

Hydrogen and Fuel Cells Program
2019 Annual Merit Review and Peer Evaluation Meeting
Washington, DC – April 30, 2019

Viability Study for Bipolar Membrane Electrode Assembly (BPMEA) Water Splitting

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Project ID: p180

Overview

Timeline

- **Project Start date:** October 1, 2018
- **End date:** Jun 30, 2019

Budget

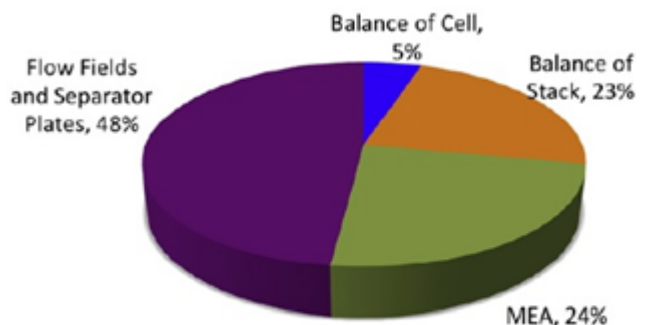
- **FY19 funding:** \$ 50k
 - Total Recipient Share: \$0k
 - Total Federal share: \$ 50k

Barriers

- **F. Cost**
 - **Expensive materials:** Platinized titanium flow filed and PGM-free catalysts for PEM electrolyzer anode
 - **Efficiency:** (i) Slow acidic OER and alkaline HER for the acidic and alkaline water electrolysis, respectively; (ii) High overpotential for PEM and AEM electrolyzers
 - **Durability:** Slow acidic OER and alkaline HER accelerating electrolyzer degradation

Relevance

Objectives: This is a viability study of bipolar membrane electrode assembly (BPMEA) water splitting system by integrating polyaromatic anion exchange membrane(AEM), Nafion® proton exchange membrane (PEM), water dissociation (WD) catalyst, and electric field intensifying materials (EFIM) to ultimately reach the DOE-established hydrogen production cost target of < \$2.30/gge from water electrolysis

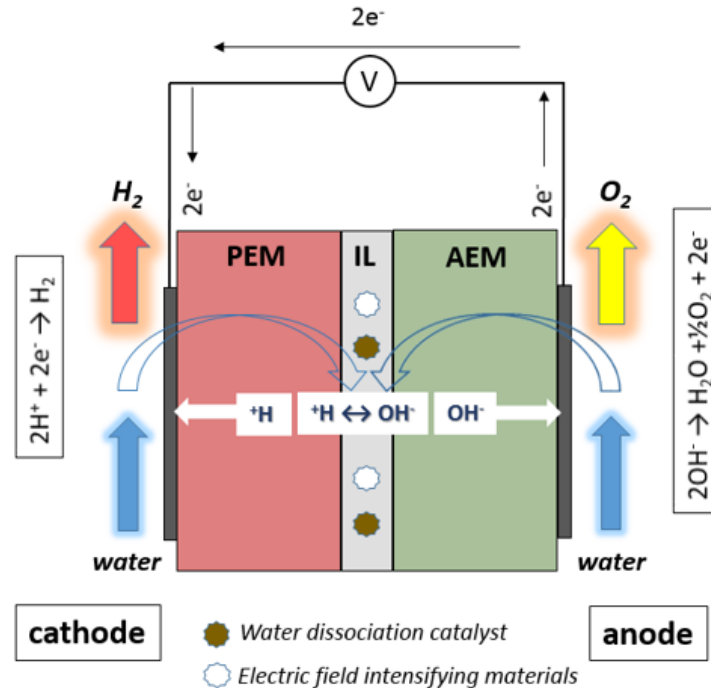


PEM electrolyzer stack cost breakdown

Carmo *et al.*, "A comprehensive review of PEM water electrolysis" *Int. J. Hydro. Energy* **38**, 4901 (2013)

Barrier	Impacts of BPMEA
Expensive platinized titanium flow fields for PEM anode	Stainless flow fields can replace platinized titanium flow fields for PEM anode
Expensive IrO ₂ OER catalyst	PGM-free catalyst can replace IrO ₂ catalyst for PEM anode
Low efficiency	Slow acidic OER and alkaline HER can be eliminated, which will increase kinetics of OER/HER as well as overpotential
Durability	Using only fast acidic HER and alkaline OER will lead to improvement of durability

Approach: BPMEA Water Electrolyzer Working Principle and Benefits

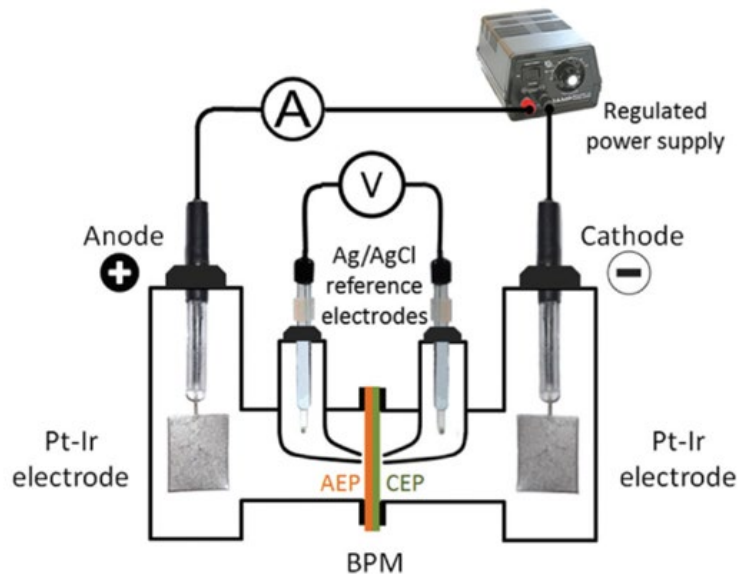


In BPMs, water molecules residing at the interface layer (IL) of PEM and AEM become polarized by a very large electric field ($\sim 10^8 \text{ V m}^{-1}$) and dissociate into proton (H^+) and hydroxide ion (OH^-). Then the H^+ migrates toward the cathode *via* PEM and the OH^- toward the anode *via* AEM. At the cathode, hydrogen evolution reaction (HER), $2H^+ + 2e^- \rightarrow H_2$, takes place in acidic condition, while at the anode in alkaline condition, oxygen evolution reaction (OER), $2OH^- \rightarrow H_2O + \frac{1}{2}O_2 + 2e^-$, occurs. Slow alkaline HER and acidic OER, the bottleneck for the alkaline and acidic water electrolysis, respectively, can be eliminated. Furthermore, compared with single membrane water electrolysis, the OH^- and H^+ , produced by WD at BPM, can be more readily oxidized and reduced than water molecule at the anode and cathode respectively. This will largely decrease the over-potentials in water electrolysis, and thus will endow potential for advanced water splitting technology.

Approach: BPMEA Water Electrolyzer Device Test

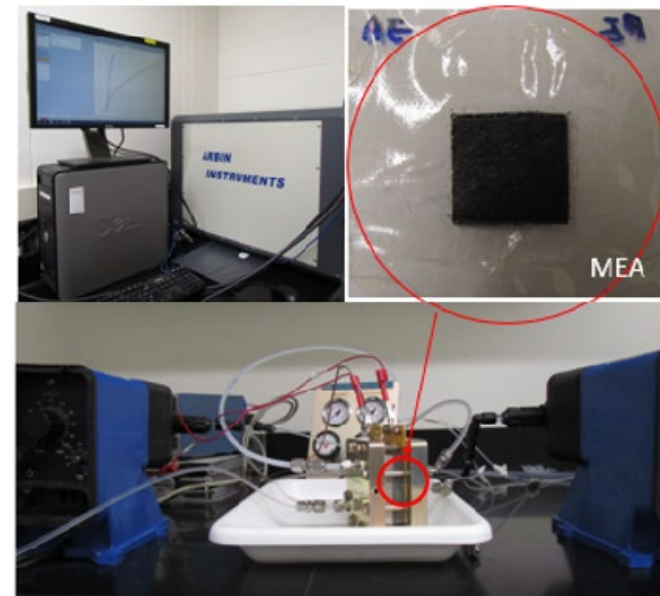
Bipolar membrane water electrolysis has been demonstrated only in an electrochemical cell, but not in the water (no added salts or acid/alkaline solutions) flowing bipolar membrane electrode assembly (BPMEA)

A typical electrochemical cell



Shen *et al.*, *Energy Environ Sci.*, **10**, 1435 (2017)

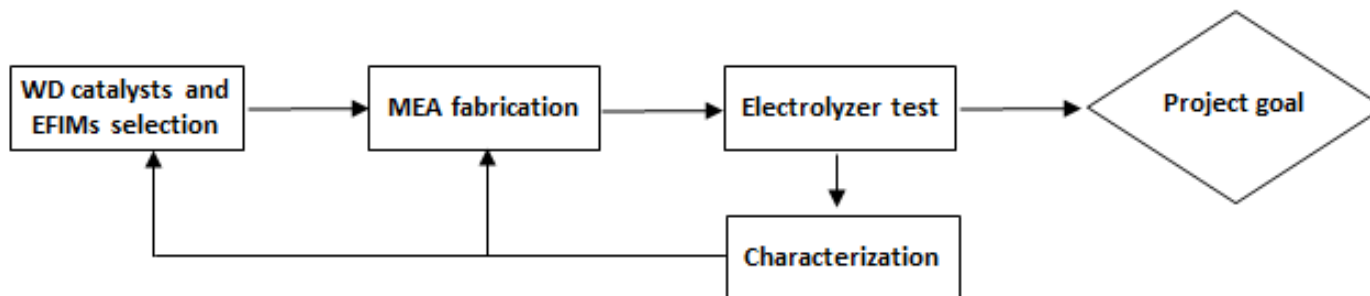
BPMEA water electrolyzer system in this project



This is the first BPMEA water electrolysis test in device level

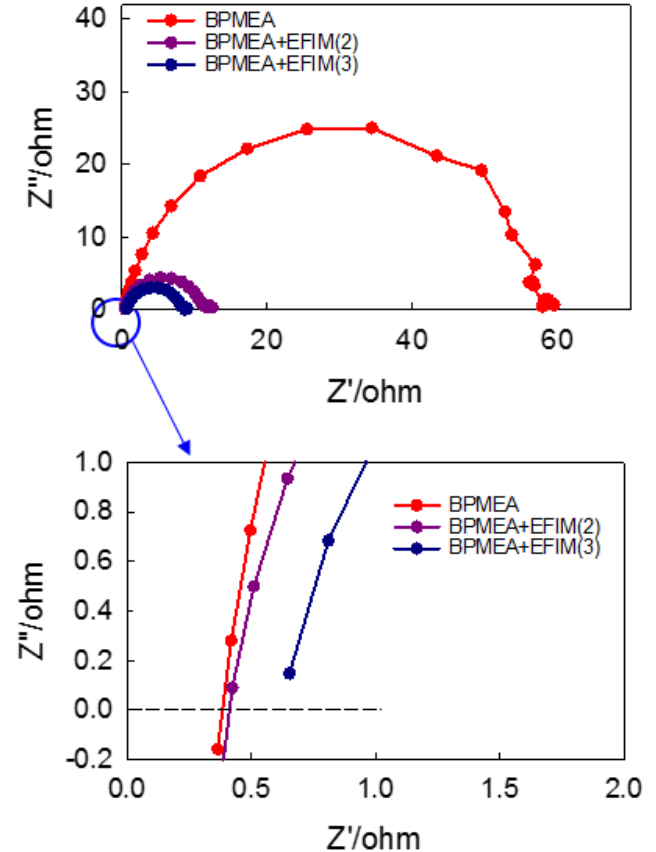
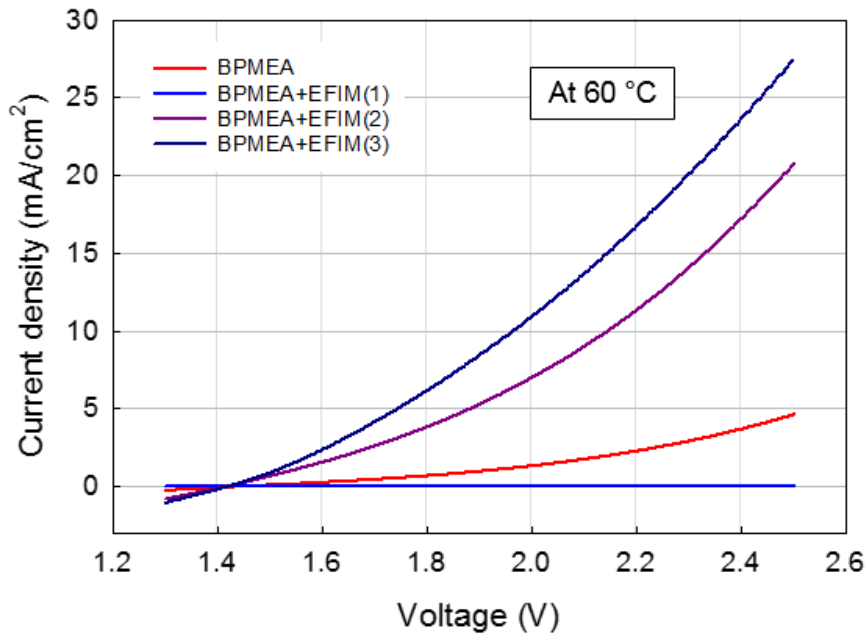
Approach: Research Plan

Focus: A key in BPMEA water electrolysis is to boost the water dissociation (WD) efficiency at the interface layer (IL): WS catalysts and electric field intensifying materials (EFIMs) are tested to improve the efficiency



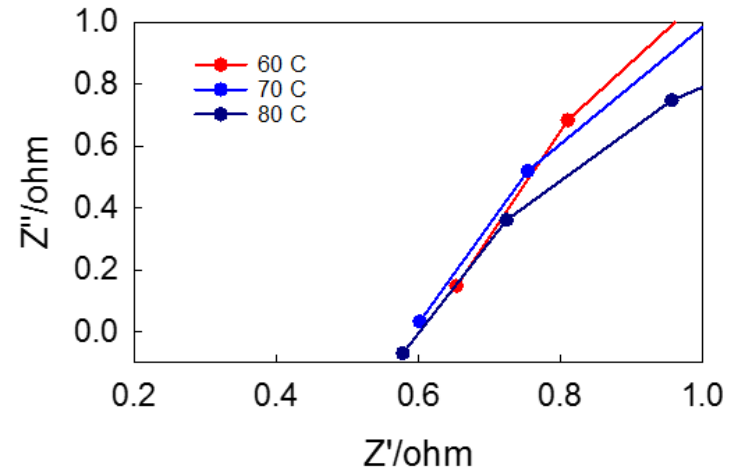
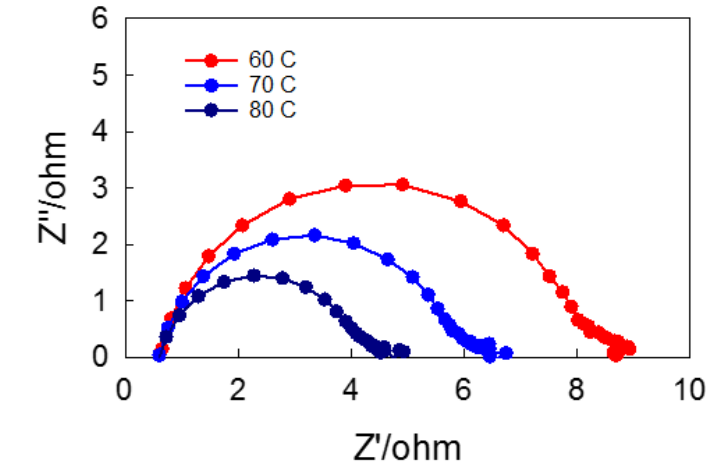
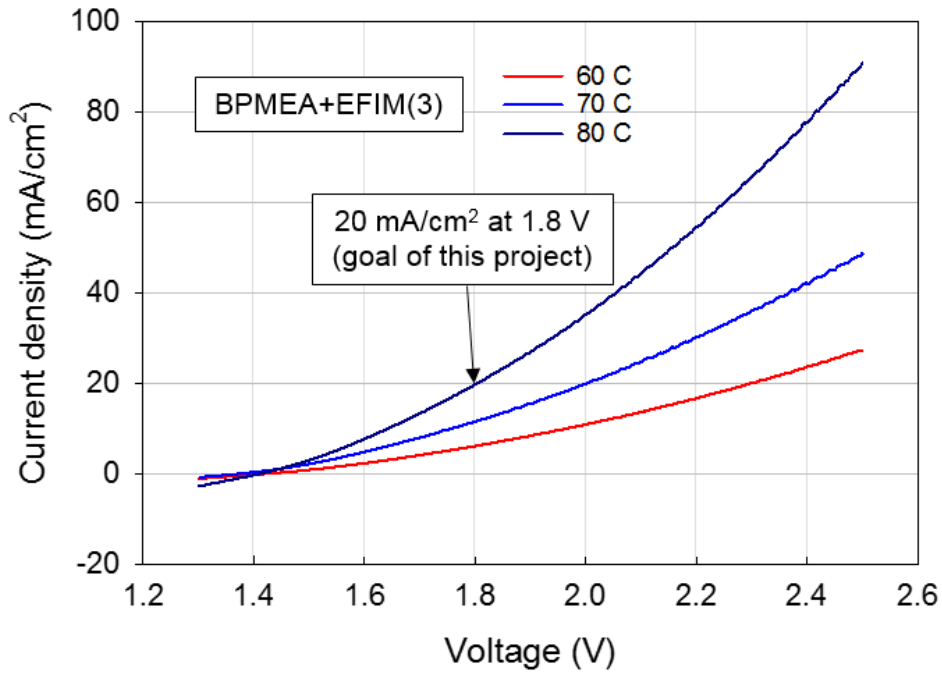
Milestone Summary Table		
Date	Quaternary Progress Measure	Status
December 2018 (FY19 Q1)	Optimize EFIM catalyst deposition technique and BPMEA water electrolysis test	Completed
March 2019 (FY19 Q2)	Optimize WD catalyst deposition technique and BPMEA water electrolysis test	On track
June 2019 (FY19 Q3)	Combine the optimized WD catalyst and EFIMs in BPMEA fabrication to demonstrate 5 times improvement of current density (20 mA/cm ²) at 1.8 V compared with current status, 4 mA/cm ² .	On track (Performance target achieved and further improvement underway)

Accomplishments: Three Types of EFIMs Tested



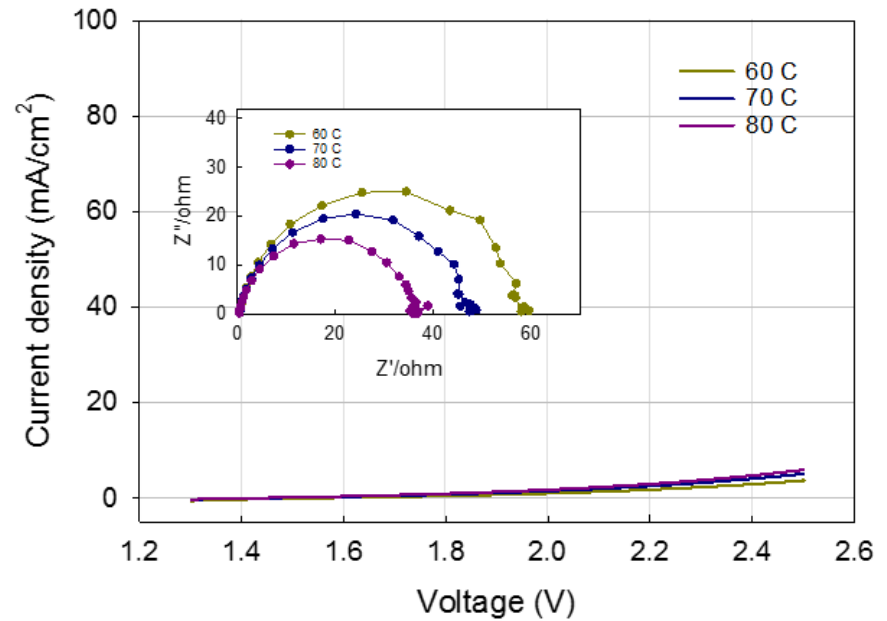
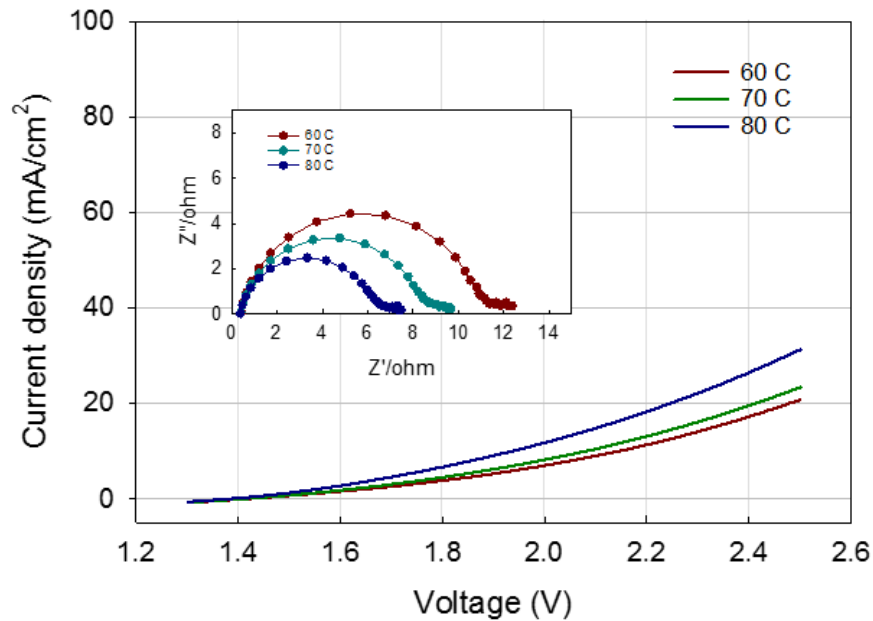
- Water-feeding (no acid/alkaline solutions) BPMEA device demonstrated successfully
- EFIMs (2) and (3) significantly decrease the charge transfer resistance, leading to a big performance improvement
- Membrane resistance (~ 0.4 ohm) is more than 4 times higher than that of AEM \rightarrow resistance decrease needed

Accomplishments: Temperature Effect



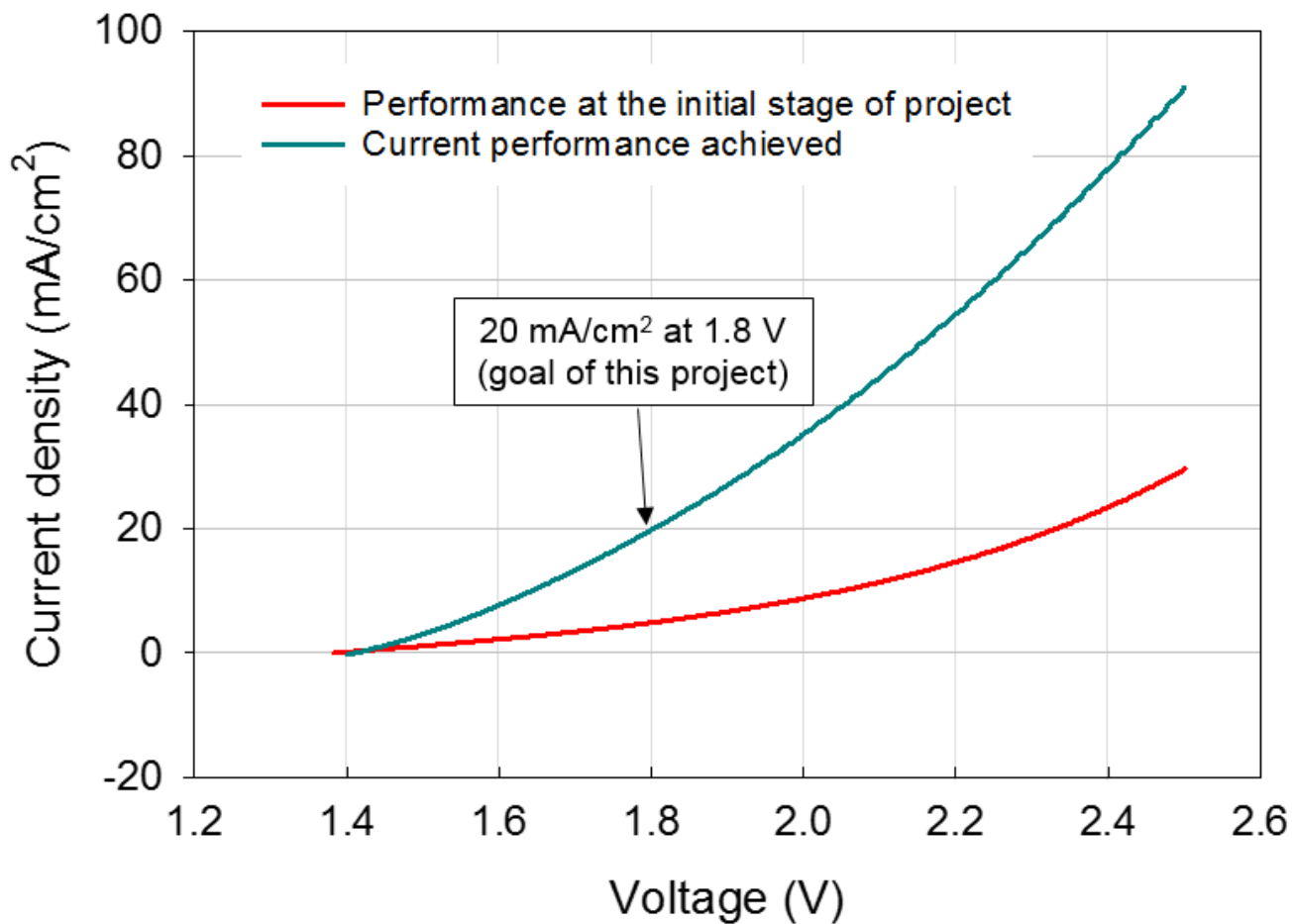
- Significant temperature effect on performance observed with EFIM(3)
- The project goal of 20 mA/cm² at 1.8 V achieved

Accomplishments: Temperature Effect



The temperature effect insignificant with low performance MPMEAs

Progress: A Big Performance Improvement



A big progress in performance achieved

Collaborations

- **No-cost collaborator:**
 - ✓ Sandia National Laboratory, Albuquerque, NM – AEM membranes and ionomers

Future Work and Summary

- **Future work**
 - ✓ WD catalyst application to interface layer (IL);
 - ✓ Adjust the ratio of EFIM and WD catalyst to achieve optimized BPMEA water electrolysis performance;
- **Summary**
 - ✓ A viability of water-feeding (no acid/alkaline solution) BPMEA electrolyzer successfully demonstrated;
 - ✓ The project goal achieved and further improvement of performance underway;