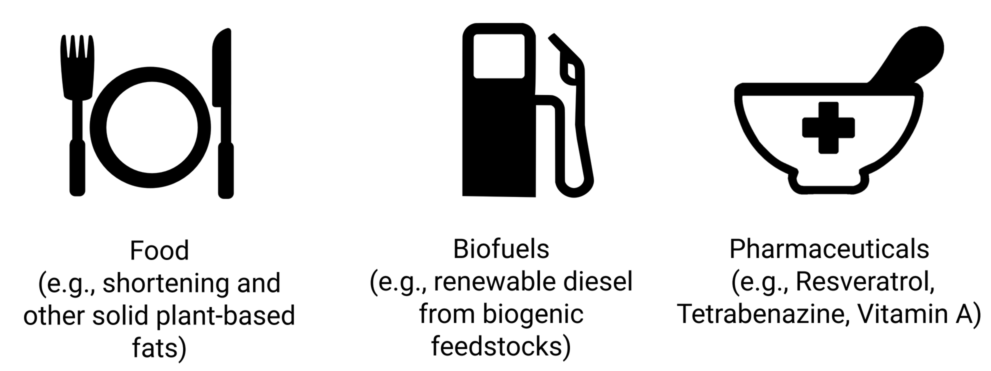
Sustainable hydrogenation using a palladium membrane reactor

Ryan Jansonius, Aiko Kurimoto and Curtis P. Berlinguette*

Departments of Chemistry and Chemical & Biological Engineering, and The Quantum Matter Institute, The University of British Columbia, Vancouver, BC, Canada

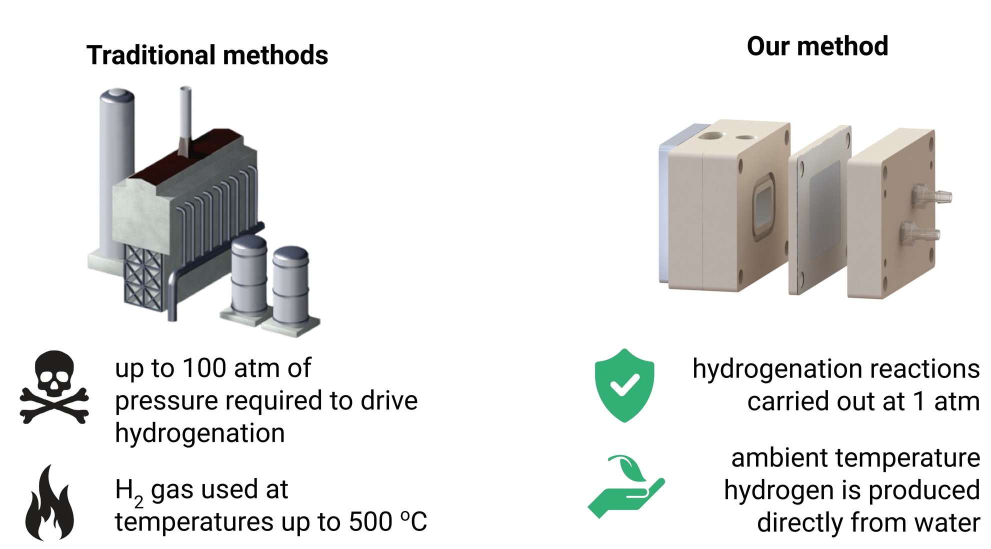
Hydrogenation is a process used in the manufacture of useful chemicals

Hydrogenation reactions are used at large scale in the petrochemical, fine chemical and food industries. Together these reactions consume 113 million metric tons of hydrogen gas annually.[1]



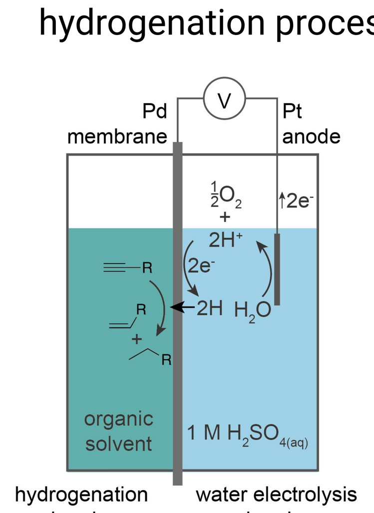
Hydrogenation reactions traditionally require harsh reaction conditions

Industrial hydrogenation is unilaterally carried out at high temperature and pressure and uses H_2 gas as the hydrogen source.[2] These processes have inherent safety risks and environmental costs owing to the flammability of H_2 gas derived from fossil fuels.[1] We are developing a hydrogenation reactor to address these concerns.



Our reactor can uses electricity and water to hydrogenate chemical feedstocks

Our hydrogenation reactor, called Thor, can enable safer, more sustainable hydrogenation by using only electricity and water to hydrogenate organic molecules.[3,4] The hydrogenation process happens in the following steps:



1. an electrical voltage is applied between the platinum anode and palladium cathode
2. water is oxidized at the anode to produce O_2 and protons
3. protons are reduced at the palladium membrane surface to produce hydrogen
4. hydrogen diffuses through the palladium membrane
5. hydrogen atoms hydrogenate an unsaturated organic molecule

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Renewable electricity can be used to drive **useful** chemical transformations

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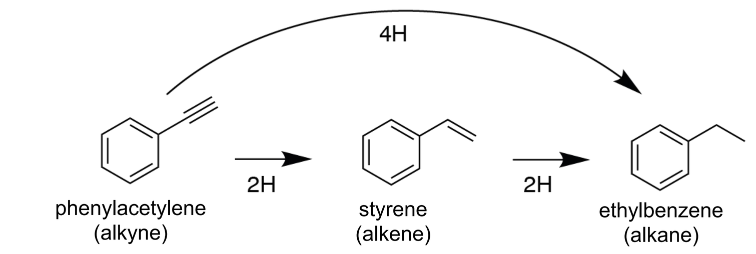
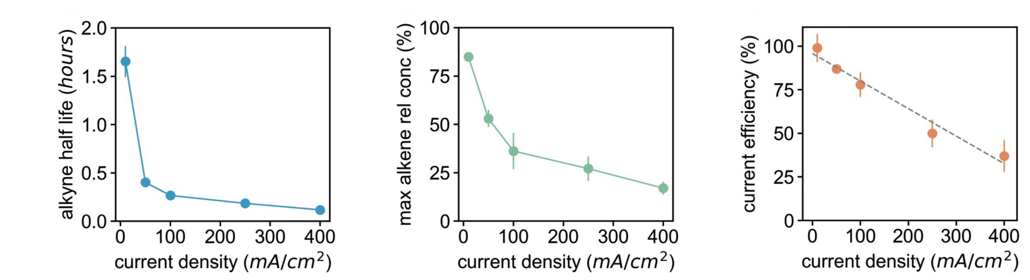
Proof of concept: We can control the reaction performance by changing the electrical current

The reaction performance (i.e., rate, selectivity, and efficiency) of the reaction can be controlled by adjusting the electrical current used to drive the water electrolysis reaction.[4]

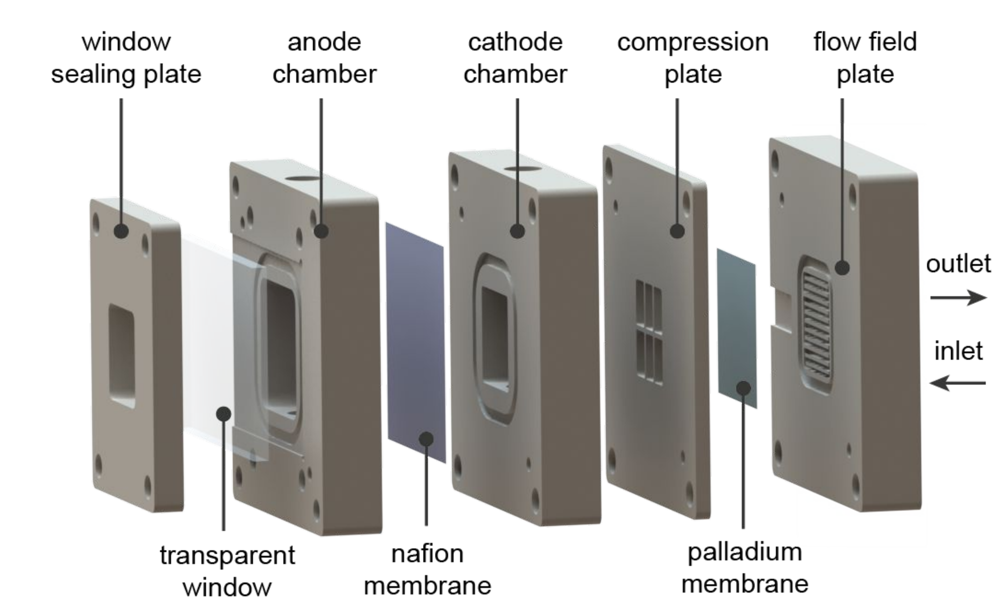


proof of concept: phenylacetylene hydrogenation



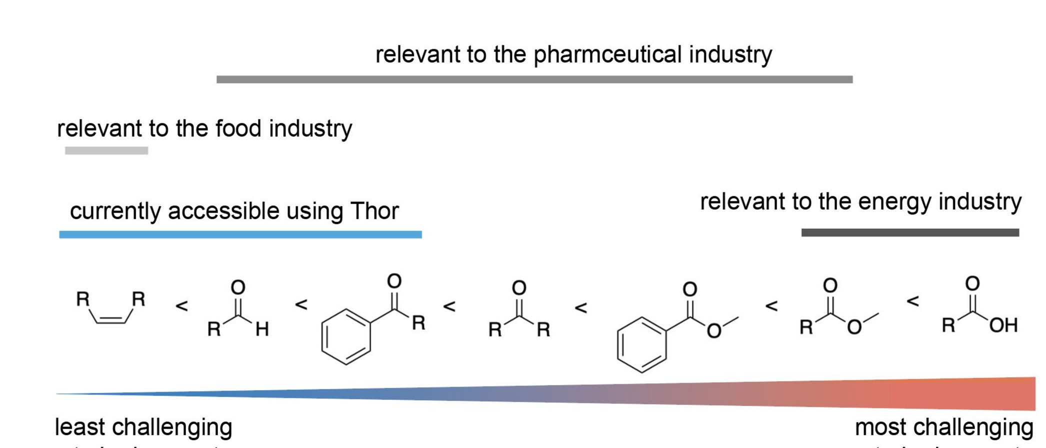
A palladium membrane flow cell for faster hydrogenation

Making an impact in commodity chemical synthesis requires high reaction rates, and a scalable reactor platform. Toward this goal, we constructed a flow cell that enables ~20x faster reaction rates than previous batch-reactor designs. This approach was informed by the technical development of electrocatalytic flow-cell systems such as hydrogen fuel cells[5] or CO_2 electrolyzers.[6]



We are working toward applying this technology to large-scale commodity chemical synthesis

We are currently limited to hydrogenation of carbon-carbon, and some carbon-oxygen double bonds. We are developing catalysts to expand the diversity of bonds we can hydrogenate. We are looking for industrial partners to help us develop this technology for impactful applications!



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extra

Sustainable hydrogenation using water and electricity

First author, Other Author, and Curtis P. Berlinguette*
Departments of Chemistry and Chemical & Biological Engineering, and The Quantum Matter Institute, The University of British Columbia, Vancouver, BC, Canada

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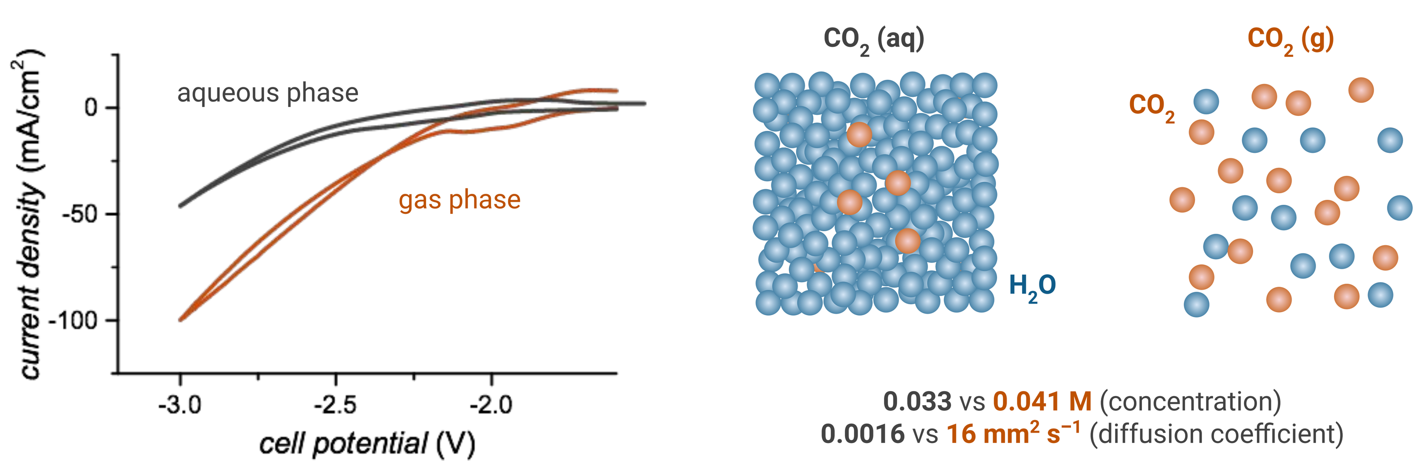

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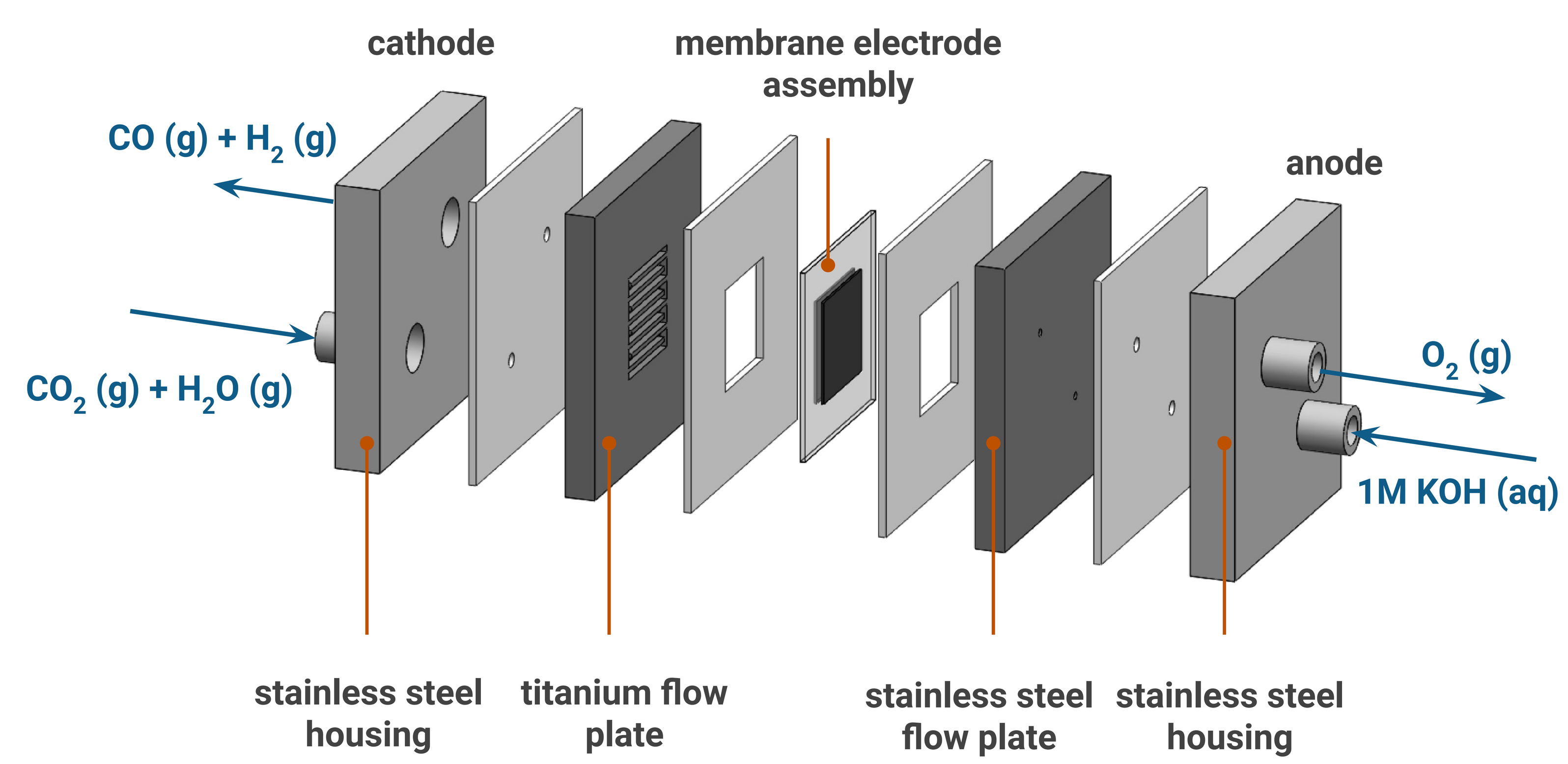

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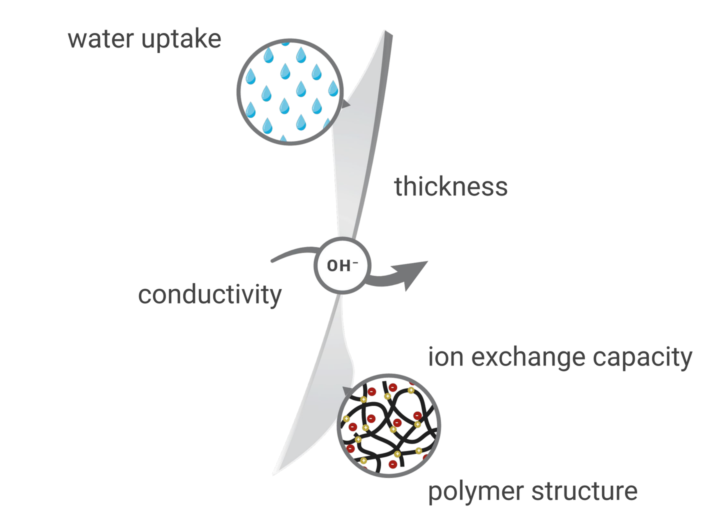

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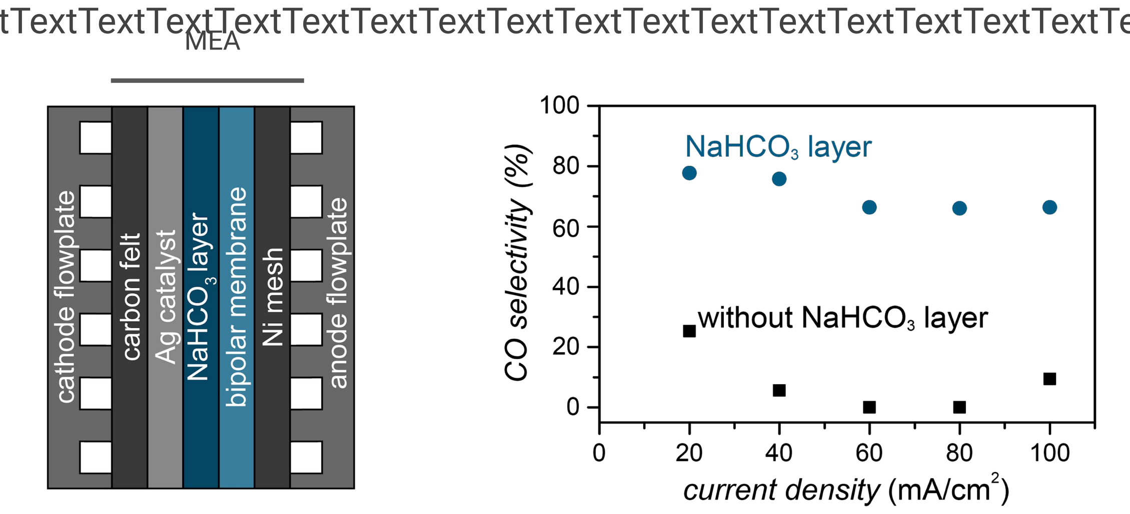

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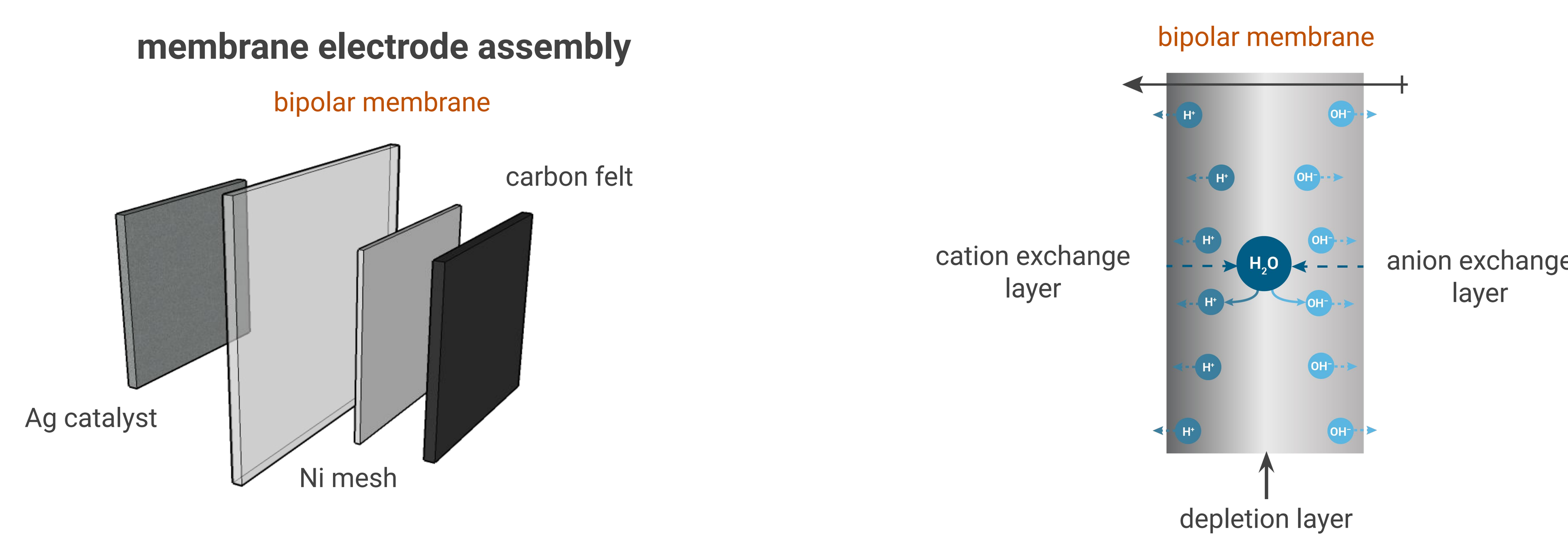

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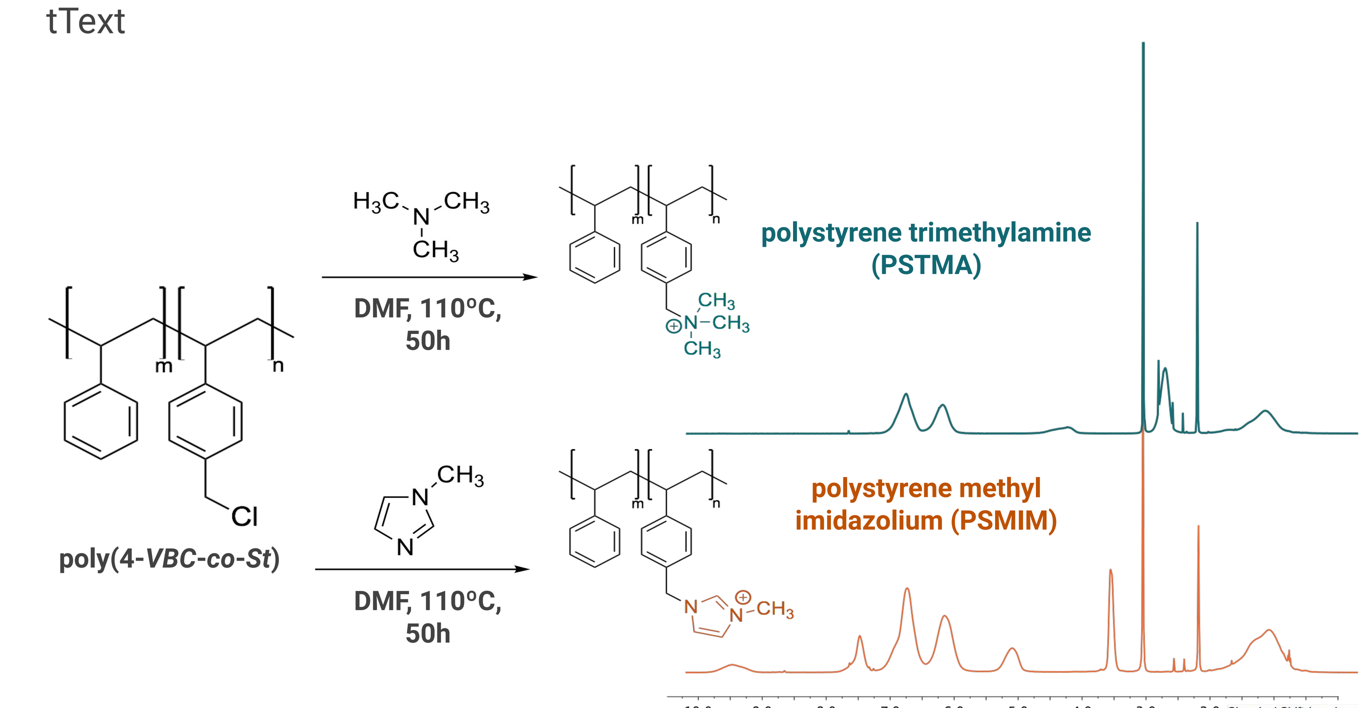

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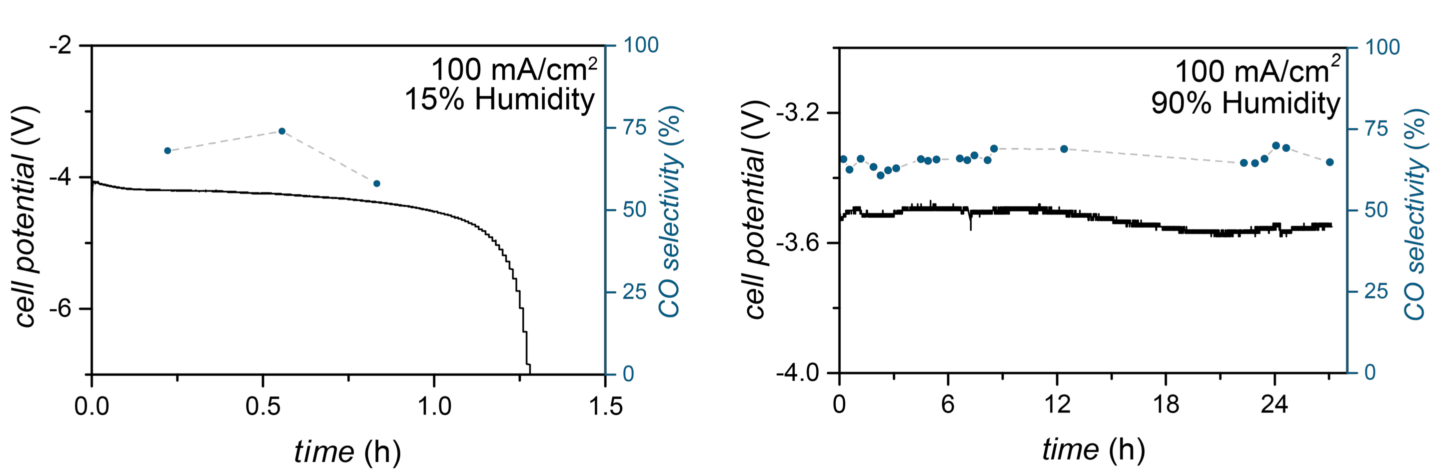

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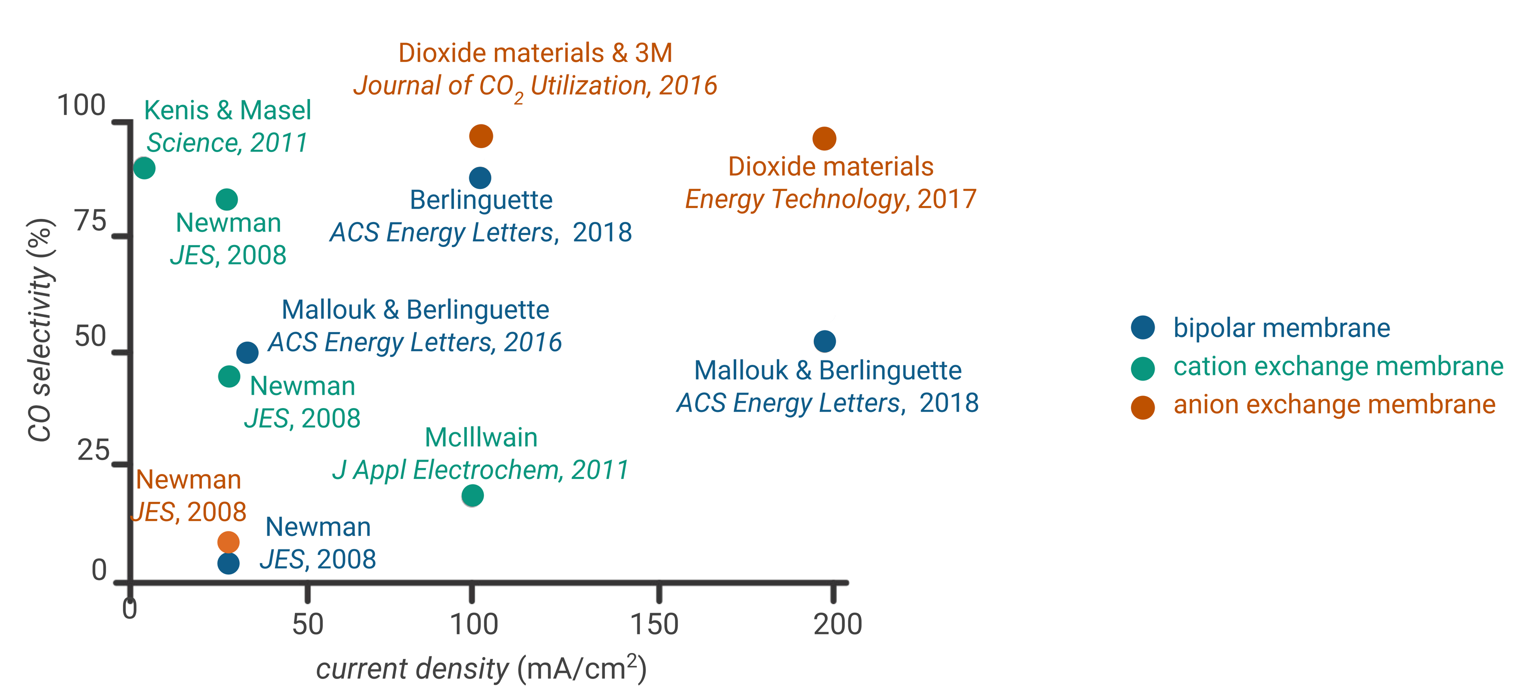

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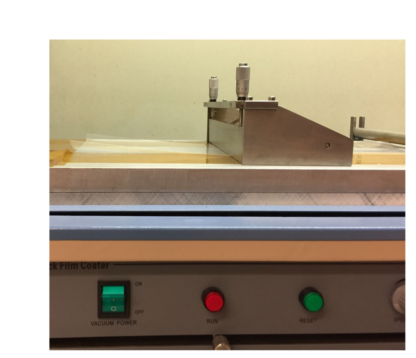

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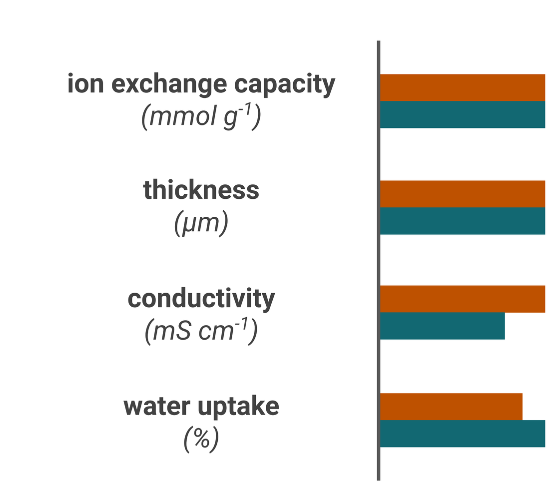

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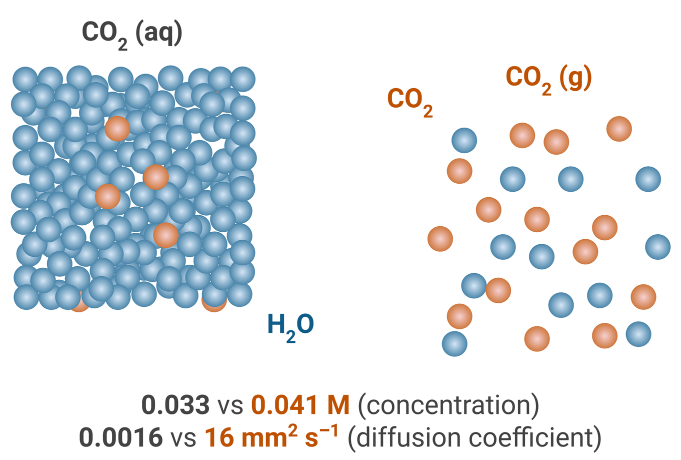

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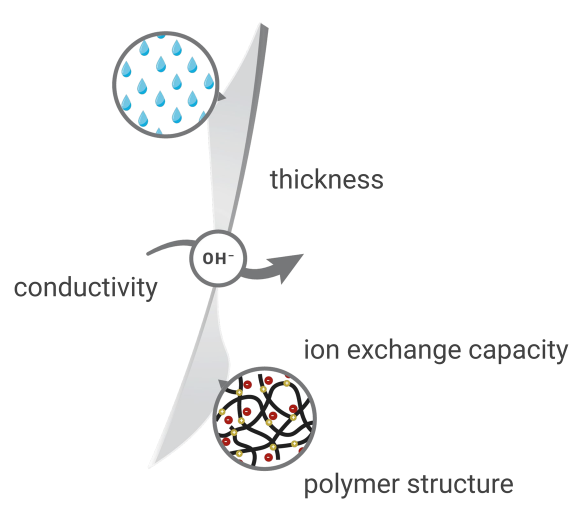

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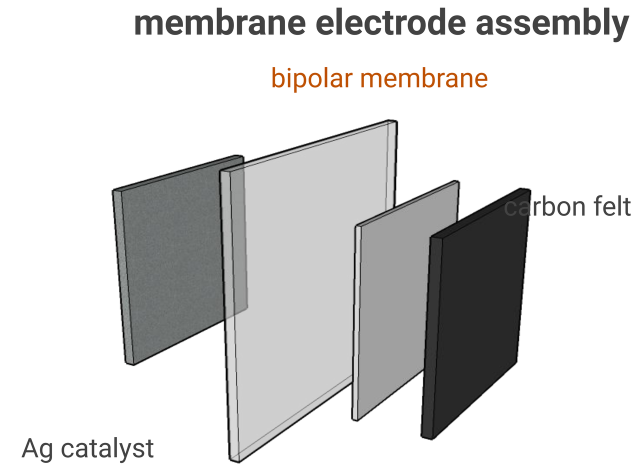

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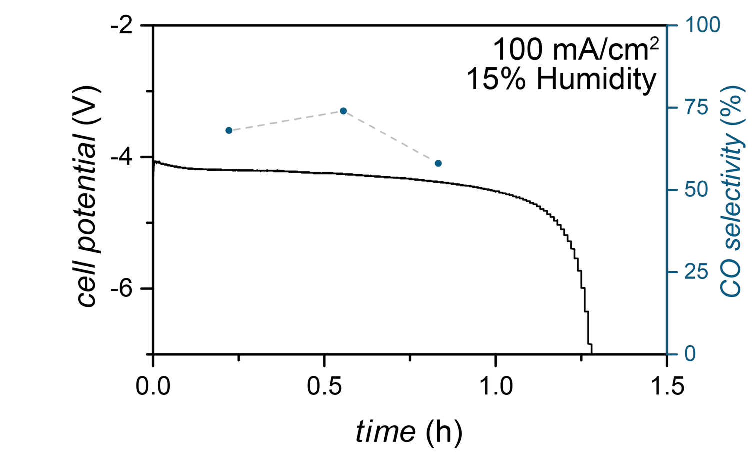

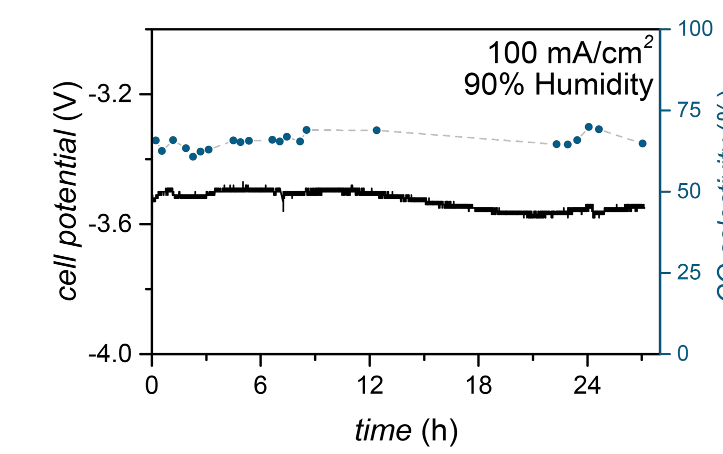

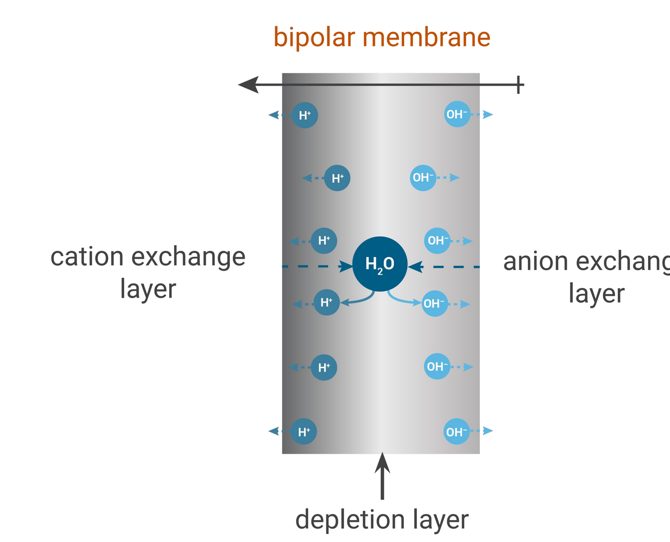

Comparison of solution processed WO_3|electrolyte|V_2O_5 electrochromic devices

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doctor-blade from V_2O_5 powder[4]	12	~ 8	-	-	200
spin-coated xerogel[5]	35	> 5	> 5	17	-
photodeposition	47	3	2	166	14,000 +
photodeposition	46	8	4	59	-

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  - "Are you relaying your story effectively?"

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  - Respect symmetry, have even whitespace sizes
  - Consistent sentence alignment & heading capitalization
  - Keep in mind how big things will be when you print the poster
  - White space is good - avoid unnecessarily large text
  - Consider left justifying rather than justified paragraphs -- stretched out short lines of text look weird & are hard to read/confusing

- **Use the template to help you save time!**
  - Colors, font sizes, etc have already been chosen for you to make your life easier!
  - Don't waste time moving away from the template unless you have a strong creative reason to do so

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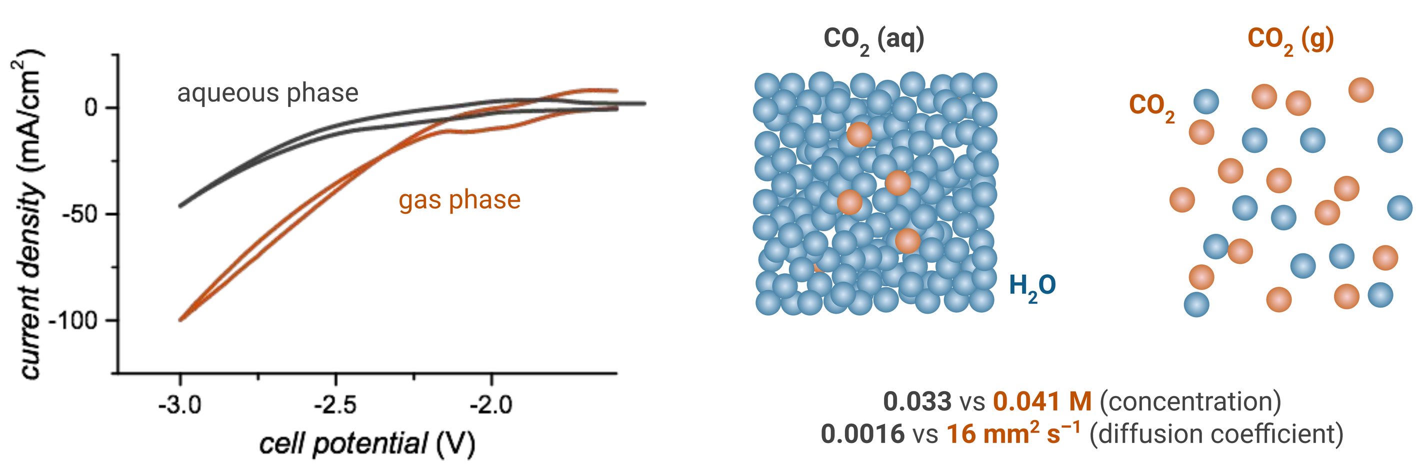

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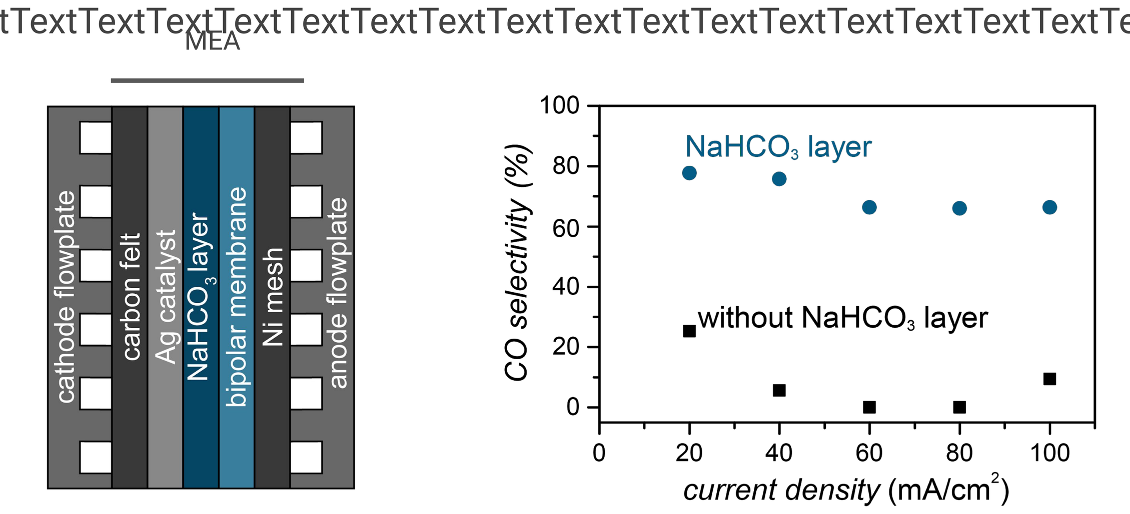

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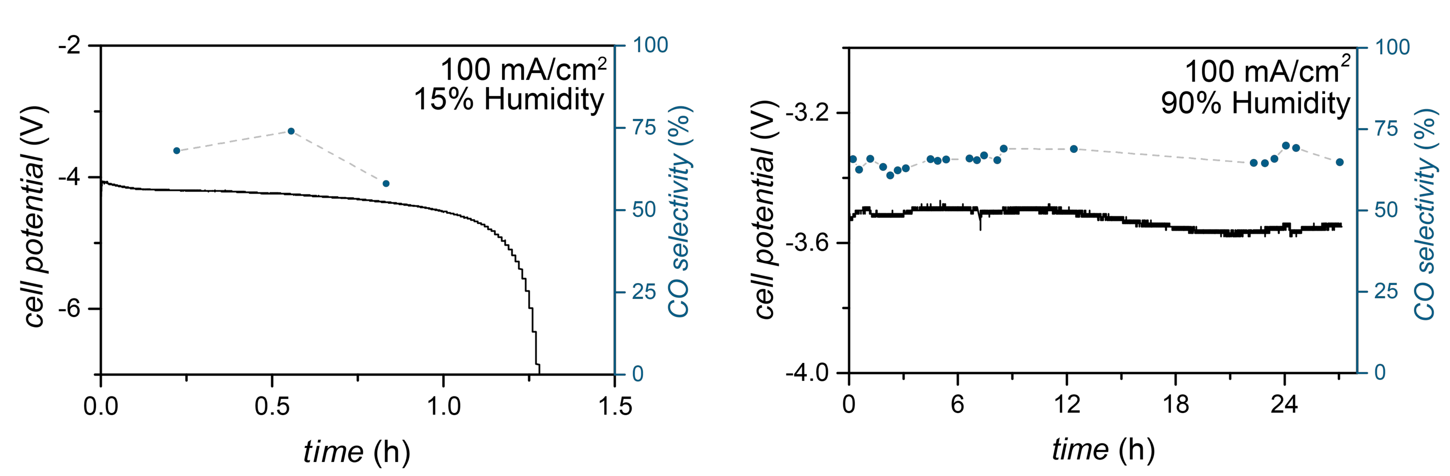

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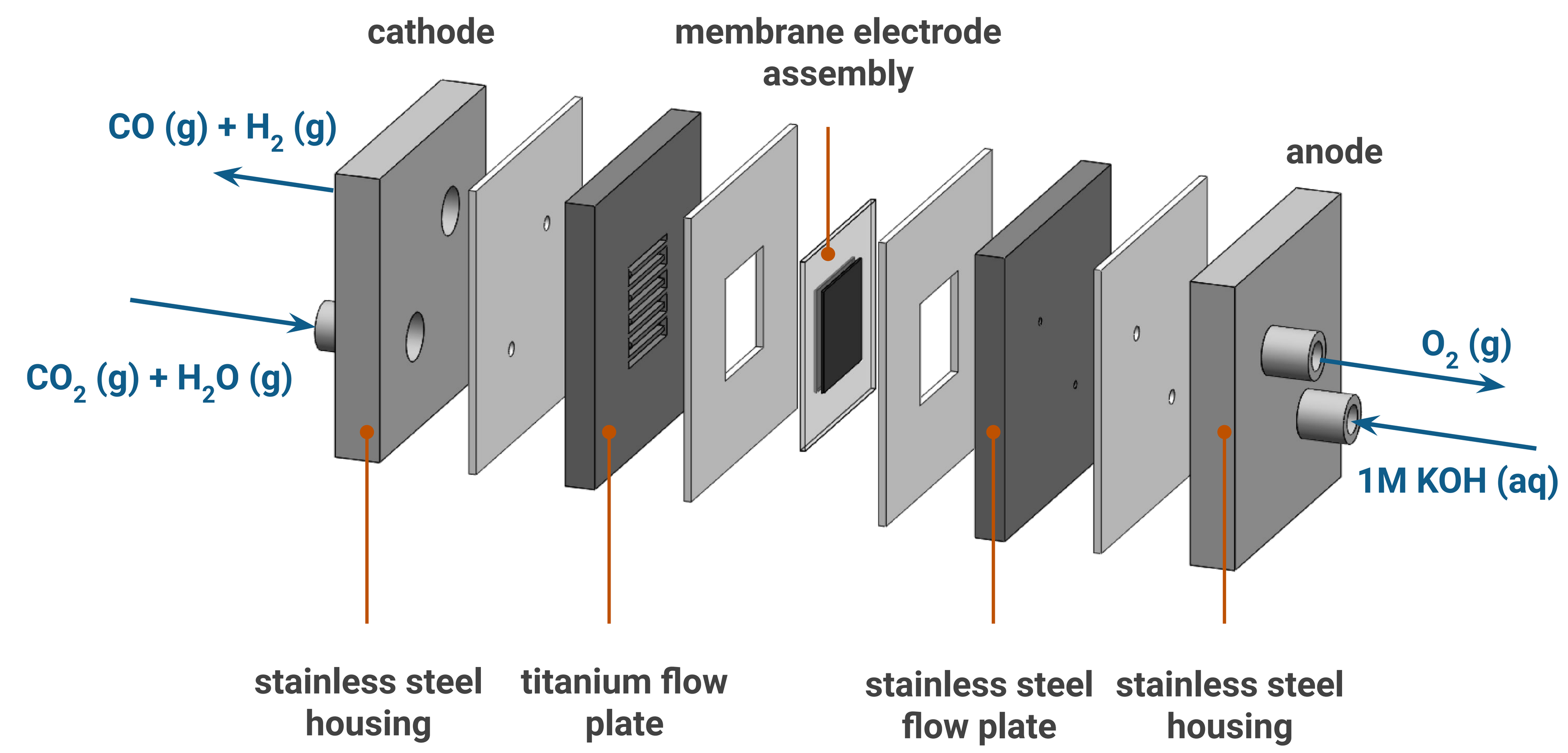

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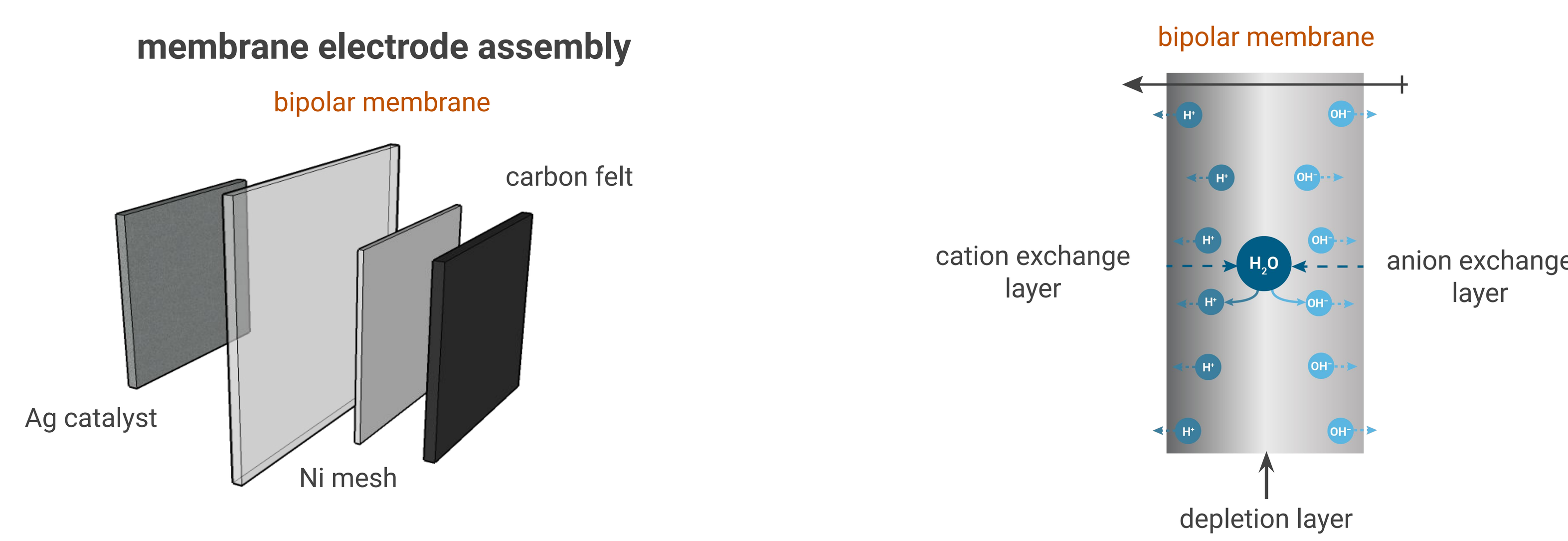

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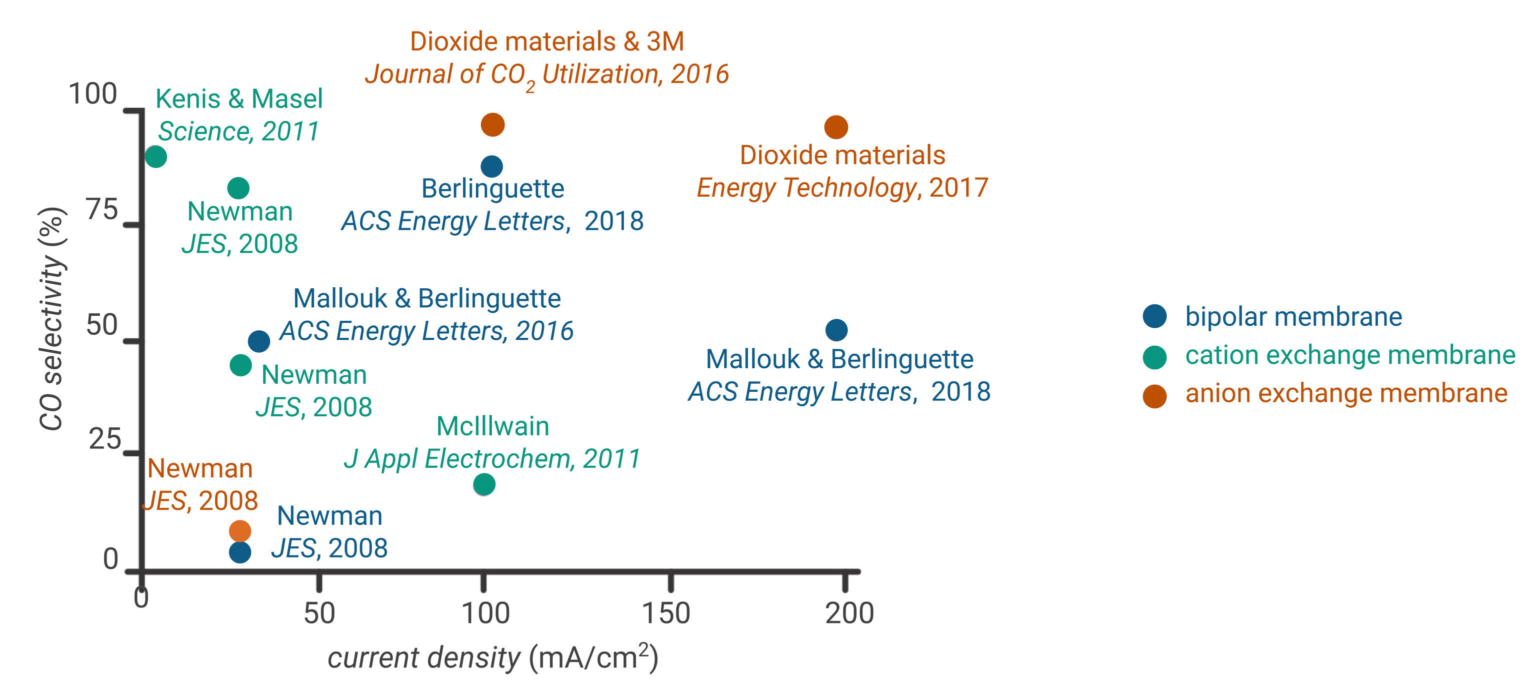

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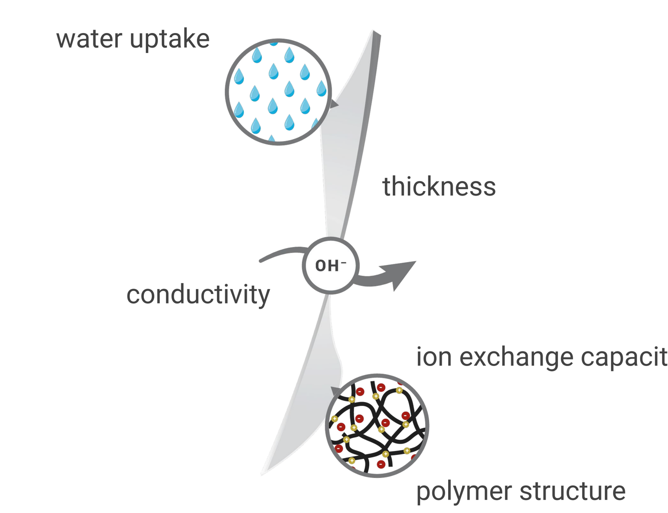

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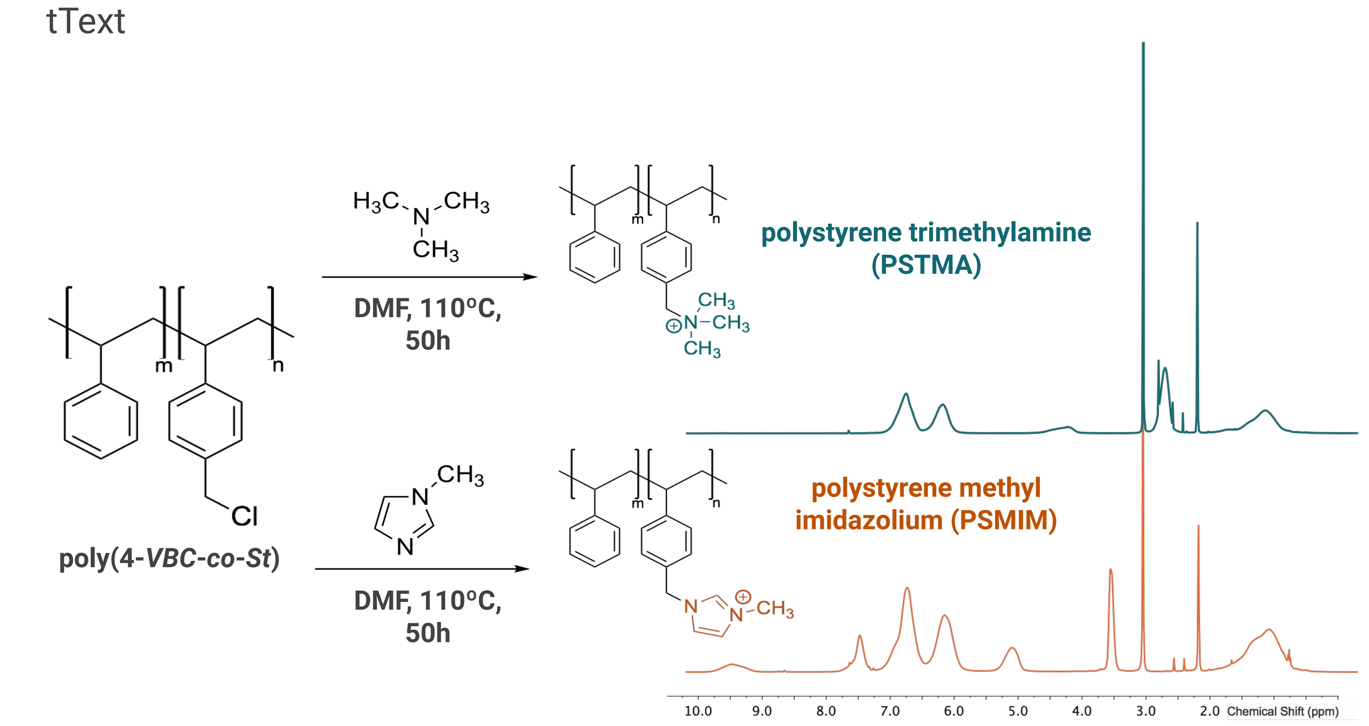

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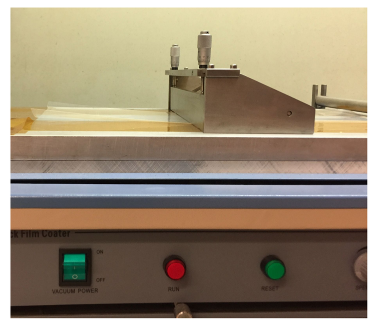

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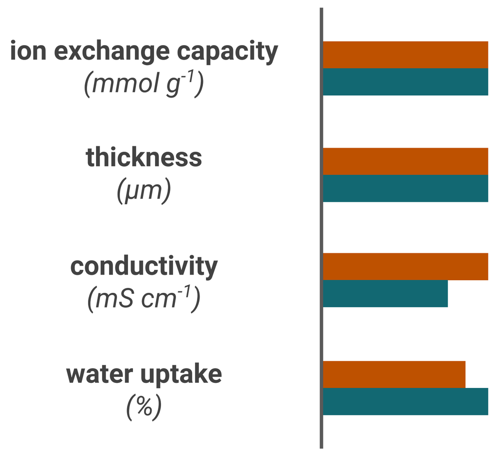

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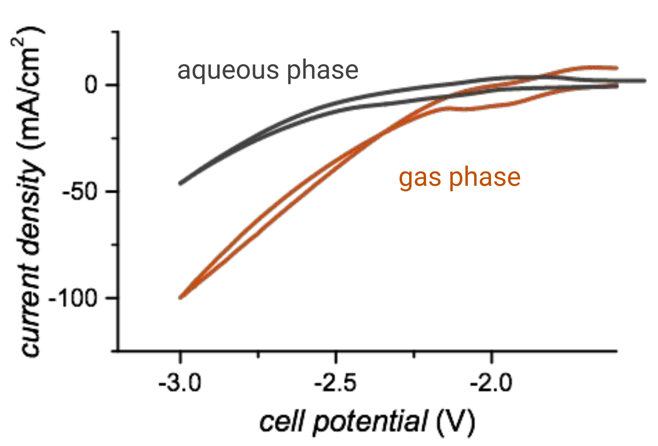

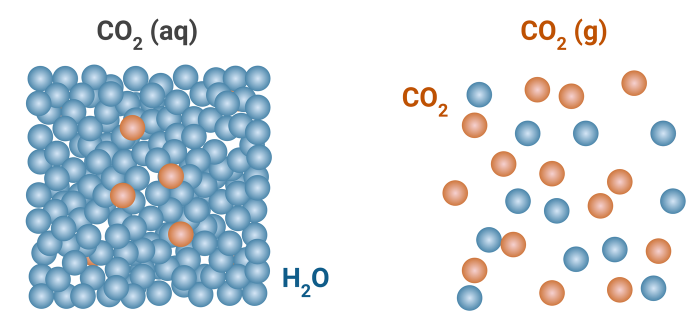

0.033 vs 0.041 M (concentration)
0.0016 vs 16 mm² s⁻¹ (diffusion coefficient)

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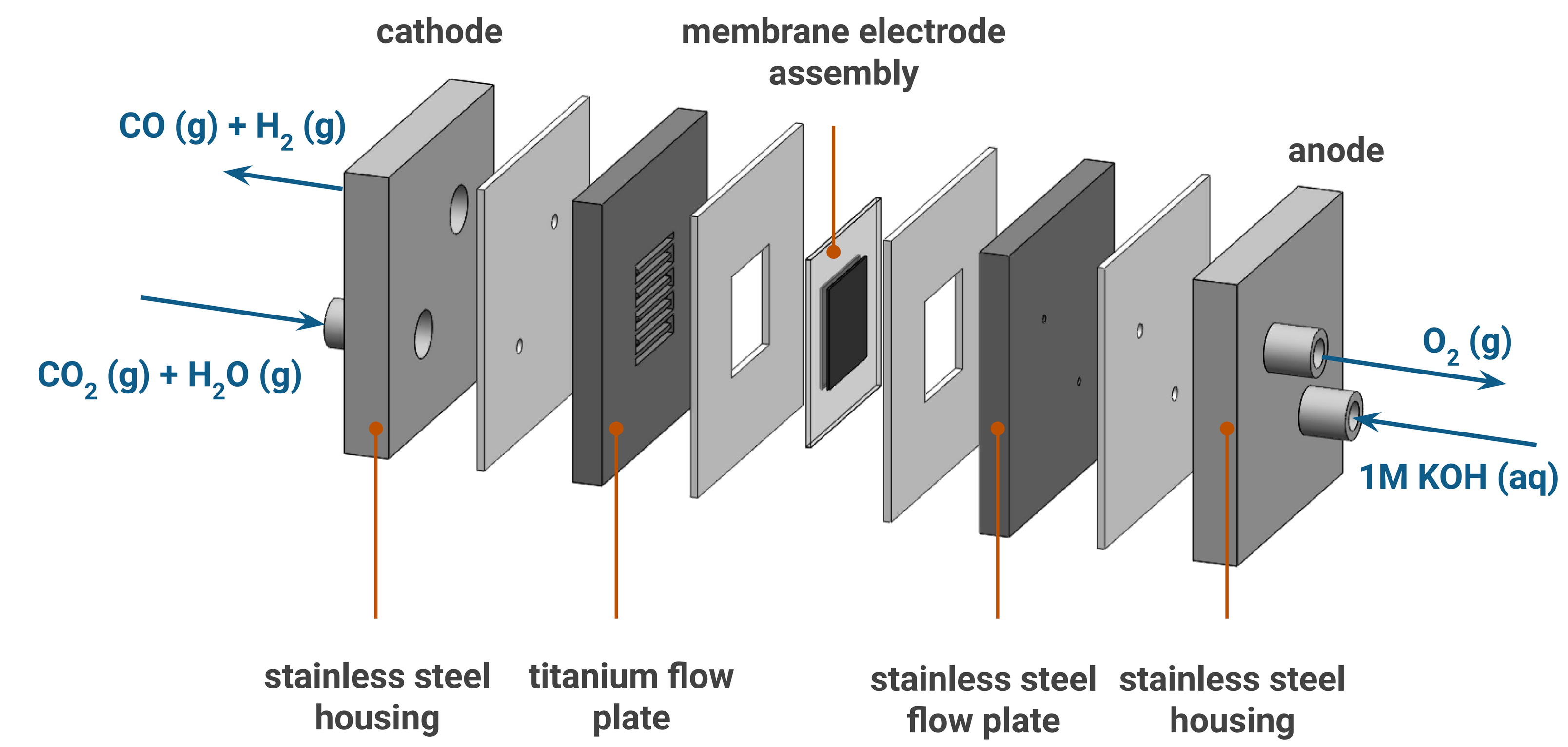

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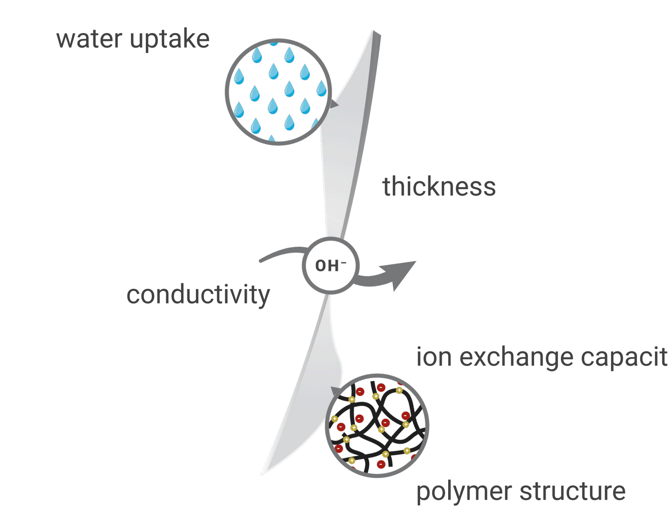

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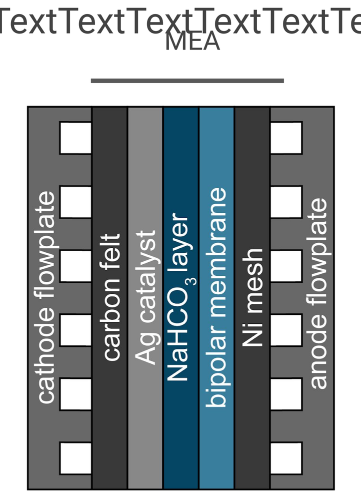

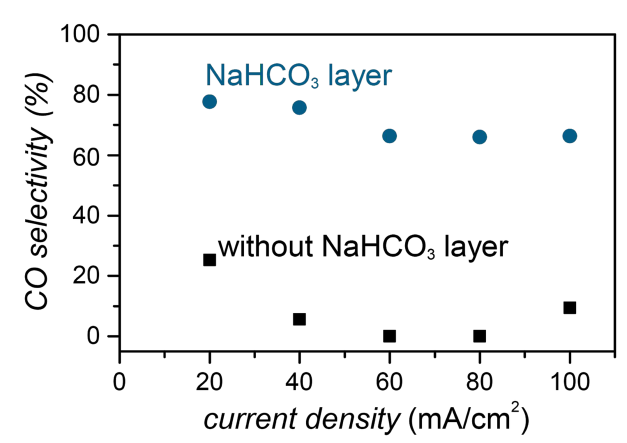

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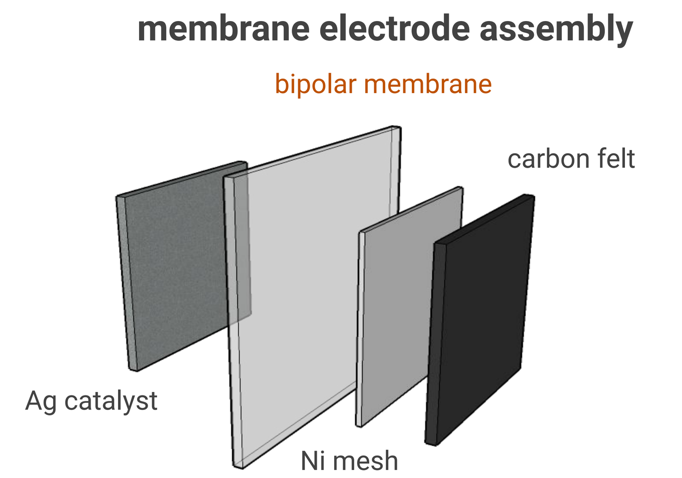

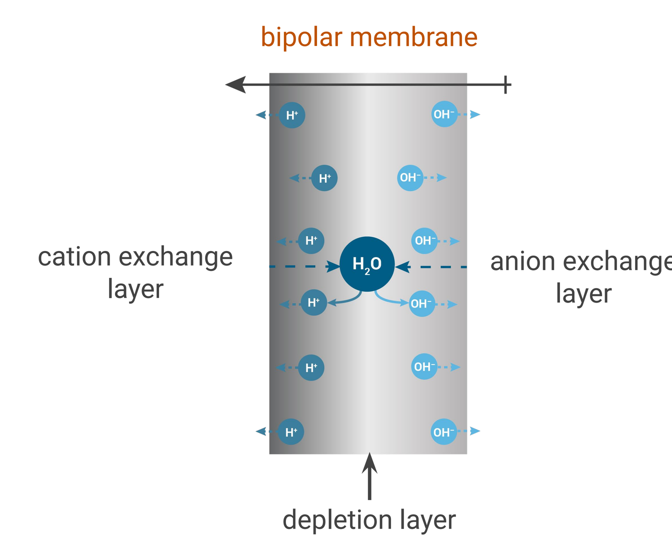

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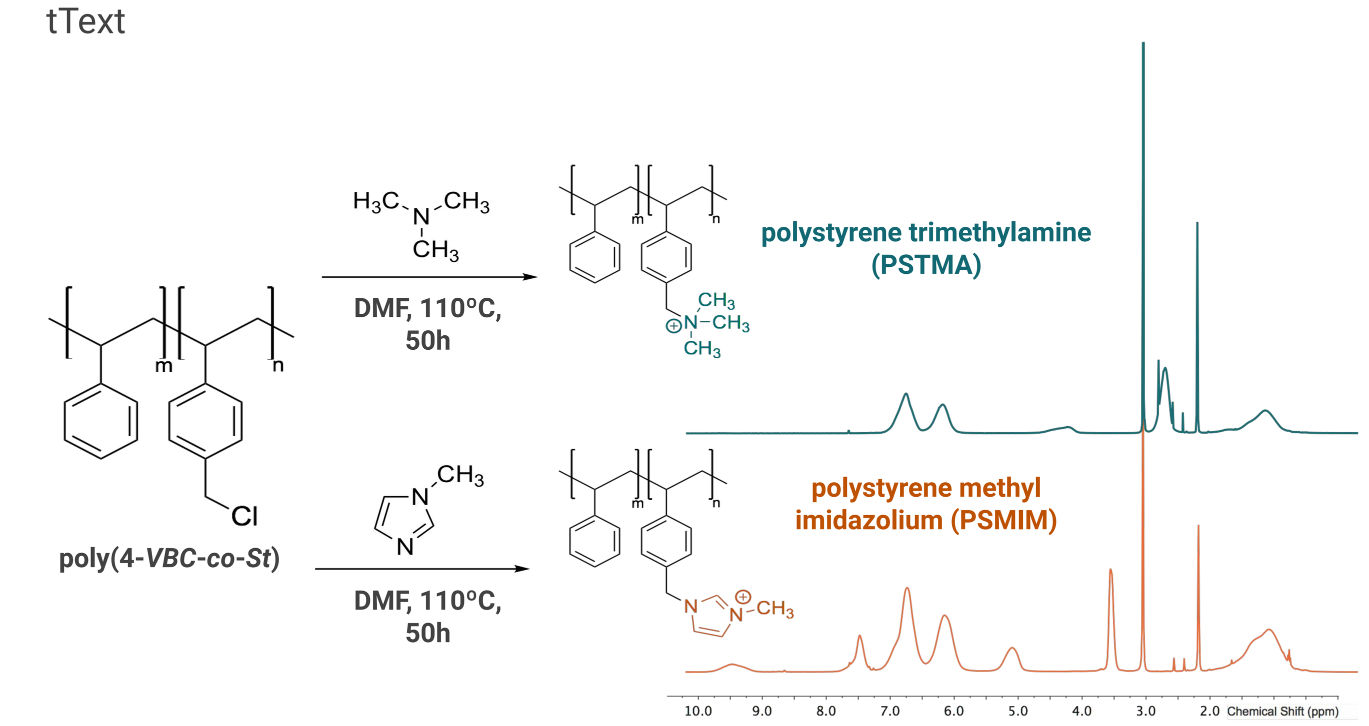

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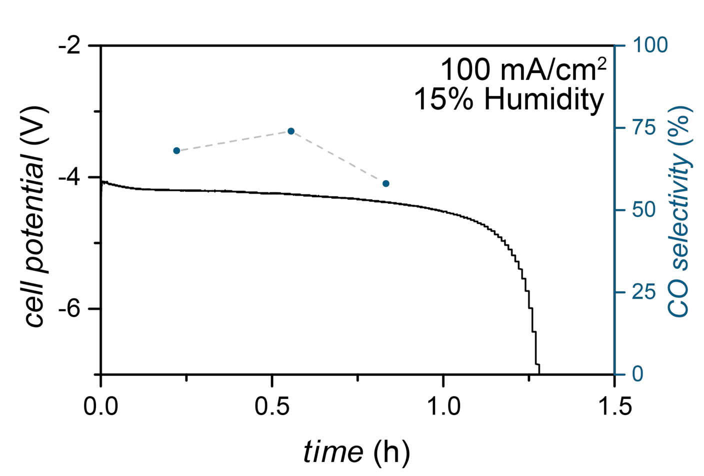

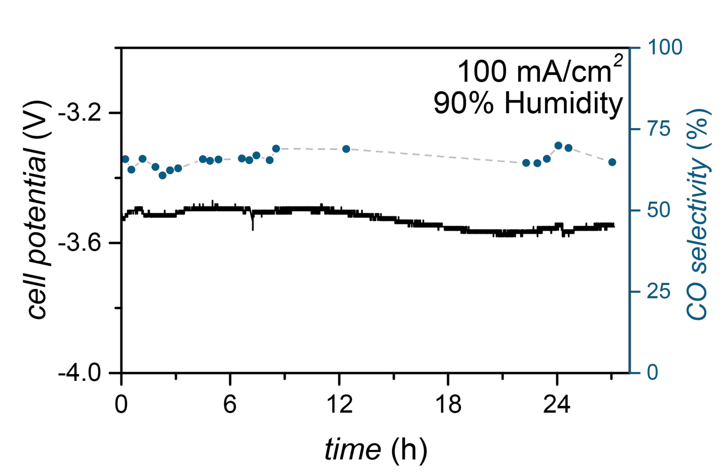

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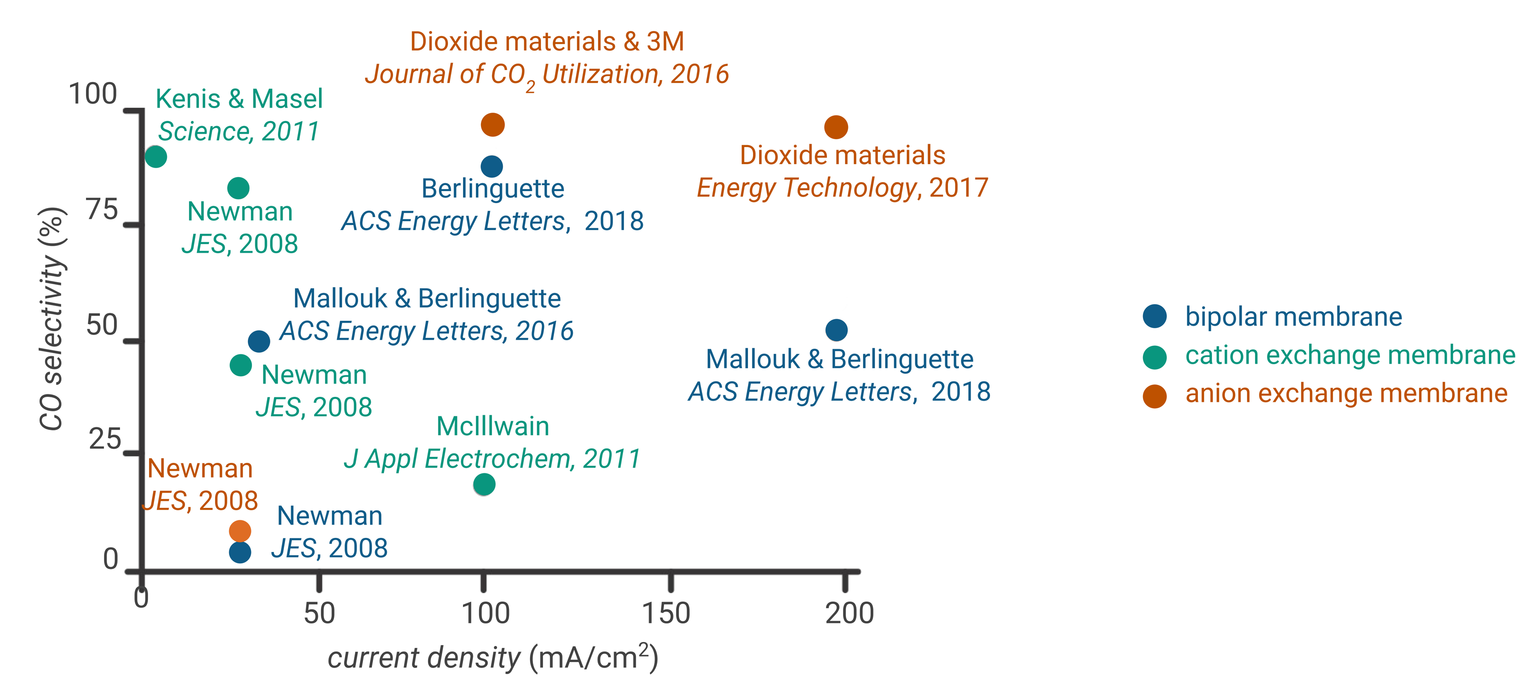

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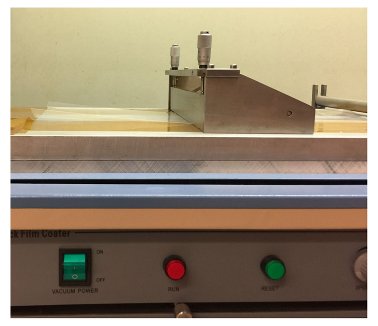
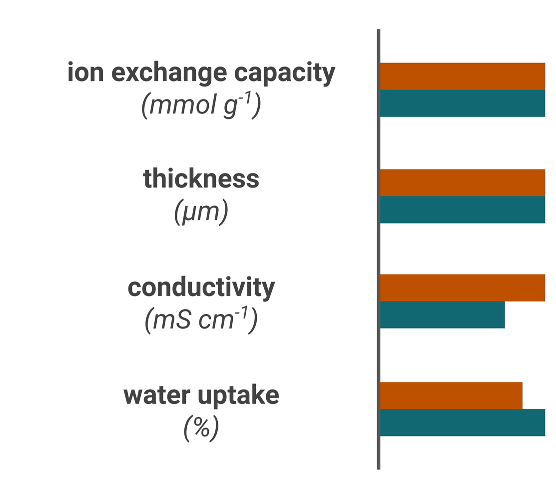


Achieving uniform membrane film thickness by doctor blading



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Stewart Blusson Quantum Matter Institute THE UNIVERSITY OF BRITISH COLUMBIA
CIFAR CANADIAN INSTITUTE FOR ADVANCED RESEARCH

Template colours

Tungsten
#424242FF
RGB(66,66,66)

CPB Orange
#E06C26FF
RGB(224,108,38)

CPB Blue
#4574A2FF
RGB(69,116,162)

Separator Box
“Pale Grey”
#EBEBEBFF
RGB(235,235,235)

Clover
#008E00FF
RGB(0,142,0)

Steel
#797979FF
RGB(121,121,121)

Cayenne
#941100FF
RGB(148,17,0)

Tungsten
#424242
RGB(66,66,66)

CPB Orange
#E06C26FF
RGB(224,108,38)

CPB Blue
#4574A2FF
RGB(69,116,162)

Clover
#008E00FF
RGB(0,142,0)

Steel
#797979FF
RGB(121,121,121)

Cayenne,
#941100FF
RGB(148,17,0)