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Design of flexible solid state pseudocapacitor for wearable technologies

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Introduction

Capacitors and batteries both store potential energy. As shown in the Ragone plot below (Figure 1) capacitors are high power devices while batteries are higher in energy. Both devices have advantages and disadvantages. Capacitors are able to cycle a high number of times and have the ability to deliver a large amount of power quickly.

For this project the goal was to fabricate a flexible solid state pseudocapacitor that would be useful in wearable devices. These wearable capacitors need to be capable of powering an LED for a minimum of one hour as well as able to be cycled thousands of times with minimal performance loss. Size and cost must also be kept in mind throughout the project.

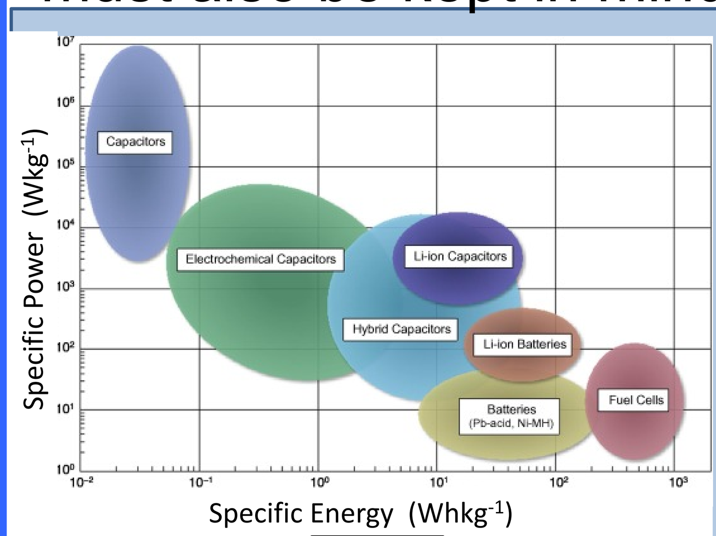


Figure 1

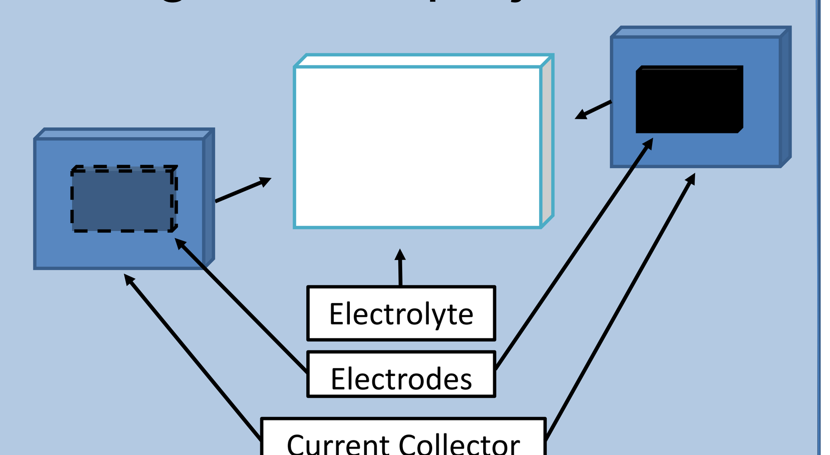


Figure 2

Electrode Fabrication for Pseudocapacitor

Our Pseudocapacitors (figure 2) consist of two electrodes, and a solid state electrolyte that separates them. In some cases a current collector was also used. Various materials were considered and tried when fabricating the parts of the capacitor. Most of these materials were also used uncoated and then also coated with a polypyrrole coating applied using electrodeposition (Figure 3). Electrodes were then cut to the size needed

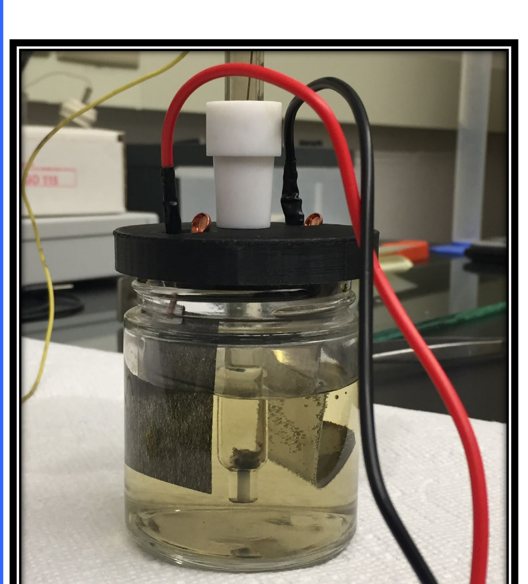
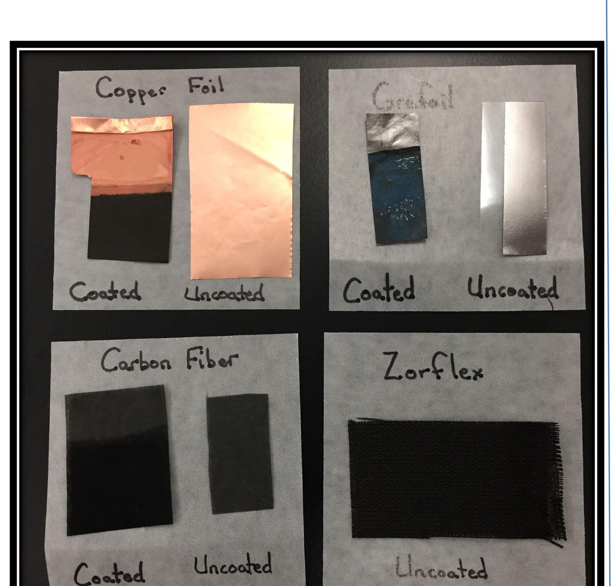


Figure 3

Left: a piece of copper foil being coated through electrodeposition.

Right: Comparison of different materials that were coated throughout the six weeks



Electrolyte

A solid state electrolyte solution was made using polyvinyl alcohol, phosphoric acid and glutaric dialdehyde and then cast onto a plastic sheet to dry and set for 48 hours (Figure 4).

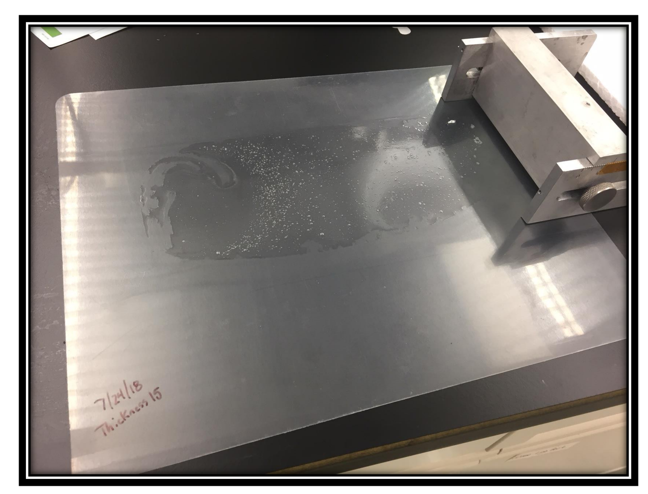
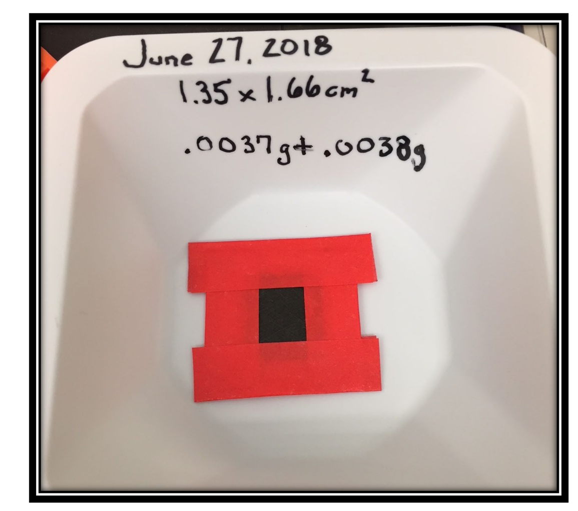


Figure 4

Left: a piece of PVA membrane that was just cast and will need to set and dry

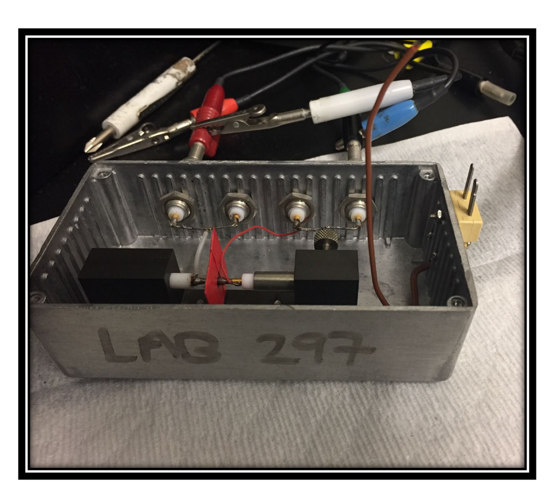
Right: A sample pseudocapacitor



Pseudocapacitor cells were created making a sandwich using the materials as current collectors, electrodes, and the electrolyte.

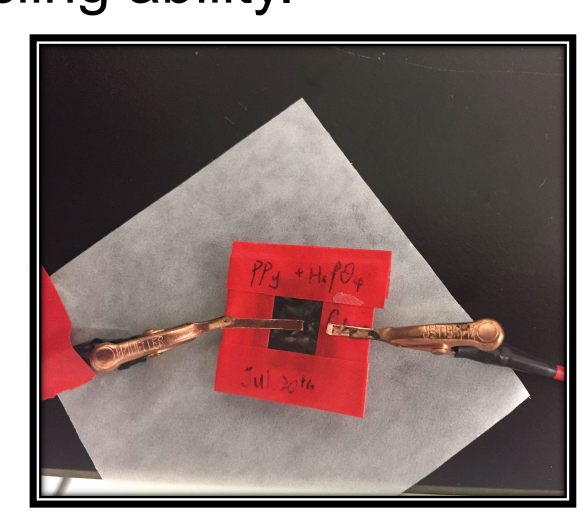
Testing

After production the cells were then tested for, impedance, capacitance, and cycling ability.



Left: a taped cell that is being tested by pins pressing on the cell

Right: a taped cell that is being tested by clips attached to copper leads coming from the sample



Test 1-Impedance

Impedance is done using Electrochemical Impedance Spectroscopy or EIS. This testing shows the overall resistance of the pseudocapacitor.

Test 2-Capacitance testing

Capacitance testing is done through a cyclic voltammetry test. This testing shows the amount of energy capable of being stored by the pseudocapacitor.

Test 3-Charge/Discharge

During the charge discharge testing we are testing the retention ability of the pseudocapacitor after repeated charges and discharges

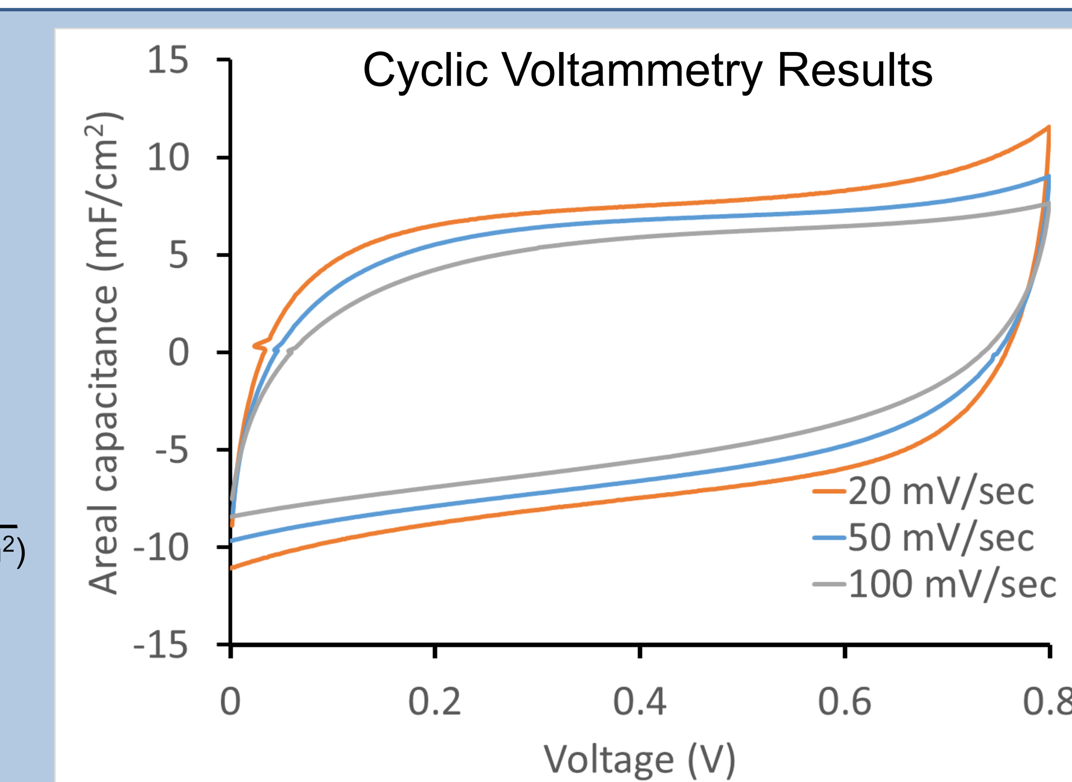
Results

Many sample cells were created and then tested in the lab. Some samples shorted not allowing testing to take place. Others the results were encouraging (Figure 5) in some areas and disappointing in others . Some cells showed promise for the current ASSIST application and some show promise for other applications.

Figure 5

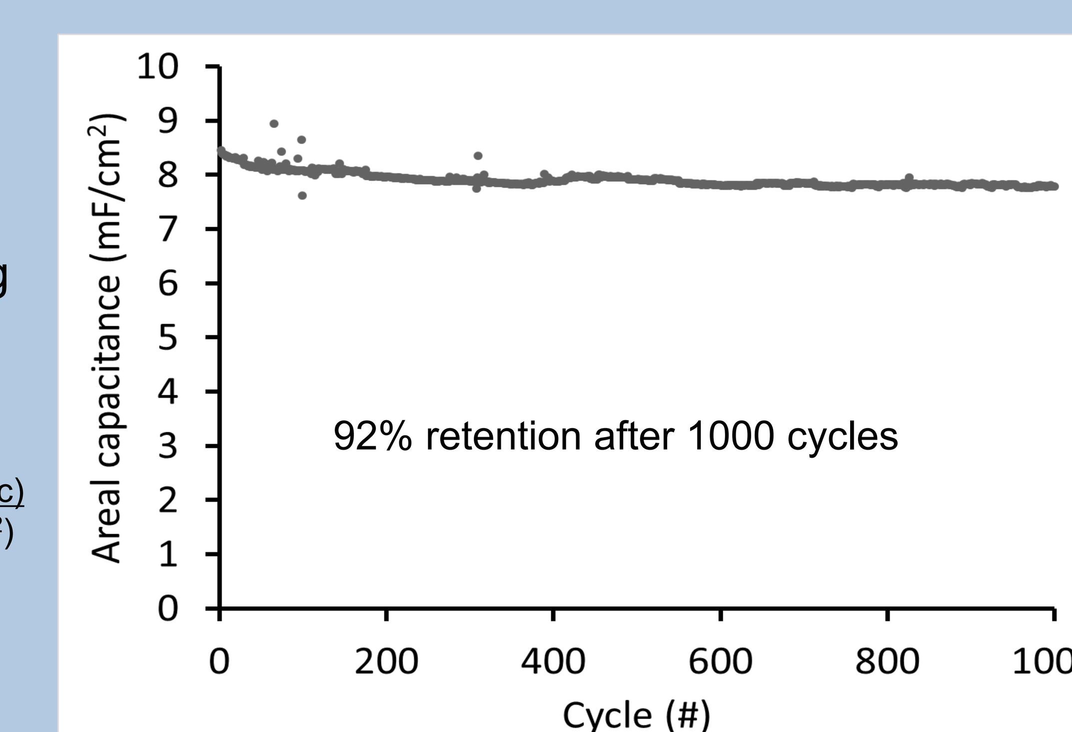
Top: CV Testing results calculated using the formula

$$C(mF/cm^2) = \frac{I\ (mA)}{V(V/s) \times A\ (cm^2)}$$



Bottom: CD testing results calculated using the formula

$$C(mF/cm^2) = \frac{I\ (mA) \times t\ (sec)}{\Delta V \times A\ (cm^2)}$$



Summary with Next Steps

At the time of this poster creation psudocapacitors have been fabricated from various materials that achieved the capacitance and longevity requirements we were looking for. The next step in the research would to begin testing the flexibility of the cell to determine if the performance is compromised when bending and manipulating the sample.

Acknowledgements

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