Laboratory for Membrane Science and Technology

Membrane Development for Desalination and Hydrogen Energy Economy

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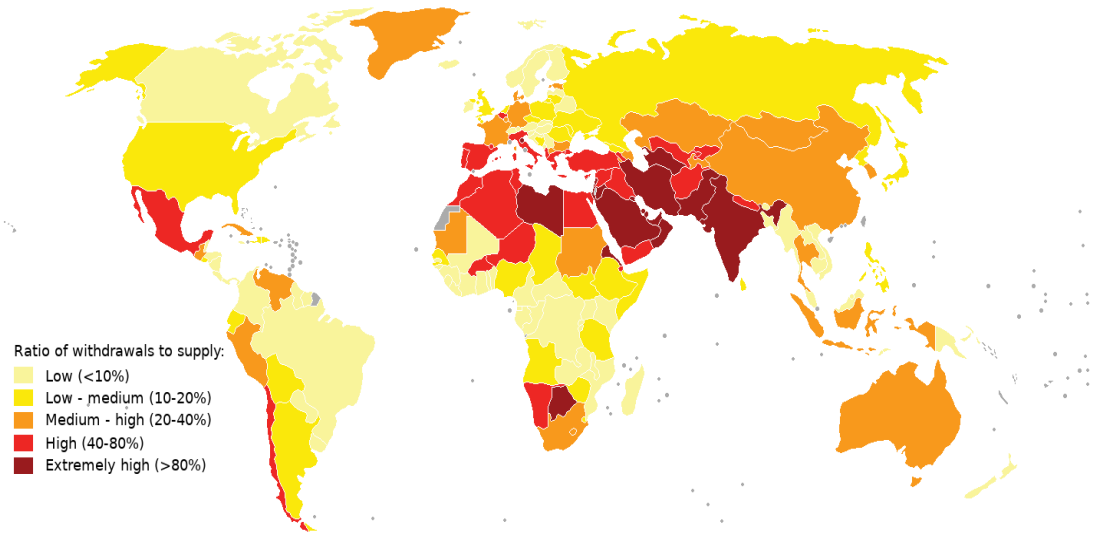
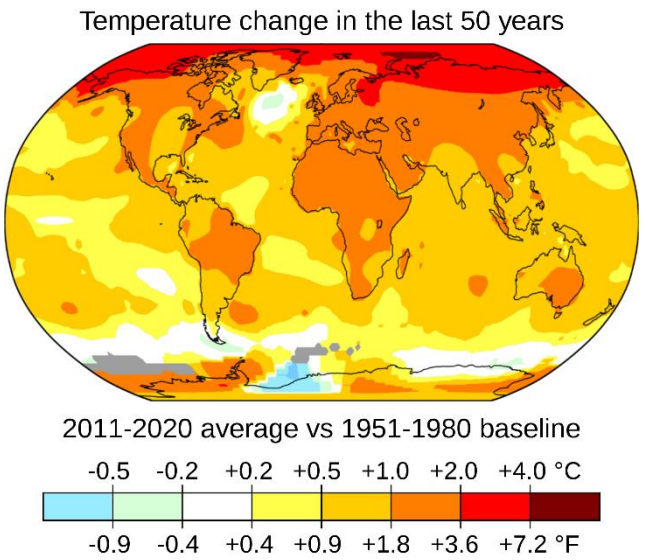
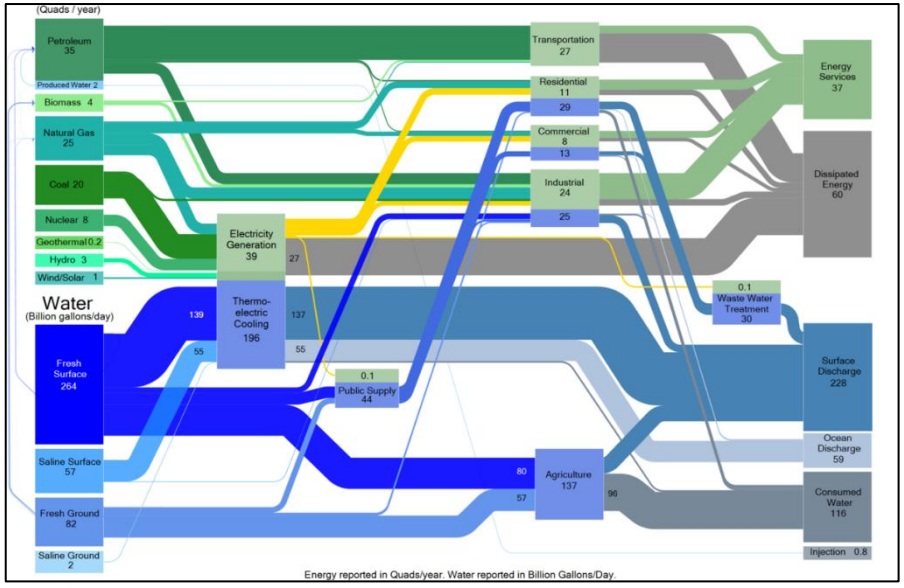
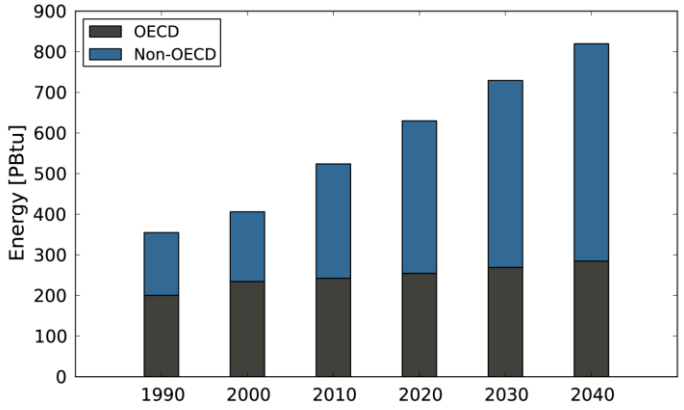
Water-energy nexus







US DOE report, 2014



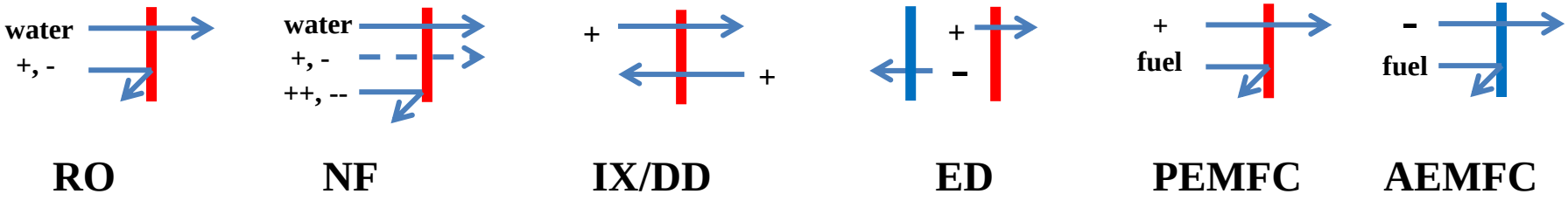
Membrane Technology: Solutions and Challenges

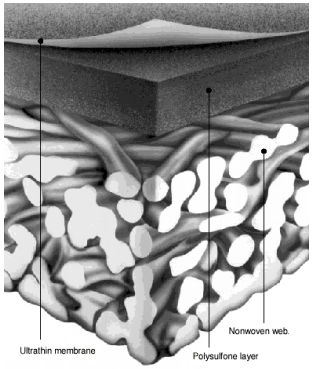
Desalination and Water Purification

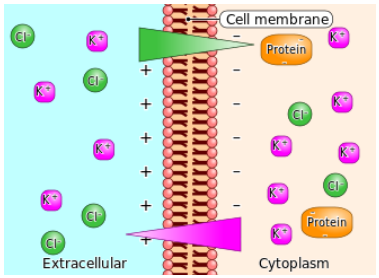
Clean Energy Generation, Backup and Storage

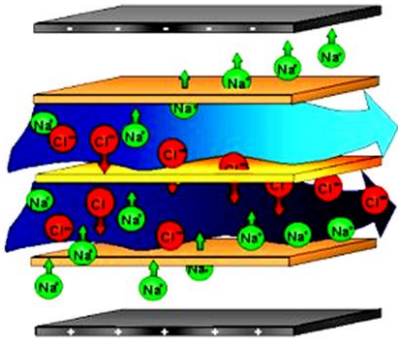
- Membranes enable the most efficient solutions (water-salt separation, fuel cells, membrane electrolysis)
- Yet innovations and improvements in resistance, selectivity and stability are still desired

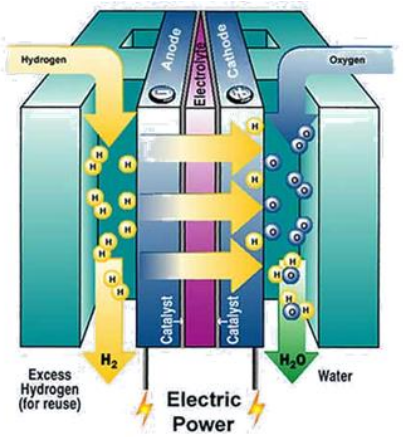
Ion Transport in Membranes: Multitude of Selectivities and Uses









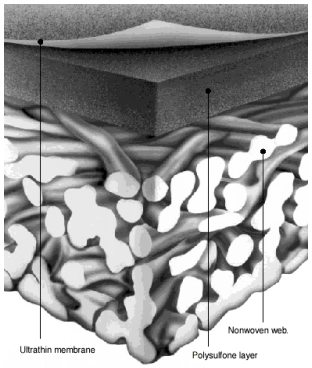


- Polyelectrolytes are the basis for many well-established membrane processes, but there is still much room for innovations

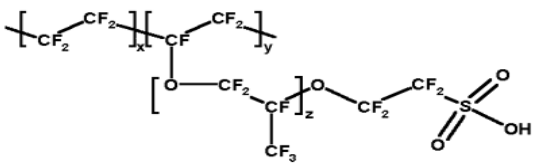
Current Needs and Challenges

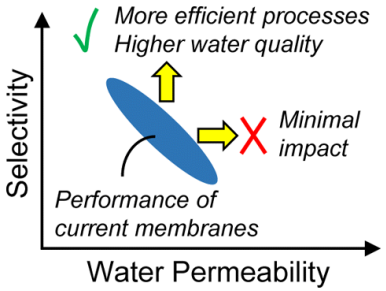
What has been delivered:

- **Water purification**: excellent total salt and hardness removal, high flux, high energy efficiency, reasonable fouling resistance/prevention



- **PEMFC, ME (Nafion)**: reasonably low resistance and H_2/O_2 cross-over, chemical stability



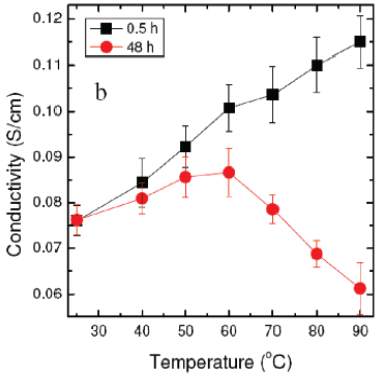


Werber et al, 2016

What needs to be improved/still presents a challenge

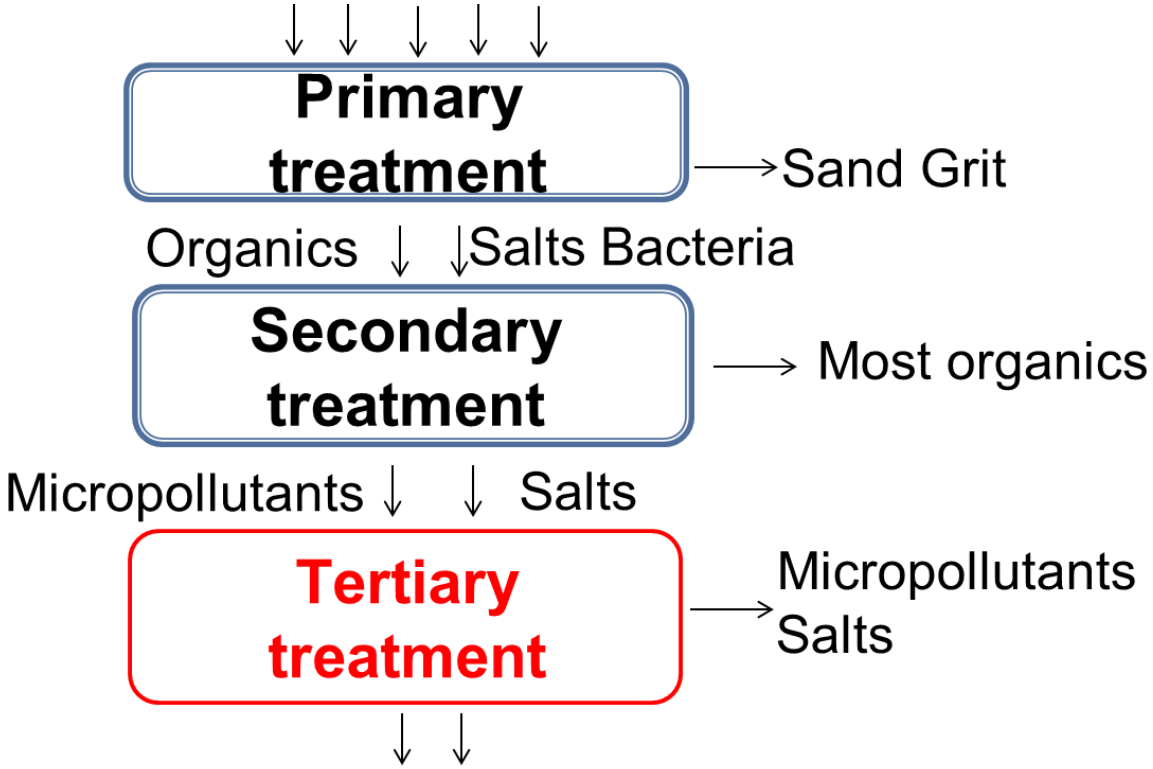
- **Water purification**: susceptibility of polyamides to chlorine, poor selectivity to neutral pollutants (boron, EDCs etc.), low or unfavorable ion-ion selectivity

- **PEMFC, ME (Nafion)**: high resistance at low RH, temperature stability, fuel cross-over (MeOH etc.)



Park et al, 2007

1. Novel NF tailored for wastewater desalination

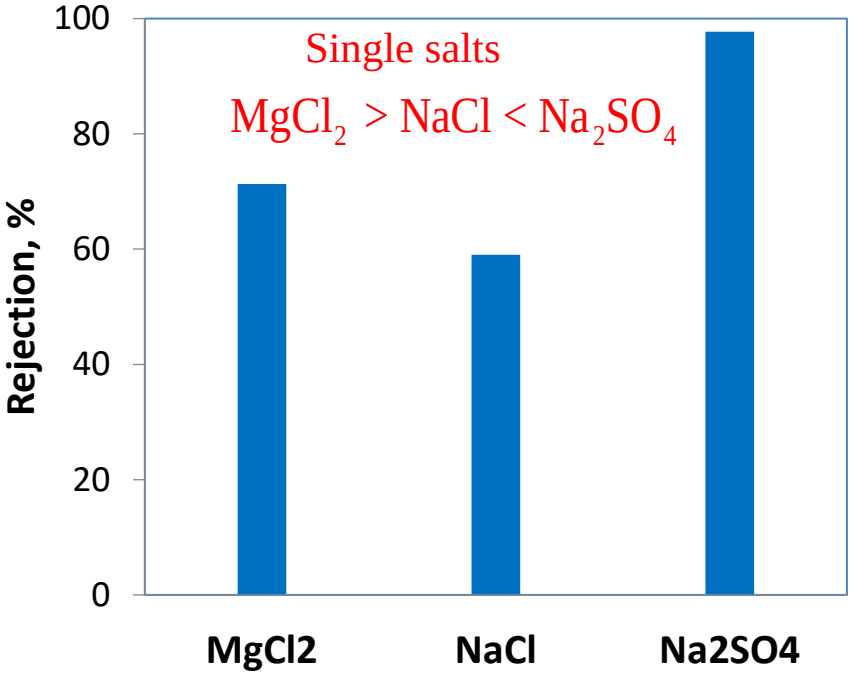


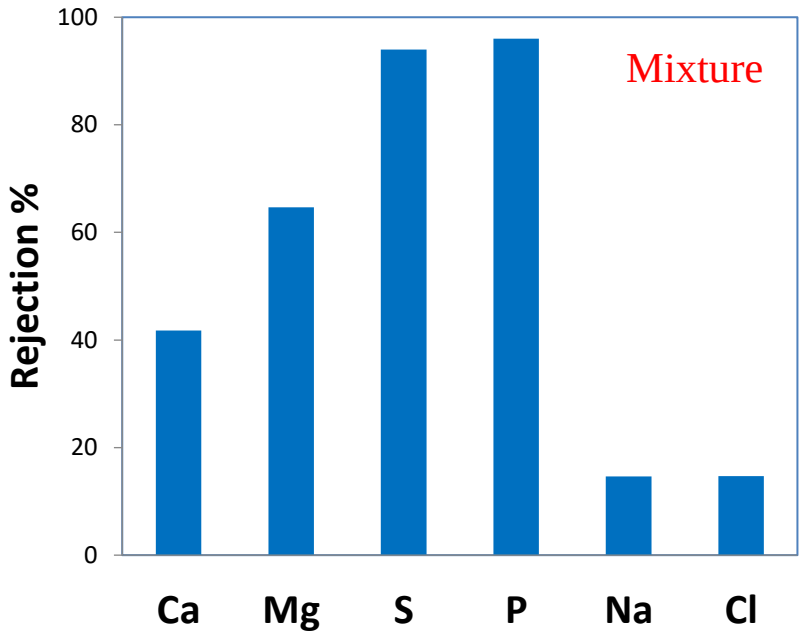
Wastewater	
Ion	Conc (mg/L)
SO4	93-105
PO4	6.1-7.7
Cl	279-329
Ca	60-70
Na	117-134

- If not much salt has to be removed, NF is an attractive option. However, calcium phosphate scaling becomes a major issue.

Why do commercial NF membranes scale?

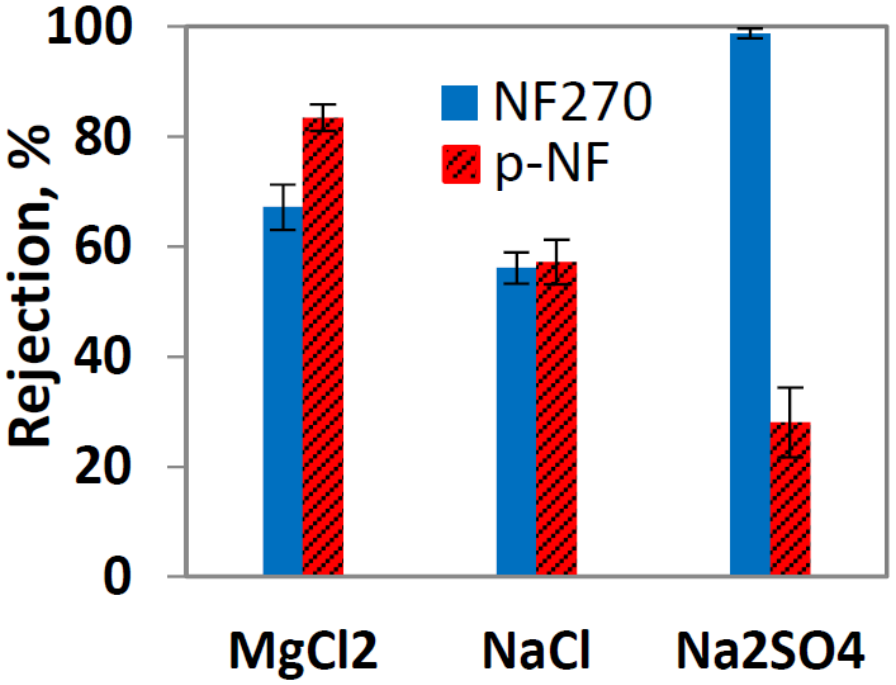
NF270: a representative NF membrane

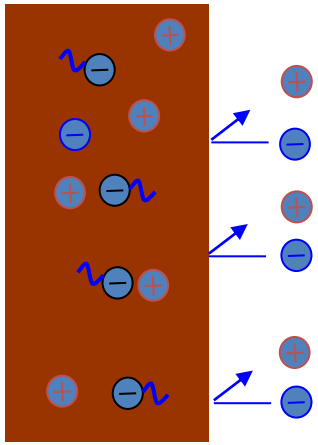




This pattern in a signature of dielectric mechanism that strongly rejects divalent scale-forming ions

A Membrane that Breaks Symmetry



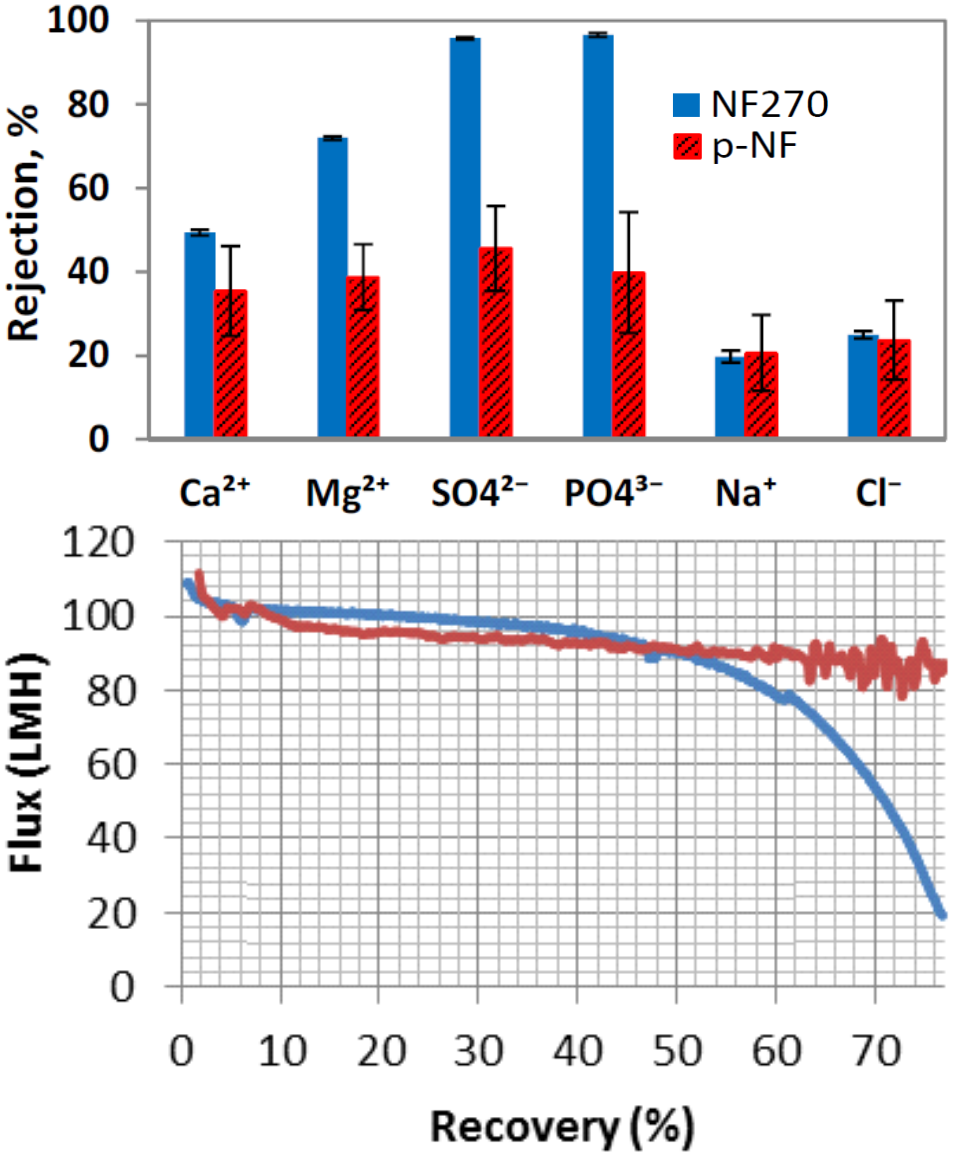


Donnan exclusion

- Donnan exclusion allows a sulfate and phosphate rejection lower than NaCl.
- A loose polyelectrolyte membrane use Donnan mechanism and allows NF selectivity and reduced scaling, beneficial for wastewater recycling

Levchenko & Freger, 2016; Kaganovich et al, 2020, Zelner et al., 2021

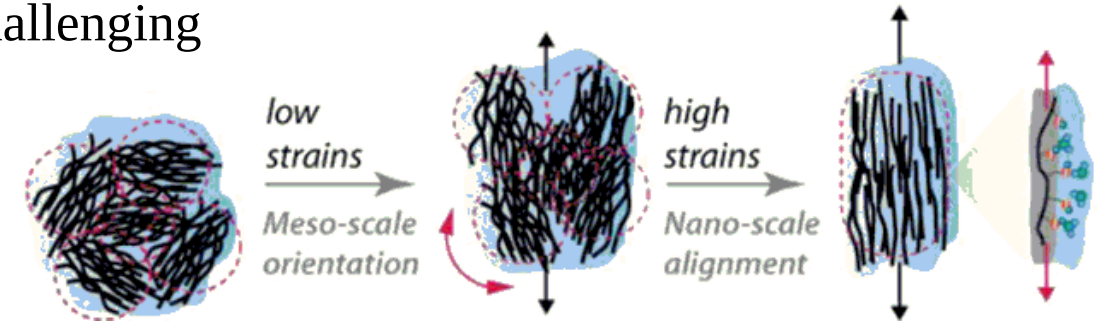
Ion Rejection vs. Phosphate Scaling

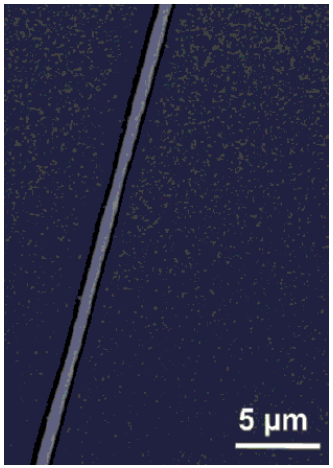


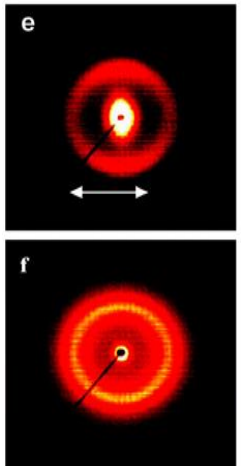
Levchenko & Freger, 2016; Kaganovich et al, 2020, Zelner et al., 2021

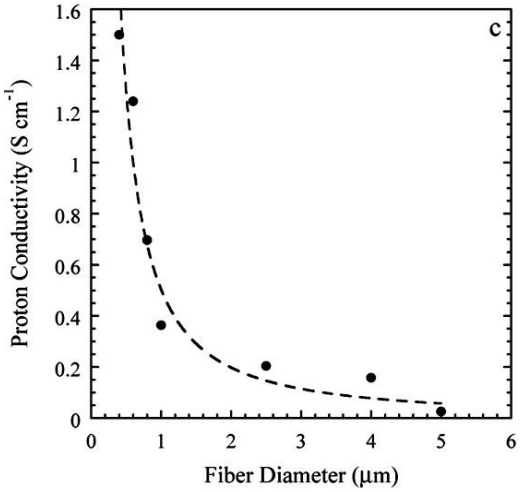
2. Improving Nafion conductivity and stability via nano-alignment

- Nafion has a unique nano-structure; its alignment may enhance conductivity but utilizing this effect for making improved membranes has been challenging



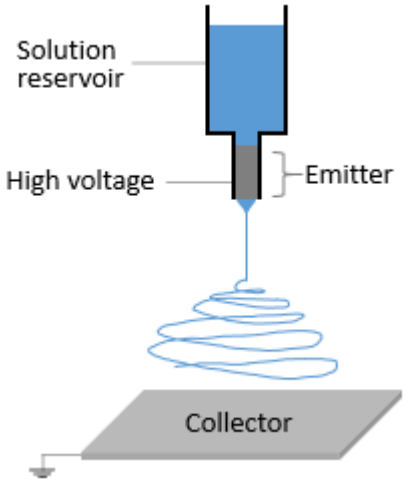


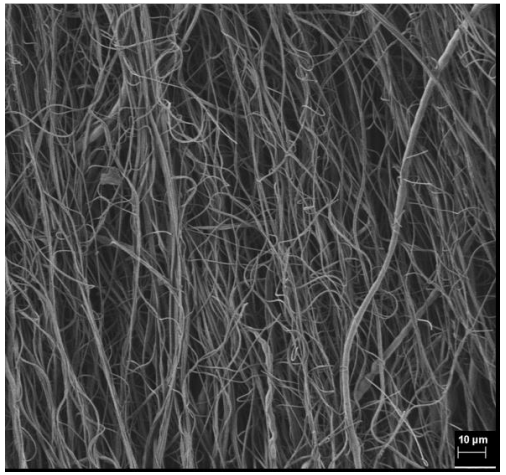


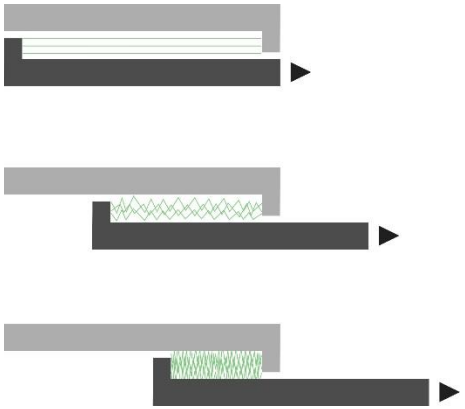


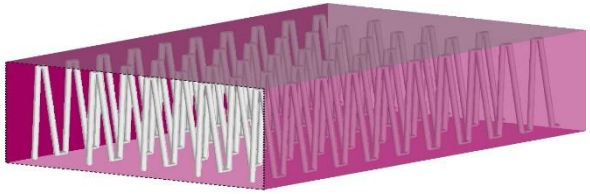
Kusoglu & Weber, 2017; Dong et al, 2010

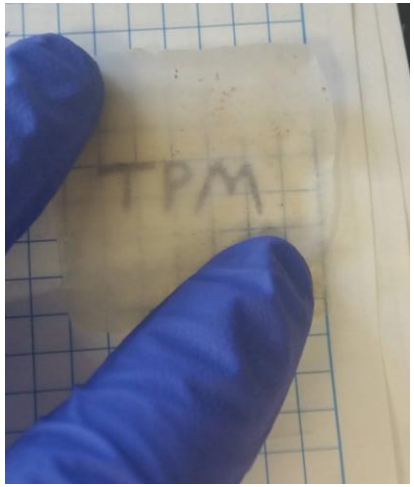
Novel TP-aligned electrospun Nafion/PVDF composite





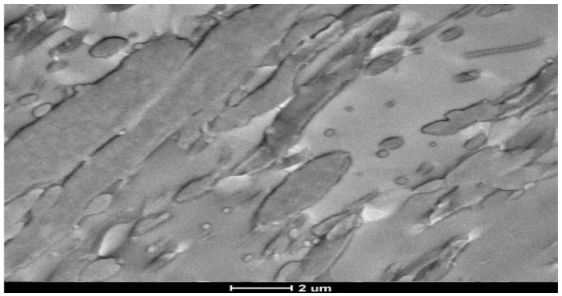


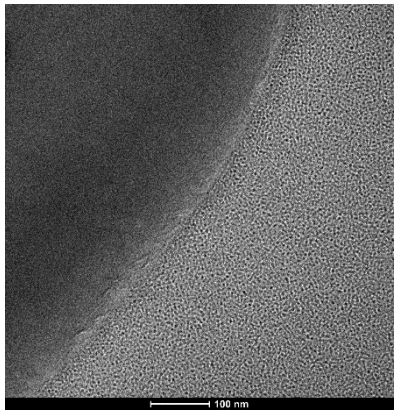


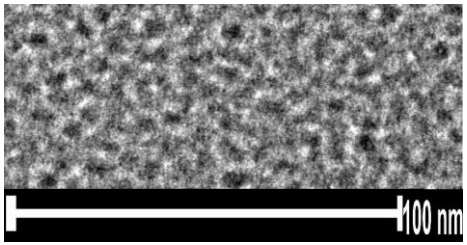


Odess et al, 2021

Nano-Alignment and Conductivity

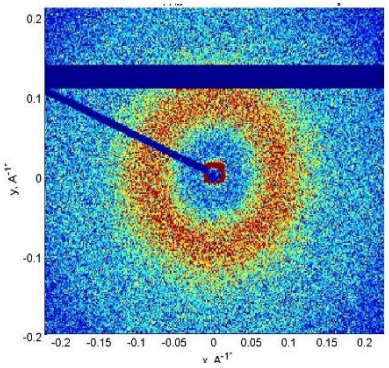




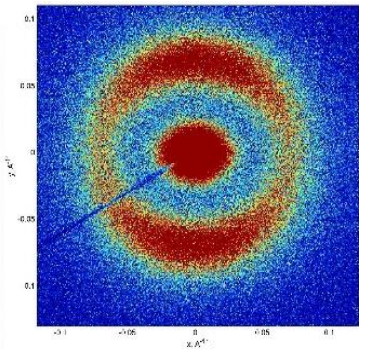


TEM images

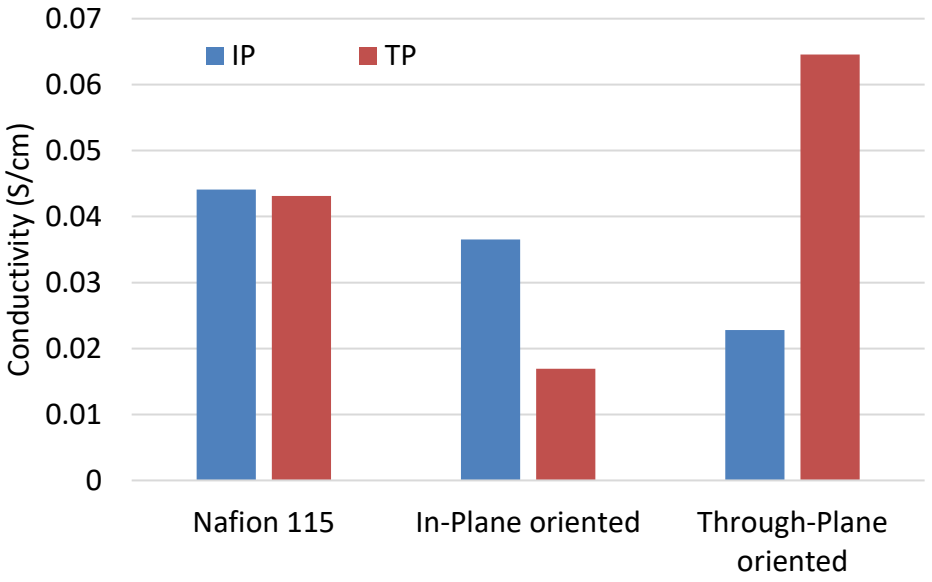
Pure Nafion



Nafion-PVDF composite (across fibers)



Normalized Conductivity



Odess et al, 2021

Bedankt Thanks תודה

https://freger-membrane.net.technion.ac.il/

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