Assembly and Testing of Poly(3,4-Propylenedioxythiophene)-Based Electrochemical Supercapacitors

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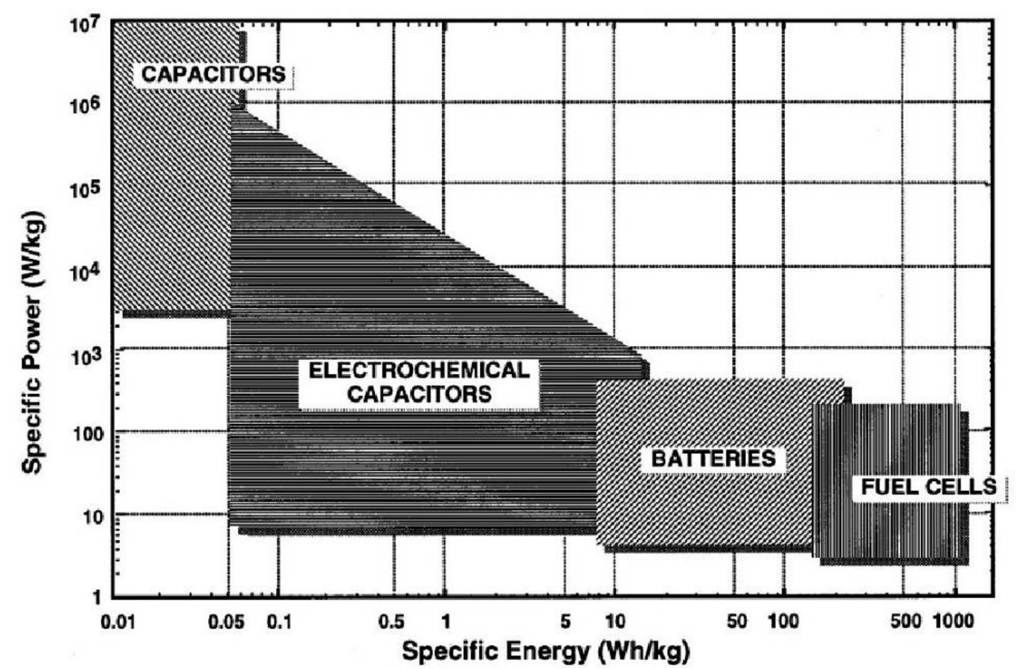
Sunfest 2007

Ragone Plot for Different Types of Power Sources



R. Kotz and M. Carlen, "Principles and applications of electrochemical capacitors". *Electrochimica Acta*, Volume 45, Issues 15-16, , 3 May 2000, 2483-2498.

- **Batteries: high energy, low power**
- **Capacitors: low energy, high power**
- **Supercapacitors**
  - **Hybrid between batteries and capacitors**
  - **Common Materials:**
    - **Metal Oxides**
      - **RuO_2**
    - **Electroactive Polymers (EAPs)**
      - **Polypyrrole**
      - **Polyaniline**

Advantages of EAPs

- **Redox processes allow their use in charge storage devices**
- **Lower cost, weight, and environmentally friendly**
- **Tailoring of properties**
  - **Voltage window**
  - **Conductivity**
  - **Stability**
  - **Morphology**

Types of EAP-Based Supercapacitors

- **Type I: same p-doping polymer for both electrodes**
- **Type II: different p-doping polymers on each electrode**
- **Type III: same material as n-doping and p-doping polymer**
- **Type IV: different polymers as the n-doping and p-doping electrodes**

Symmetric: Type I and III

Assymetric: Type II and IV

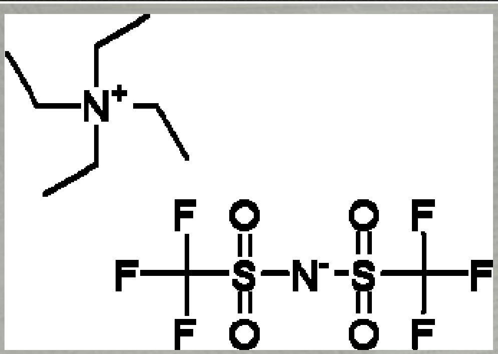
Irvin, J., Irvin, D., Stenger-Smith, J.D. Electrically Active Polymers for Use in Batteries and Supercapacitors. In Handbook of Conducting Polymers, 3rd Ed., Skotheim, T., Reynolds, J.R., Eds., Taylor & Francis, Boca Raton, FL, 2007, 9-1-9-29.

Research Objectives

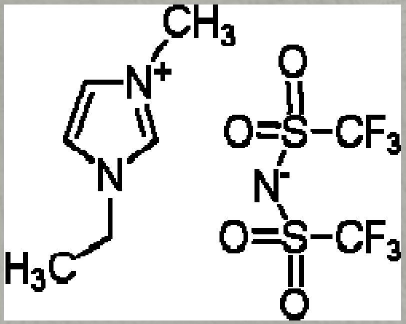
- **Evaluate Poly(3,4-propylenedioxythiophene) (PProDOT) as a material for the assembly of a Type I electrochemical supercapacitor**
  - **Stability of the polymer itself**
  - **Charge storage properties upon device assembly**
- **Compare different electrolyte solutions composed of ionic liquids and organic solvent**

Experimental Setup

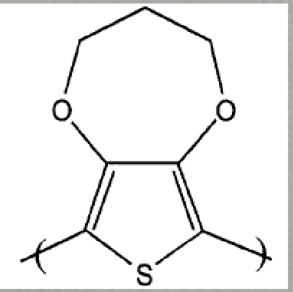
- Electrolyte solution 1
  - ProDOT: ~30 mg
  - TEA-BTI: ~150 mg
  - EMI-BTI: ~150 mg
  - Propylene carbonate (PC): 10 mL
- Electrolyte solution 2
  - ProDOT: ~30 mg
  - EMI-BTI: ~300 mg
  - PC: 10 mL
- Three-electrode system
  - Working: Pt disc (A = 0.2 cm^2)
  - Reference: Ag wire
  - Auxiliary: Pt foil strip
- Separator Paper
  - Two pieces of Scrim Cloth
- Instrument: Pine AFCBP1 bipotentiostat
- All solution preparation, assembly, and studies done inside a nitrogen-filled glovebox



TEA-BTI



EMI-BTI



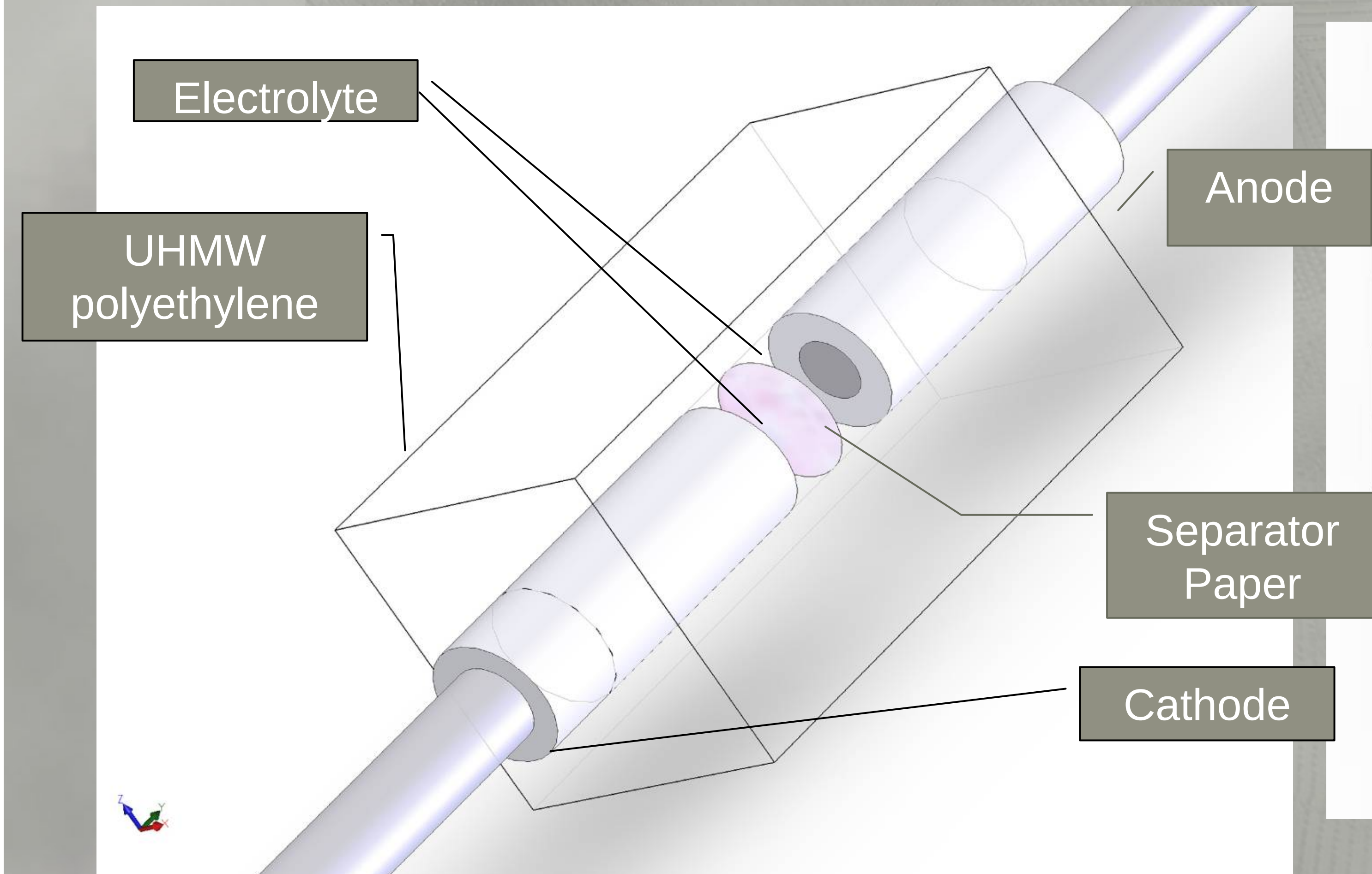
PProDOT

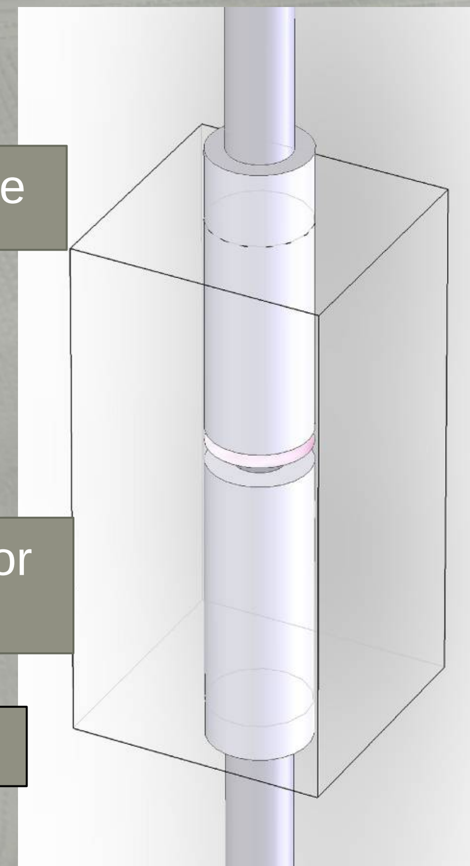
Polymer Evaluation

For a potential p-dopable material examine:

- **Reducing voltage window: cycle to increasingly positive voltages to identify the voltage at which the polymer shows signs of degradation**
- **Scan rate dependence of the current at the oxidizing voltage range**
  - **Care must be taken to ensure that the surface-immobilized film is well-adhered to the electrode**
- **Cycling the polymer film at several scan rates in monomer-free solution**
  - **Current response should be directly proportional to the scan rate**

Prototype Device Assembly

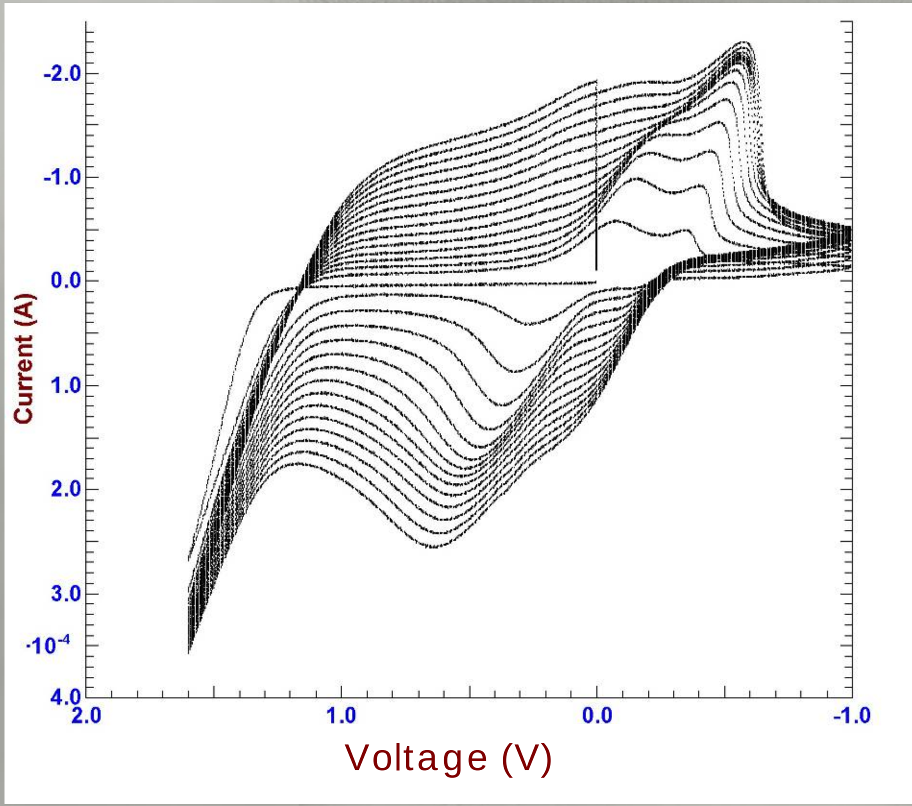




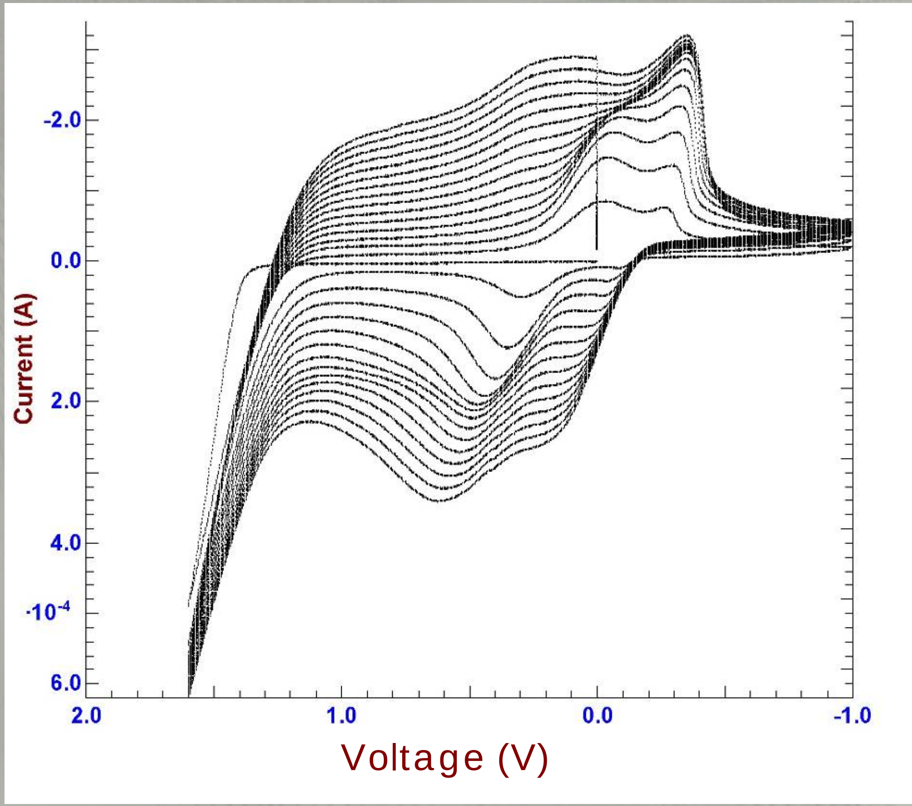
Results: Electropolymerization and Polymer Evaluation

Electropolymerization of ProDOT

PProDOT/EMIBTI/TEABTI/PC



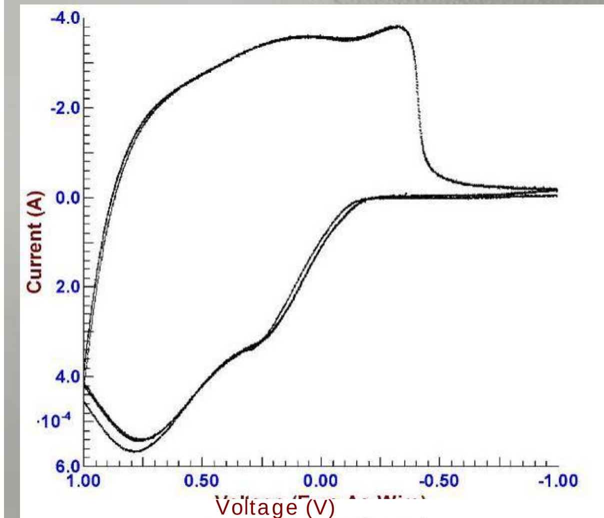
PProDOT/EMIBTI/PC



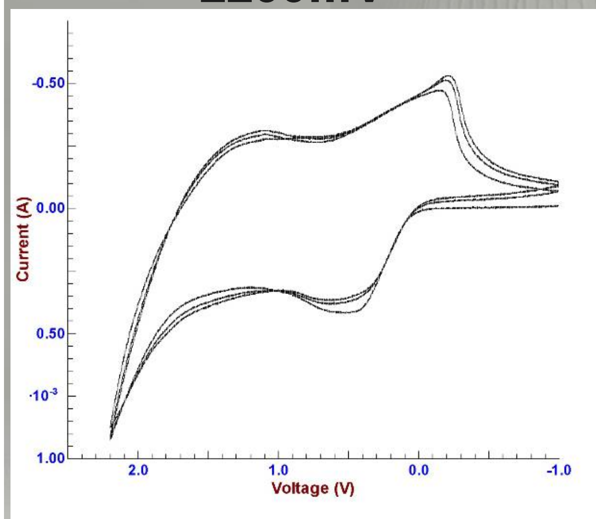
- **Voltage (E vs Ag Wire) range: -1000 to 1600 mV**
- **scan rate (υ): 100 mV/s,**
- **Number of Cycles: 15**

Oxidizing Voltage Limit Test

1000mV



2200mV

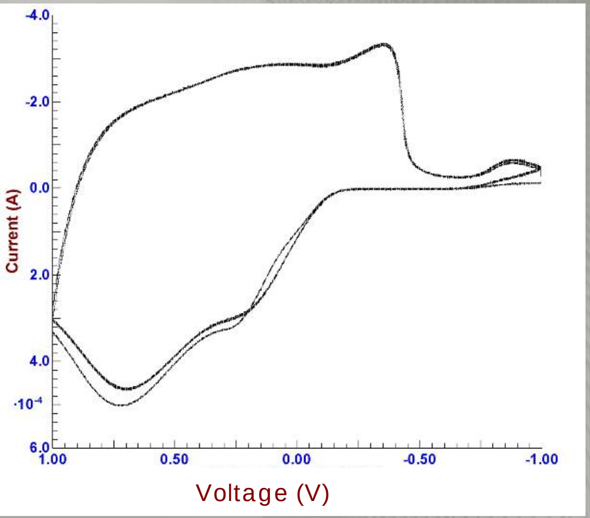


PProDOT/EMIBTI/TEABTI/PC

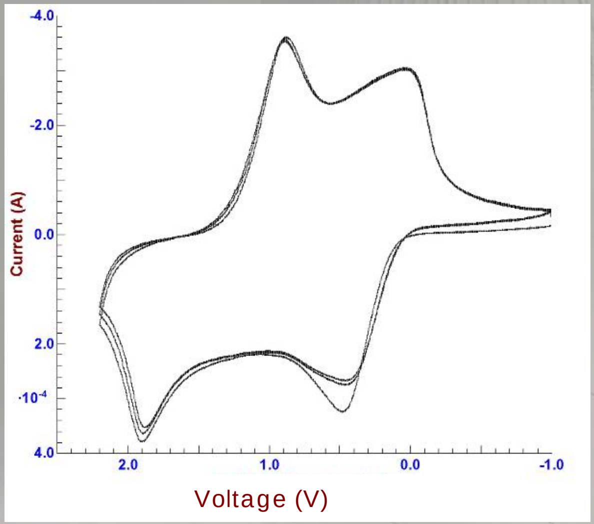
E limit (mV)	Cathodic charge (mC)	Anodic charge (mC)	Coulombic efficiency (%)
900	3.720	3.739	99.49
1000	4.134	4.158	99.42
1100	4.427	4.457	99.33
1200	4.706	4.748	99.12
1300	4.969	5.017	99.04
1400	5.23	5.305	98.59
1500	5.486	5.588	98.17
1600	5.750	5.908	97.33
1700	6.044	6.287	96.13
1800	6.270	6.676	93.92
1900	6.268	7.080	88.53
2000	6.421	7.398	86.79
2200	7.969	10.13	78.67
2400	6.713	8.281	81.07

Oxidizing Voltage Limit Test

1000mV



2200mV

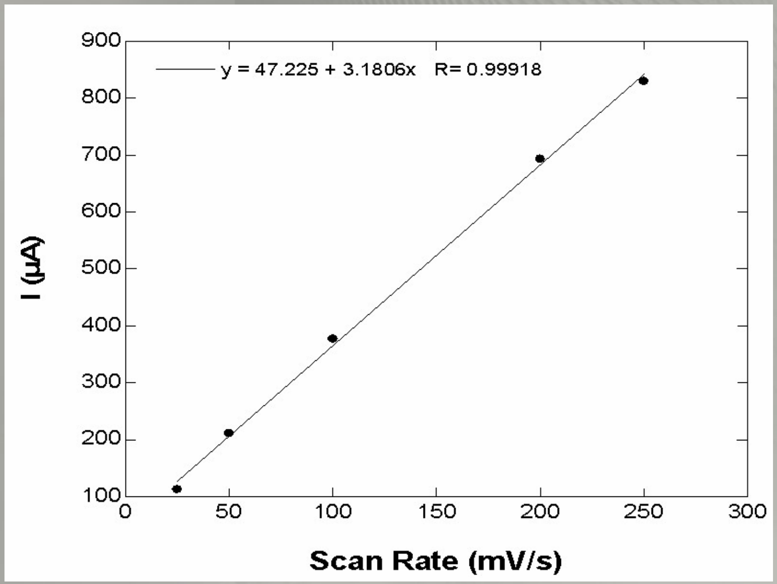


PProDOT/EMIBTI/PC

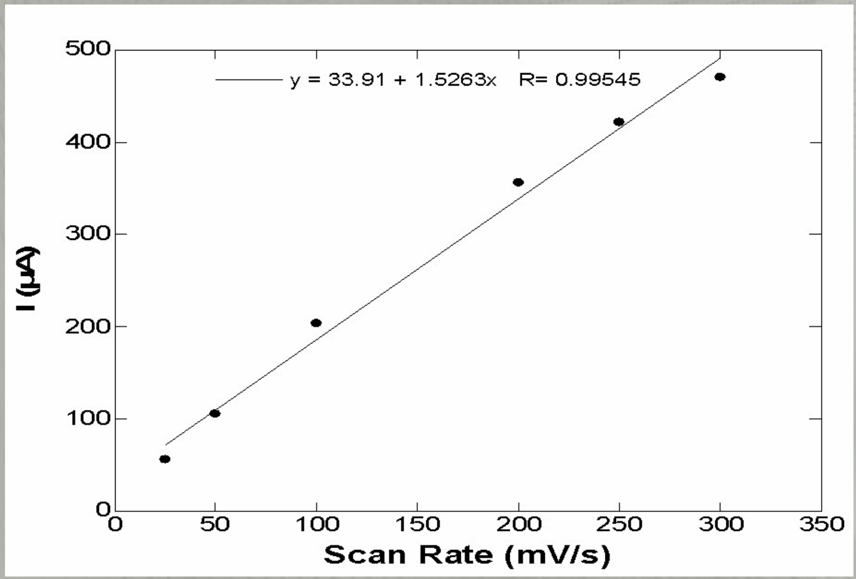
E limit (mV)	Cathodic Charge (mC)	Anodic Charge (mC)	Coulombic Efficiency (%)
900	3.357	3.342	99.55
1000	3.582	3.575	99.80
1100	3.764	3.767	99.92
1200	3.949	3.944	99.87
1300	4.100	4.101	99.98
1400	4.239	4.246	99.84
1500	4.380	4.391	99.75
1600	4.483	4.504	99.53
1700	4.027	4.082	98.65
1800	4.163	4.282	97.22
1900	4.478	4.735	94.57
2000	4.803	5.172	92.87
2100	4.787	5.133	93.26
2200	4.547	4.868	93.41
2300	4.274	4.544	94.06
2400	4.018	4.325	92.90

Scan Rate Test

PProDOT/EMIBTI/TEABTI/PC



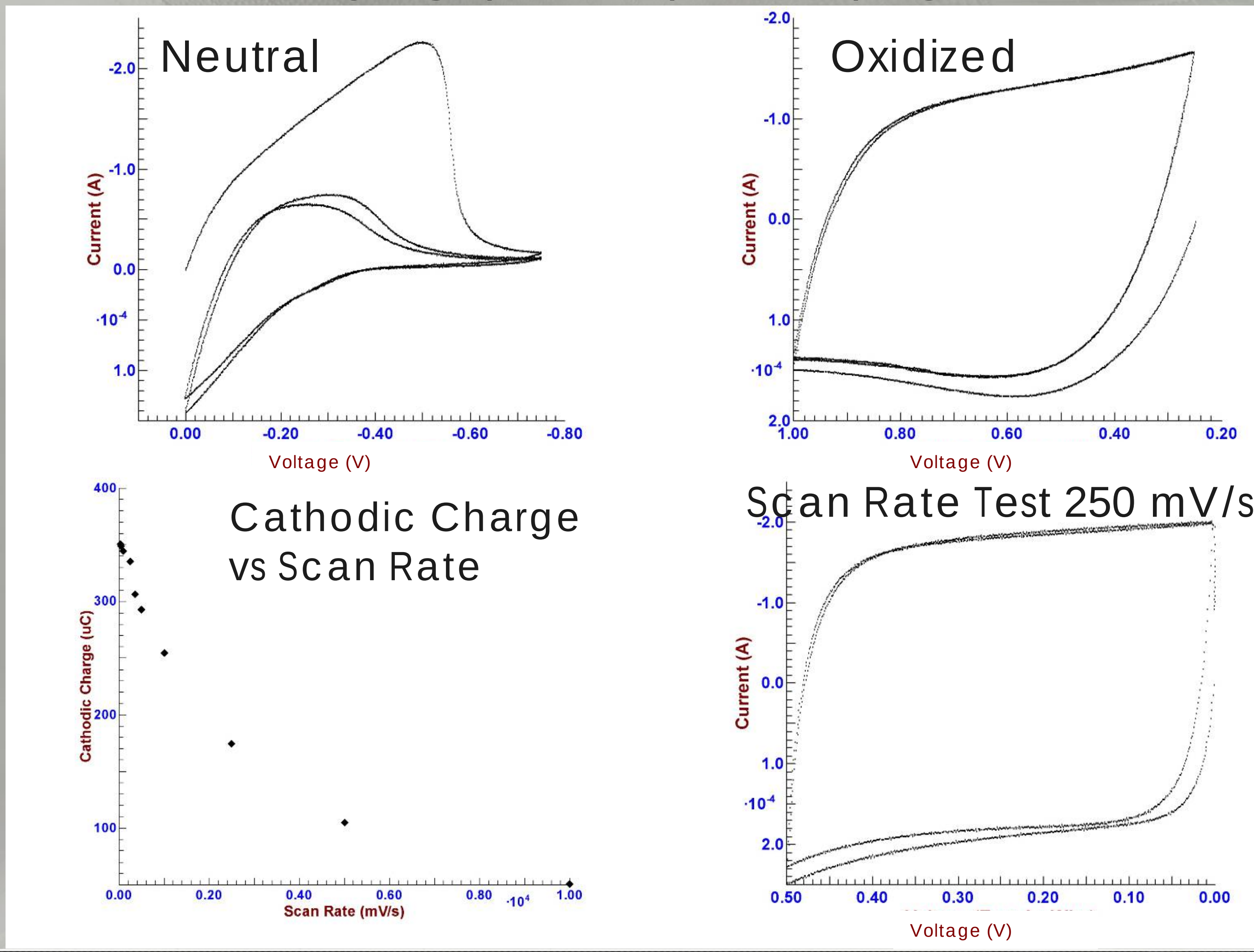
PProDOT/EMIBTI/PC



Results: Device Assembly and Characterization

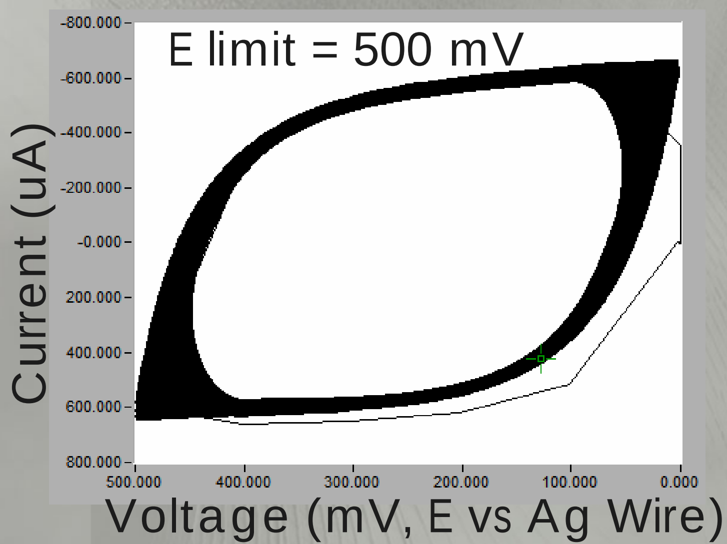
Device Scan Rate Test

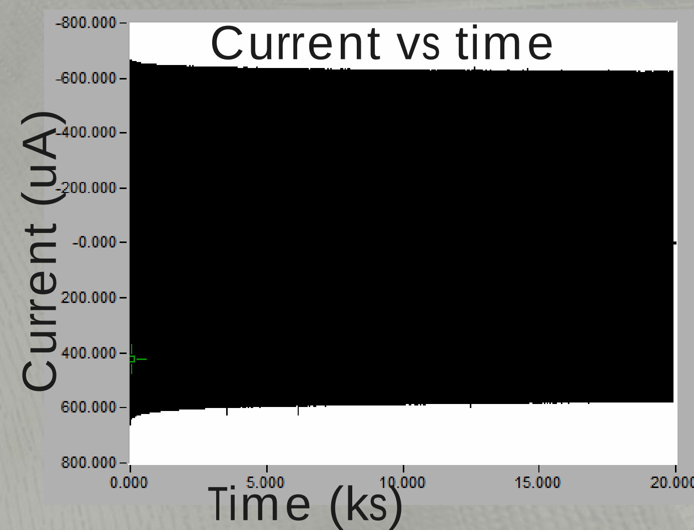
PProDOT/EMIBTI/TEABTI/PC

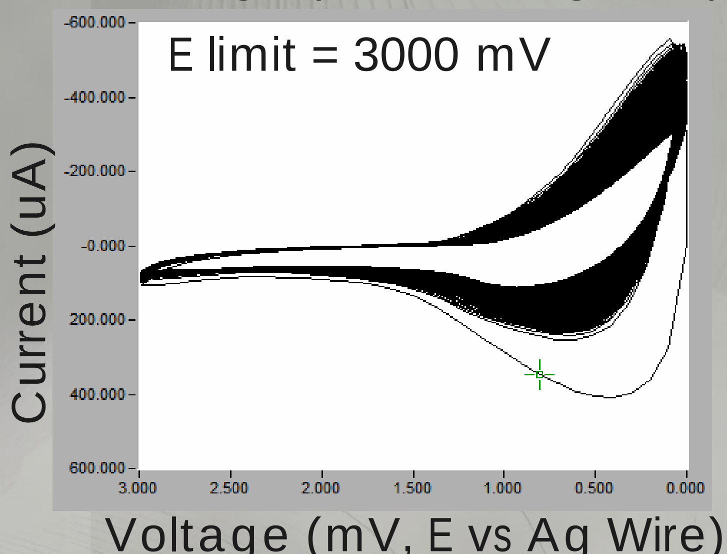


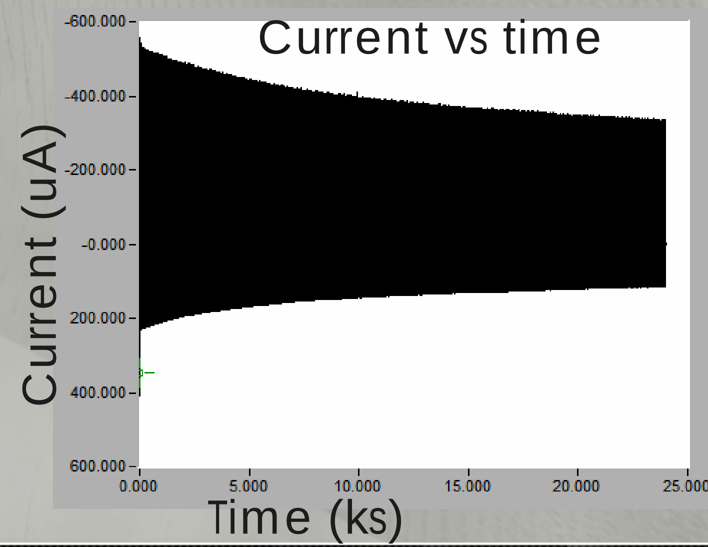
Device Testing

PProDOT/EMIBTI/TEABTI/PC









Continuing Work

- **Assemble and test a supercapacitor using Poly(3,4-ethylendioxythiophene)**
- **Test hybrid materials by adding carbon nanotubes (CNTs)**
  - **Perform morphological characterization**
- **Test other potential n-dopable and p-dopable materials synthesized in the laboratory**

Acknowledgments

- **Dr. Jorge Santiago**
- **Dr. Michael Therien**
- **Dr. Mariem Rosario-Canales**
- **Dr. Jan Van der Spiegel**
- **National Science Foundation**