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Incorporation of Aquaporins into Membranes for Water Desalination

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Introduction

- Desalination of non-traditional water sources (seawater and brackish water) is more vital than ever due to the increasing scarcity of traditional water sources.
- About 1.6 billion people suffer from economic water scarcity, meaning they do not have the means to access water, regardless of whether it is physically available (1).
- Thermal vs membrane processes for desalination: membranes are cost-effective and less energy intensive (2).
- Thus, it is important to develop novel membranes for desalination to provide an economical option of increasing water supply and quality.

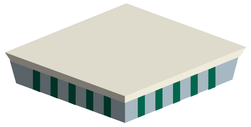
Objectives

- Develop a biomimetic membrane using RsAqpZ - a membrane that mimics the function of RsAqpZ-containing lipid bilayer.
- Create biomimetic reverse osmosis (RO) membranes with high salt rejection and/or flux.

Background

<u>Thin-film-composite Membranes</u>

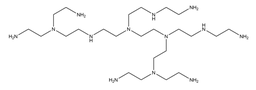
- Nanofiltration (NF) membranes:



- Reverse osmosis (RO): most common membrane for desalination
- Aquaporin-Z (AqpZ): a protein channel in *E. coli* with quick and highly selective water transport (3)

<u>Biomimetic membranes</u>

- Poly(butadiene)-b-poly(ethylene oxide): block copolymer to mimic lipid bilayer
- Branched PEI (positively charged polymer)

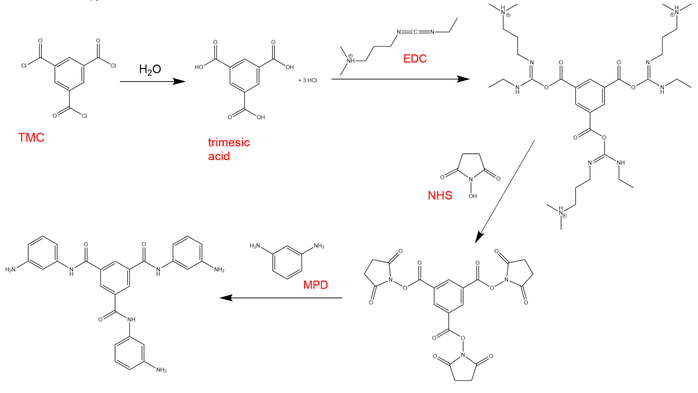


- EDC NHS: crosslinking of PEI to crystal, and of PEI to polyamide selective layer

<u>Sealing method</u>

- Defects are present in membrane after deposition, requiring sealing
- Interfacial polymerization in commercial RO membranes:

- Mimicking the above reaction in water:



Methods

<u>Layer by layer deposition (3 repetitions)</u>

- PEI deposited on membrane, crystals onto PEI
- EDC NHS: crosslinking of crystals with PEI, and PEI with membrane

<u>Sealing method:</u>

- Polymerization done in water rather than an organic solvent to avoid possible damage to proteins
- Reaction done on crosslinked layers to grow polymer between crystals
- Not very selective: COOH groups on membrane surface and crystals; Amine groups on both the PEI and MPD

<u>Three experimental membranes</u>

- NF270: crosslinked PEI/crystals (no sealing method)
- NF90: crosslinked PEI/crystals (no sealing method)
- NF90: crosslinked PEI/crystals, with sealing method

<u>Dead end cell: flux and rejection tests</u>

- 2000ppm NaCl with about 1.6x10^{-4} M sodium bicarbonate buffer was used for target pH 7
- Neutral pH importance: rejection changes with pH due to changes in surface charge
- The flux and rejection were tested in a dead-end cell for each of the membranes: results were taken before the depositions and/or sealing method, as well as after
- Conductivity measured for rejection calculation

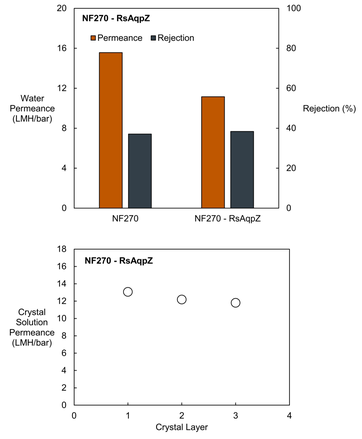
<u>Equations</u>

$$J_w = A(\Delta p - \Delta \pi) \qquad J_w = \frac{1}{Area \times t}\left(\frac{m_f}{\rho} - \frac{m_i}{\rho}\right) \qquad R_{apparent} = \left(1 - \frac{c_{sl}}{c_{so}}\right) \times 100\%$$

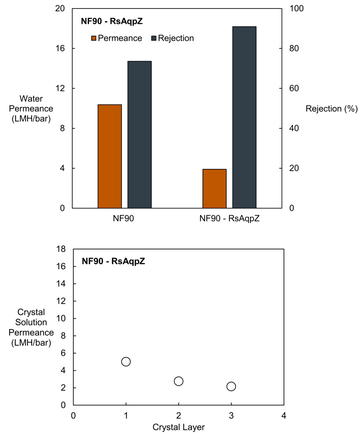
- A is water permeance (LMH/bar), Δp is the pressure drop (bar), and $\Delta \pi$ is the osmotic pressure difference (bar) across the membrane
- $Area$ is the membrane area (m^2), t is time (hr), m_f is final mass of permeate (g), m_i is initial mass of permeate (g), ρ is fluid density (g/L)
- $R_{apparent}$ is apparent rejection of membrane (%), c_{sl} is the permeate concentration, c_{so} is the feed concentration

Results

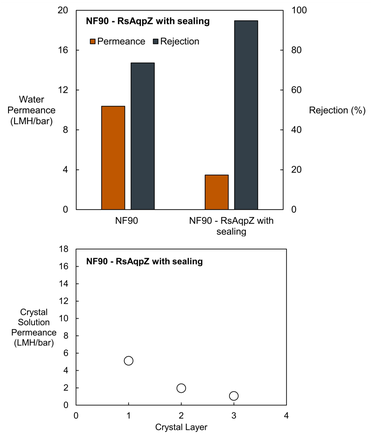
NF270 – No Sealing



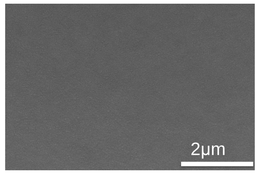
NF90 – No Sealing



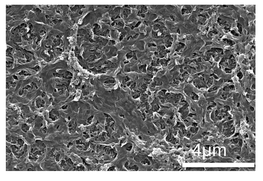
NF90 – Sealing



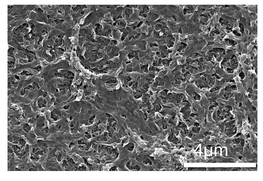
NF270 Before Crystals



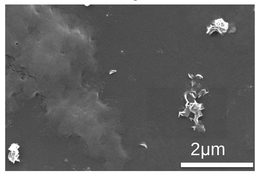
NF90 Before Crystals



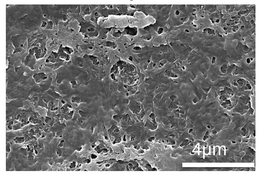
NF90 Before Crystals



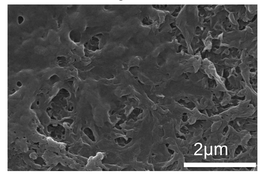
NF270 After Crystals



NF90 After Crystals



NF90 After Crystals and Sealing



Conclusion

- Crystal deposition increased rejection and lowered permeance
- Good rejection of about 94.8% using sealing on NF90: however, ideal rejection is in high 90s
- Another challenge: lessening the large drop in permeance
- NF270 is a good candidate for higher permeance, but challenging for high rejection
- Despite the obstacles, there is good potential for developing a biomimetic membrane with high rejection

References

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Acknowledgements

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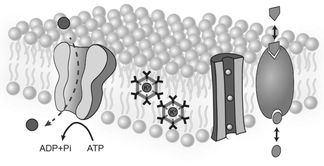

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