Project ID: FC301

Membrane Working Group

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Overview

Timeline

- Project start date: 10/1/2018
- Project end date: TBD
- Percent complete: TBD

Budget

- Total project funding: $200K
  - DOE share: 100%
- Funding received in FY18/19: $200K
- Total DOE Funds Spent*: $160K

*As of 5/29/2020

Barriers

- B. Cost
- C. Electrode performance
- A. Durability

Project lead

- National Renewable Energy Laboratory
  Bryan Pivovar (PI)
- Los Alamos National Laboratory
  Yu Seung Kim (co-PI)

Relevance

Objective

The Membrane Working Group serves to coordinate and accelerate the research community investigating polymer electrolyte membranes for energy conversion (and storage) devices.

Why do it?

- Bring membrane community together to educate, coordinate and accelerate advances and bring synergies across.
- Maximize the efficiency of project funding in membrane area.
- Provide common research information and gaps
  - Targets
  - Baselines
  - Protocols
- Growing importance of (low TRL) R&D needs in the area of polymer electrolytes
- Broader application than fuel cells, including electrolyzers, flow batteries, water purifications
- Prioritization of research needs/areas and input to DOE program office.

Approach

Background

Previous High Temperature Membrane Working Group consisted of government, industry, and university researchers interested in developing high temperature membranes for fuel cells. The working group focuses on hot and dry PEM operation (https://www.energy.gov/eere/fuelcells/high-temperature-membrane-working-group).

The new Membrane Working Group focus different polymeric materials used in fuel cells and other energy devices.

Coordinate fuel cell membrane research (present)

- Fuel cells: AEM, PEM, High Temp. PEM, Ionomeric Binder

Extended scope for interests (future)

- Membranes for different applications: Electrolyzers, Flow Batteries, Water desalination, Ammonia Synthesis and CO_2 Reduction.

Planning to socialize/refine premise/approach

- Webinar (March 5, 2019)
- DOE AMR (April 29 – May 1, 2019, Washington D.C.)
- AEM Workshop (May 30, 2019 at Dallas)

Approach

Membrane Working Group Coordination

Bryan Pivovar (NREL)

Yu Seung Kim (LANL)

Donna Ho (DOE, FCTO)

Participants

Project PIs and subrecipients of funded projects

- FCTO membrane-related projects (present)
- FCTO HydroGEN electrolysis projects (present)
- SBIRs/FCTO (present)
- ARPA-E IONIC – AEM (Topic 3), Flow Batteries (Topic 2) (present)
- ARPA E OPEN (present)
- FCTO EHC projects (future)
- BES projects (future)
- SBIRs/AMO (future)

Many funded projects focus on membrane synthesis so project PIs who are doing characterization/device performance/material interaction with other components will be brought to balance.

Accomplishments: Feedback from MWG Webinar (3/5/19)

Participants: Over 30 participants from DOE, National Labs, Academia and Industry.

Topics discussed

- Mission and scope of MWG
- Justification of MWG
- Who to include, how to coordinate MWG
- AEM Workshop plan

Feedback from the participants

- The MWG should start focused and small, then be allowed to naturally expand more broadly later.
- An initial focus on anion exchange membranes seems like a logical approach.
- Unclear of value of making effort broad across different technology approaches.
- Coordinating or collecting information across efforts spanning different program offices seems sensible.

Accomplishments: 2019 Anion Exchange Membrane Workshop

- Participation: > 50 industrial, academic, national laboratory and government experts
- Topics
  1. Identifying further challenges of AEMs and ionomers toward device development
  2. Baselining of membrane and ionomer materials
  3. Testing protocols

- Breakout sessions

  Morning session: Membrane focus
  Breakout session 1: Standardized protocols – conductivity and CO_2
  Breakout session 2: Standardized protocols – degradation, IEC, and mechanical properties
  Breakout session 3: Membrane Metrics and Targets

  Afternoon session: Device focus
  Breakout session 1: Electrode performance
  Breakout session 2: Water and CO_2 Management
  Breakout session 3: Device performance and durability milestones, metrics, and targets

Accomplishments: 2019 Anion Exchange Membrane Workshop

Suggested Milestones and Targets for AEM Fuel Cells

Proposed Milestones	
2021	Efficiency: 100 mW/cm^2 performance at 0.8 V (T ≥80°C) with 0.2 mg PGM, P ≤250 kPa
2022	AEM fuel cell initial performance 0.65 V at 1,000 mA/cm^2 on H_2/O_2 (maximum pressure of 1.5 atm) in MEA with total <0.2 mg_{PGM}/cm^2 and <10% voltage degradation over 1,000 h, T >80°C
2022	CO_2 tolerance: <65 mV loss for steady state operation at 1.5 A/cm^2 in H_2/air scrubbed to 2 ppm CO_2
2022	Catalyst durability: H_2/CO_2-scrubbed air after accelerated stress test <40% loss after 10,000 cycles from 0.6 V to 0.95 V Membrane durability: 1,000-h open circuit voltage hold at 70% RH and ≥80°C
2025	1 W/cm^2 at 0.65 V; H_2/CO_2-free air with total PGM loading <0.125 mg/cm^2, T >80°C, P ≤250 kPa
2030	AEM fuel cell peak power performance >600 mW/cm^2 under H_2/air (maximum pressure of 1.5 atm) in PGM-free MEA
Ultimate	1 W/cm^2 at rated power (~0.65 V at 95°C), PGM-free MEA, T ≥80°C, P ≤250 kPa

Accomplishments: 2019 Anion Exchange Membrane Workshop

Suggested Changes to ARPA-E IONICS AEM Targets

Metric	ARPA-E Targets	Suggested Change
Membrane chemical stability (at ≥80°C immersed in a pH ≥14 solution)	≥1,000 h with ≤2% loss in IEC, ionic ASR	≥1,000 h with ≤5% loss in IEC and conductivity; should include spectroscopic characterization
Component area over which property values are achieved to within ≥90% uniformity	≥100 cm^2	Delete this target or decrease priority
Ionic ASR (hydroxide form, 80°C, liquid equilibrated)	≤0.04 Ω-cm^2	No change to 80°C target Add a target at 40°C: 0.04 Ω-cm^2
Ionic ASR (80°C, ≤50% RH, under air exposure [i.e., in presence of 400 ppm CO_2])	≤0.08 Ω-cm^2	Change to a measurement at 80% RH under CO_2-free air exposure; keep target at ≤0.08 Ω-cm^2.
Mechanical durability during RH cycling	≥20,000 RH cycles	Delete this target
Electronic ASR	≥1,000 Ω-cm^2	No change proposed
Humidity stability factor	>5	No change proposed
Swelling in liquid water at 25°C	<50%	To be measured as linear swell in X-Y plane in water, membrane in OH^- form
Pressure differential	≥1 bar	Delete for fuel cell and flow battery applications; electrolyzer industry input on burst test or other relevant test and metrics needed
H_2 crossover and O_2 crossover	≤25 nmol/cm^2-s	Change to <5 mA/cm^2 for H_2 crossover, eliminate O_2 crossover target
Cost for membrane that can be practically integrated in a device	≤20 \$/m^2	No change proposed
H_2O transport	---	Proposed for water transport: >4 μmol/cm^2-s
Ionic permeability	---	Proposed for flow batteries to limit permeability of other ions: <7x10^{-8} cm^2/s

Accomplishments: 2020 High Temperature Membrane Fuel Cell Workshop (proposed)

- **Objective**: To connect the industry and research community to discuss the future development of high-temperature polymer electrolyte membrane fuel cells and intermediate temperature fuel cells.

- **Topics**

1) Industrial need for HT-PEMFCs/ITFCs including heavy-duty automotive applications,
2) Targets and test protocol for HT-PEMFCs/ITFC materials,
3) State-of-the-art and emerging proton conductor technologies,
4) Research directions of the proton conductor and MEA development.

- **Contents**

First day: **Industrial need for HT-PEMFCs/ITFCs**

Breakout session 1: Automotive applications

Breakout session 2: Liquid fuel/reformate and other applications

Second day: **State-of-the-art and emerging technology**

Breakout session 1: HT-PEMFC

Breakout session 2: ITFC

Accomplishments: Agenda for 2020 HT-PEMFC Workshop

(First day)

1:00 - 1:20 Workshop Introduction, FCTO/ARPA-E (Dimitrios/Grigorii)

Industrial need for HT-PEM/ITFCs

1:20 - 1:40 Vehicle Applications (Gittleman, GM)

1:40 - 2:00 Vehicle Applications (Jia, Toyota)

2:00 - 2:20 Heavy Duty Vehicle Applications (Brockbank, Ricardo Inc.)

2:20 - 2:40 Liquid Fuel/Reformate Applications (de Castro, Advent)

2:40 - 3:00 Stationary Applications and Beyond (Chisholm, SAFcell)

3:00 - 3:20 Suggested heavy-duty target criteria (Borup, LANL TBD)

3:20 - 3:40 Break

3:40 - 5:30 **Breakout session: Proton conductor targets and test protocol**

1. Automotive applications (heavy-duty vehicles)
2. Liquid fuel/reformate and other applications

Each talk has 5 min Q&A at the end of the presentation

(Second day)

Current DOE Research projects

8:00 - 8:15 FCTO program (Donna)

8:15 - 8:30 ARPA-E program (Grigorii)

State-of-the-art and emerging technology

8:30 - 8:50 PFSA & composite (80-120C) (Yandrasits, 3M)

8:50 - 9:10 Phosphonic acid based (80-120C)

9:10 - 9:30 Discussion

9:30 - 9:50 Break

9:50 - 10:10 PBI based (140-200C) (Jones, U. Montpellier)

10:10 - 10:30 Ion-pair based (80-240C) (Kim, LANL)

10:30 - 10:50 Discussion

10:50 - 11:10 Metal phosphates (200-300C) (Garzon, UNM)

11:10 - 11:30 Solid acid (200-300C) (Haile, NWU)

11:30 - 11:50 Discussion

1:00 - 4:00 **Breakout session: Research direction and performance targets for new technologies**

1. LT-PEMFC (80-120C)
2. HT-PEMFC (80-240C)
3. ITFC (> 200C)

4:00 - 4:20 Break

4:20 - 5:30 Joint Session Readout from Breakout Groups

5:30 Concluding Remarks

Responses to Previous Year Reviewers' Comments

- This your project was not reviewed last year.

Proposed Future Work

- 2020 HT-PEMFC Workshop

  Due to the Covid-19, on-site meeting at NREL is cancelled.

  Virtual option is considered.

- Complete the organization of MWG
  - DOE Funding Agents
  - National Labs
  - Academia
  - Industries

- Plans for 2021 MWG meetings

Any proposed future work is subject to change based on funding levels.

Collaboration and Coordination

Project coordination

- Los Alamos National Laboratory (Yu Seung Kim)
- National Renewable Energy Laboratory (Bryan Pivovar)
- HFTO (Donna Ho)
- ARPA-E (Grigorii Soloveichik)

Interactions

- HydroGEN Consortium
- HFTO-funded project teams (membrane-related)
- Other membrane research institutions including 3M, U. South Carolina, and LSU.

Summary

Objective: The Membrane Working Group serves to coordinate and accelerate the research community investigating polymer electrolyte membranes for energy conversion (and storage) devices.

Relevance: Ion exchange membranes and ionomers are critical component of fuel cells and other energy device. MWG helps the membrane community to educate, coordinate and accelerate advances and bring synergies across. MWG also helps DOE to maximize efficiency of funding and provide information on membrane research priority.

Approach: MWG is coordinated by NREL, LANL and DOE FCTO. Participants include DOE funded project leader and sub-recipients. MWG starts with information exchange and organizing workshop and meetings for interactions between membrane researchers and related people.

Accomplish-ments (FY 19) MWG started with Webinar on March 5, 2019 discussing the mission, scope, justification and future meetings. AEM Workshop was held after the ECS spring meeting at Dallas.

Collaborations: Collaborations with academia, industry and other national labs. MWG will interact with DOE programs with other funding agents including OE, AMO, ARPA-E, BES, etc.