Bio-based Carbon/Polyvinyl Alcohol Piezoresistive Sensor Material

David DeVallance

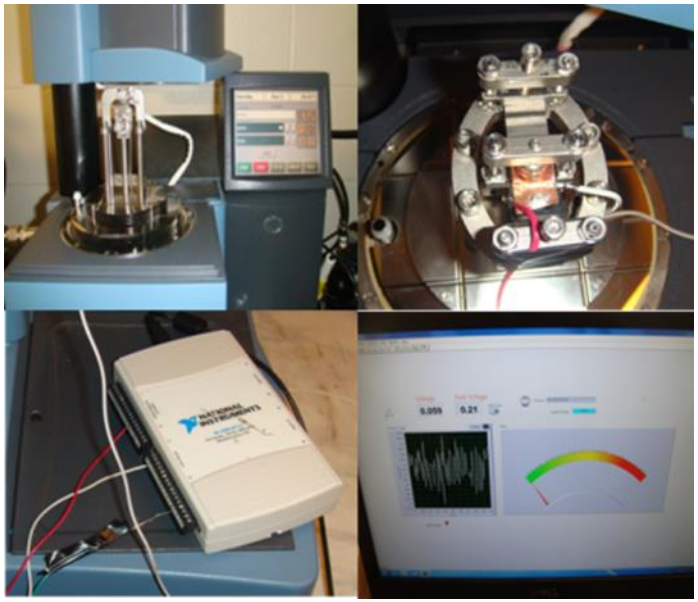
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Is Wood a Conductor or Insulator?





- Very weak conductor
- Molecules are far apart
- Moisture and higher voltage make conduction better

Background: Biochar

Biochar produced from the thermal decomposition of biomass in the absence of atmospheric oxygen

- The fast pyrolysis process produce a solid residue (char), liquid condensate, and gas products
- Slow pyrolysis process produces biochar more suited for soil amendment applications





Background: Biochar

Biochar produced from pyrolysis may have beneficial properties

- Slow pyrolysis
  - Used for carbonization when the resulting principal product is solid charcoal or char (biochar)

- Biochar Applications
  - For combustion
  - As an absorbent
  - Soil amendment
  - Catalyst development
  - Composite materials?

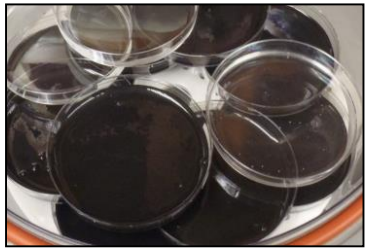


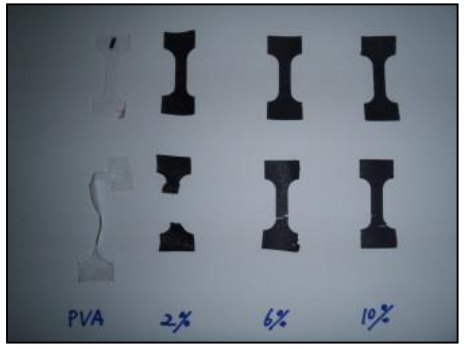
Biochar

Background: Prior Research

Biochar is typically used as a soil amendment, but has been researched for other potential uses

- **Fuel cell electrodes (Huggins et al. 2014)**
- **Replacement of carbon black using corn stover biochar (Peterson 2012)**
- **For strengthening of epoxy matrix (Ahmetli et al. 2013)**
- **As a filler for wood plastic composites (DeVallance et al. 2014)**
- **As a filler for biodegradable packaging film (Nan and DeVallance 2014)**







Research Objectives

The main goal of this research was to evaluate the pizeoresistive properties of a polyvinyl alcohol/biochar film sensor material

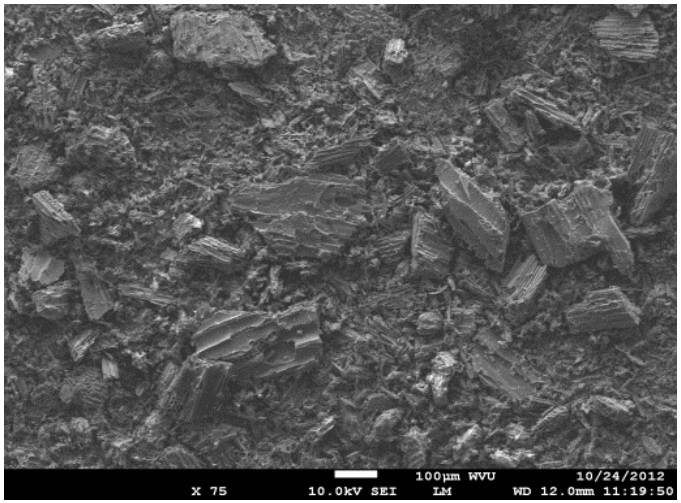
The specific research objectives to:

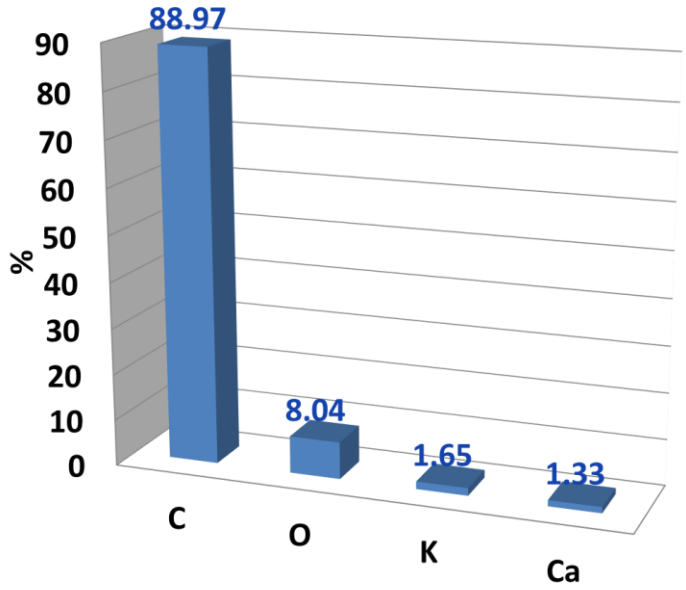
1. **Investigate the influence of different biochar loading levels of 8 wt%, 10 wt%, and 12 wt% on the piezoresistive properties of the bio-based sensor**
2. **Determine the influence of film thickness on the piezoresistive properties of the sensors films developed using bio-based carbon (i.e., biochar) as the electrical conductive filler material**
3. **Evaluate the repeatability and response of the bio-based sensor**

Methods: Materials

Commercially available mixed hardwood biochar was used as the electrical conducting material in the films

Mixed hardwood biochar manufactured by CharcoalHouse™ (ground and sieved to pass 250 micron (µm) sieve)





PVA solution at 10% by weight made from PVA crystals (Acros Organics, MFCD-00081922)

Methods: Sensor Preparation

The biochar (3 loading levels) and PVA 10% were mixed manually then ultrasonically prior to being film casted and degassed

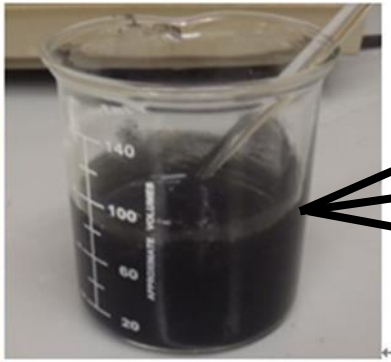
Biochar Loading Levels



Biochar



PVA 10% solution



Mixed

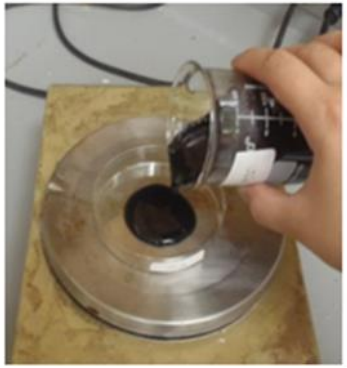
8%

10%

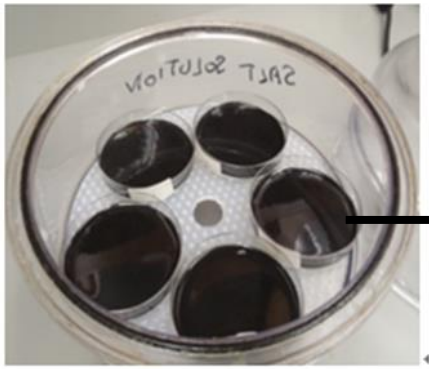
12%



Ultrasonic Treatment



Weight



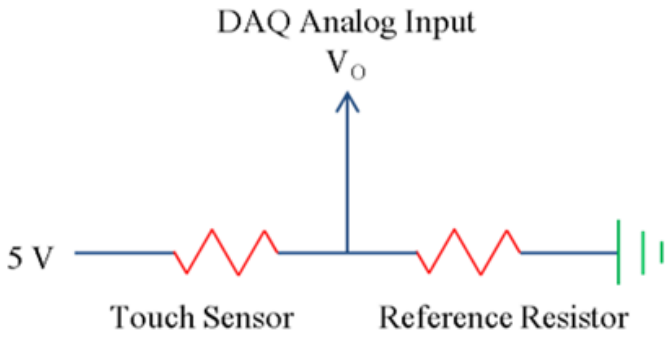
Samples



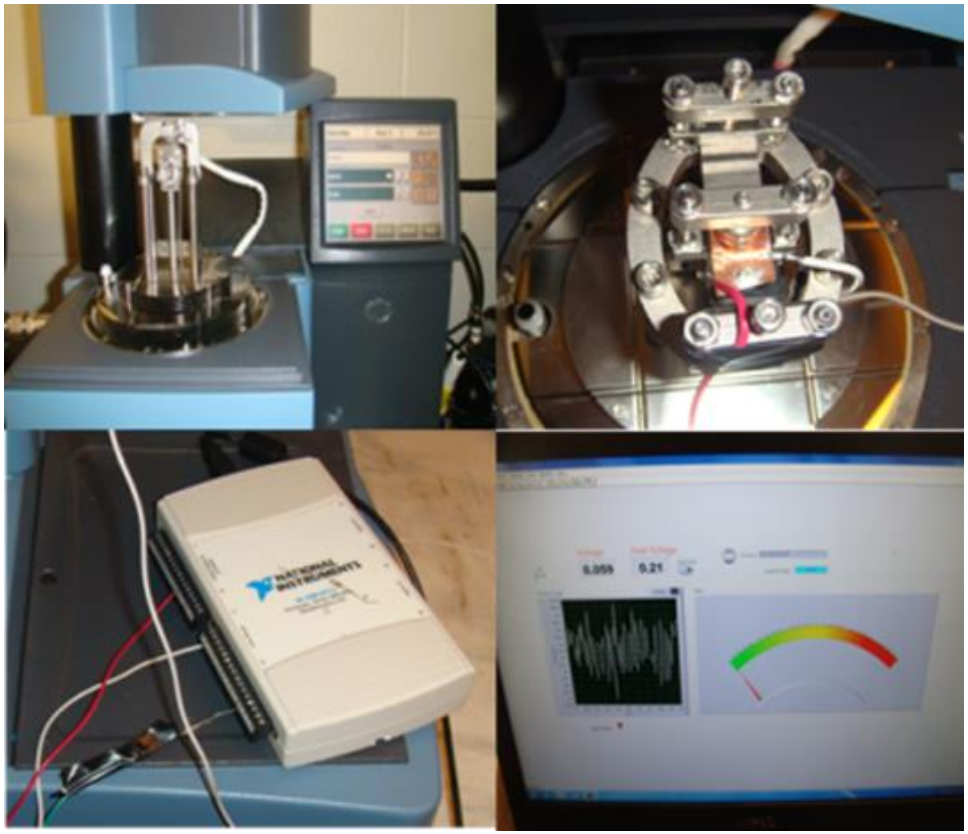
Methods: Sensor Testing

The resulting PVA/biochar piezoresistive sensors were tested for at room temperature using a TA Q800 dynamic mechanical analysis system

- **Characterization of the sensor was performed using a quasi-static loading scheme with a rate of 2 kPa/second up to a maximum stress of 350 kPa.**

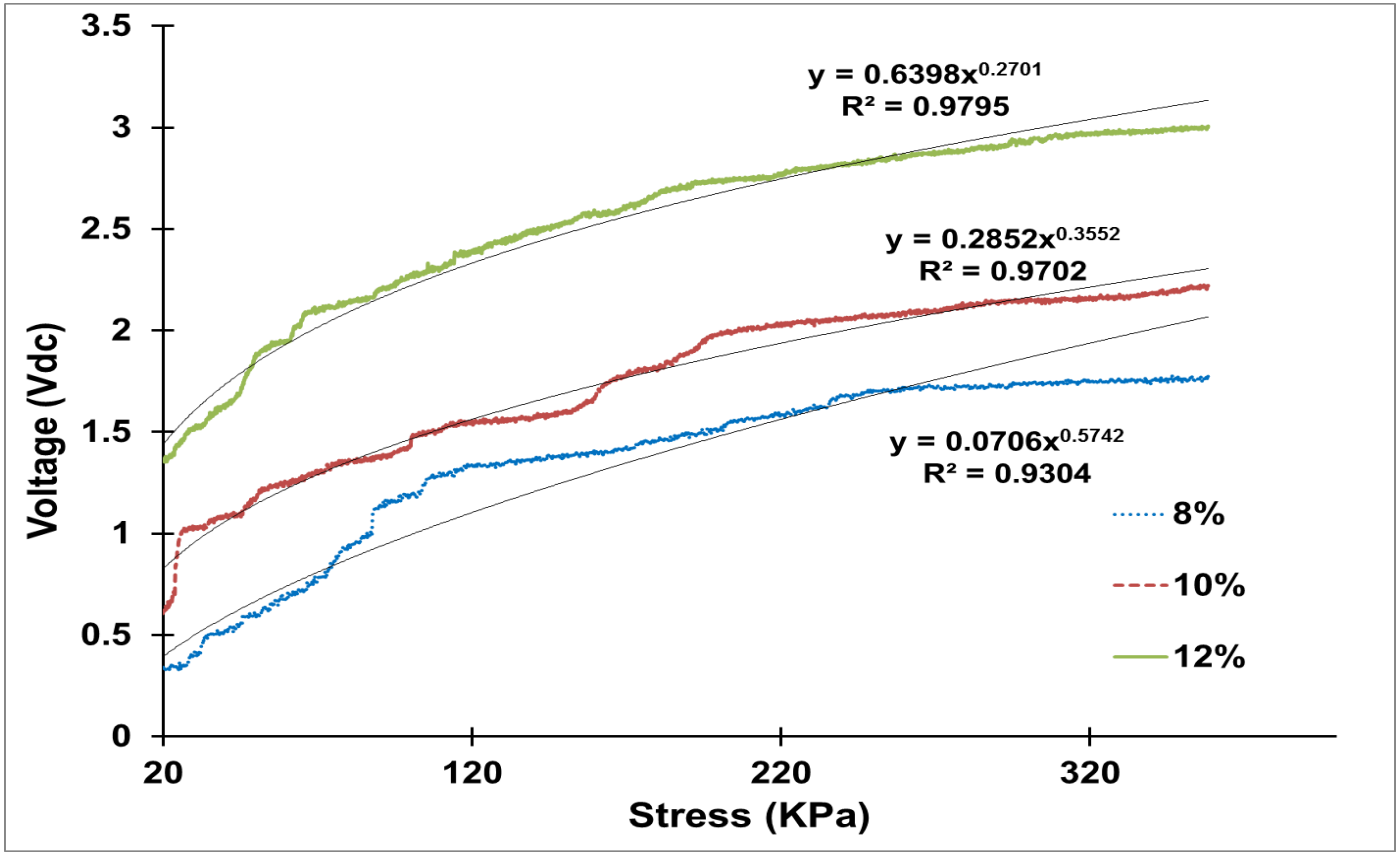


Circuit used for testing



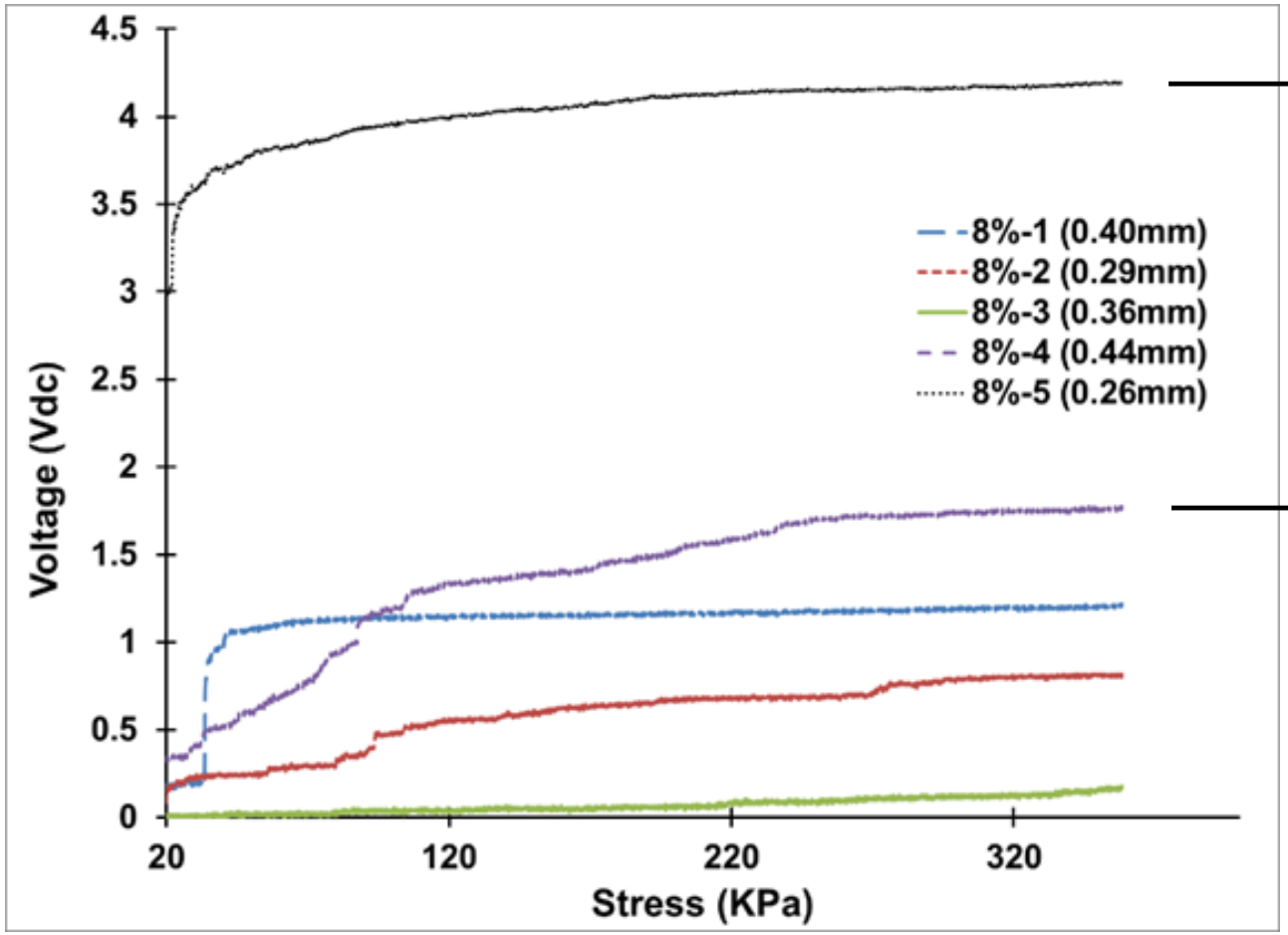
Results: Effect of Loading Level

The resulting voltage output of each sensor increased with increased loading and the 12% biochar filled sensor had the highest overall voltage response



Results: Effect of Film Thickness

No particular significant trends were found between film thickness and overall piezoresistive response of the sensors



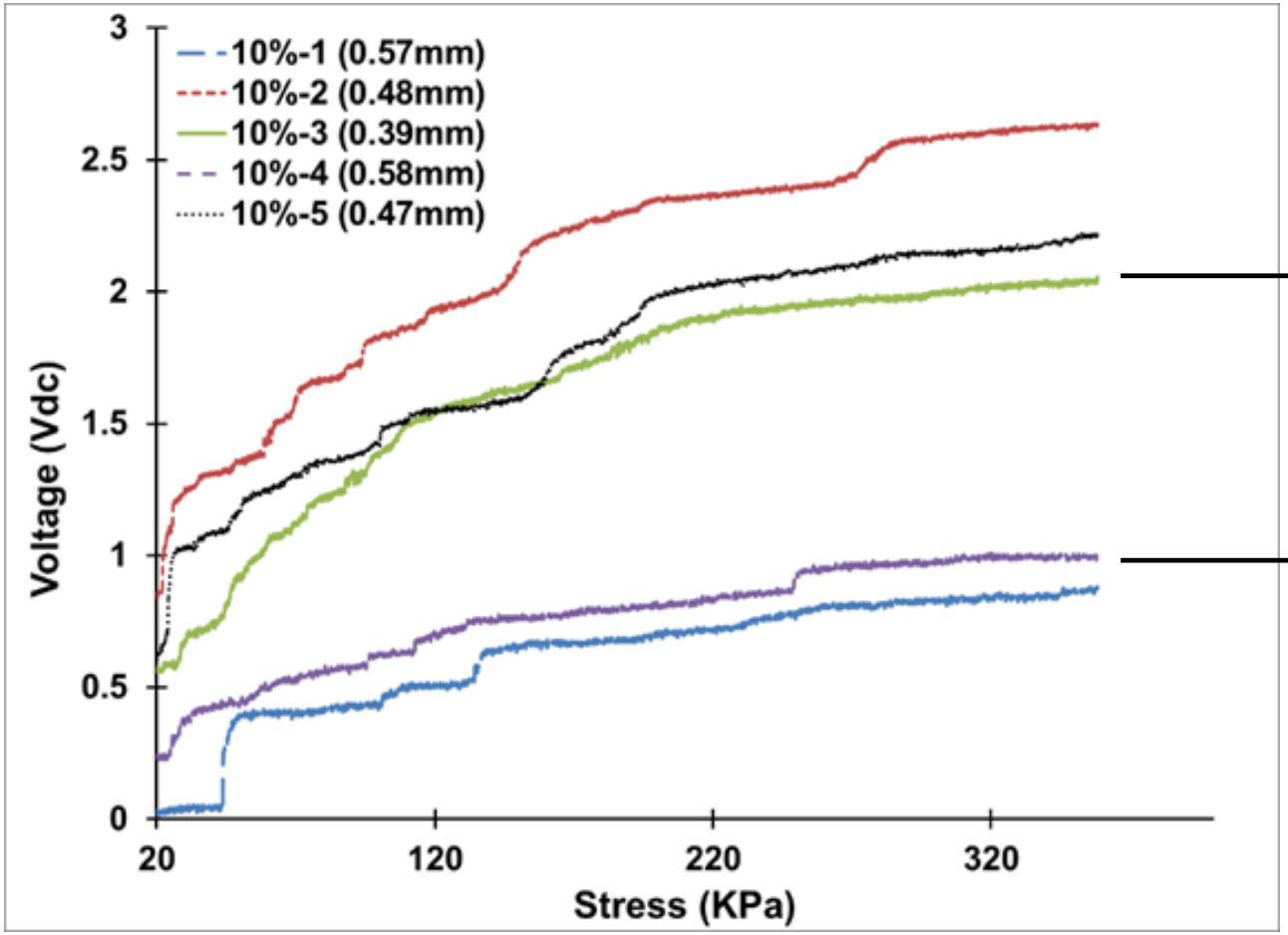
Thinnest Film

Thickest Film

8%

Results: Effect of Film Thickness

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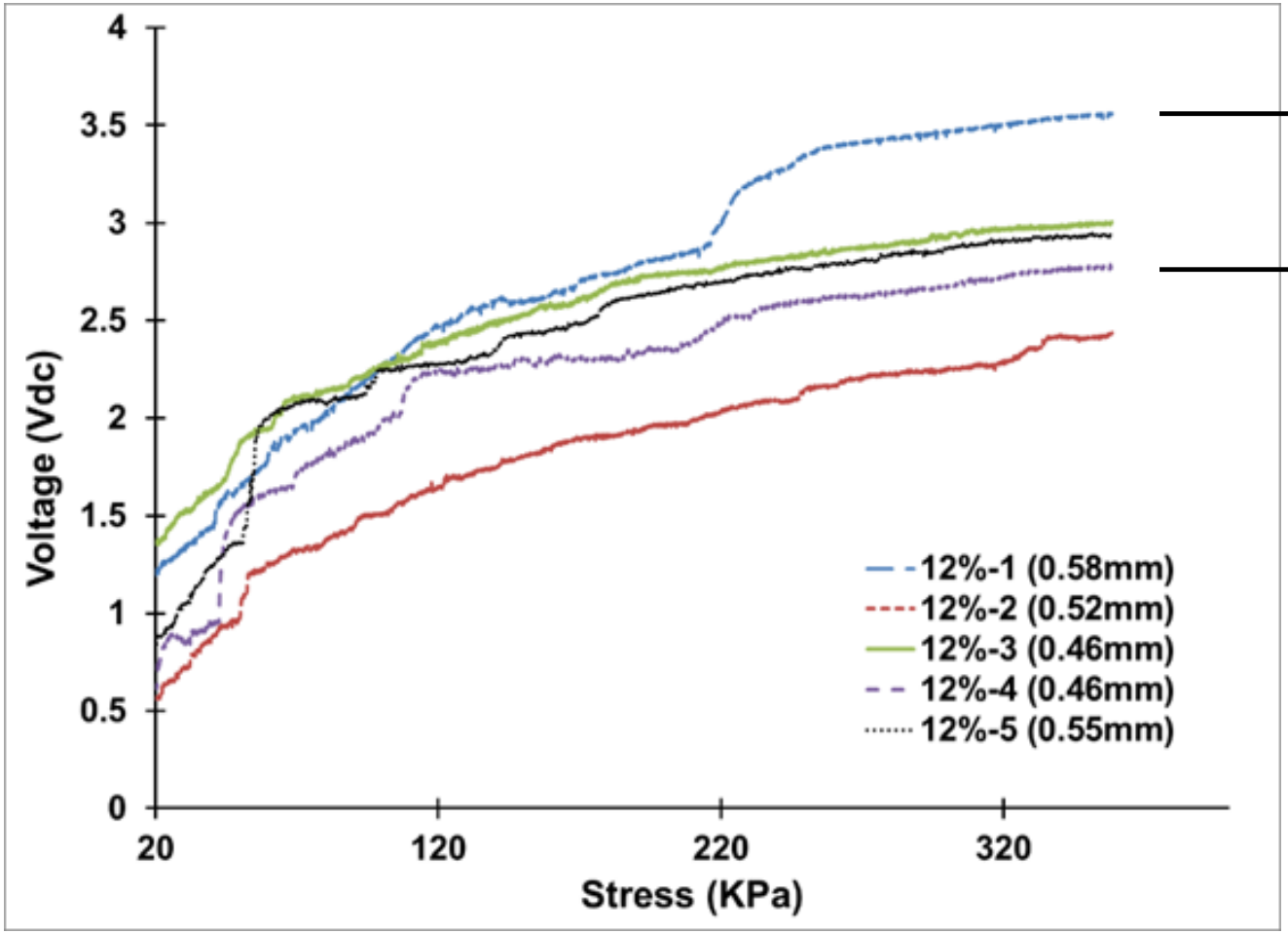
Thinnest Film

Thickest Film

10%

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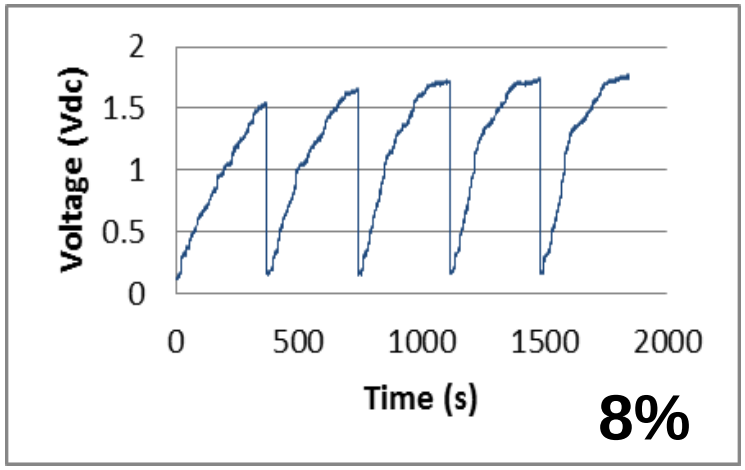
Thickest Film

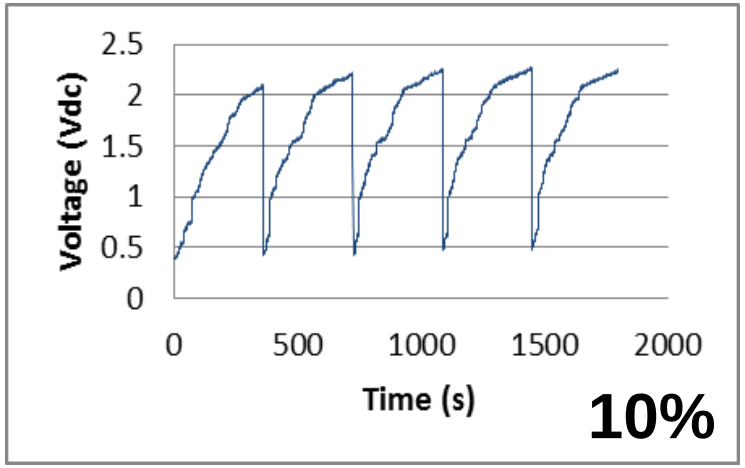
Thinnest Film

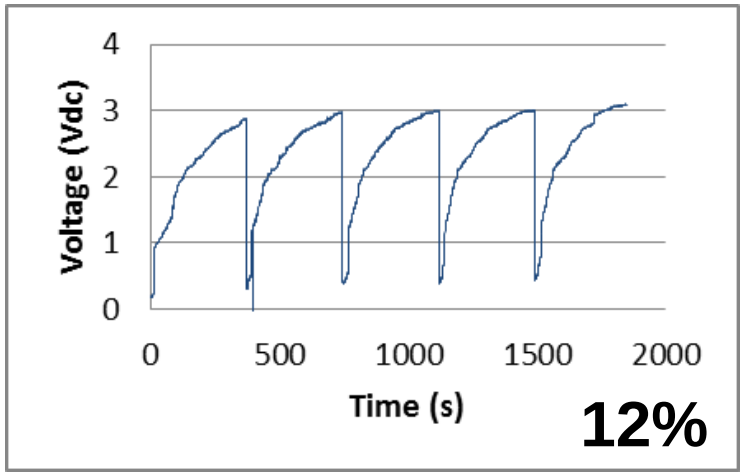
12%

Results: Release Testing

Overall piezoresistive response of repeated tests of the sensors indicated a favorable release recovery







- A more stable peak voltage after 1st cycle was noted
- Peak voltage increased as biochar loading level increased

Conclusions

The overall conclusions of the research were:

- Under room temperature conditions, the voltage response of PVA/Biochar sensors gradually increased as pressure was applied
- As the biochar particle loading level increased, there was an increase in the voltage response of PVA/Biochar sensors
- The release tests indicated that all of the sensors types exhibited favorable recovery capability
- The results indicated that biochar particle filled films possess suitable electrical conductivity and piezoresistive response and would be likely materials for piezoresistive sensors
- Future work is needed, however, to investigate the influence of particle size and distribution on the piezoresistive properties of these film materials

Questions?

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Biomaterials and Wood Utilization Research Center
(http://www.wdscapps.caf.wvu.edu/BioMatWURCtr)
http://forestry.wvu.edu/faculty_staff/david_devallance

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