Electrospun Nanofiber Bipolar Membranes

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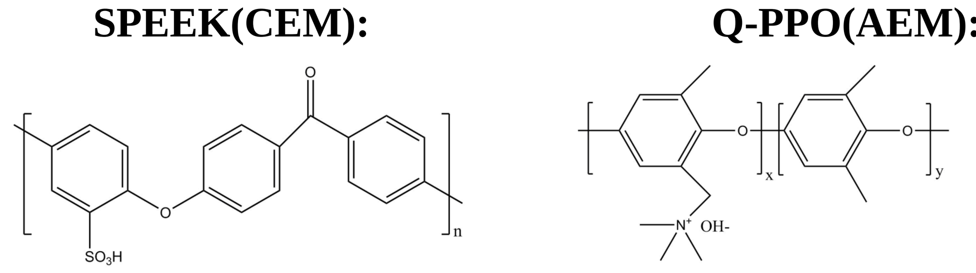
Introduction

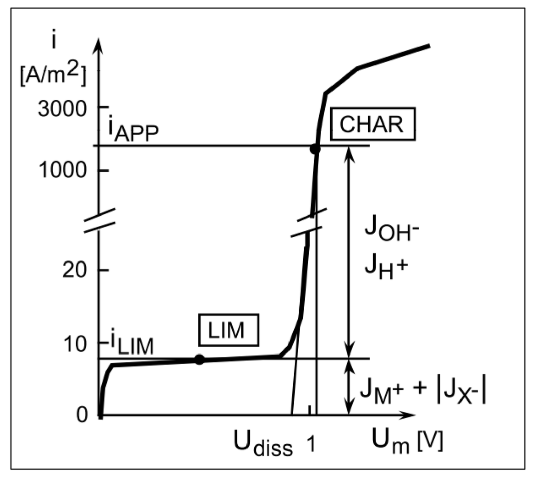
Background

Bipolar membranes (BPMs) consist of cation exchange and anion exchange membranes stacked together to form a bipolar junction. They are commonly utilized in commodity chemical production and water purification. BPMs enable water splitting into protons and hydroxide ions without the evolution of hydrogen and oxygen gas. Thus water splitting can theoretically occur at 0.83V in a BPM, significantly lower than 1.23V required in standard electrolysis. Previous studies have found the morphology and composition of the bipolar junction to be a key determinant of BPM performance.

SPEEK(CEM): **Q-PPO(AEM):**

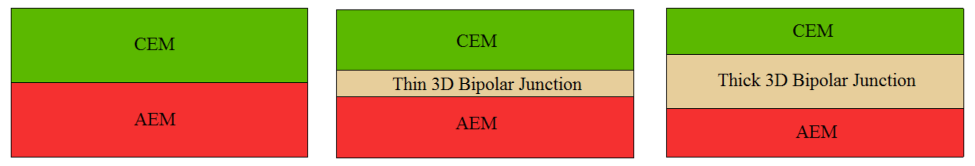


Theoretical IV Curve



Wilhelm,et al.(2001)

3D Bipolar Junction:



Objectives

- Fabricate selective, conductive, and stable ionomer layers
- Characterize electrospun bipolar membranes with novel 3D Bipolar Junctions

Methods

Ionomer nanofiber mats were collected using electrospinning. The mats were densified into membranes via solvent exposure and hot pressing. Bipolar membranes were tested in an electrodialysis cell.

Figure 1:Bipolar Membrane Fabrication Process

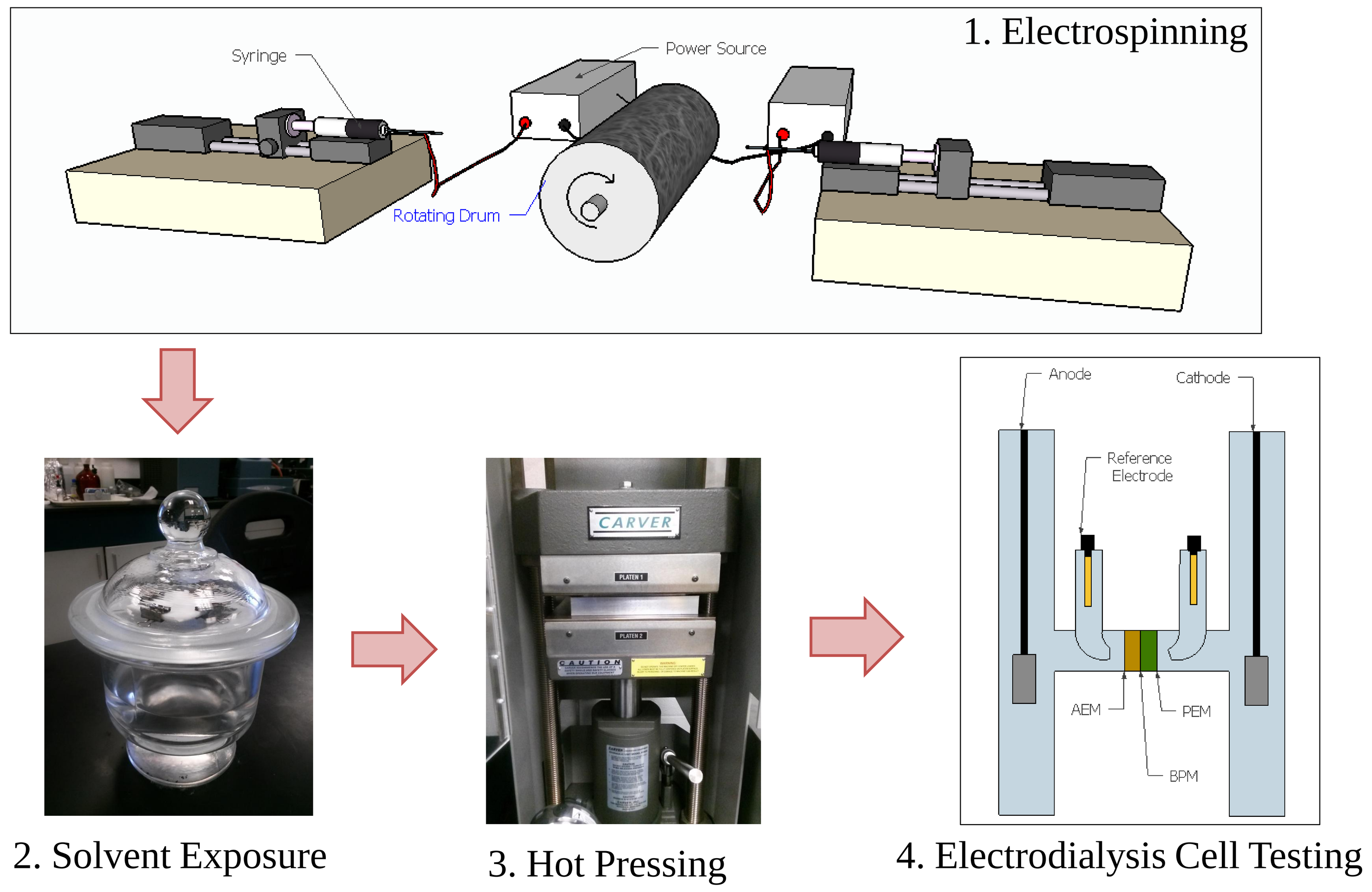


Table 1: Electrospinning Conditions

Ionomer	Solution	Tip Distance (cm)	Relative Humidity	Flow rate (ml/hr)	Applied Voltage(kV)
SPEEK	20 wt% in DMAc	7.5	50%	0.20	12
Q-PPO	23 wt % in 8:2 DMF-THF	8.0	45%	0.15	14

Membrane Characterization

Table 2: Membrane Properties

Membrane	Conductivity(S/cm)	Gravimetric Swelling in Water
SPEEK	0.046	33%
Q-PPO	0.022	54%

Figure 3: Macroscopic View and SEM of Mats and Membranes

SEM verified that nanofibers had a diameter of 250-300 nm. Densification methods were successful in pore closure.

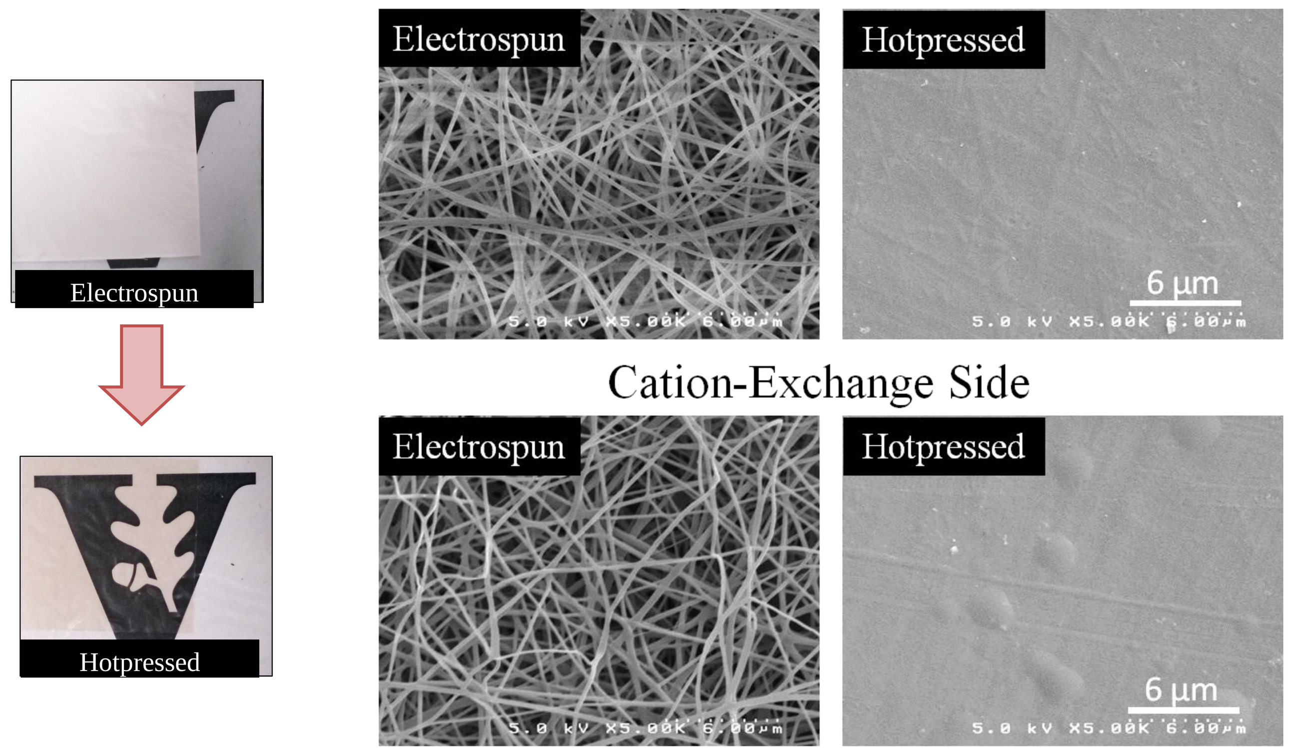
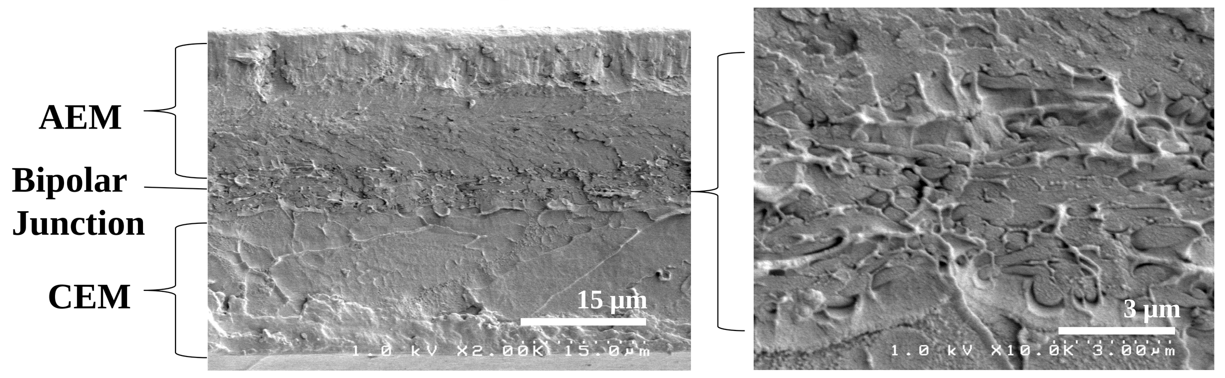


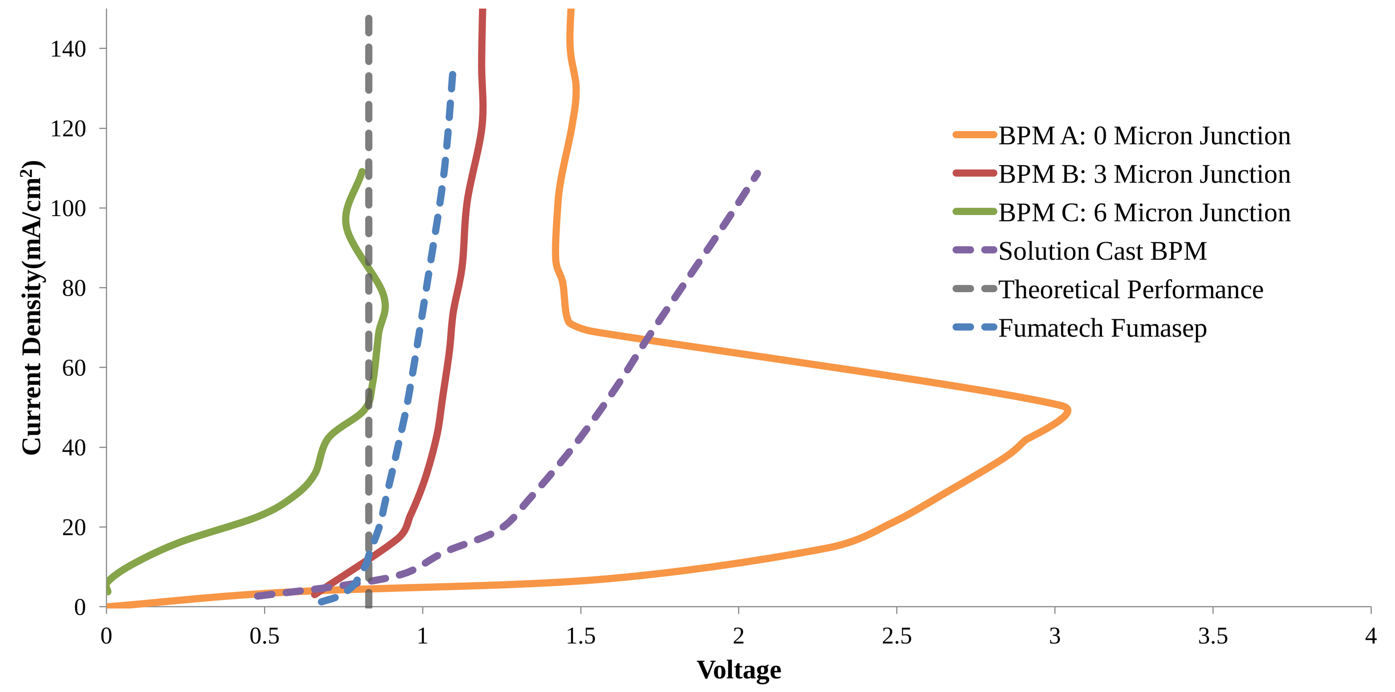
Figure 4: SEM of Cross Section of Bipolar Membrane



- Cross section analysis via SEM confirmed the presence of a 3D Junction

3D Bipolar Junction Optimization

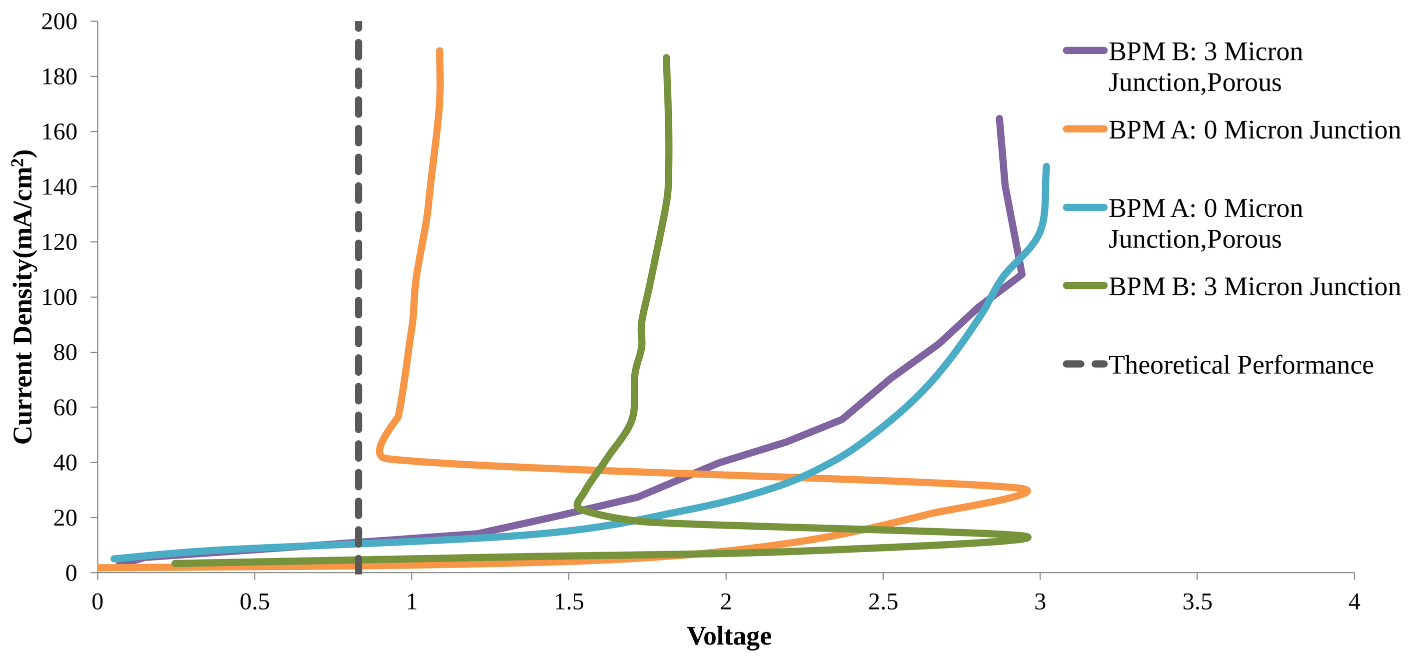
Figure 4:Current-Voltage Curves of BPMs with Different Junction Thickness



- The introduction of the 3D Bipolar Junction lowered the voltage drop across the membrane.
- The lower limiting current was greatest for BPM C

Junction Self Repair

Figure 5: Junction Self Repair and Performance of Imperfectly Densified BPMs



- Junction Self Repair: Voltage drop was lowered above threshold current densities
- Porous membranes exhibited greater voltage drops

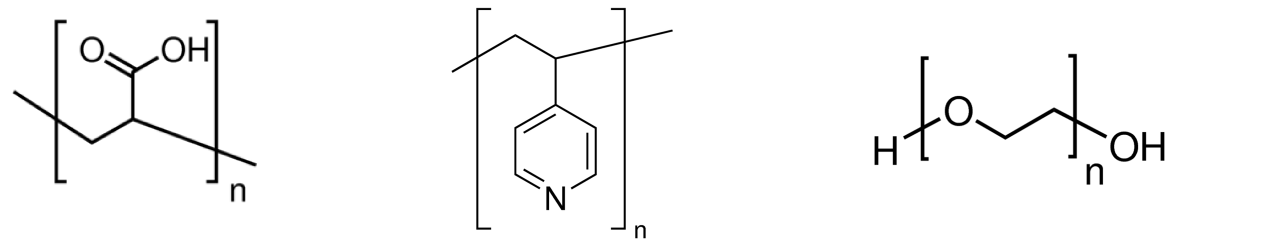
Conclusions

- **Use of a 3D Junction significantly improves bipolar membrane performance**
- Electrospinning conditions produced uniform and smooth nanofibers
- Thin ionomers layers(<10 microns) or porous membranes had significant co-ion leakage
- **Junction Thickness**: Low relative thickness resulted in an increased voltage drop. High relative thickness resulted in a loss of selectivity.

Future Work

- Optimize ionomer IEC/swelling, fiber diameter, and thickness/composition of the junction
- Introduce the following catalysts to improve the kinetics of water splitting

Poly(acrylic acid) **Poly(4-vinylpyridine)**: **Poly(ethylene oxide)**



- Focus on 3D Bipolar Junction effects on the upper limiting current
- Quantify effective junction thickness via EIS and water splitting potential via chronopotentiometry

Acknowledgements

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Figure 1: Step 1 is courtesy of Ethan Self and Emily McRen

References

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