



National Alliance
for Water Innovation



Bipolar membranes electro dialysis for water purification and resource recovery

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Presenter: Bin Yang

Authors: Bin Yang, Nurshaun Sreedhar, Chance Parrish, Caleb Reese, Olivia McIntee, Mou Paul, Manish Kumar and Abhishek Roy

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Outline

Background of Low Salinity Desalination

Overview of Experimental Approach

Role of Catalyst on lamination

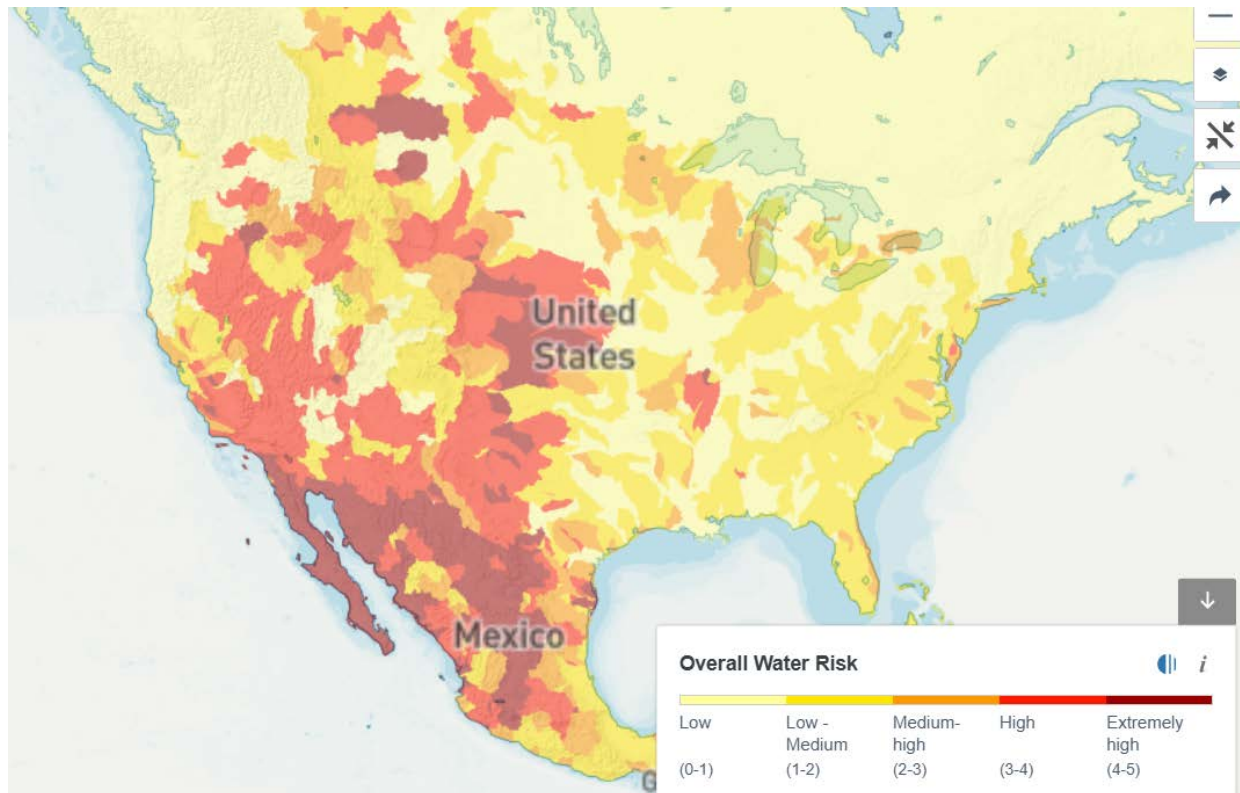
Preliminary BPM ED performance

Summary and Conclusions

Acknowledgement

Low Salinity Desalination

Low-salinity desalination refers to desalination processes that target water sources with lower salt concentrations, like brackish water or treated wastewater, rather than seawater.

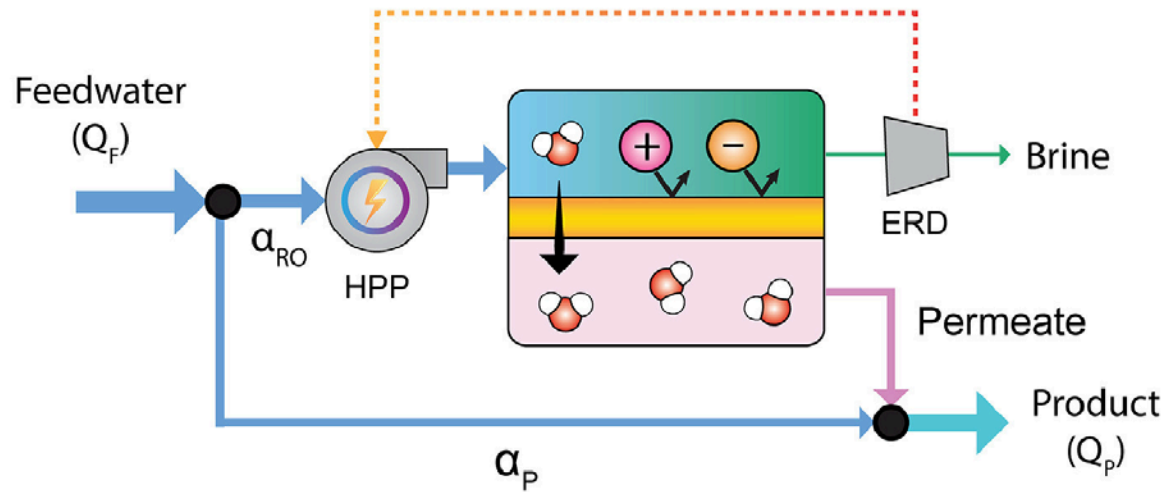


Source: WRI, *Aqueduct Water Risk Atlas*

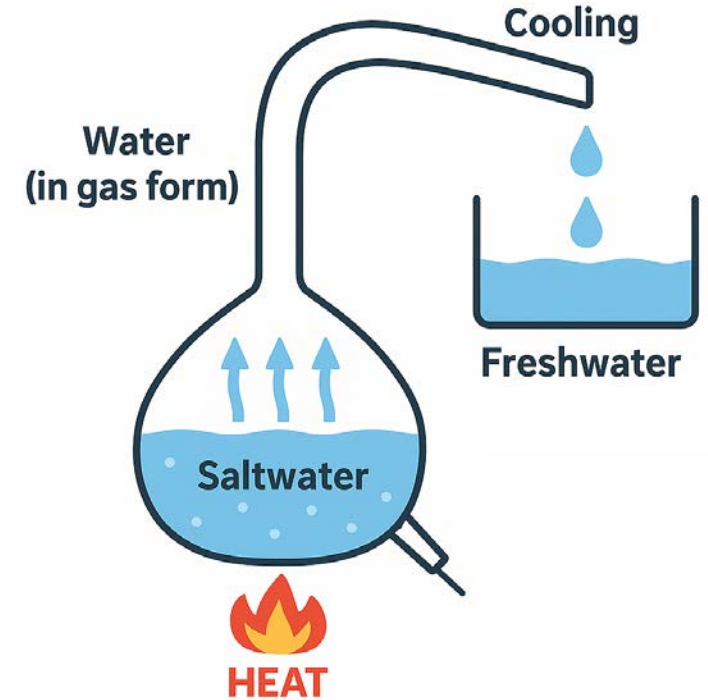


Source: foodandwaterwatch.org

Conventional Methods for Low Salinity Desalination

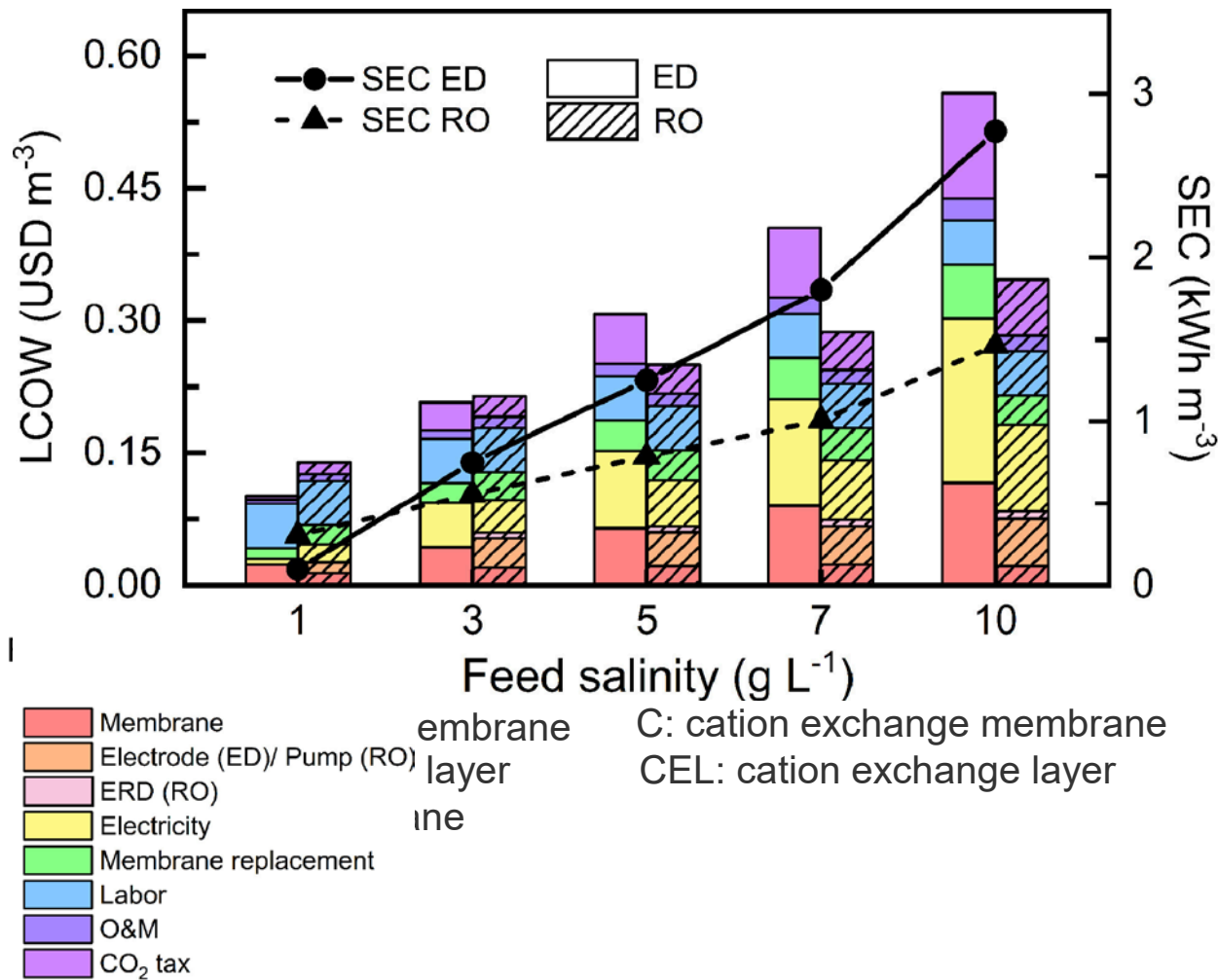


Reverse osmosis (RO) uses membranes to separate salt and impurities from saline water under high pressure.



Thermal desalination relies on heating seawater to produce steam, which is then condensed into fresh water.

Why Bipolar Membrane Electrodialysis (BMED)?



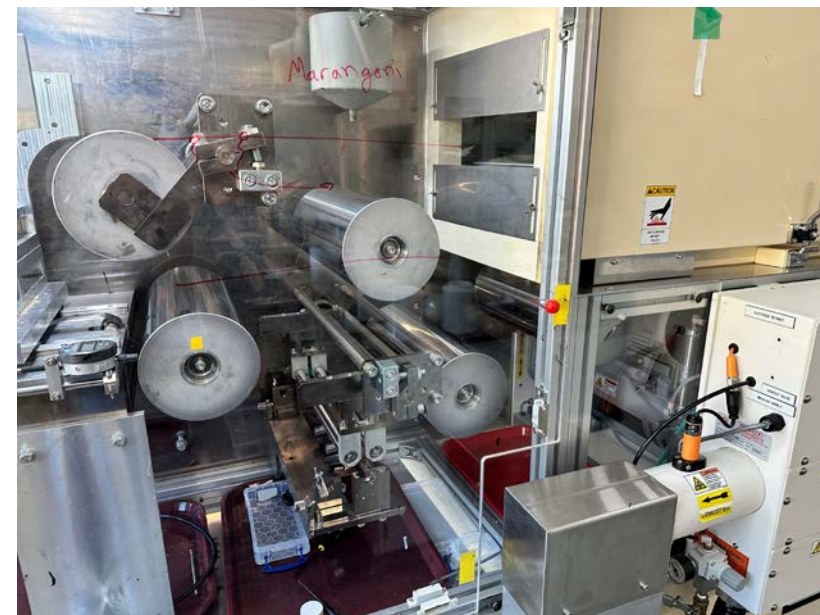
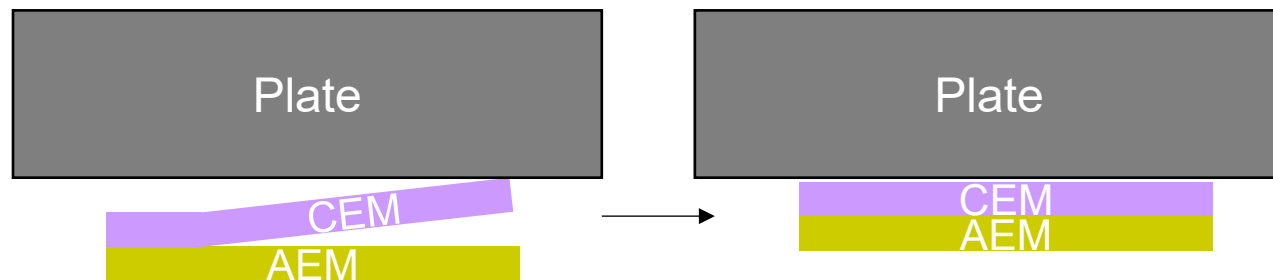
Advantages:

- Integration of BPMs into electrodialysis stacks.
- Converts salts into corresponding acids and bases.
- Simultaneous desalination and chemical production, zero-liquid-discharge

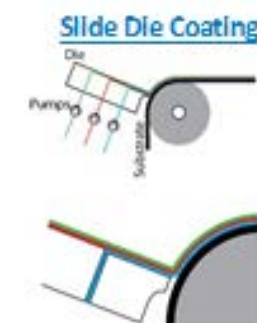
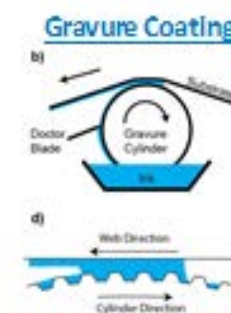
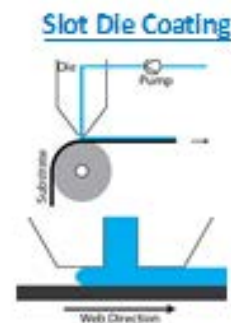
**Challenges in ED and BPM ED:
high cost of membranes**

Patel et al. Water Research 250 (2024) 121009

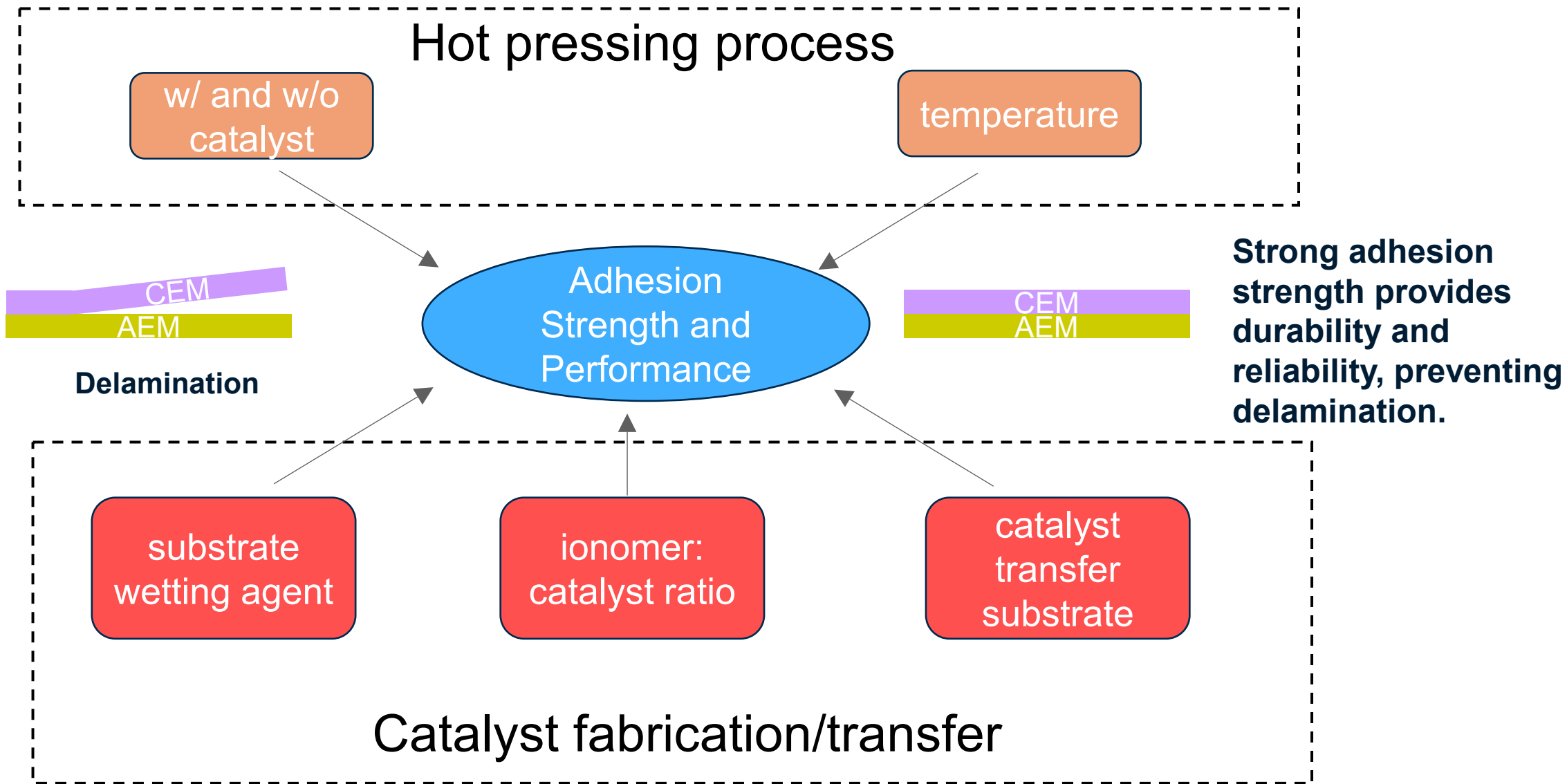
Translation from Bench Scale to Roll-to-Roll (R2R) Technology



- Hot pressing used in BPM fabrication creates a dense and stable structure.
- Roll-to-Roll (R2R) technology is a high-throughput manufacturing process where flexible materials (like films or membranes) are continuously processed while moving through a series of rollers.



Key Factors in Adhesion Strength at BPM Junction



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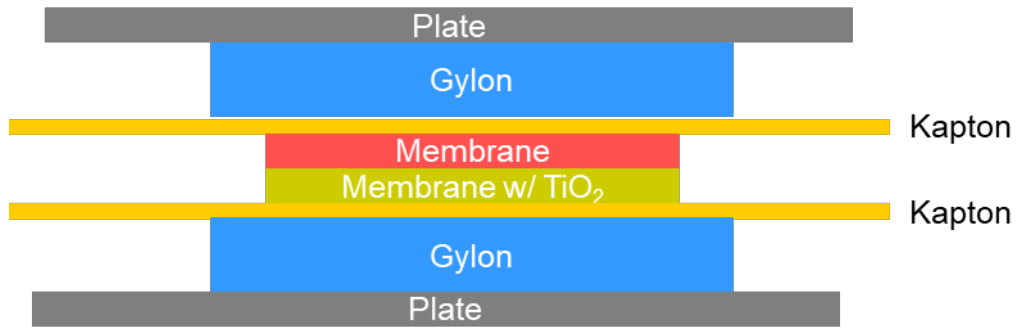
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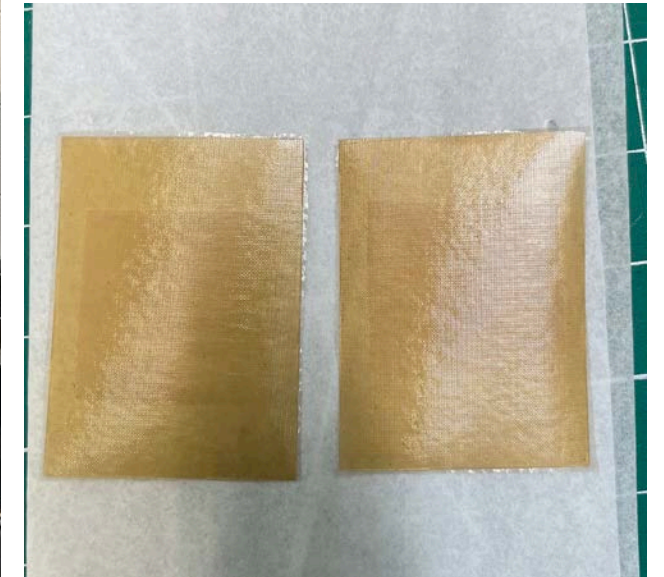
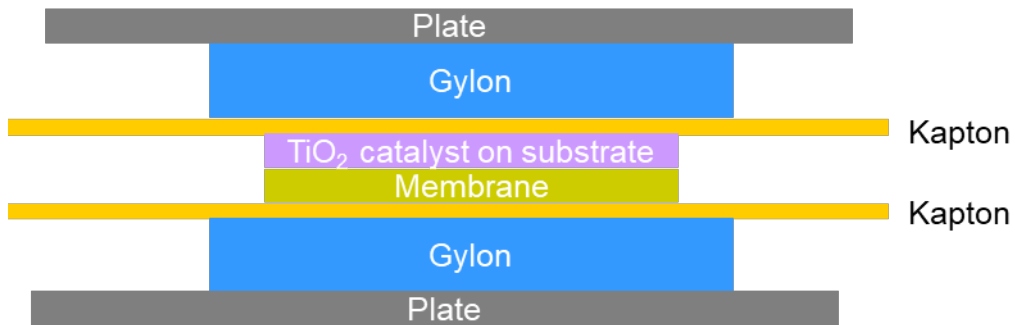
Overview of Experimental Approach

BPM fabrication w/ catalyst



- Applied force: 350 kg/inch²_{membrane area}
- Holding time: 7 min for each side
- Cooling down for 10-15 min

Catalyst transfer to membrane process



Material selection

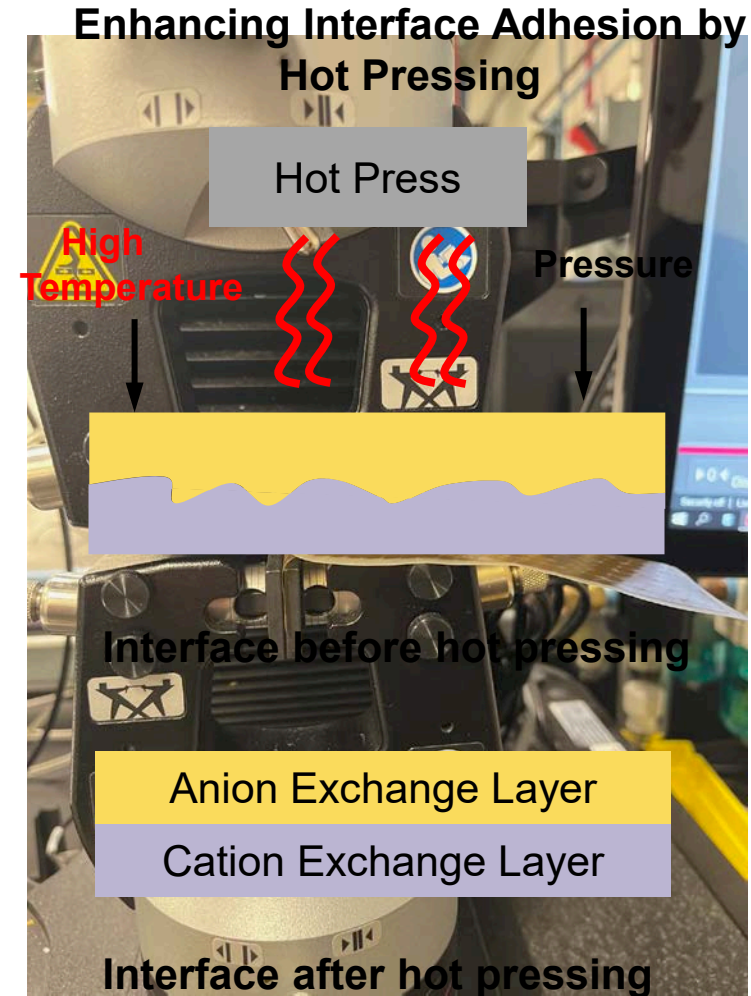
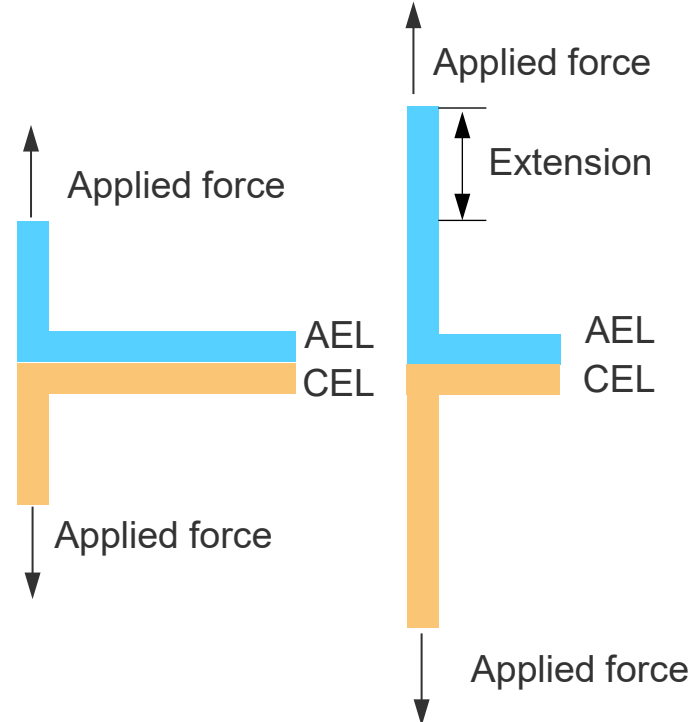
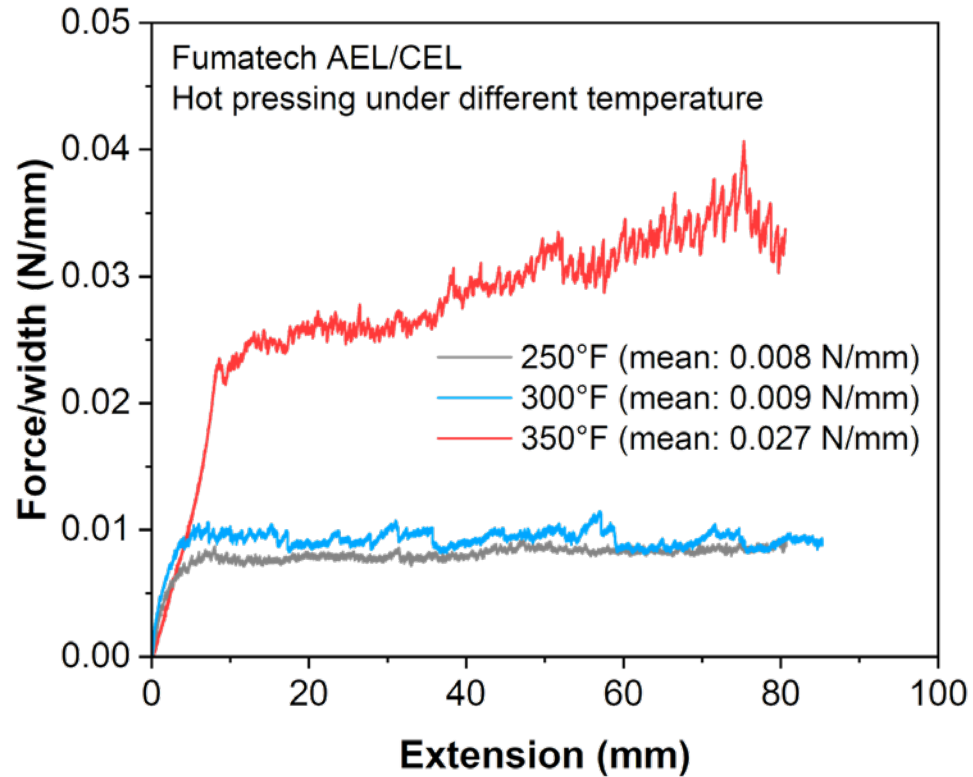
FAB-PK-130, FKL-PK-130, FAS-50 from Fumatech. BPSH-35 synthesized by NREL



	FAB-PK-130	FKL-PK-130	FAS-50	BPSH-35
Ion exchange type	AEM	CEM	AEM	CEM
Water uptake (%)	6.1	17.8	15.8	31
IEC	0.97	0.90	1.57	1.12
Conductivity (mS/cm)	13.84	25.88	25.26	76.36
NaCl Diffusivity (cm ² /sec)	2 x 10 ⁻⁹	6 x 10 ⁻⁹	4 x 10 ⁻⁹	/

Catalyst-free Hot Pressing

Using an Instron Mechanical Testing system with tensile grips (5943) with an extension rate of 6 mm/min.

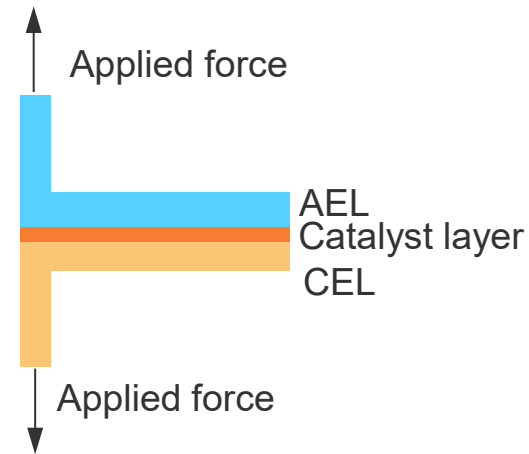
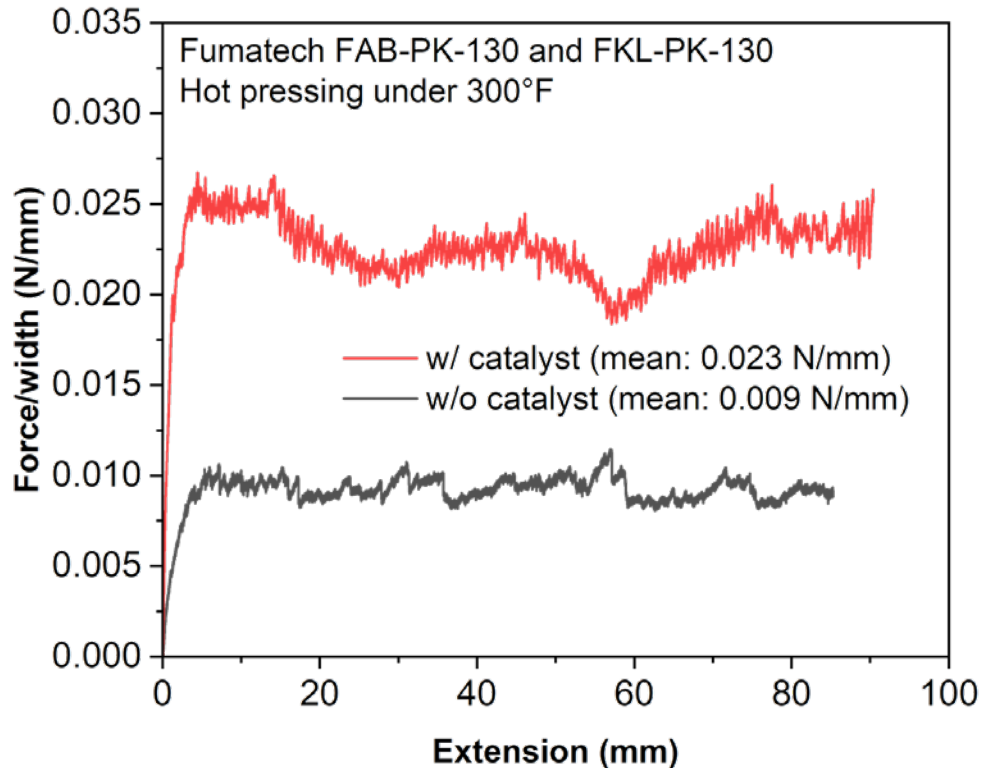


Higher temperature can produce higher adhesion strength at the interface of BPMs.

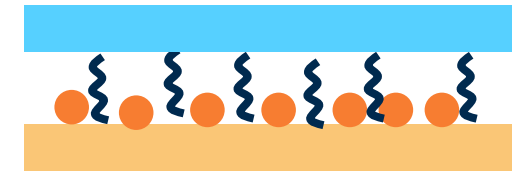
Hot pressing with Nafion+TiO₂ catalyst

Condition: 3.8 wt% Nafion ionomer

Method: catalyst transfer by hot pressing



Before hot pressing



After hot pressing



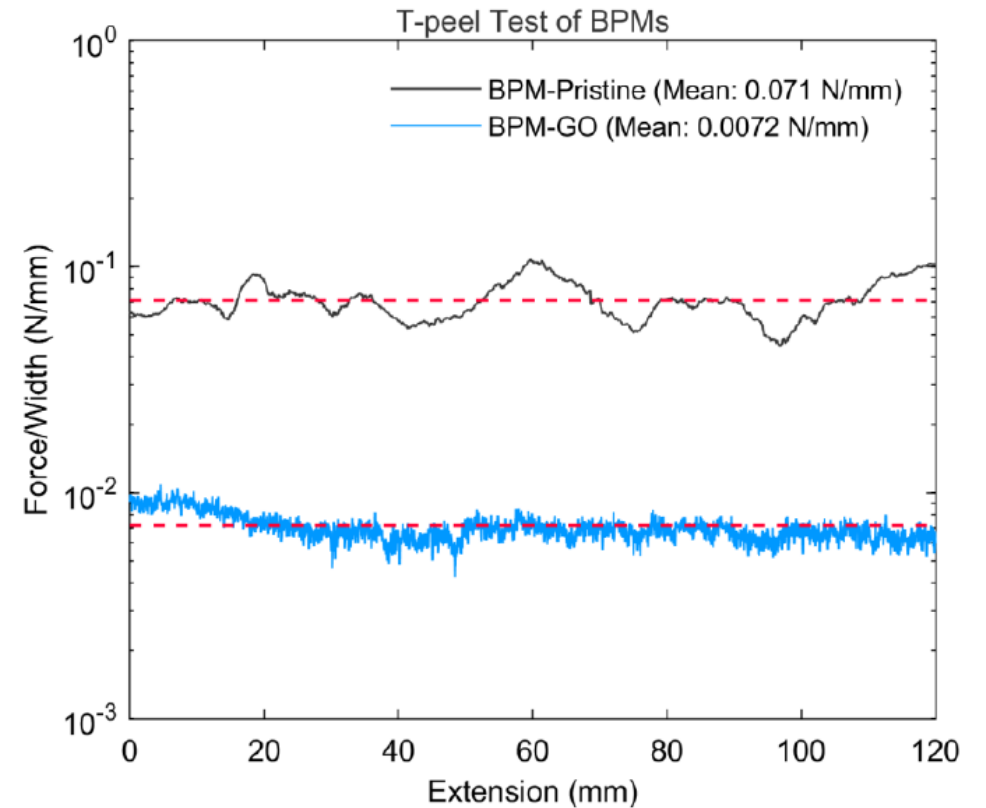
- Larger surface area of interface
- Binder effect of ionomer

Adhesion strength from literature

In the reference paper, the authors found that the adhesion strength of BPM-GO is much lower than the BPM-pristine.

Condition: 20 wt% graphene oxide in Nafion ionomer

Method: spray coating



Lucas et al. ACS Energy Lett. 2024, 9, 5596–5605

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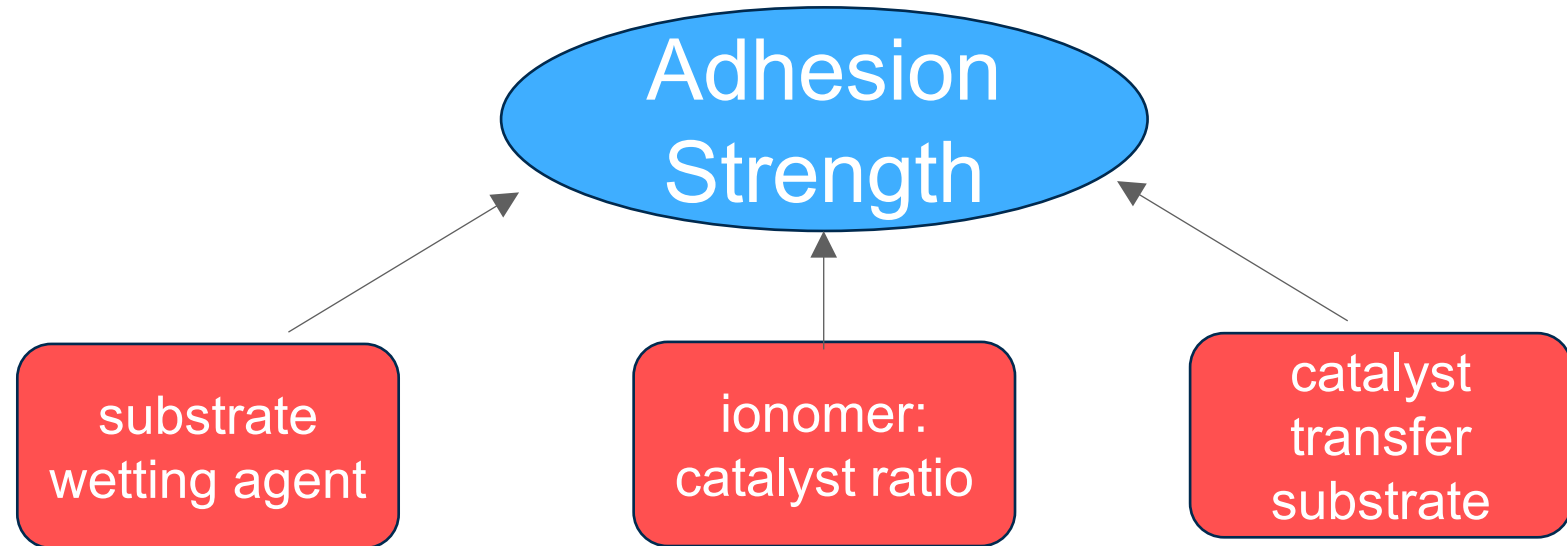
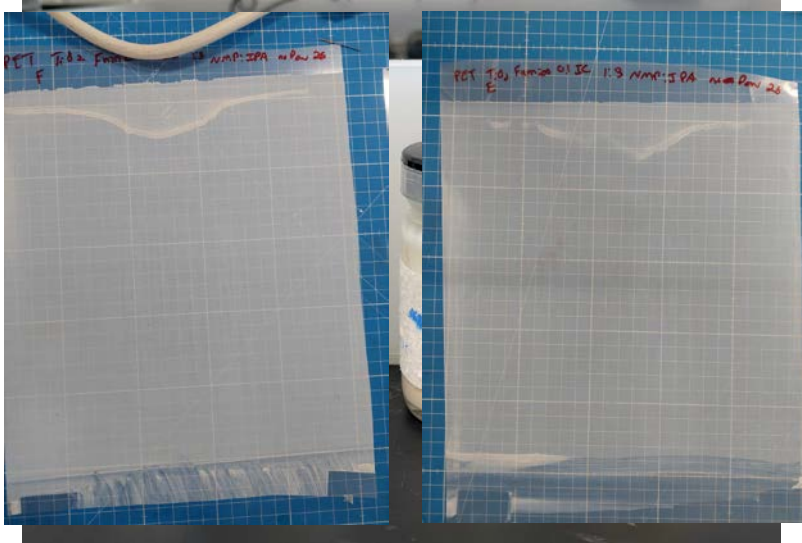
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Role of Catalyst on Lamination

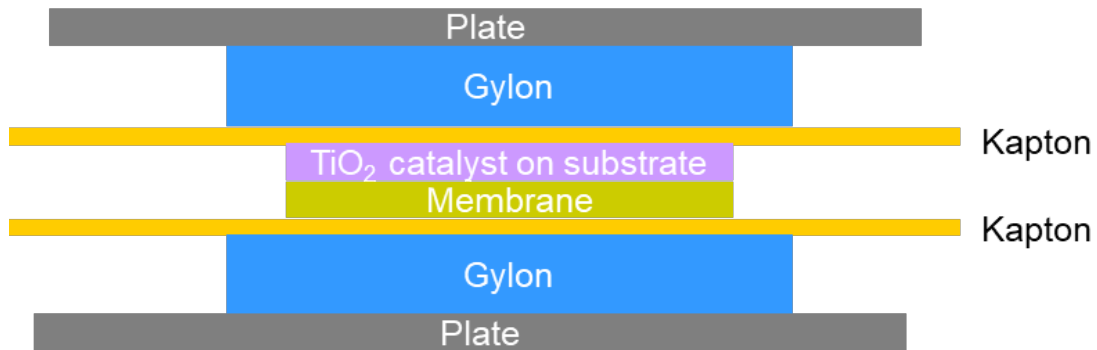
Fumion: TiO_2 ratio



- Material: Fumion ionomer+ TiO_2 as catalyst, which is more compatible with the AEM and CEM
- Electrode is a key in water splitting (performance) and adhesion strength (mechanical stability).

Catalyst formulation effects on transfer

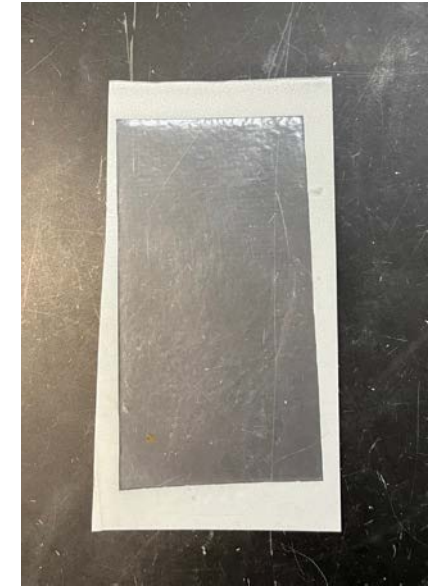
Catalyst transfer to membrane process



Catalyst substrate after transfer:

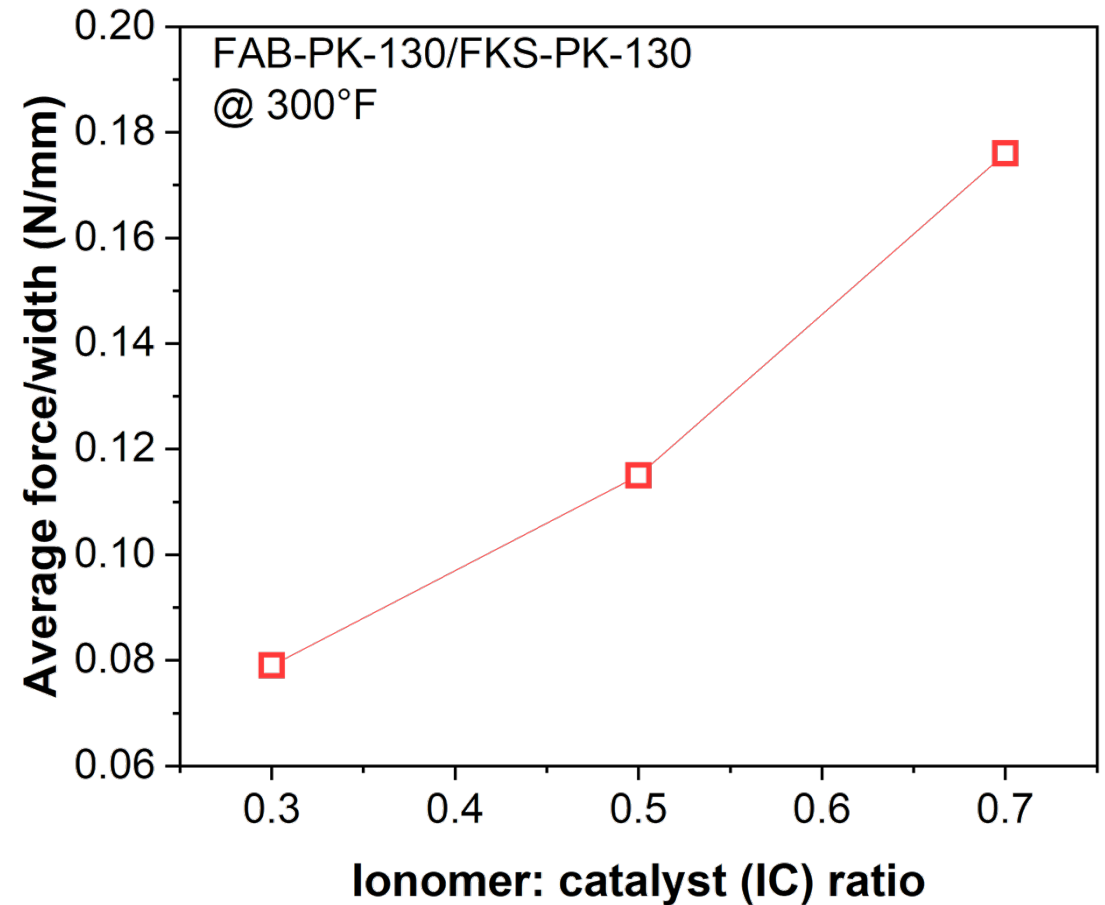
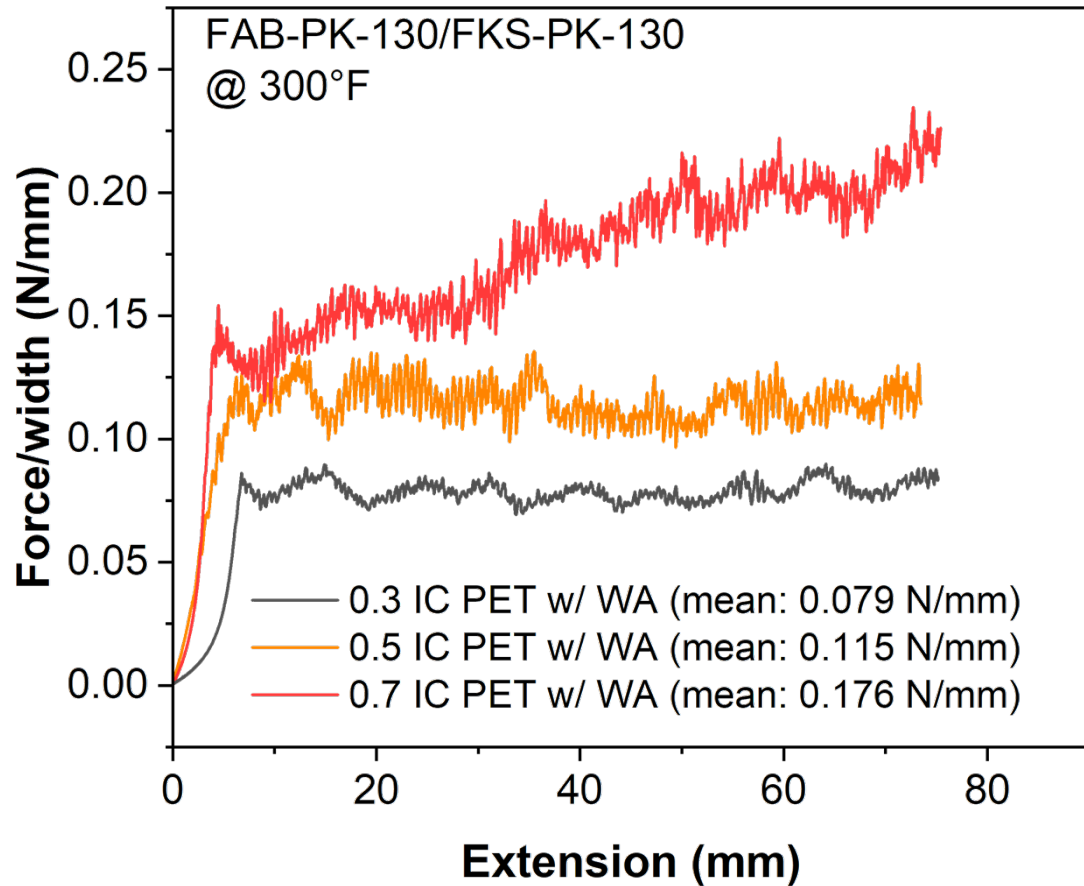


Ionomer: catalyst
ratio= 0.1

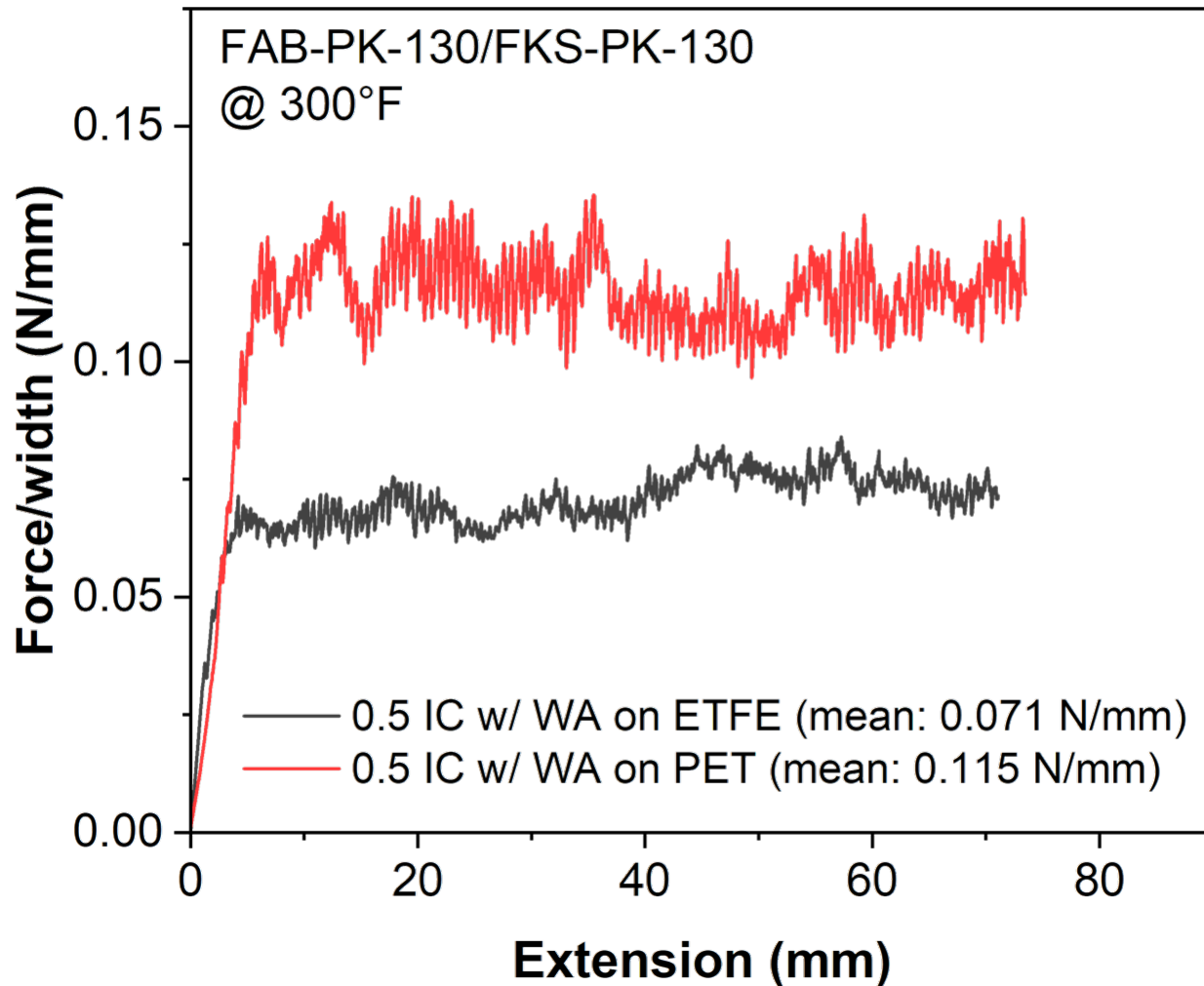


Ionomer: catalyst
ratio=0.5

T-peel test: Impact of the ionomer: catalyst ratio



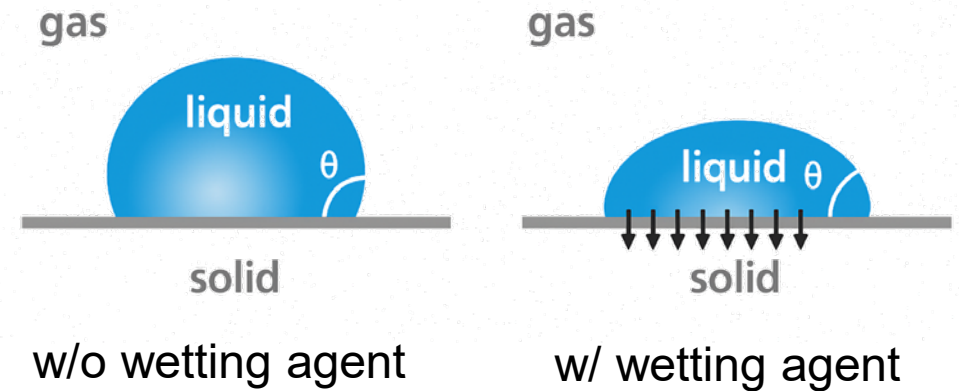
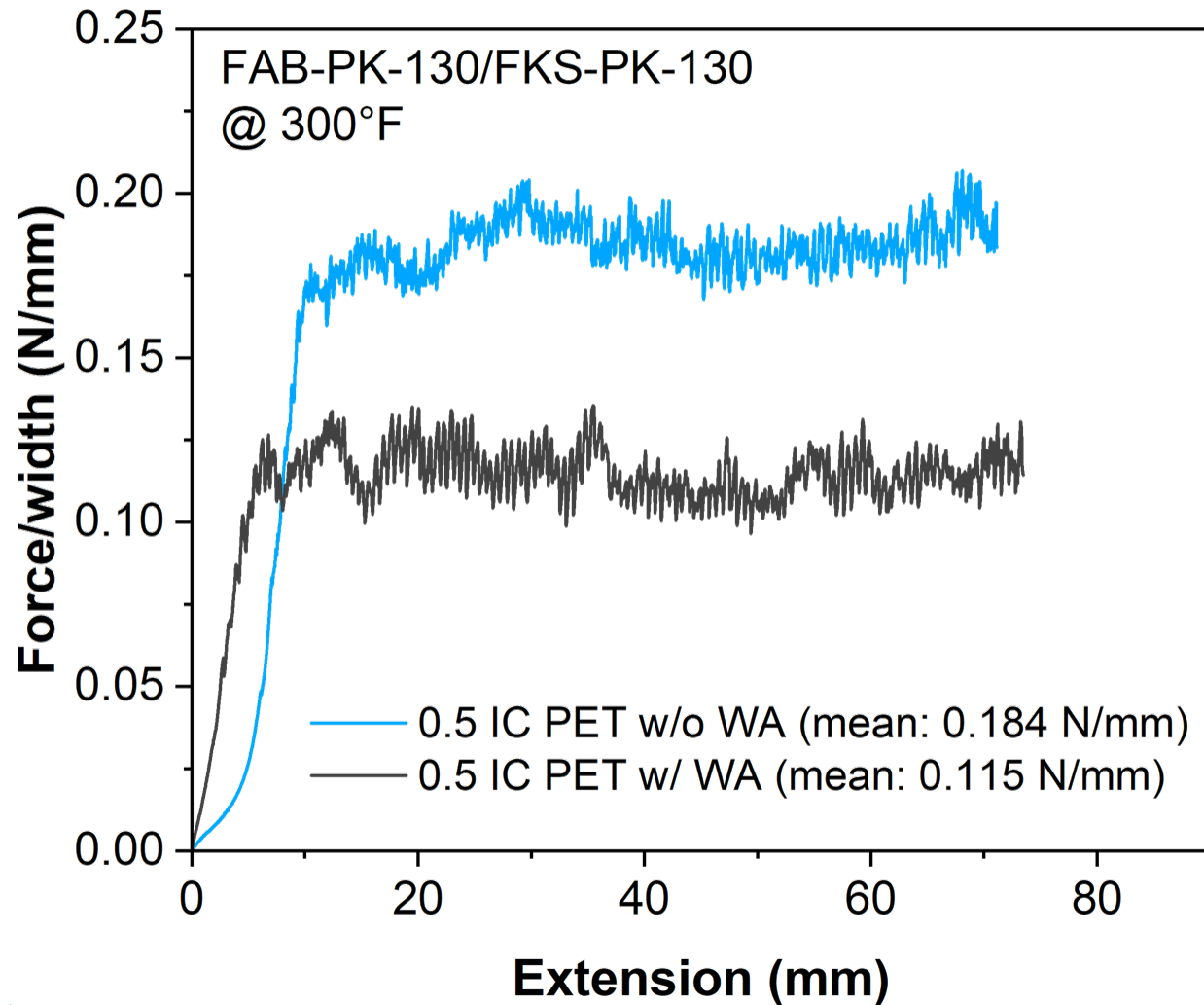
T-peel test: Impact of substrate



The PET substrate can produce a higher adhesion strength than ETFE substrate, which could result from the rigidity of PET.



T-peel test: Impact of substrate wetting agent



The wetting agent can help with the wettability of ionomer solution on PET but also decrease the adhesion strength of the interface at the BPMs.

T-peel test: Impact of membrane thickness

Condition: FAA-3-50/0.5 IC
Fumion: TiO₂/FAS-50. Both AEM and CEM have a thickness of 50 μm.

Result: incompleting peel-off

Conclusion: the adhesion strength at the interface is much stronger than the membrane itself.



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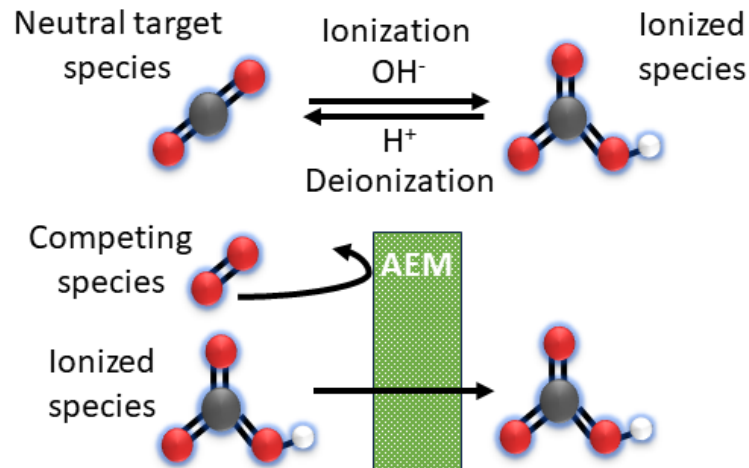
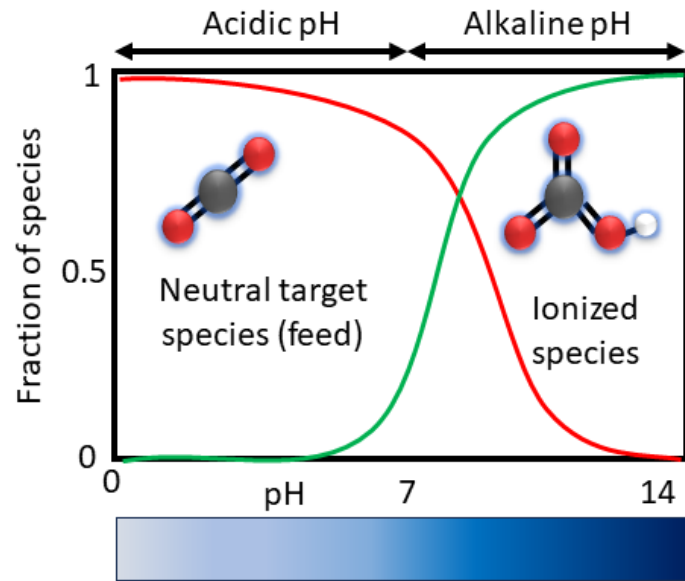
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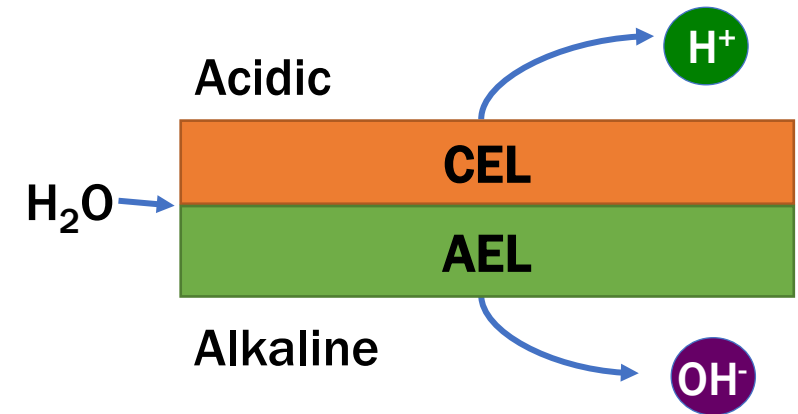
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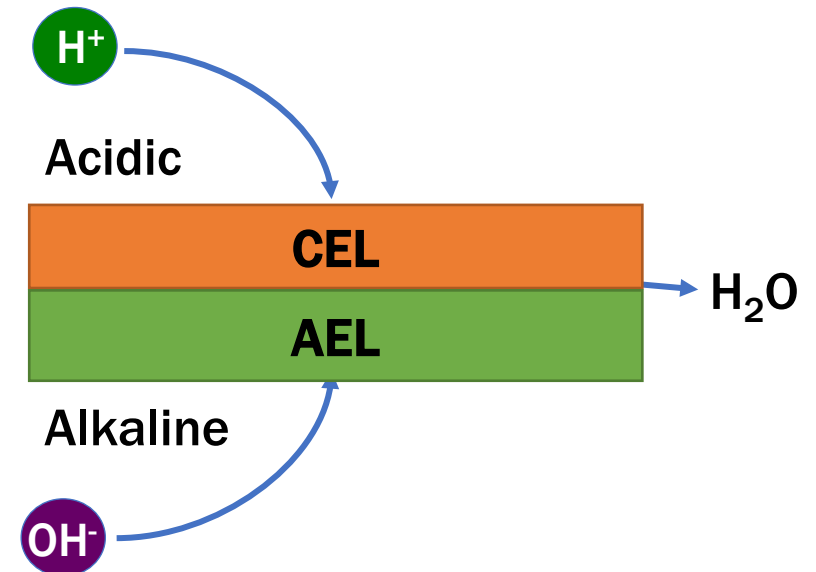
What are bipolar membranes (BPMs)?



Reverse bias
Water
dissociation



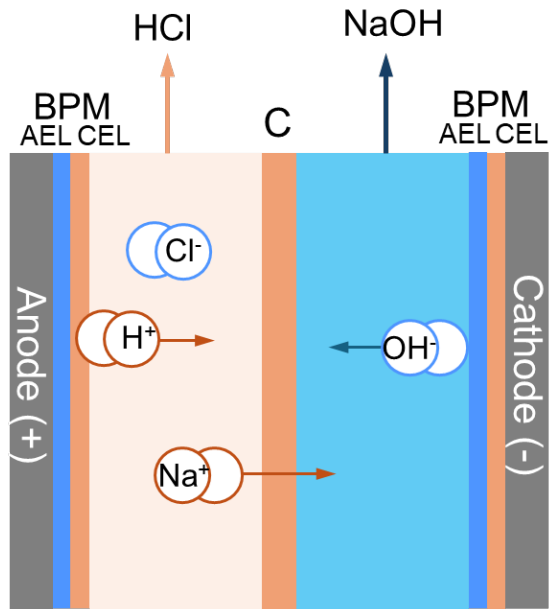
Forward bias
Water
association



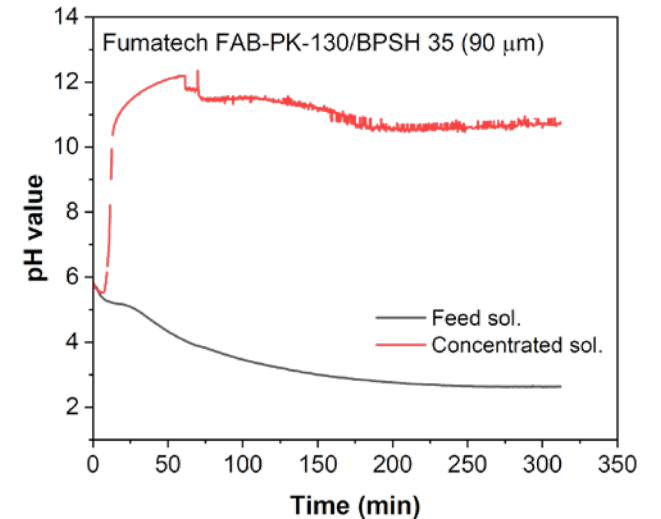
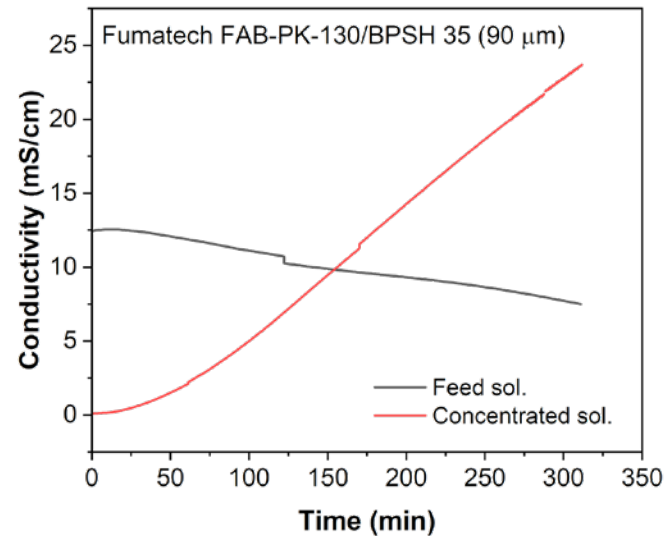
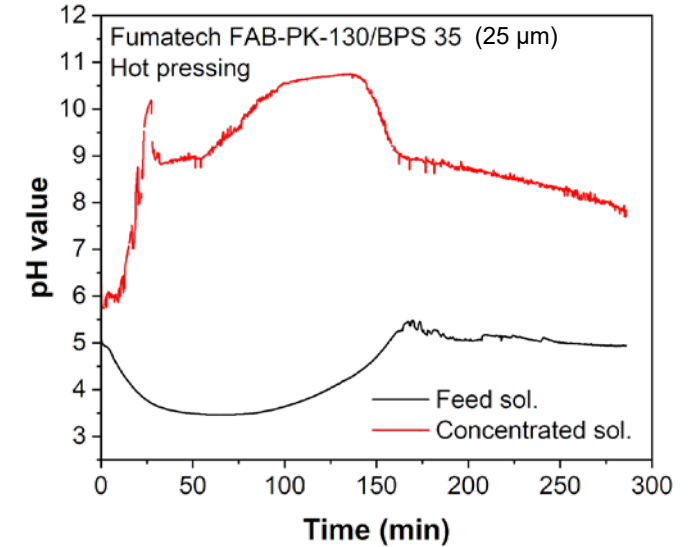
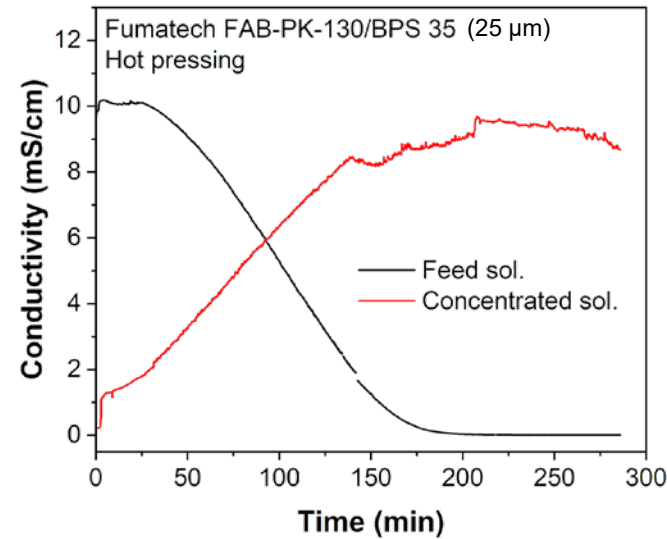
BPM Electrodesialysis test



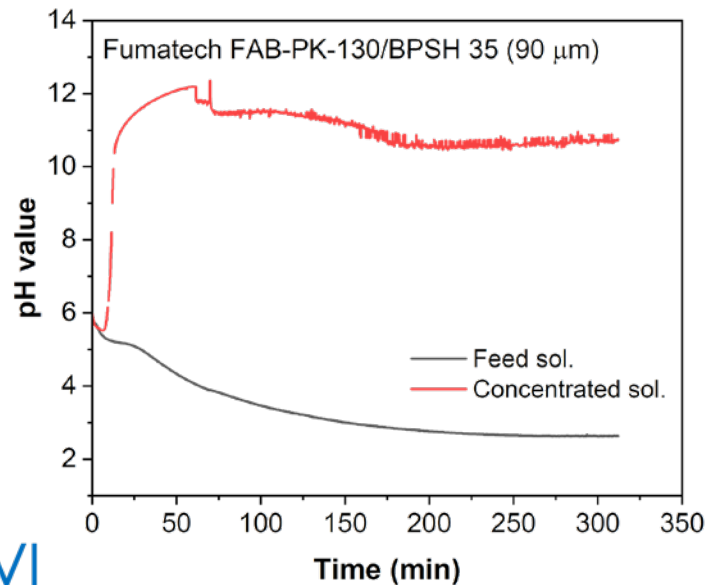
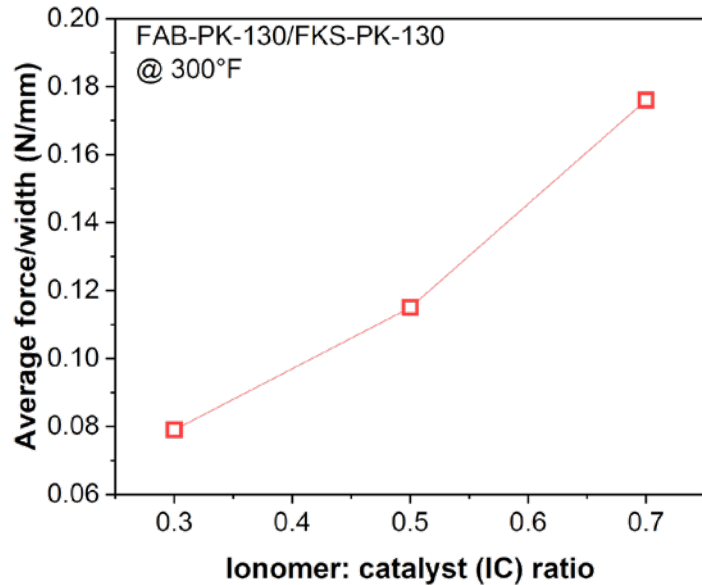
Condition: 250 mL 0.1M NaCl as the feeding solution at a constant voltage of 9V. Fumatech FAB-PK-130/TiO₂ catalyst/NREL BPS 35.



C: cation exchange membrane
 AEL: anion exchange layer
 CEL: cation exchange layer
 BPM: bipolar membrane



Summary and Conclusions



- Hot pressing temperature and addition of catalyst layer affect the adhesion strength of interface in BPMs.
- Specially, the catalyst plays an important role in water splitting (performance) and adhesion strength (mechanical stability) in BPMs.
- Rigid PET, higher ionomer: catalyst ratio can improve the adhesion strength while adding wetting agent decreases the adhesion strength.
- More BPM ED tests will be conducted to study the effects of these catalyst-related factors on ED performance such as current efficiency and product purity.

Acknowledgement

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