Affordable Fuel Cell Technology for Electric Vehicles

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Fuel Choices Summit
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Fuel Cells Progress and Status

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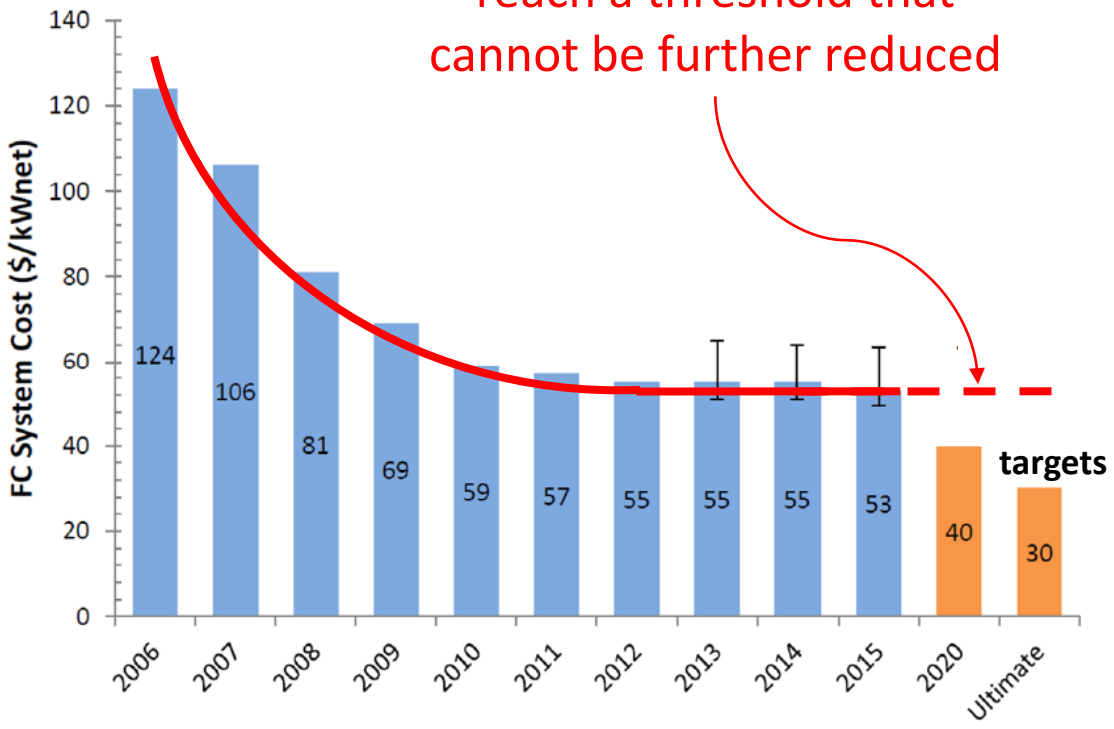
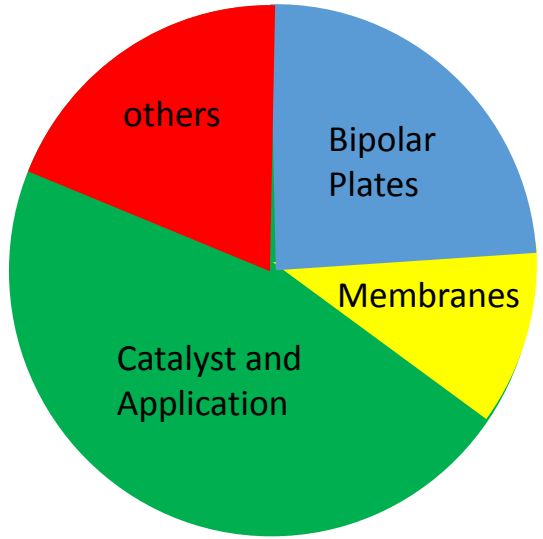
Fuel Cell Electric Vehicles (FCEVs) are here

Honda Clarity Fuel Cell Vehicle

FC cost projections seem to reach a threshold that cannot be further reduced



PEMFC Stack Cost Breakdown
(500,000 FC systems/year)



Catalyst cost is projected to be the largest single component of the cost of a PEMFC manufactured at high volume.

D. Papageorgopoulos, FC Technology Office, US DOE, 2015

Anion Exchange Membrane Fuel Cells (AEM-FCs)

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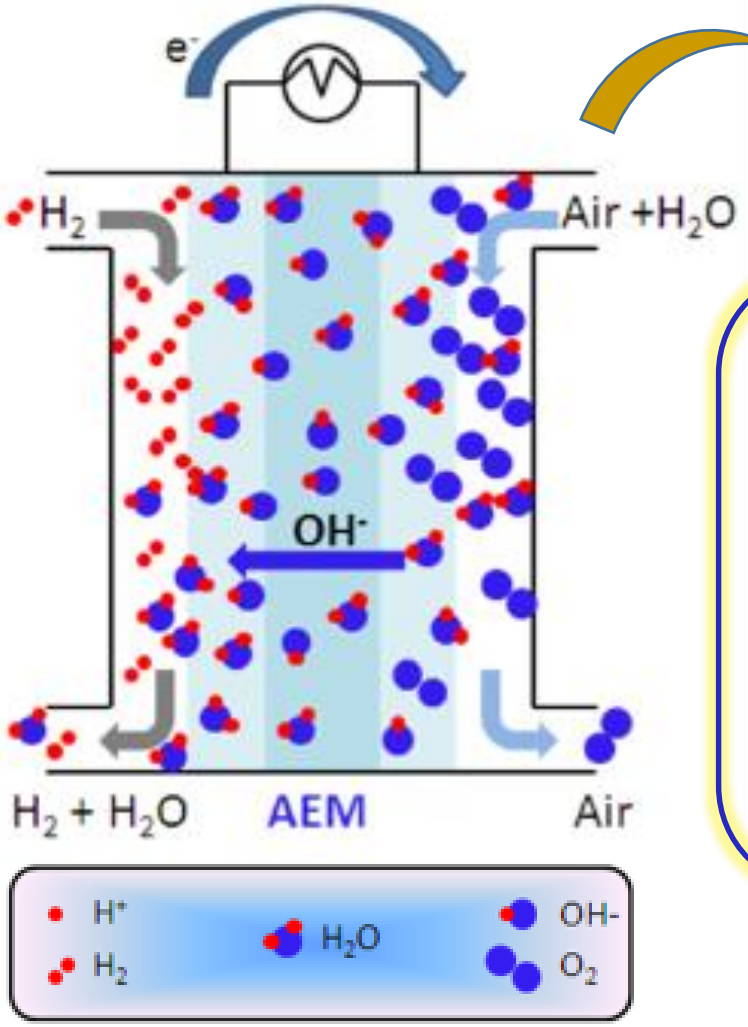
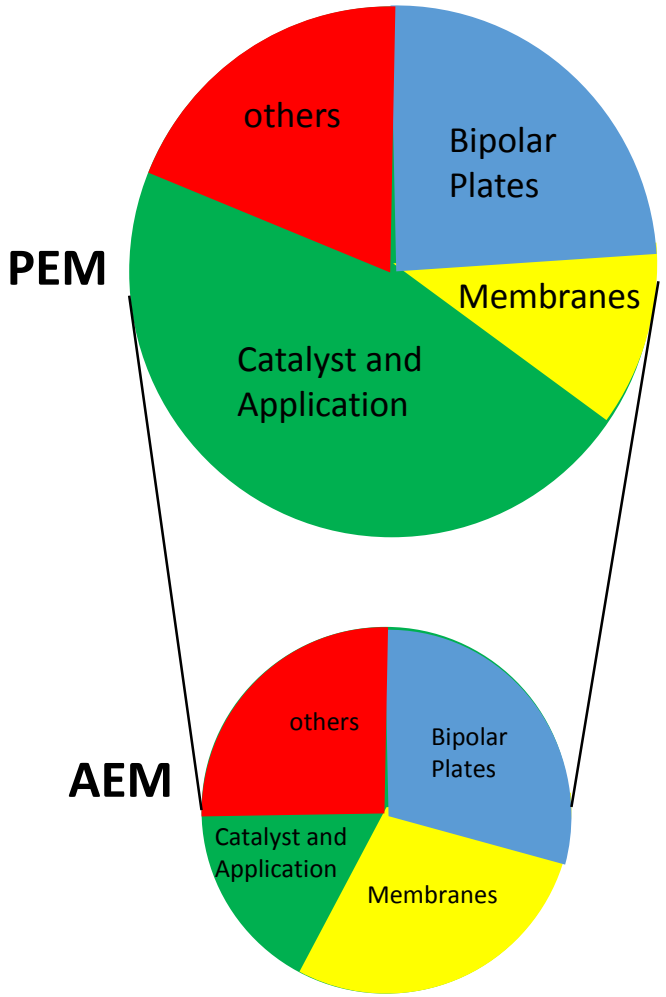


	Catalysts	Membranes
PEM-FC:	Platinum	Fluorinated
AEM-FC:	Iron, Nickel, Carbon, …	Hydrocarbon

FC Stack Cost Breakdown
(500,000 FC systems/year)



50% cost reduction

"Alkaline Membrane Fuel Cells", Dario Dekel;
In: Savinell R., Ota K., Kreysa G. (Ed.)
Encyclopedia Of Applied Electrochemistry: Springer (**2014**)

Stable polymeric membranes for AEM-FCs

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AEM Development of LANL-Led AMFC Project

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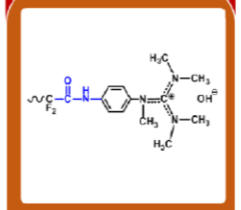
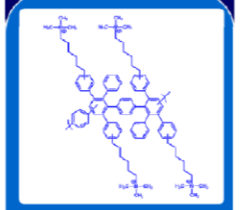
Perfluorinated AEM



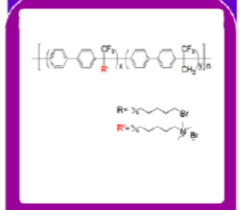
- Perfluorinated AEM
- Guanidinium functionalized stable PF anion exchange polymer
- **Strength**
  Low water uptake
  Excellent hydrophobicity
  ideal for ionomeric binder
- **Research focus**
  Amide hydrolytic stability

Diels-Alder Poly(phenylene)



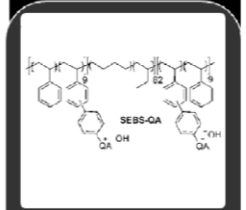
- Hexamethyl ammonium functionalized poly(phenylene) AEM
- **Strength**
  Improved cation stability
  Better gas permeability
- **Research focus**
  Incorporation with resonance stabilized cationic functional group

Ether-Free Poly(phenylene)



- Acid-catalyzed, high molecular weight (Mw: > 100 kg/mol), solution processible AEM.
- **Strength**
  Improved mechanical properties
  Exceptional alkaline stability
- **Research focus**
  water uptake control and solvent resistance

Flexible SEBS AEM



- Highly conductive and stable polymers prepared from C-H borylation and coupling reactions
- **Strength**
  High conductivity
  Good polymer stability
  High elongation (> 300%)
- **Research focus**
  AEM Processibility and water uptake control

Summary of Stability

AEM	Test conditions	IEC loss (%)
Perfluorinated	0.5M NaOH, 80°C, 3 days	8
Diels-Alder PP	4M KOH, 90°C, 14 days	0
Ether-free PP	1M NaOH, 80°C, 30 days	0
SEBS	1M NaOH, 80°C, 28 days	3

Perfluorinated AEM: Kim et al. Macromolecules 46. 7826 (2013)

Diels-alder poly(phenylene): Hibbs, J. Polym. Sci. Part B, 51, 1736, (2013)

Ether-free poly(phenylene): Lee et al. ACS Macro Letters, 4, 814 (2015)

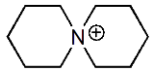
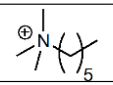
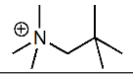
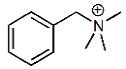
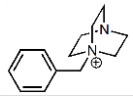
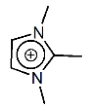
SEBS-QA: Mohanty et al. Macromolecules, 48, 7085 (2015)

Los Alamos NATIONAL LABORATORY
Sandia National Laboratories
Rensselaer

DOE stability target for AEM-FC:
Q2, 2017: Develop anion-exchange membranes with an area specific resistance ≤ 0.1 ohm cm^2, maintained for 500 hours during testing at 600 mA/cm^2 at T >60 °C.

D. Papageorgopoulos, AEM-FC Workshop;
Phoenix AZ, April 1, **2016**

New stability studies for functional groups for AEM-FCs:

quaternary ammonium	half life / h 6 M NaOH, T = 160 °C
	110
	87
	62
	32
	21
	4.2
	1.4
	< 0.1

X 25

M. G. Marino and K.-D. Kreuer;
ChemSusChem 8(3), 513–523, **2015**

Stable polymeric membranes for AEM-FCs

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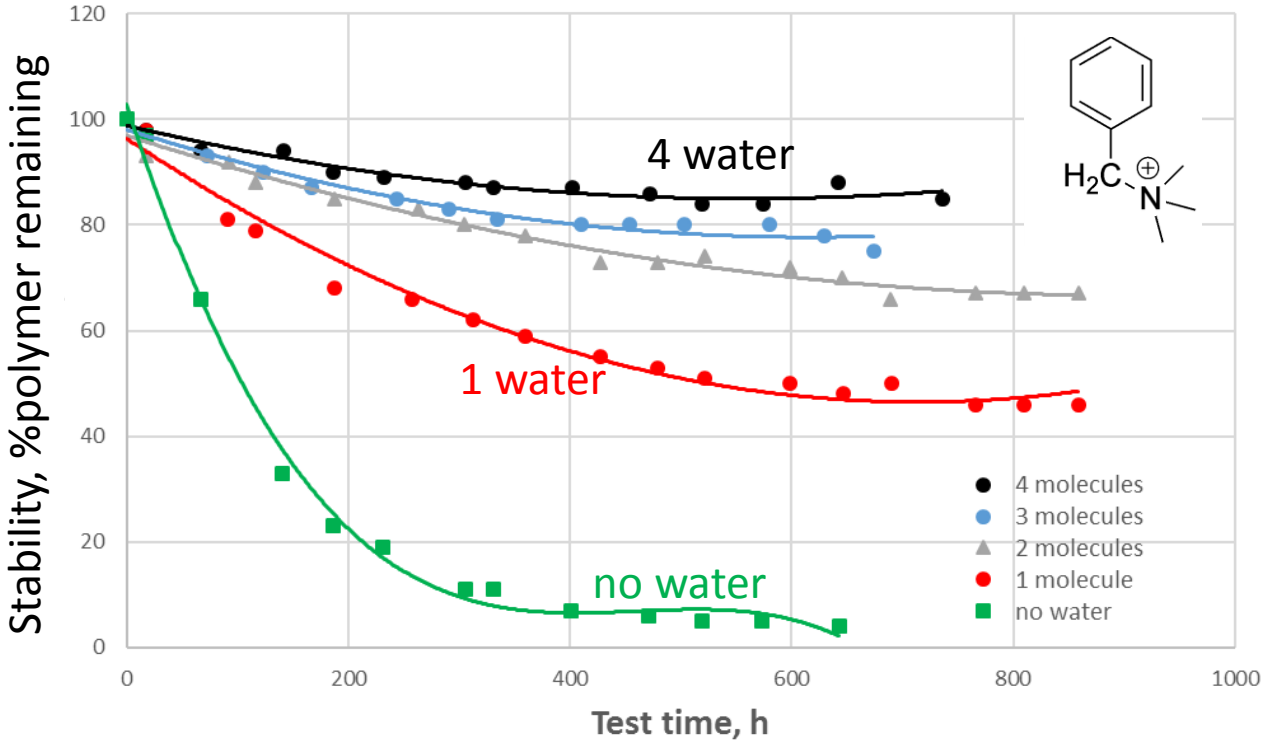
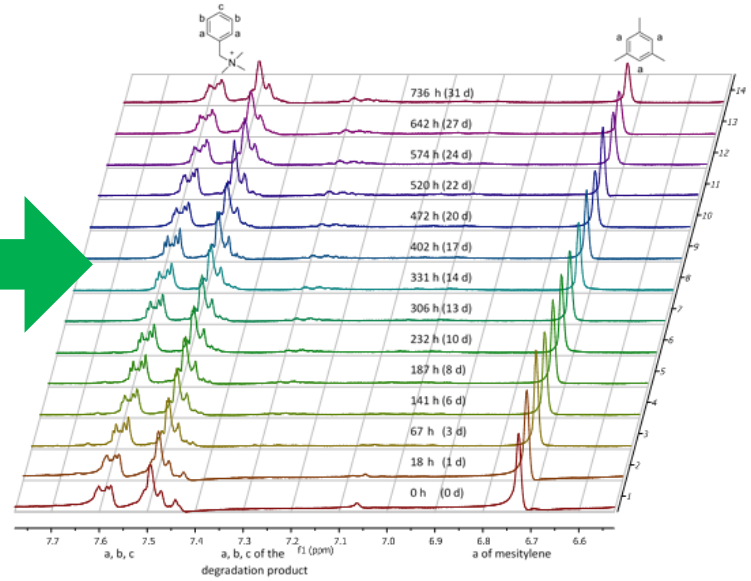
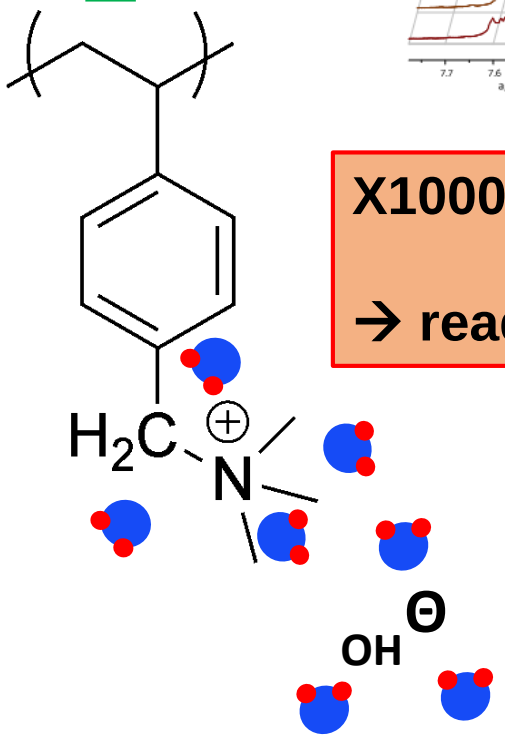
Novel protocol to test stability of membranes for AEM-FCs was, *for the first time*, successfully developed





X1000 more stable !

→ ready for FCEV applications



= water

This new ex-situ protocol will rapidly lead to selection of best stable polymers for durable and robust AEM-FCs.

Dekel et al.; JACS (submitted, **2016**)

Platinum-free catalysts for AEM-FCs

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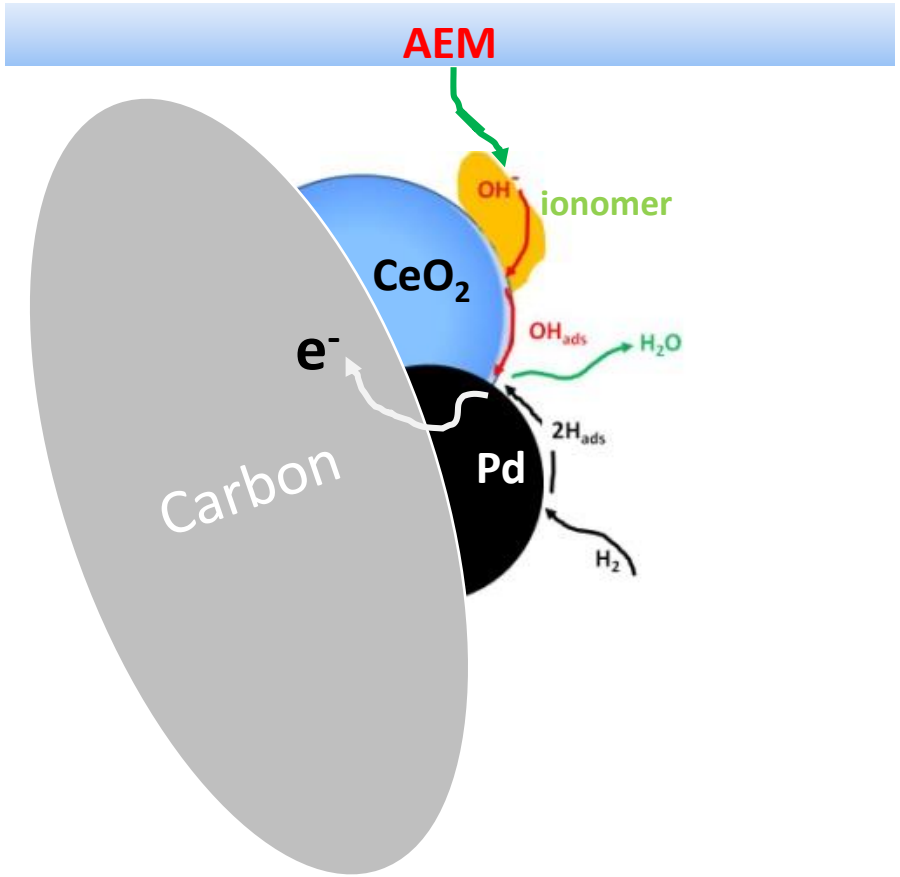
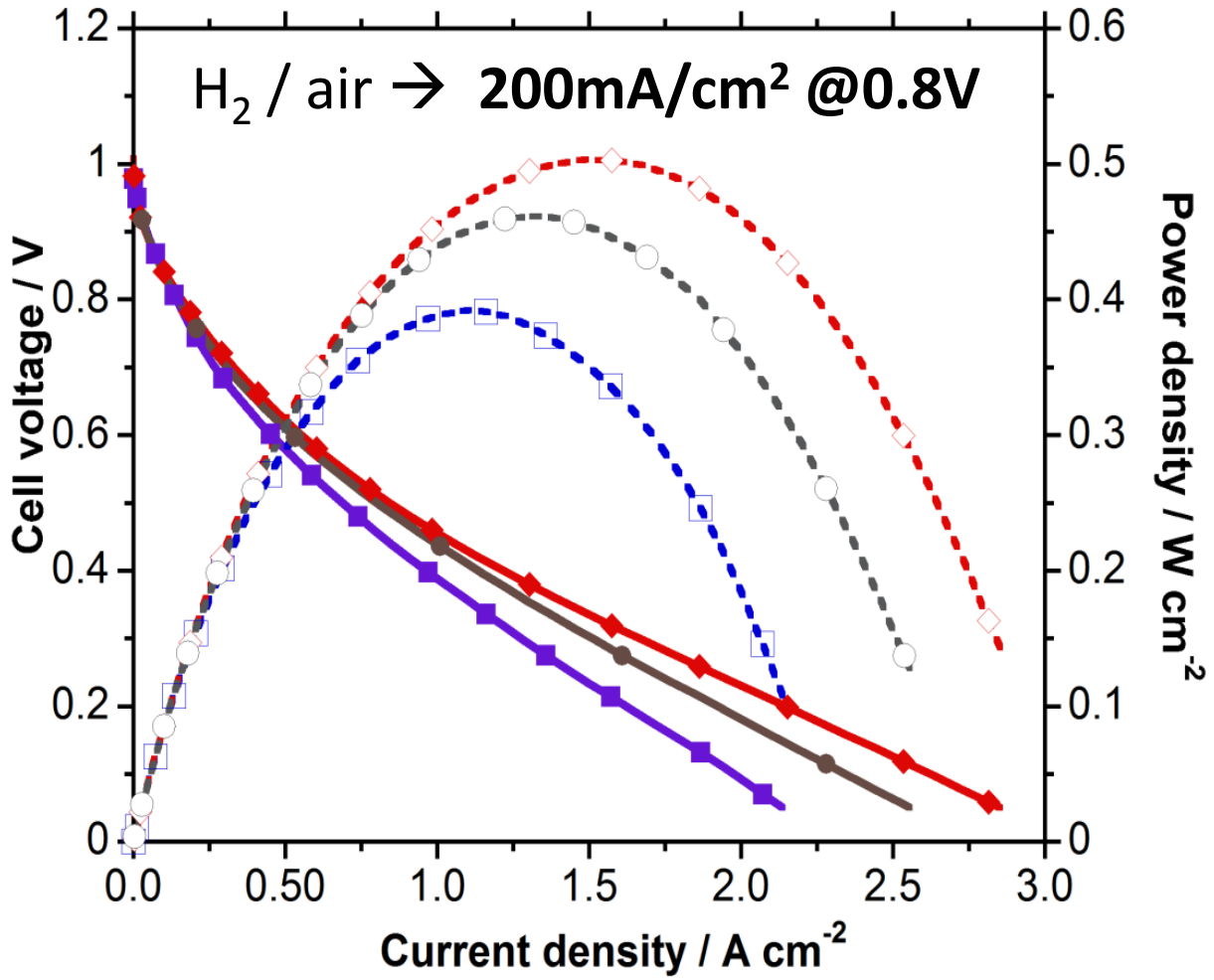
Ceria based bifunctional catalysts for AEMFCs:

Worldwide record in performance for non-Pt fuel cells





Miller, … and Dekel;
Angew. Chem. 128 (**2016**) 6108

Meets DOE target for AEM-FC for Q4, 2017

Leading AEM-FC development worldwide

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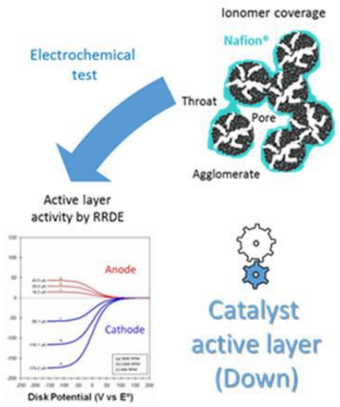
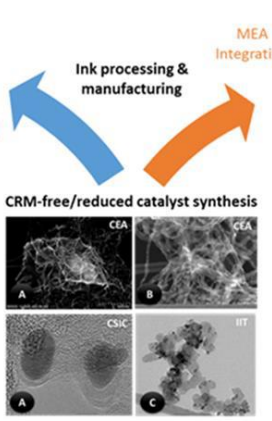
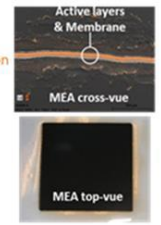
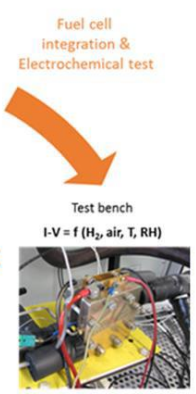
Catalysts



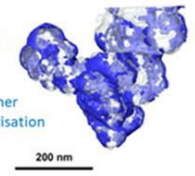


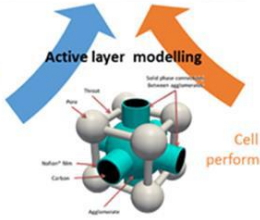


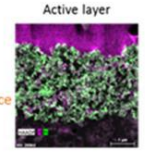
Membranes



Tests







Characterization

Dekel's group
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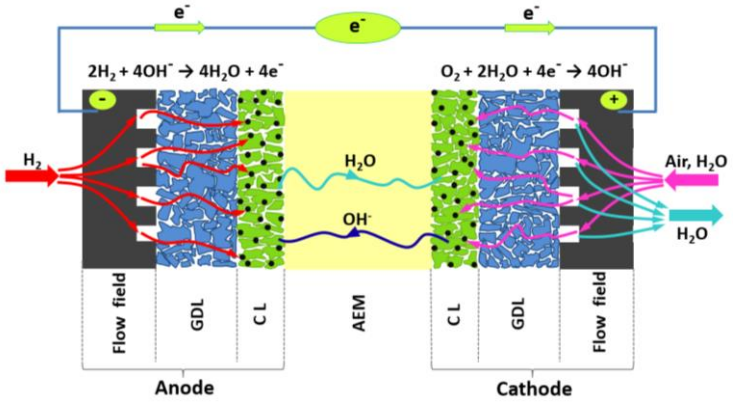
20 Countries with active collaborative projects with Dekel's group

Electrodes

Cells



Dekel's group – TEEM lab, 2016

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