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

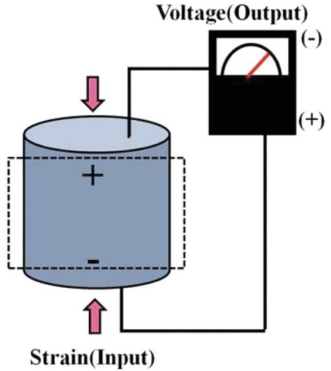
- Positive and negative charges at different centers
- Dipole moments under loading
- Electro-mechanical Coupling
- Reverse piezoelectric effect

Piezoelectric Coefficient

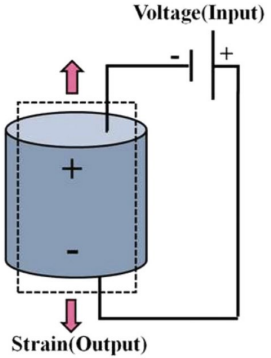
- Strength of piezoelectric response
- Induced charge / Applied force

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

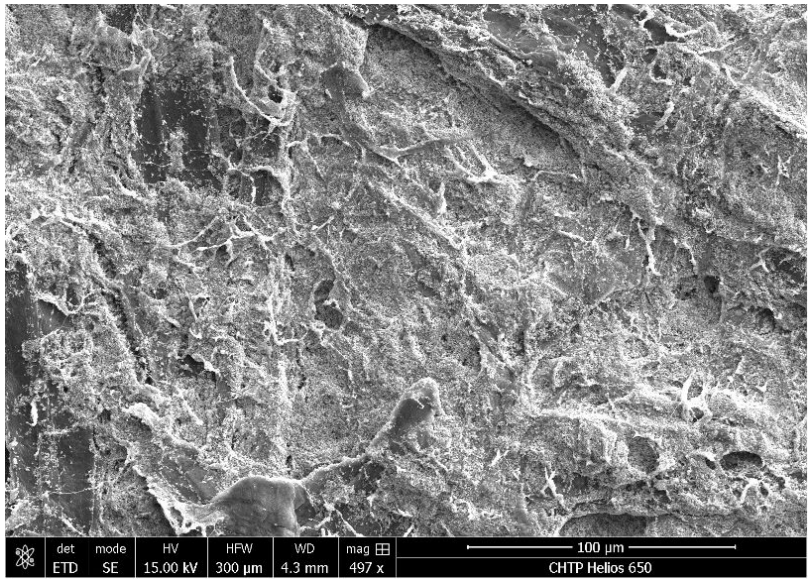
- Flexible and sustainable piezoelectric materials (Mahadeva et al., 2016)
- Research gaps on piezoelectric papers

Our Research

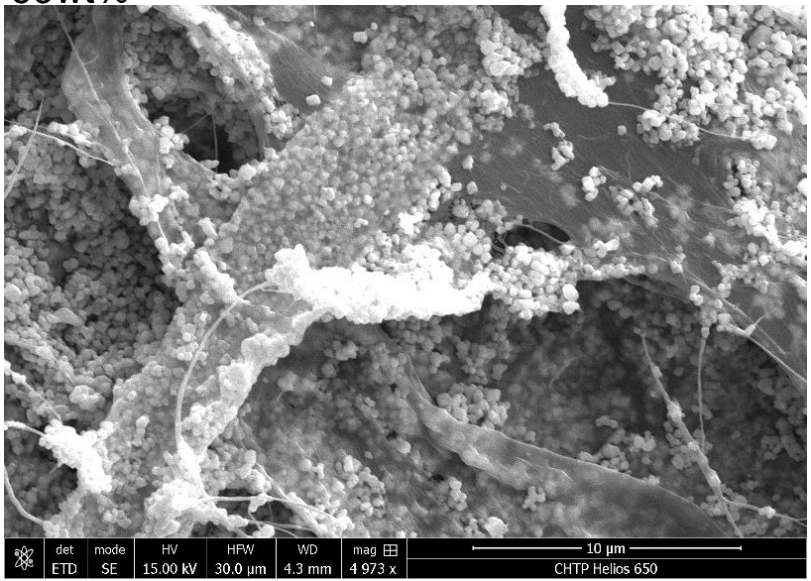
- Study fiber content and fines' effect on material properties

Materials

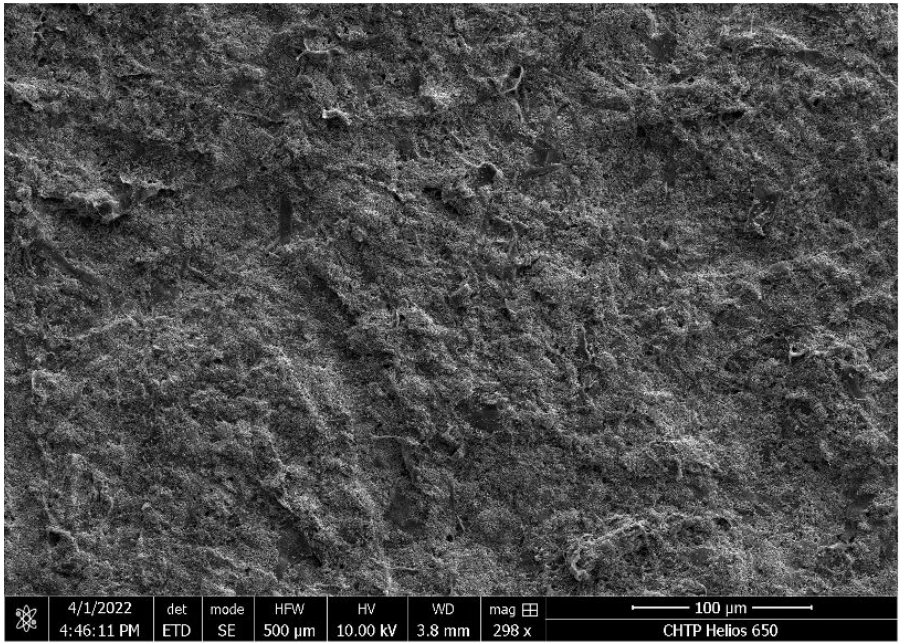
- Paper substrate with:
  A. Pulp
  B. Pulp and Fines, enhance strength
- 300nm $BaTiO_3$ particles loaded on the papers, 69wt%



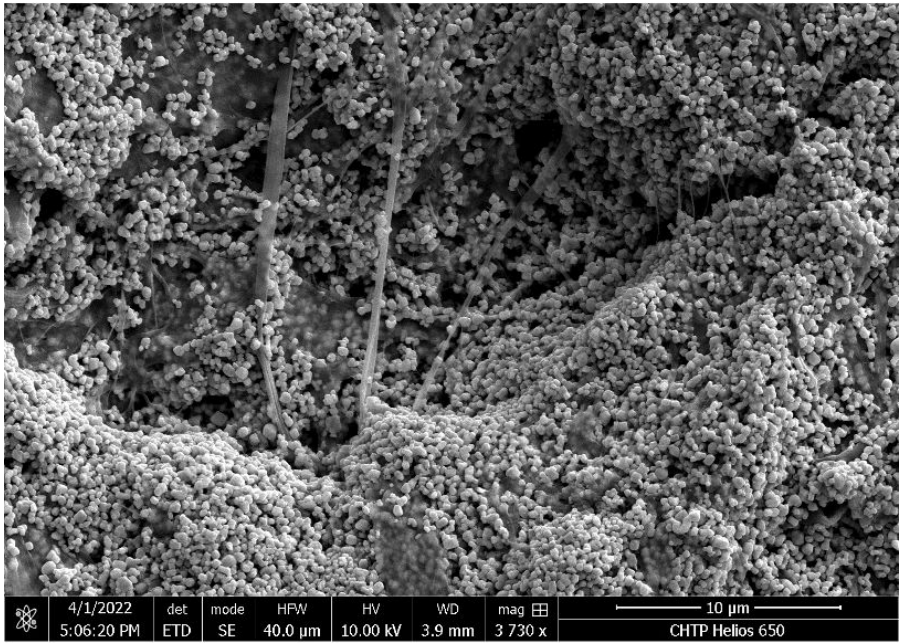
Paper with Pulp in 100 µm scale



Paper with Pulp in 10 µm scale



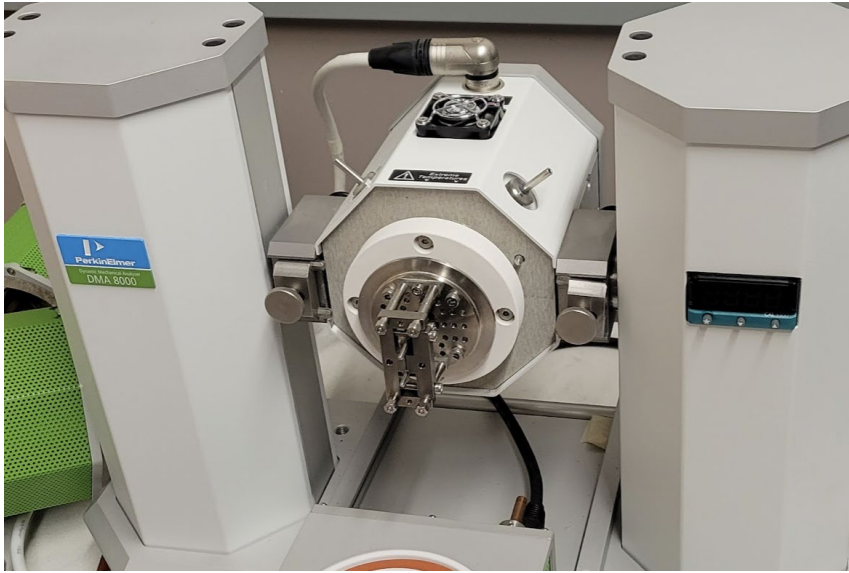
Paper with Pulp and Fines in 100 µm Scale



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



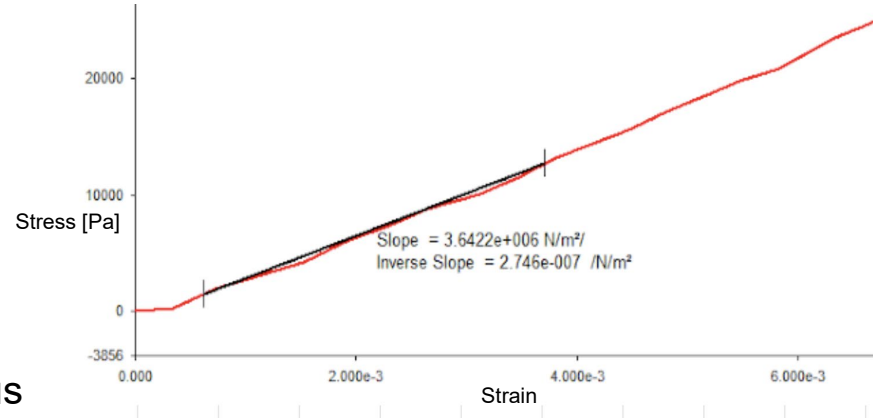
DMA Machine, DMA 8000

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)

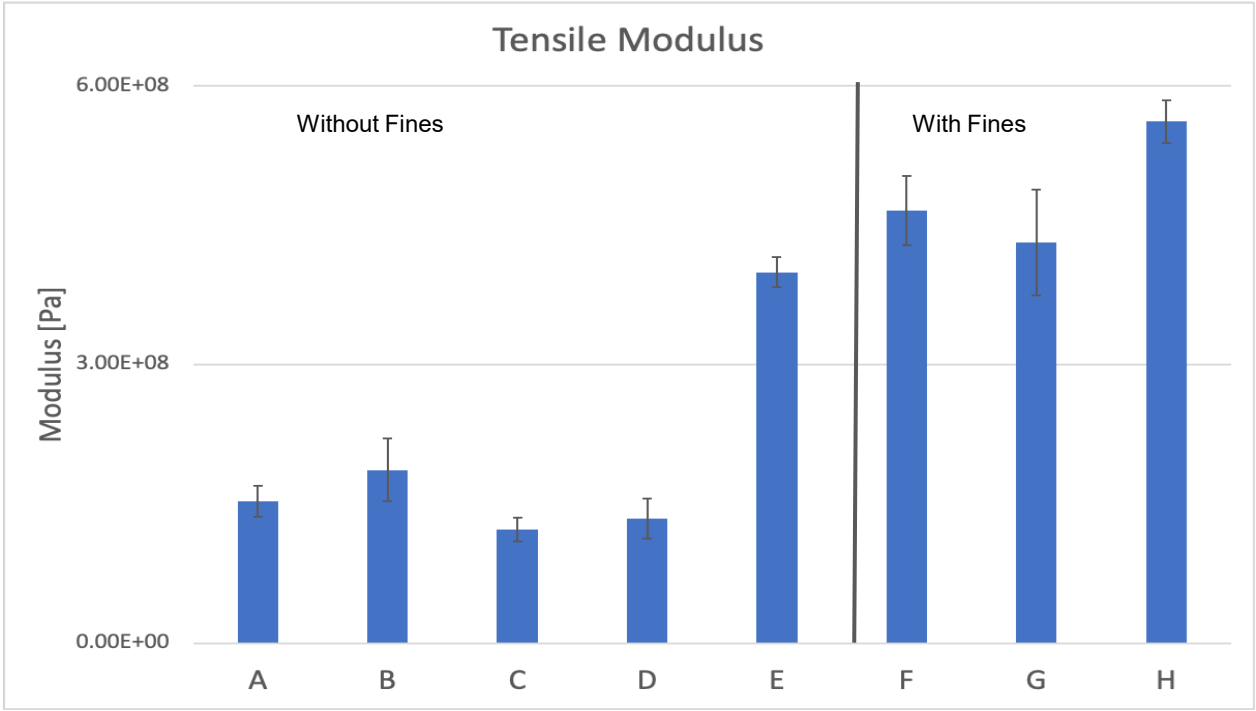
  - Generate the stress-strain plot
    - Slope is calculated as Young's modulus

  - Piezoelectric Coefficient
    - Piezoelectric coefficient meter.



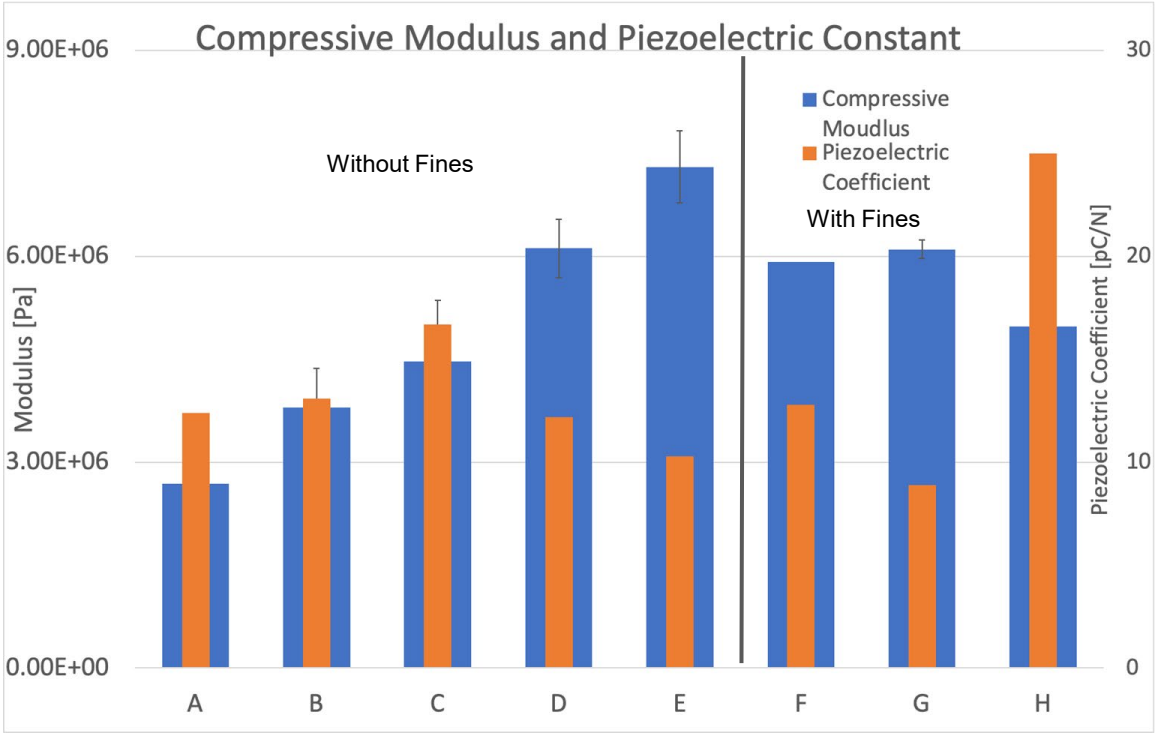
Compressive Stress-strain Plot for A4 Printing Paper

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



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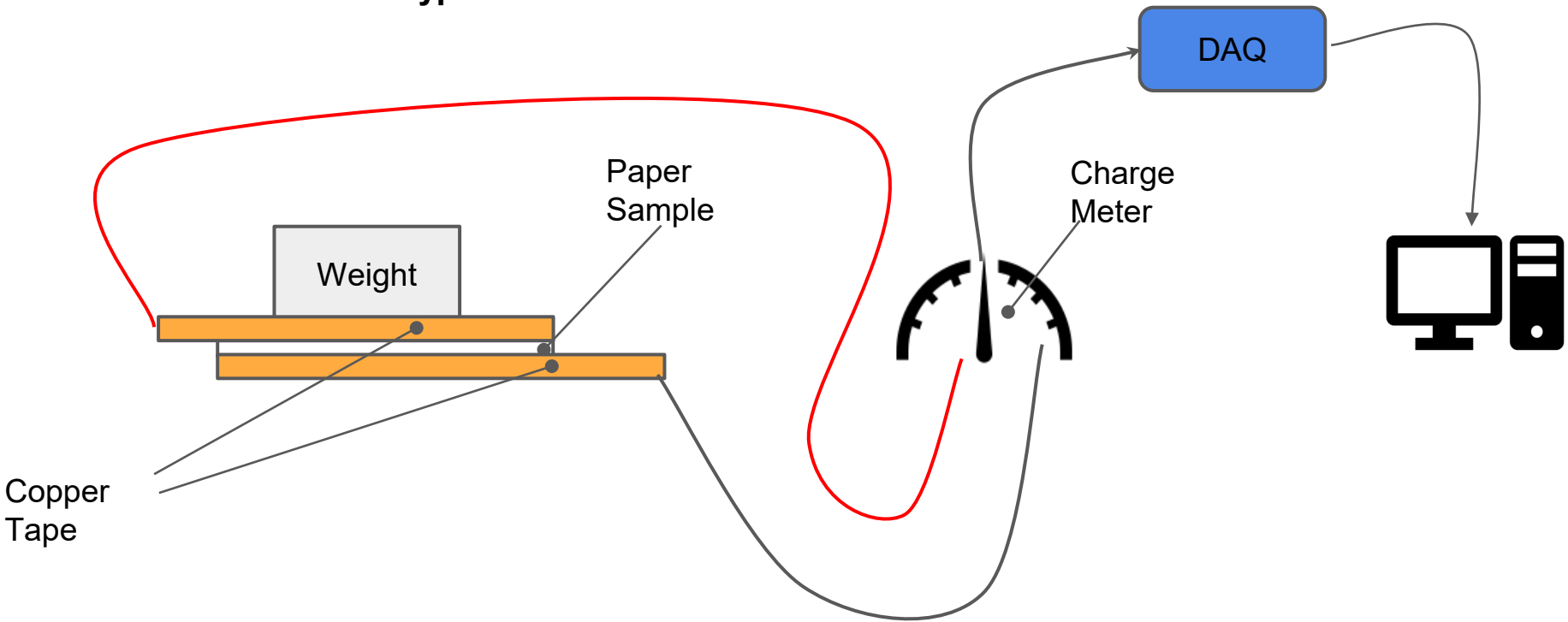
Component	300 ml Pulp	400 ml Pulp	500 ml Pulp	600 ml Pulp	700 ml Pulp	400 ml Pulp + 25 ml Fines	400 ml Pulp + 50 ml Fines	400 ml Pulp + 75 ml Fines
Thickness [mm]	0.06	0.07	0.08	0.139	0.206	0.152	0.154	0.18

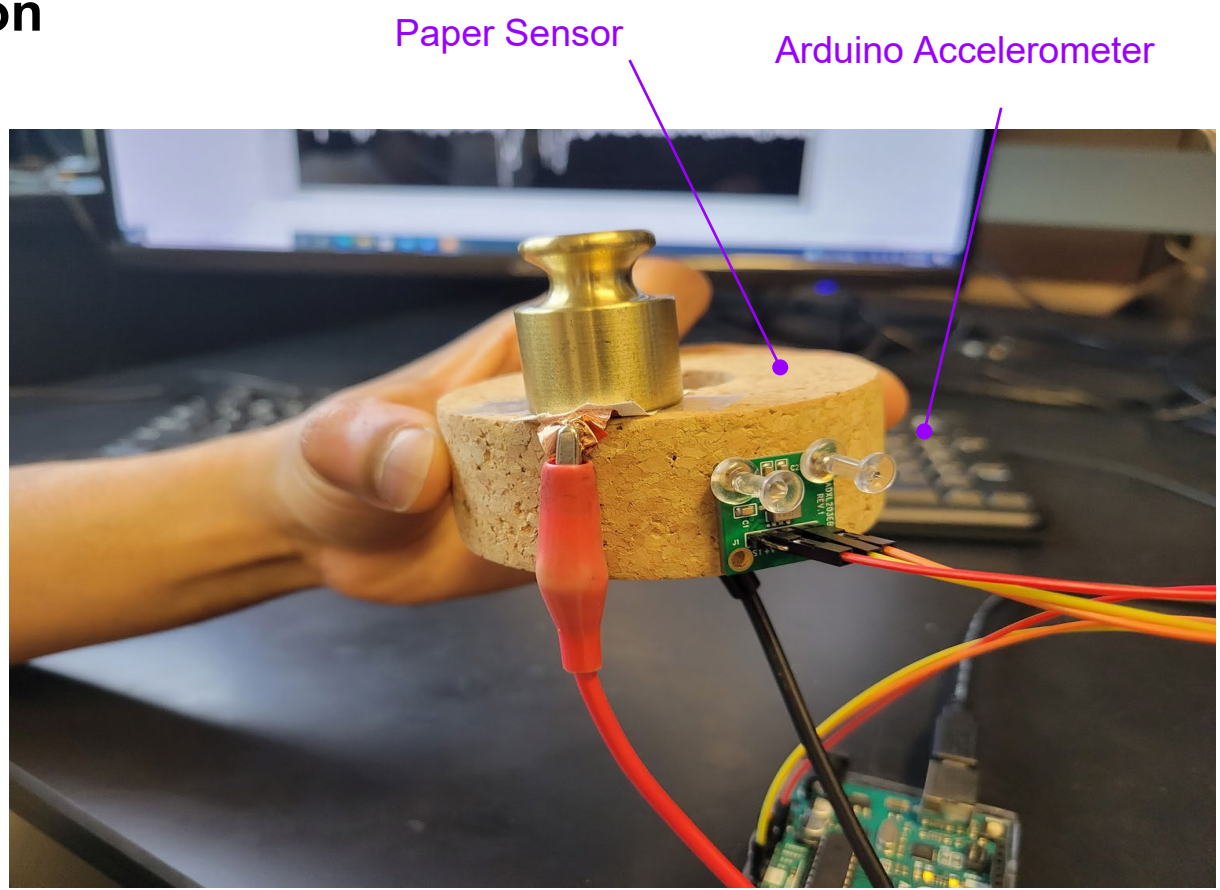
Application - Accelerometer

Paper Based Accelerometer

Accelerometer Prototype



Validation



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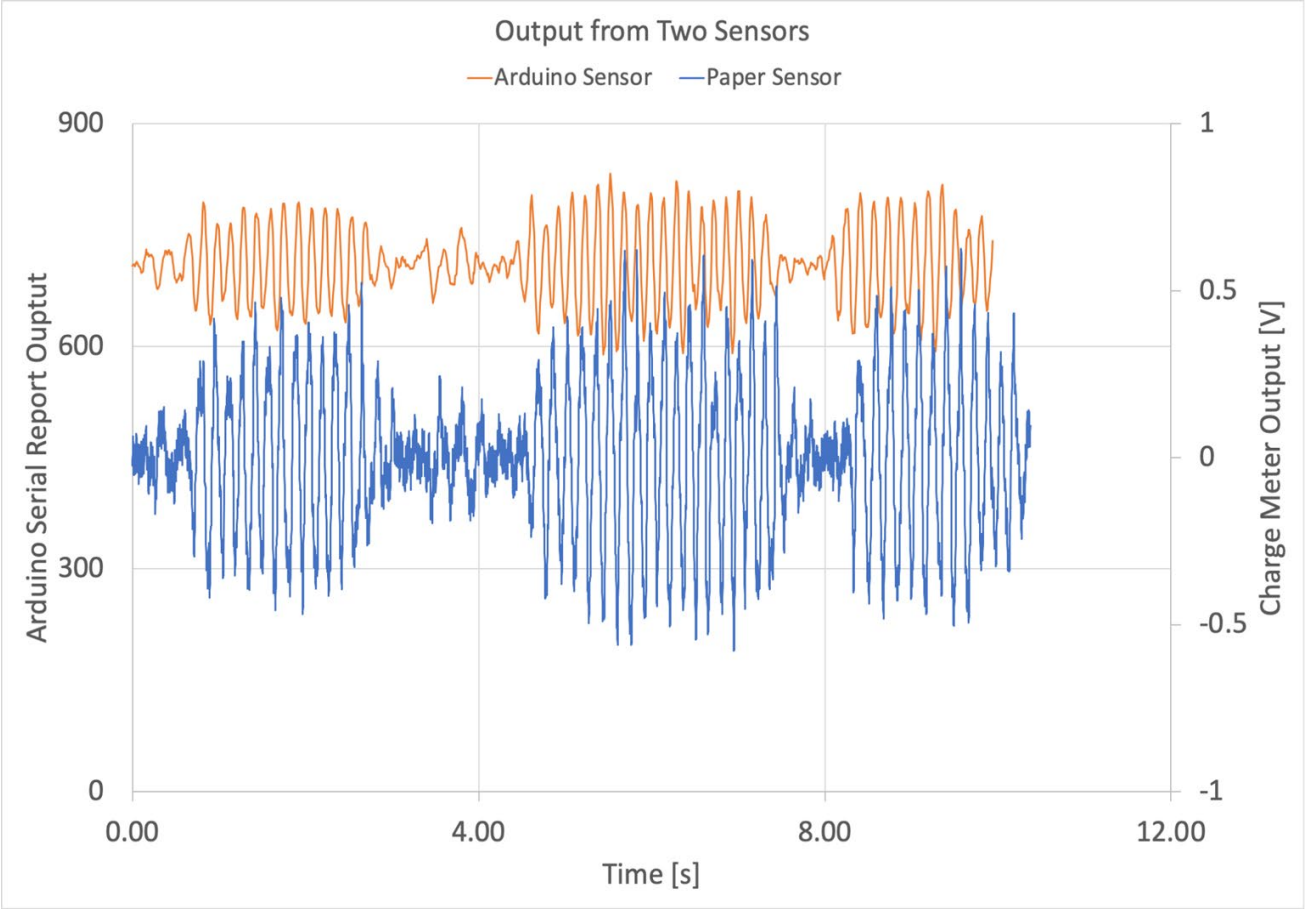

Output from Two Sensors
Arduino Sensor
Paper Sensor
900
600
300
0
1
0.5
0
-0.5
-1
0.00
4.00
8.00
12.00
Time [s]
Arduino Serial Report Ouptut
Charge Meter Output [V]

Application - Speaker

Paper Based Speaker

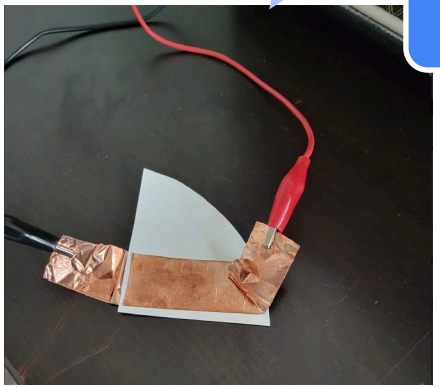
Audio signal

Guitar amplifier

Source: https://www.bestbuy.ca/en-ca/product/marshall-mg-gold-30w-guitar-combo-amp-with-digital-effects-mg30gfx/15316151

Amplified signal

Piezoelectric paper

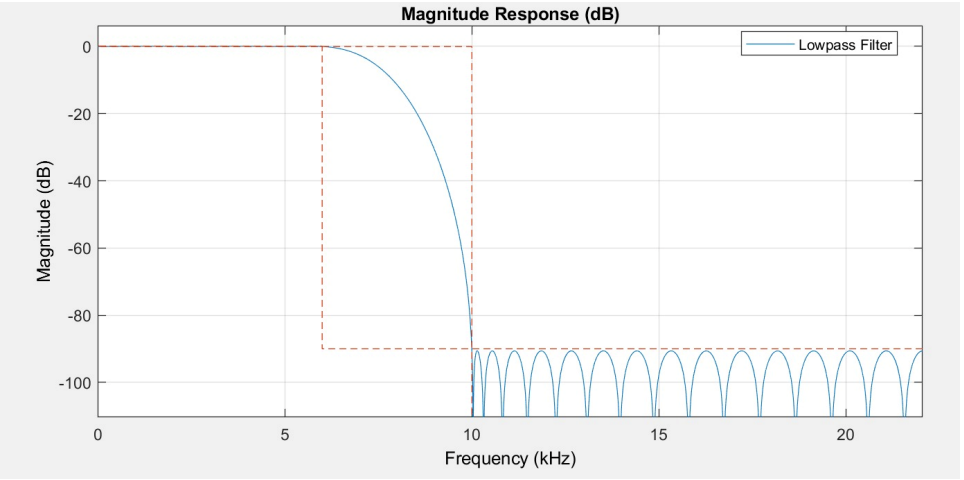


Sound (Mechanical Vibration)

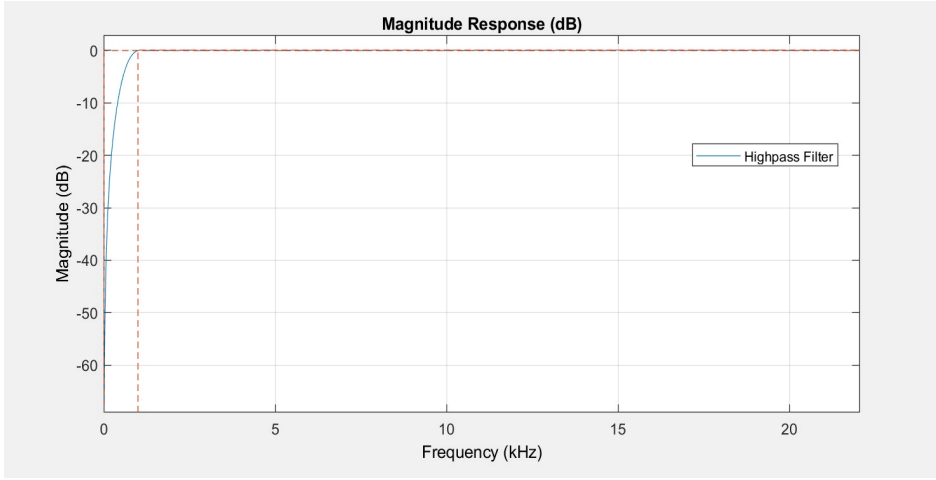
Paper Based Speaker

Original Sound is noisy

- Low pass filter to control noise from paper itself
- High pass filter to reduce environmental noise (Mostly fan and HVAC)



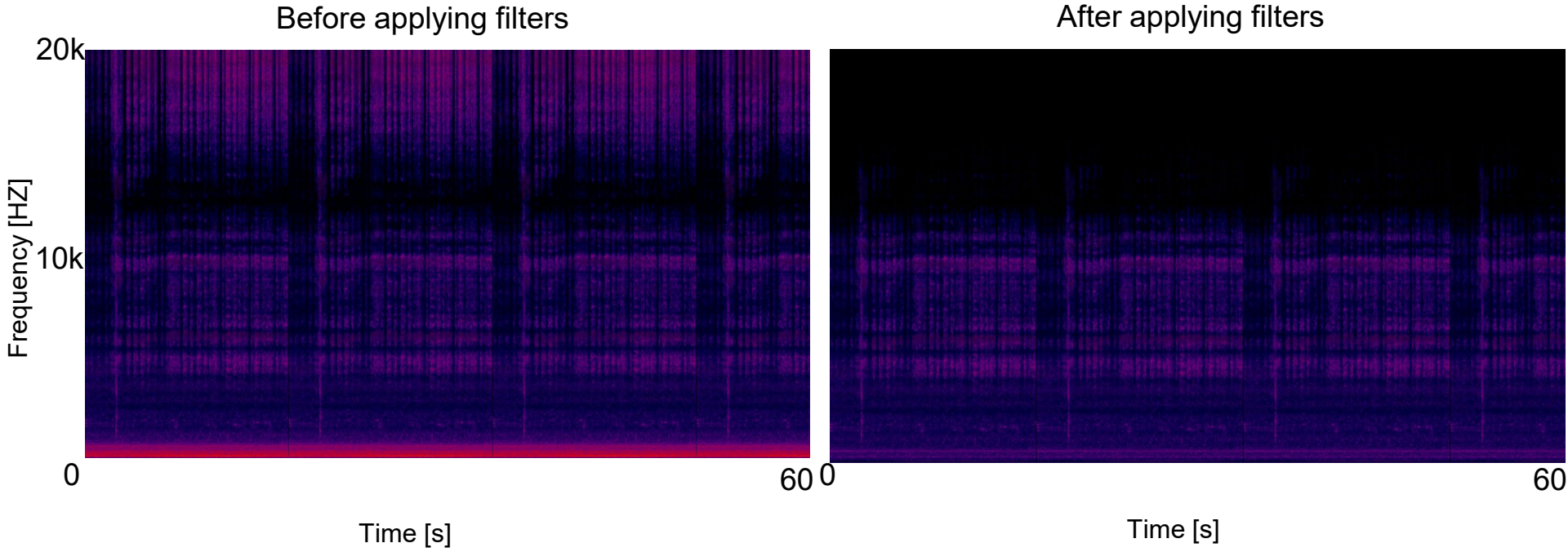
Low Pass Filter



High Pass Filter

Paper Based Speaker

Lighter color means higher amplitude



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