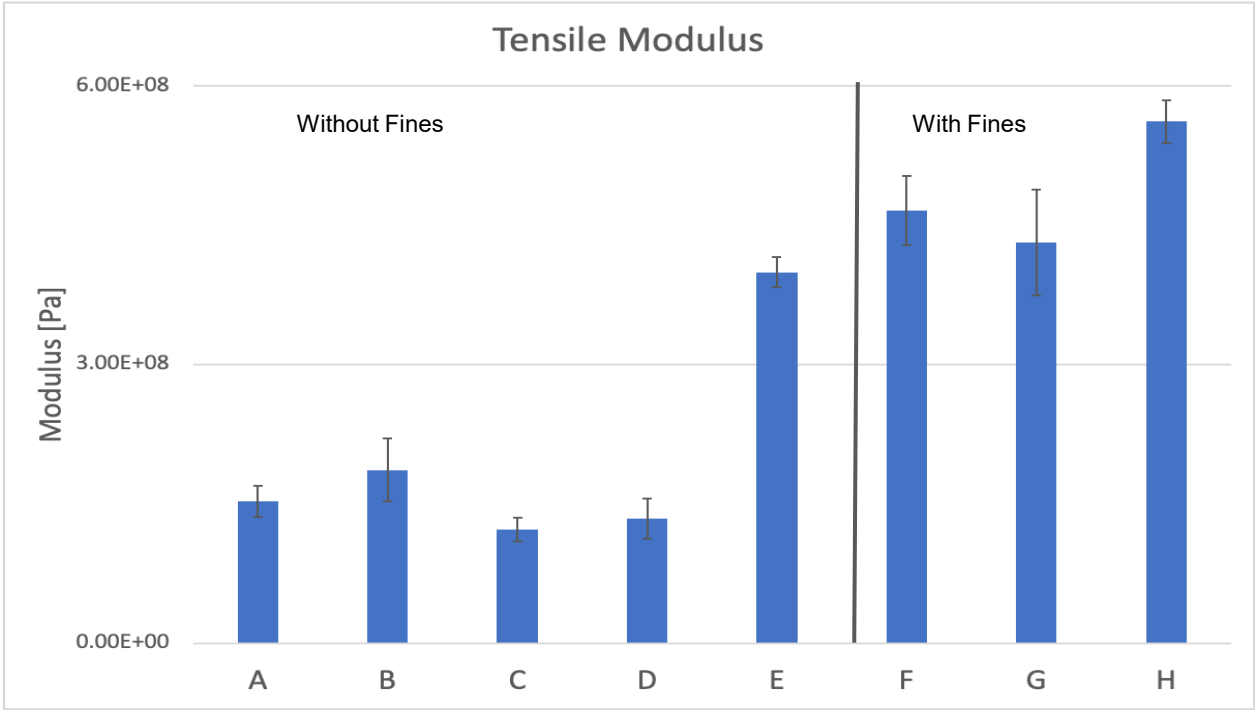
  - Generate the stress-strain plot
    - Slope is calculated as Young's modulus

  - Piezoelectric Coefficient
    - Piezoelectric coefficient meter.



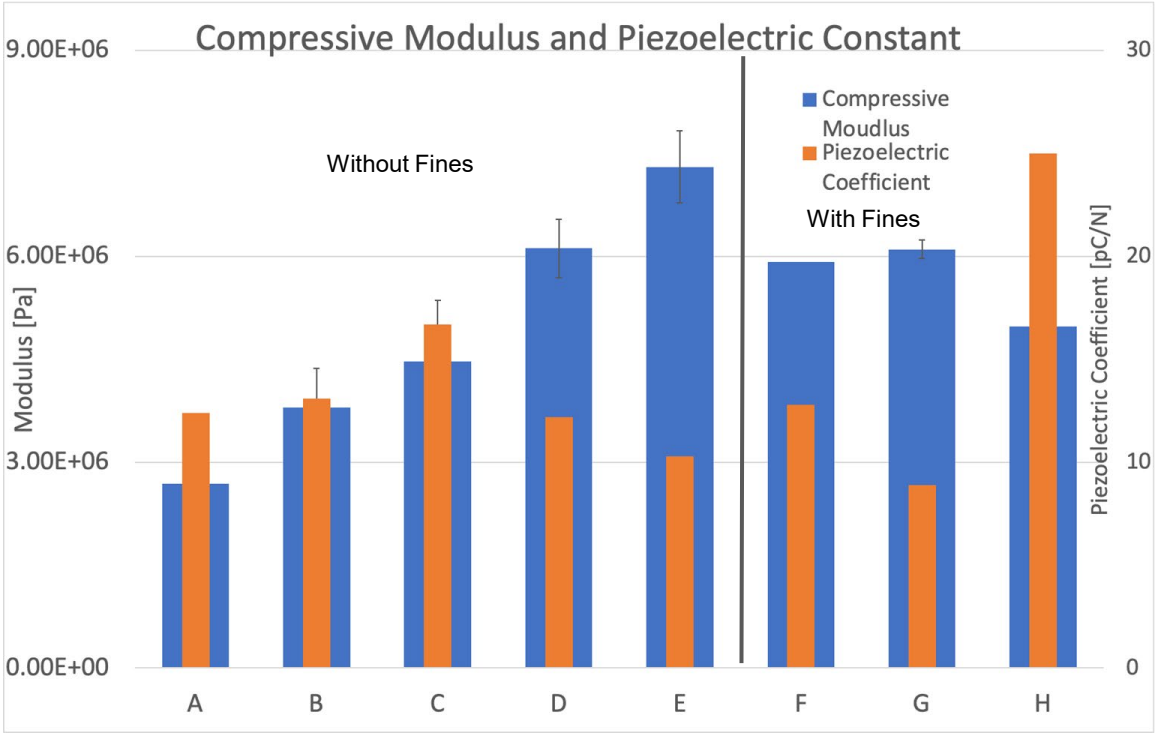

Compressive Stress-strain Plot for A4 Printing Paper

# Results




| Paper | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| Component | 300 ml Pulp | 400 ml Pulp | 500 ml Pulp | 600 ml Pulp | 700 ml Pulp | 400 ml Pulp + 25 ml Fines | 400 ml Pulp + 50 ml Fines | 400 ml Pulp + 75 ml Fines |
| Thickness [mm] | 0.06 | 0.07 | 0.08 | 0.139 | 0.206 | 0.152 | 0.154 | 0.18 |

# Results




| Paper | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
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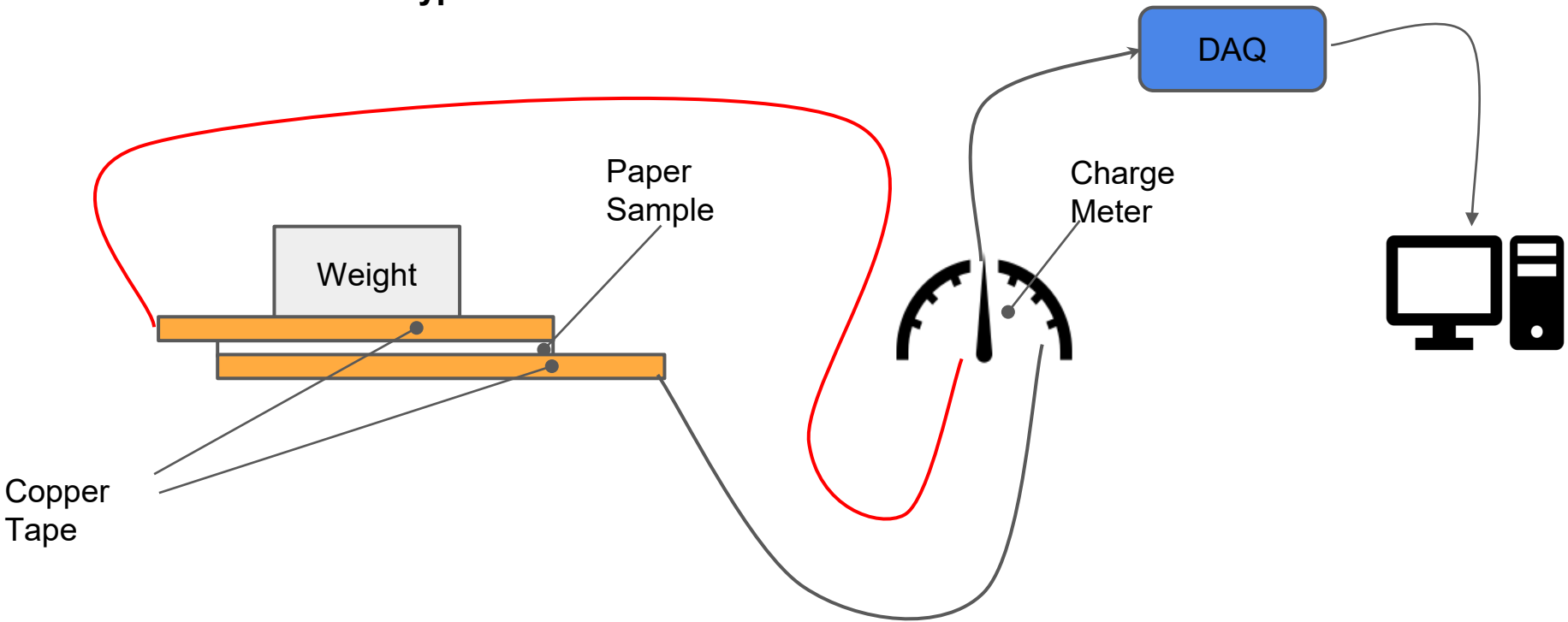
| Thickness [mm] | 0.06 | 0.07 | 0.08 | 0.139 | 0.206 | 0.152 | 0.154 | 0.18 |

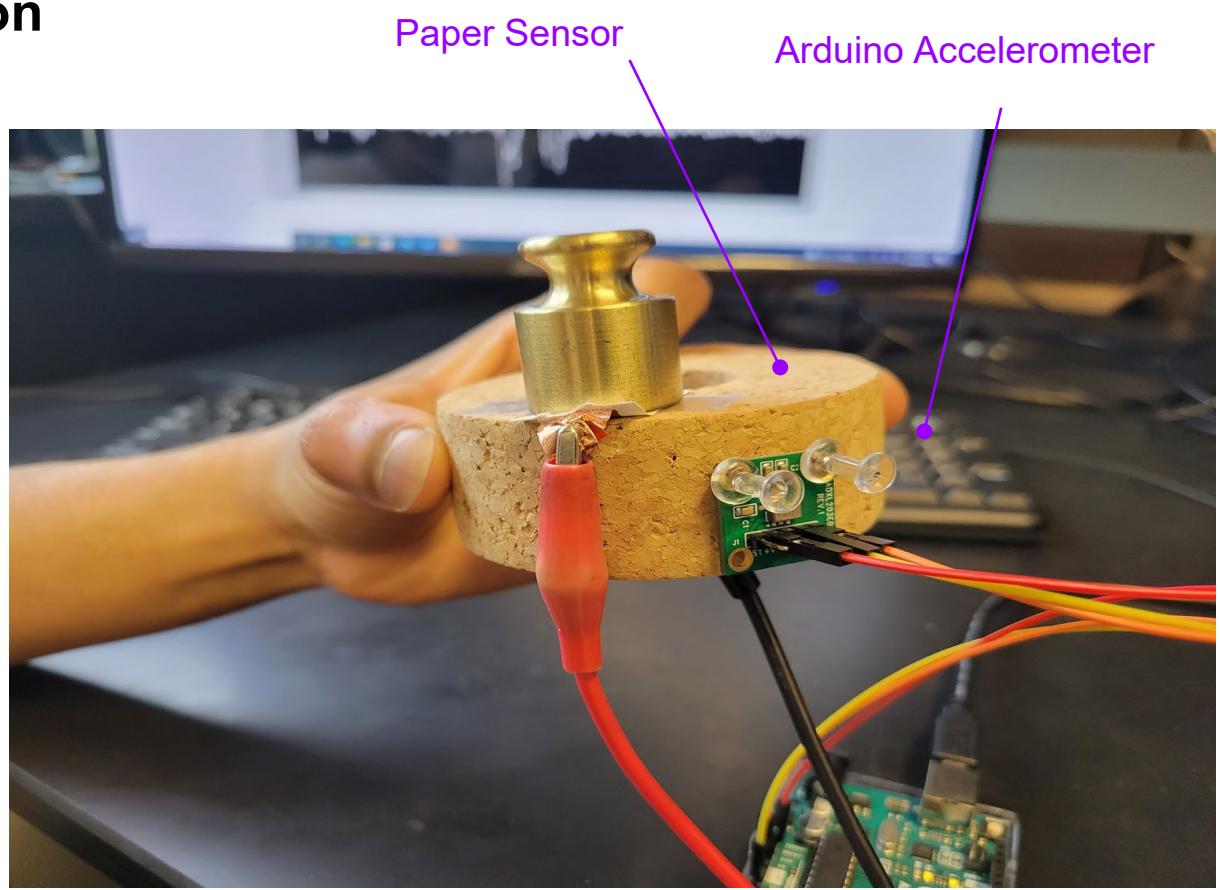
# Application - Accelerometer

# Paper Based Accelerometer

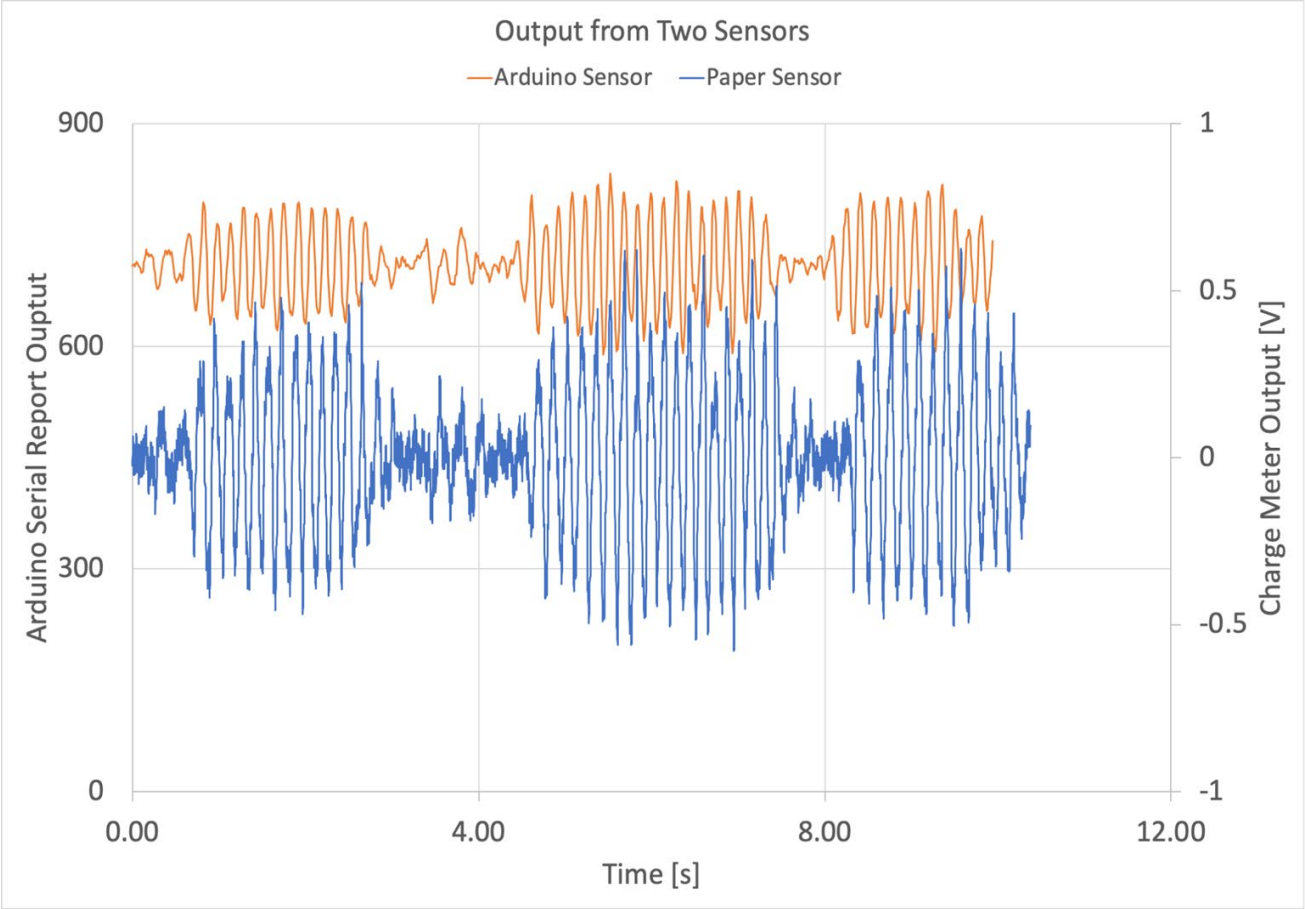
## Accelerometer Prototype



# Validation



# Validation


Output from Two Sensors
Arduino Sensor
Paper Sensor
900
600
300
0
1
0.5
0
-0.5
-1
0.00
4.00
8.00
12.00
Time [s]
Arduino Serial Report Ouptut
Charge Meter Output [V]

# Future Research Plan

# Future Research Plan

**Our Plan**

- Test electro-mechanical properties of different papers with different size of BTO particles

# Acknowledgement

# Acknowledgement


- Kanagasubbulakshmi Sankaralingam, Sajana Sumanasinghe, Ninweh Nina Jeorje, Anindya L. Roy, and Vishesh Jung Thapa for collecting the data and explaining how to use the devices.
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# Thank You & Questions