Hydrogen and Fuel Cells Program
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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

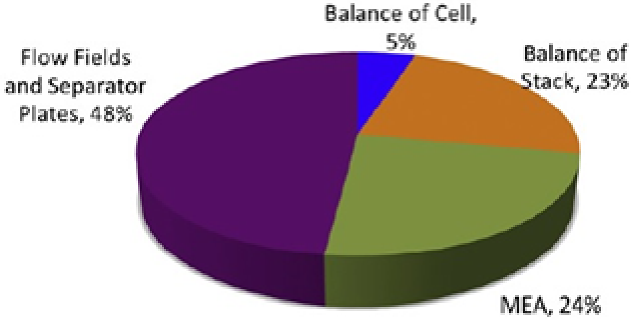
- **FY19 funding:** $ 50k
  - Total Recipient Share: $0k
  - Total Federal share: $ 50k

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

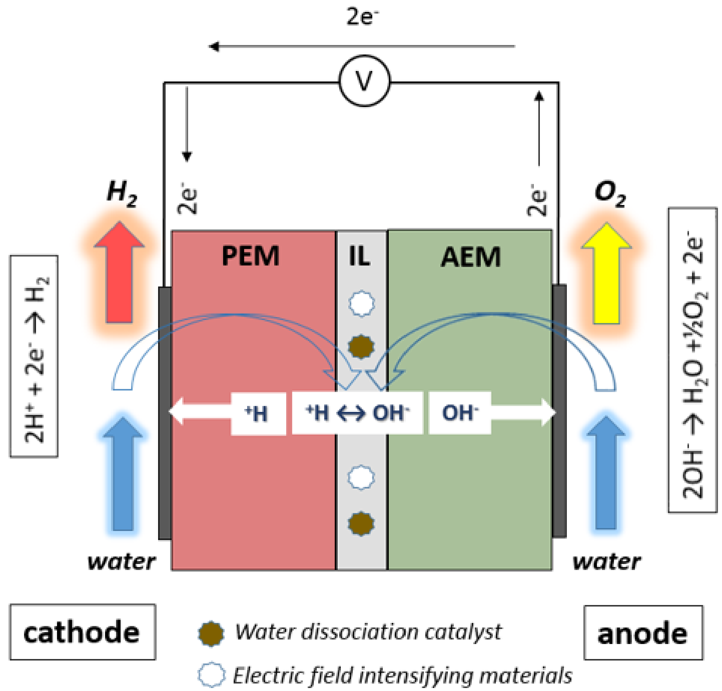


PEM electrolyzer stack cost breakdown

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

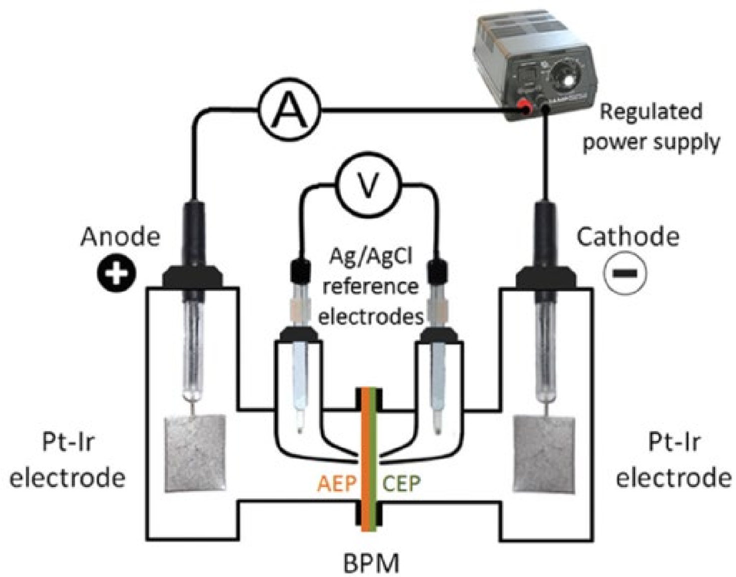


In BPMs, water molecules residing at the interface layer (IL) of PEM and AEM become polarized by a very large electric field (~ 10^8 V m^{-1}) and dissociate into proton (H^+) and hydroxide ion (OH^-). Then the H^+ migrates toward the cathode *via* PEM and the OH^- toward the anode *via* AEM. At the 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), $2OH^- \rightarrow H_2O + ½O_2 + 2e^-$, 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

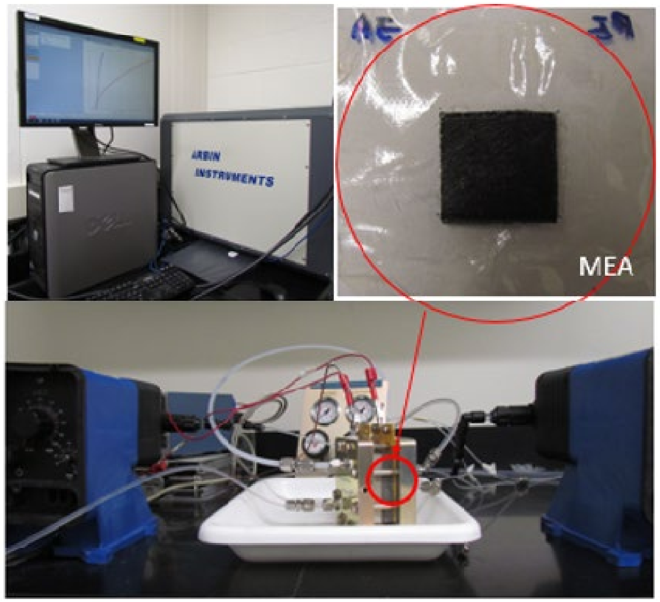
Bipolar membrane water electrolysis has been demonstrated only in an electrochemical cell, but not in the water (no added salts or acid/alkaline solutions) flowing bipolar membrane electrode assembly (BPMEA)

A typical electrochemical cell



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

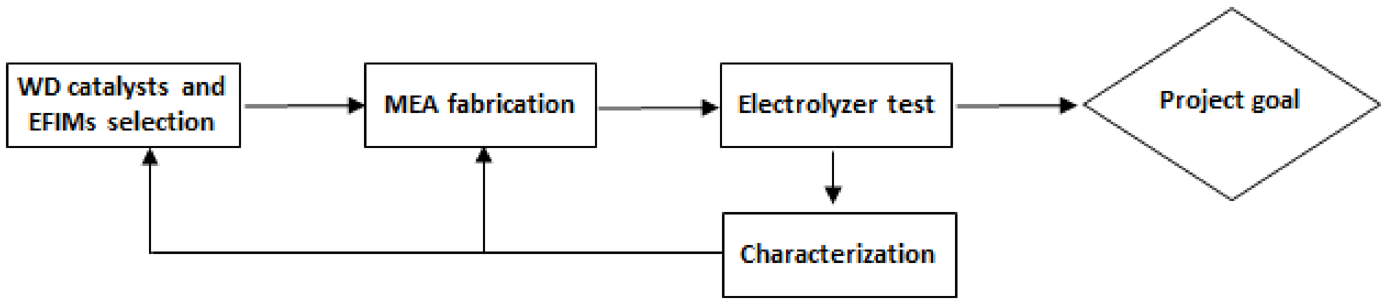
BPMEA water electrolyzer system in this project



This is the first BPMEA water electrolysis test in device level

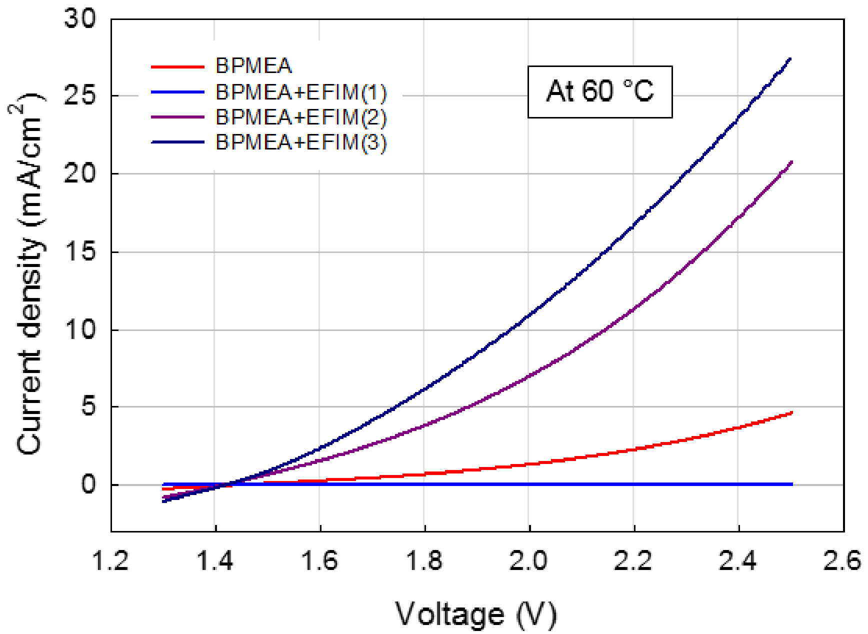
Approach: Research Plan

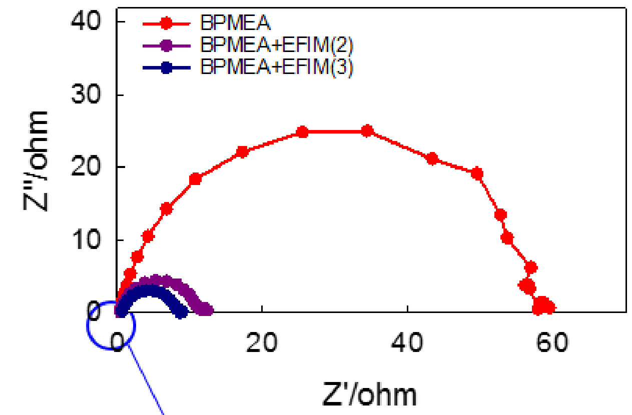
Focus: A key in BPMEA water electrolysis is to boost the water dissociation (WD) efficiency at the interface layer (IL): WS catalysts and electric field intensifying materials (EFIMs) are tested to improve the efficiency

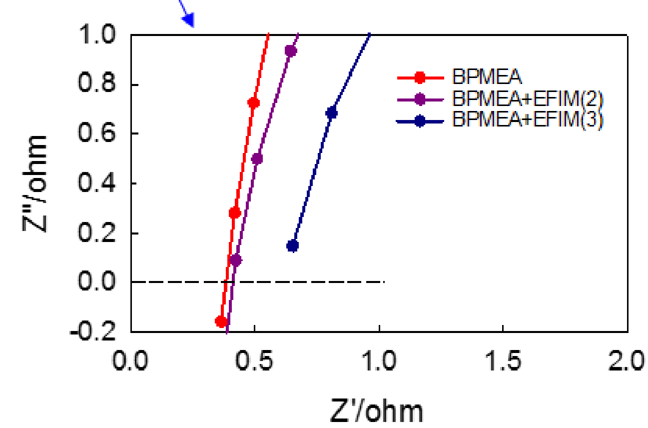


Milestone Summary Table		
Date	**Quaternary Progress Measure**	**Status**
December 2018 (FY19 Q1)	Optimize EFIM catalyst deposition technique and BPMEA water electrolysis test	**Completed**
March 2019 (FY19 Q2)	Optimize WD catalyst deposition technique and BPMEA water electrolysis test	**On track**
June 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

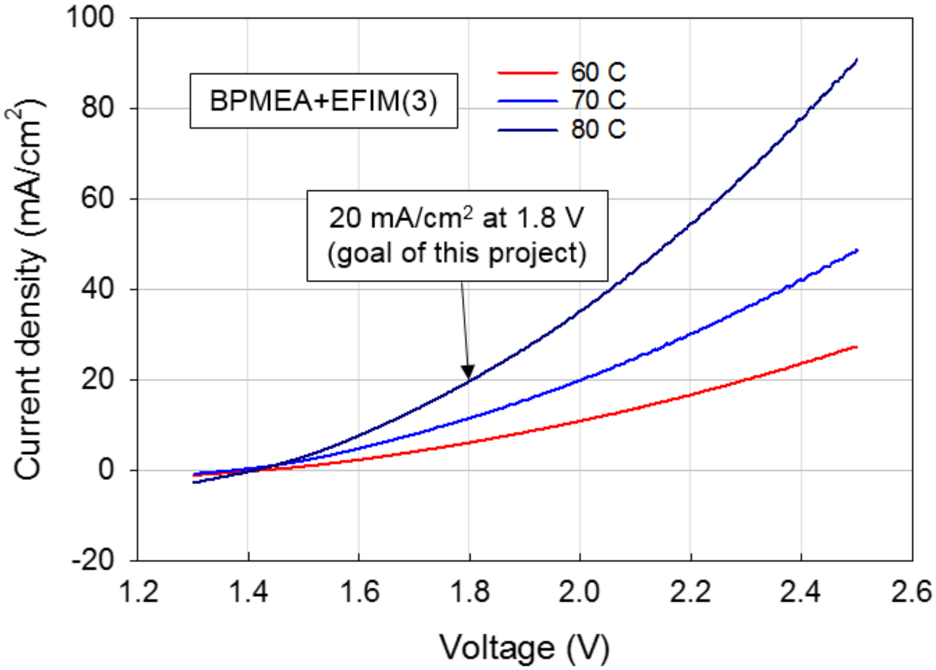


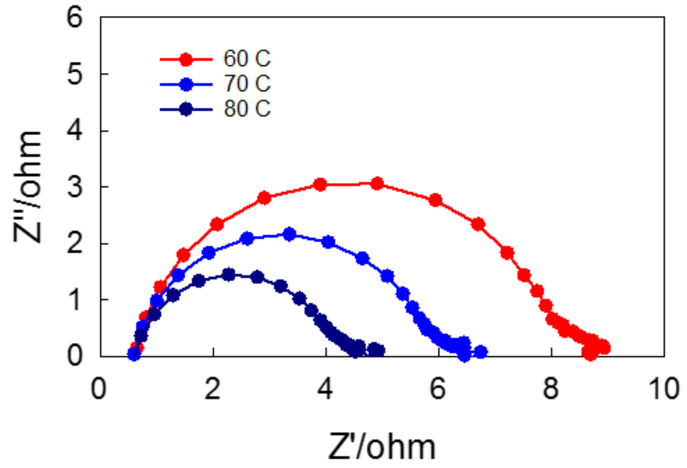


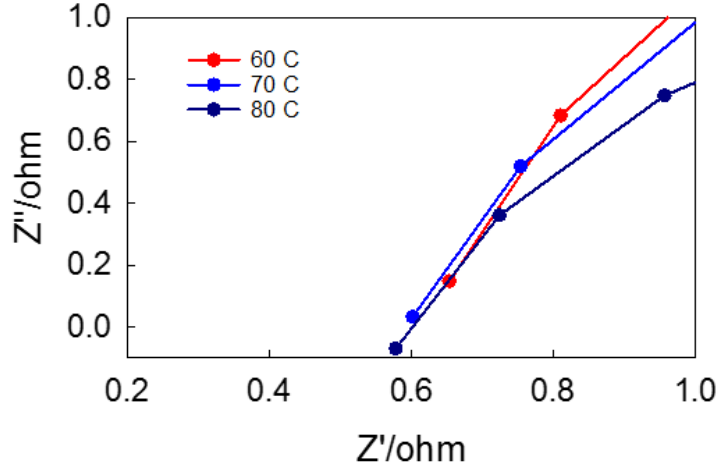


- Water-feeding (no acid/alkaline solutions) BPMEA device demonstrated successfully
- EFIMs (2) and (3) significantly decrease the charge transfer resistance, leading to a big performance improvement
- Membrane resistance (~ 0.4 ohm) is more than 4 times higher than that of AEM → resistance decrease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

Accomplishments: Temperature Effect

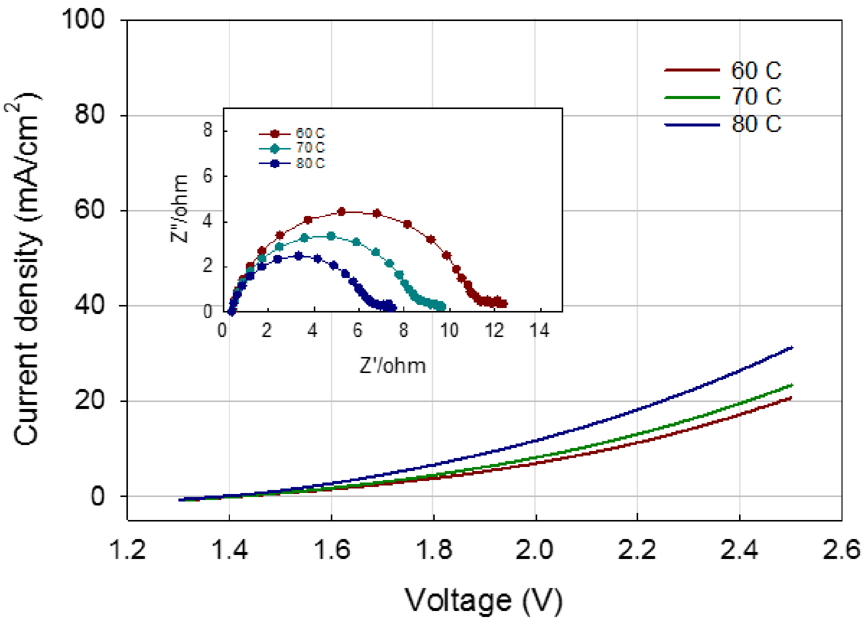


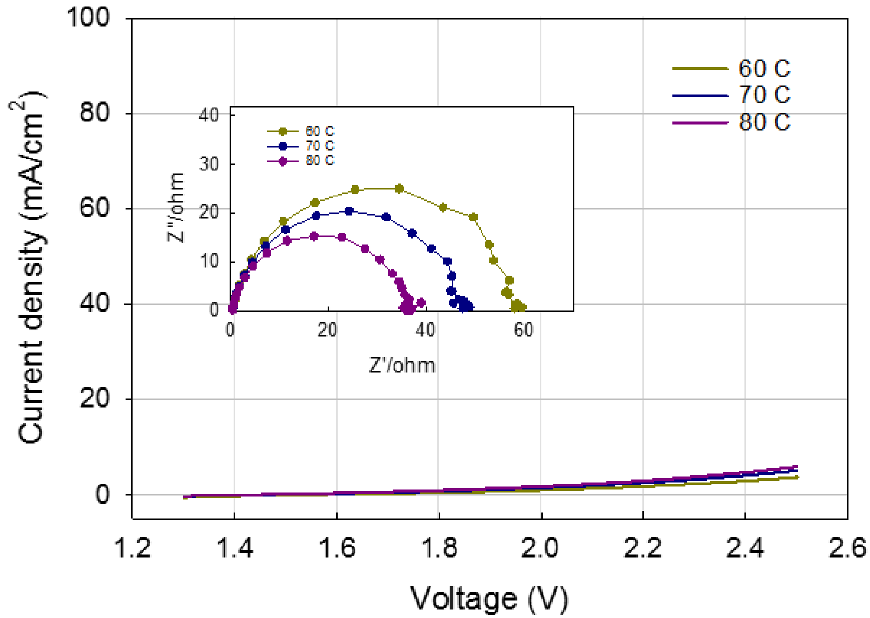




- Significant temperature effect on performance observed with EFIM(3)
- The project goal of 20 mA/cm² at 1.8 V achieved

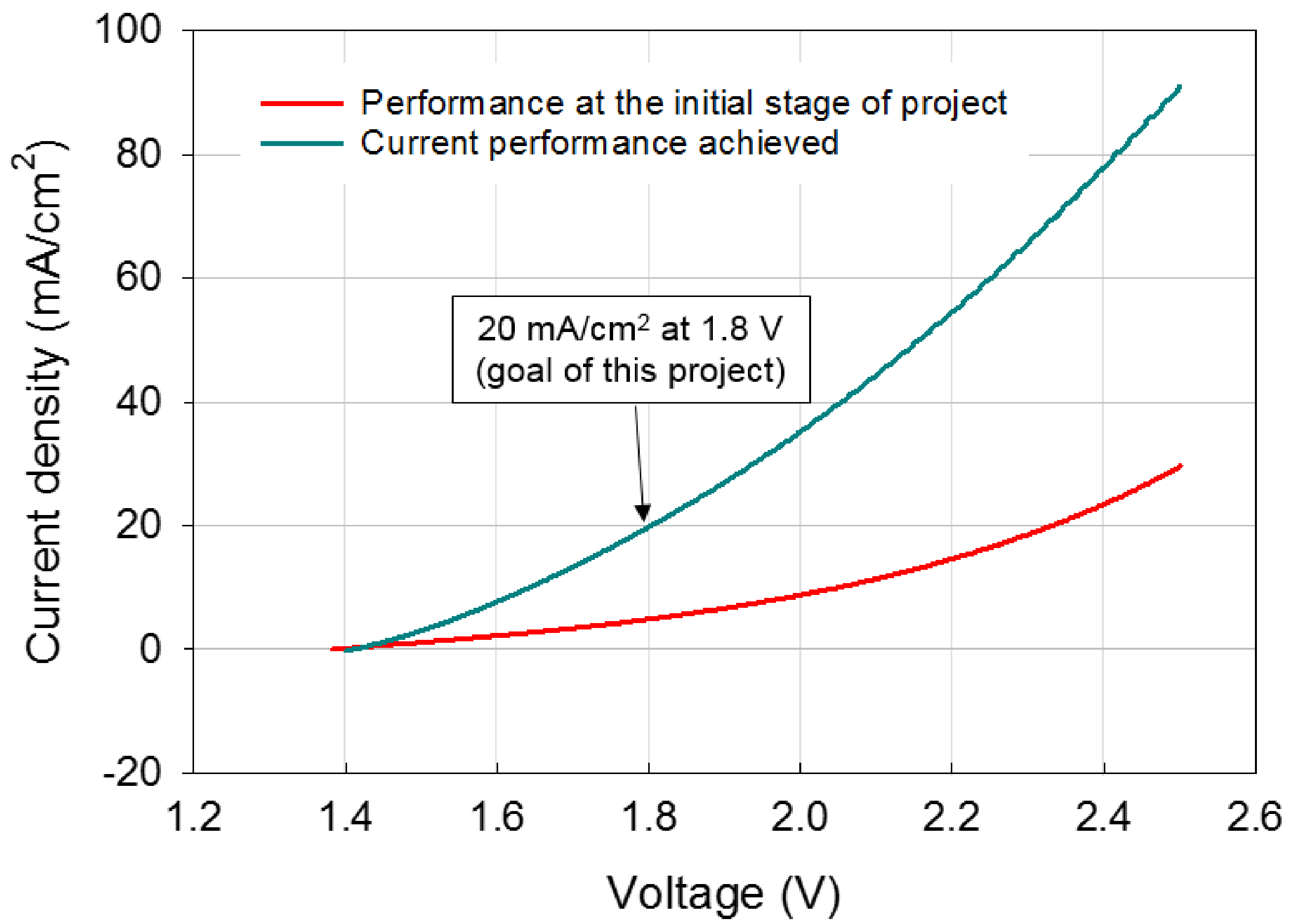
Accomplishments: Temperature Effect





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;