Ionic liquid surfactant assisted interfacial polymerization to fabricate high flux composite reverse osmosis membranes

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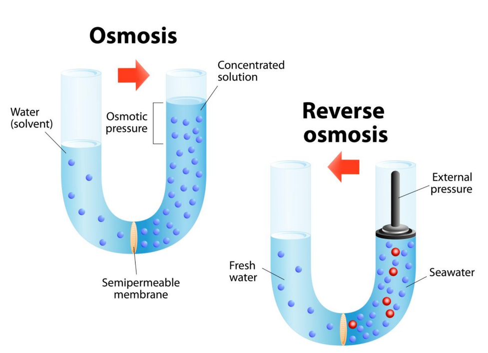
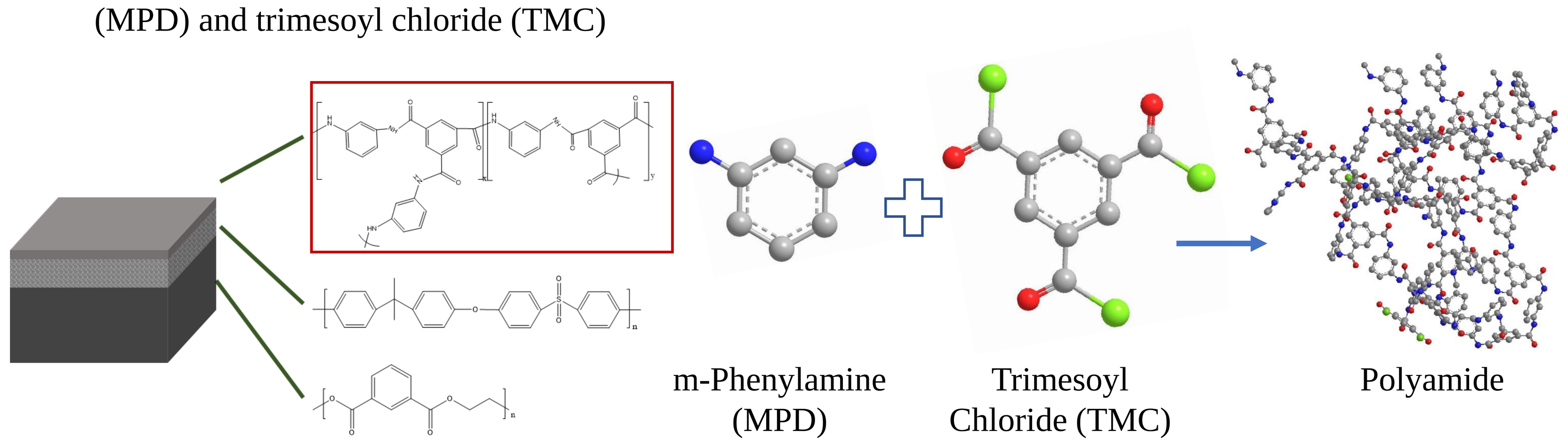
Background

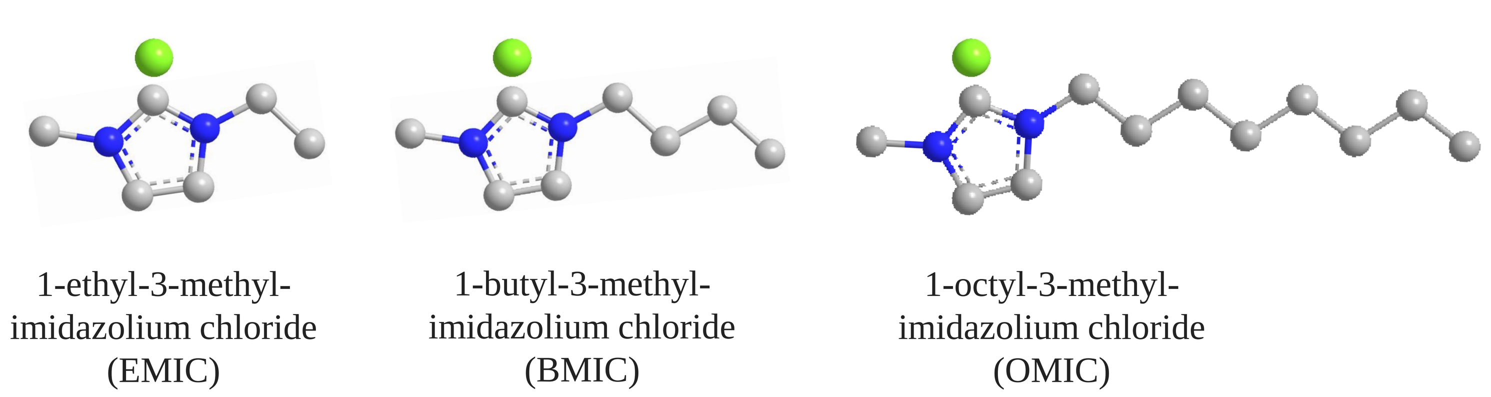


Today, 4 billion people worldwide are facing severe water scarcity. Because of climate change, population growth, this has been a serious global crisis. Reverse osmosis (RO) uses an external pressure to overcome osmotic pressure of the salt and force water to pass through a partially permeable membranes. We are interested in the use of ionic liquid surfactants on RO membranes to improve flux and rejection.

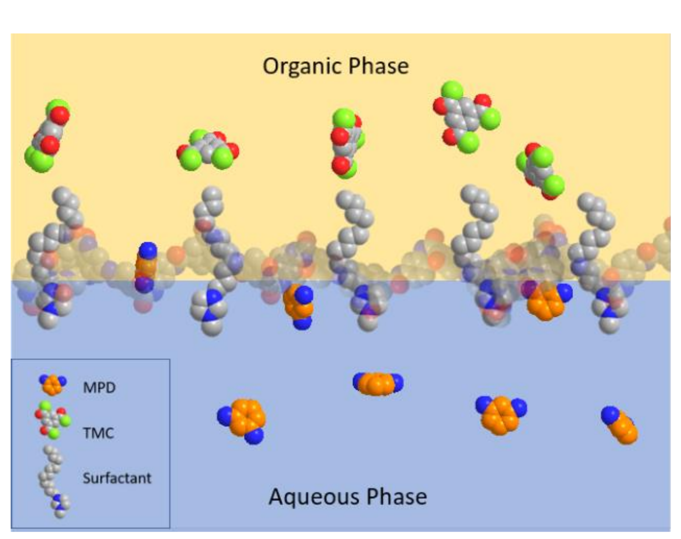
Introduction

- RO membrane is comprised of three components: polyamide, polysulfone, and polyester. (top to bottom)
- Polyamide, the layer of interest, is formed from interfacial polymerization of m-phenylenediamine (MPD) and trimesoyl chloride (TMC)

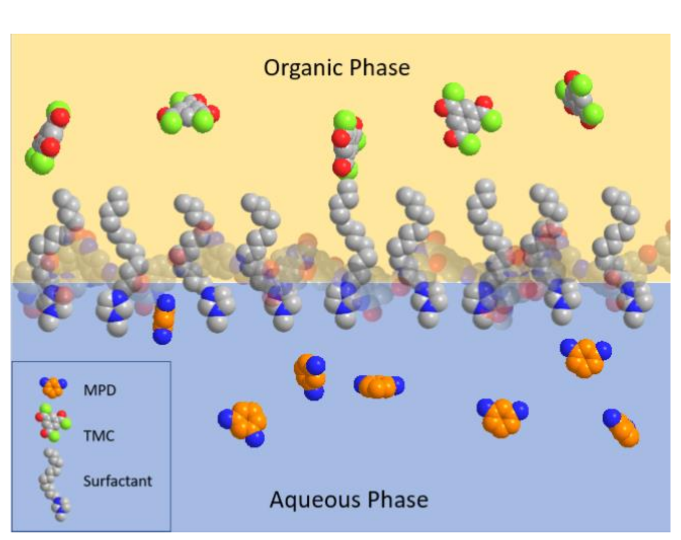




- EMIC, BMIC, and OMIC are surfactants. They all contain hydrophobic sidechains and hydrophilic headgroups and display amphiphilic properties.
- They immerse in the aqueous phase and direct MPD monomers to the organic phase to form polyamide layer.
- The varying length of sidechain would influence the performance of RO membranes.

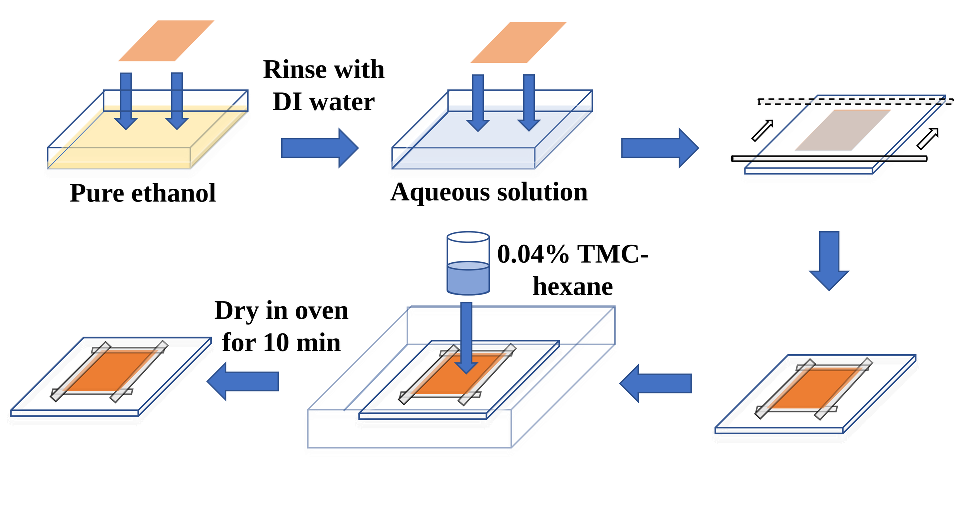


- When a low concentration of surfactants is added, the entropy is higher so they would orient themselves randomly.
- Therefore, there are more freedom for MPD to pass through to form the polyamide bilayer.
- Leading to a tighter polyamide crosslinking [1]

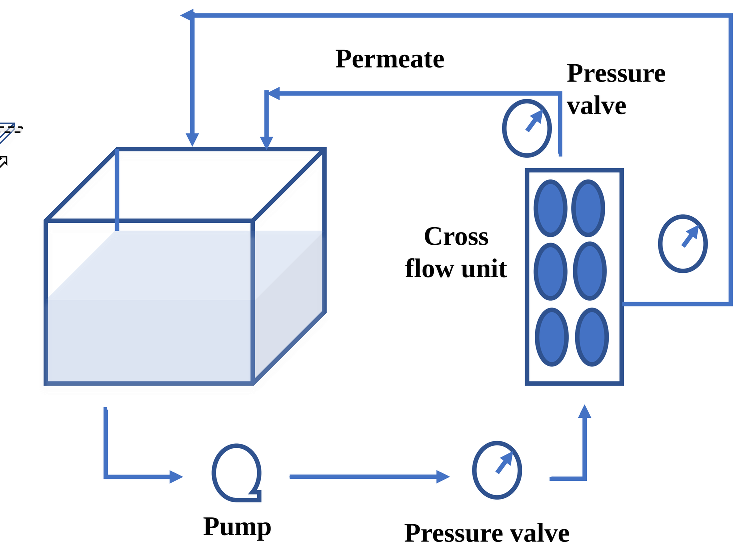


- When a high concentration of surfactant is added, the entropy is lower so the orientation of IL is more ordered.
- Therefore, there are less freedom for MPD to pass through to form the polyamide bilayer.
- Leading to a looser polyamide crosslinking [1]

Methods



Schematics of the procedure for making RO membranes

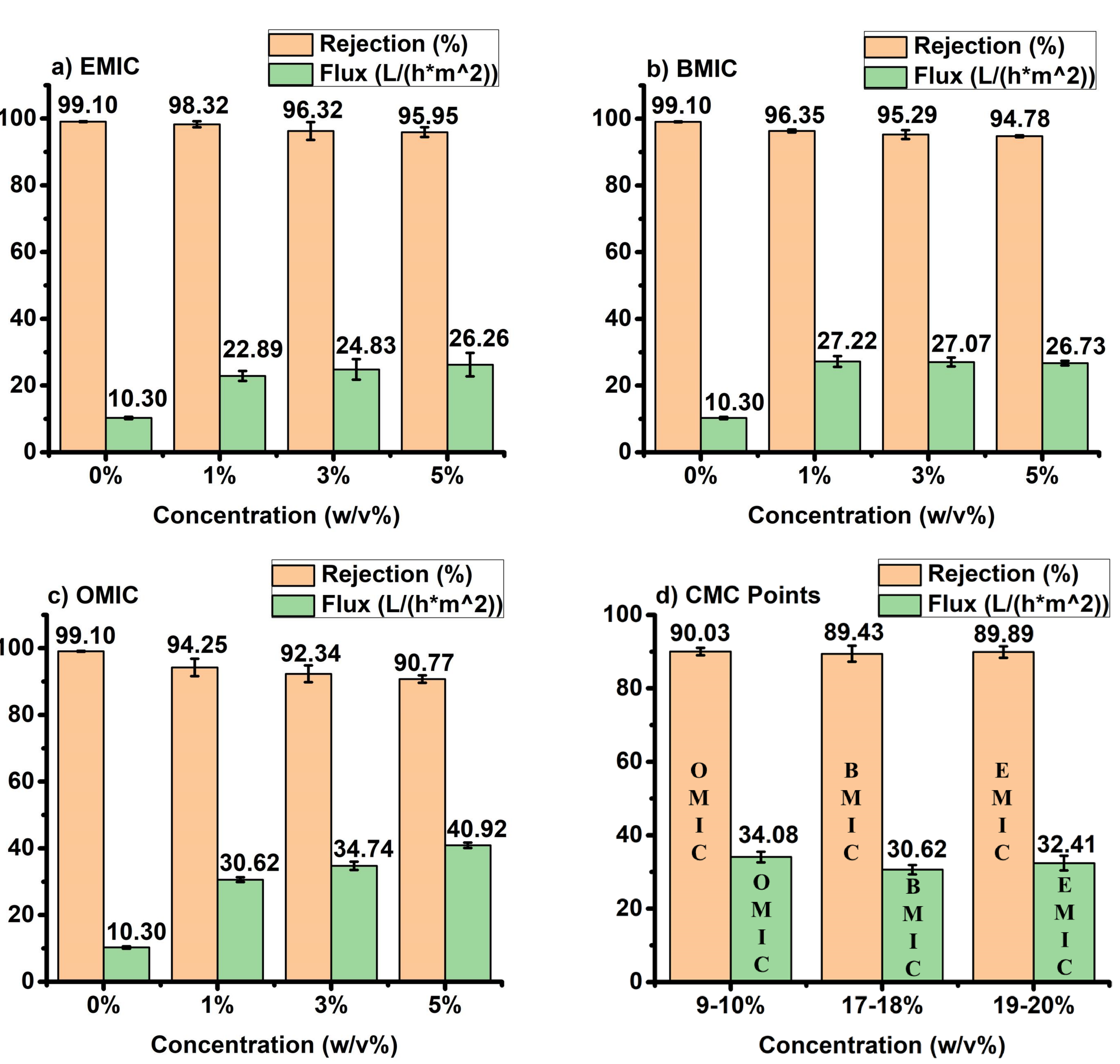


A schematics of the cross-flow system, which is used to test the performance of the RO membrane.

Filtration Results

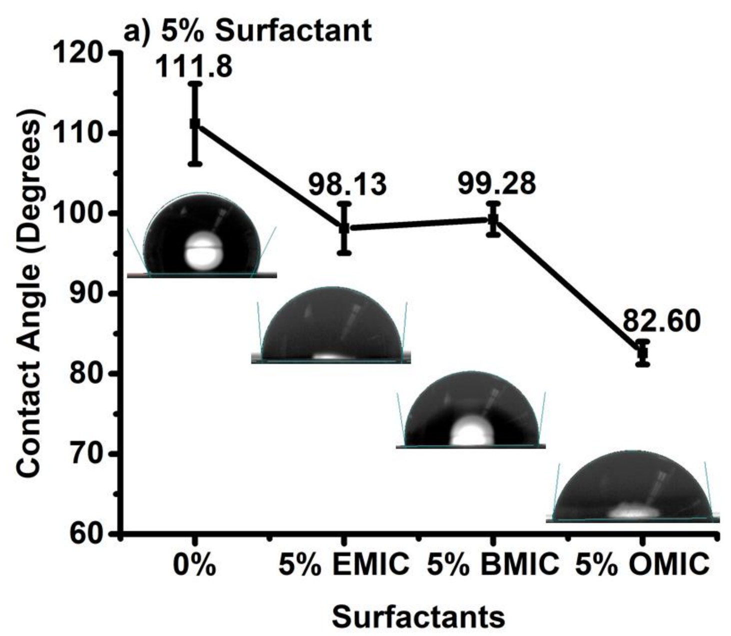
Under constant 0.1% MPD and 0.04% TMC

$$Rejection\ \% = \left(1 - \frac{C_{permeate}}{C_{feed}}\right) \times 100\% \qquad Flux = \frac{Volume(L)}{Area(m^2) \times time(h)}$$

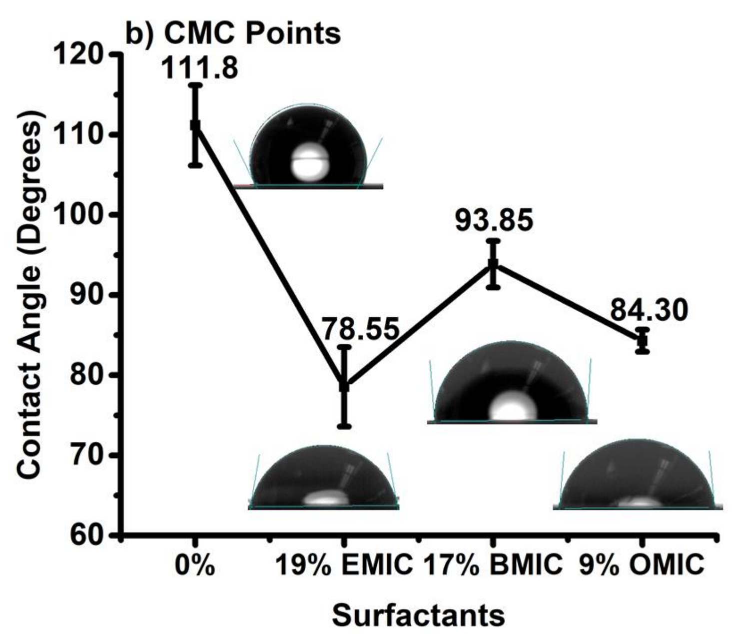


- With increasing concentration of surfactants incorporated to aqueous solution, there will be an increased flux of at least three folds with a slight compromise in rejection rate.
- Increasing length of the alkyl chain of ionic liquid surfactants leads to increasing water flux and decreasing salt rejection.
- When it reaches critical micelle concentration, it follows the same trend as when surfactant concentration decreases with no drastic increase in water flux or decrease in rejection.

Contact Angle Results



- OMIC is the most hydrophilic with the smallest contact angle degree.
- BMIC and EMIC are both less hydrophilic than OMIC and are almost equally hydrophilic to each other.
- More hydrophilic membrane is most likely attributed from the free carboxylic group or unreacted acyl chloride in TMC leading to more interactions with water molecules.



- RO membranes at CMC are more hydrophilic than RO membranes at lower surfactant concentration.
- There is a increase in hydrophilicity in RO membranes with EMIC and BMIC and a slight increase of hydrophobicity for OMIC when it reaches CMC.

Conclusions

- Increasing length of the alkyl chain in surfactants leads to increasing water flux and decreasing salt rejection.
- As the concentration of surfactant increases, there are more surfactant at the interface and will block the access of MPD to the organic phase. With less MPD moving to organic phase to interfacially polymerize with TMC, less crosslinking will happen leading to lower rejection rate and higher flux.
- RO membranes with OMIC are the most permeable with the highest water flux out of the three ionic liquids because as the membrane becomes more hydrophilic, it becomes more permeable to water and then flux would increase.
- When it reaches critical micelle concentration, RO membranes become more hydrophilic.

Future Works

- Validation of contact angle results.
- Validation of filtration results around CMC points.
- Determine size of surfactant micelles at its respective CMC.

Acknowledgement

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+ Equal Contributors

[1] Yung L, Ma H, Wang X, Yoon K et al. Fabrication of thin-film nanofibrous composite membranes by interfacial polymerization using ionic liquids as additives. J. Membr. Sci. 365 (2010): 52-58.
[2] Wang H, Li L, Zhang X, Zhang S, et al. Polyamide thin film composite membranes prepared from a novel triamine 3,5-diamino-N-(4-aminophenyl)-benzamide monomer and m-phenylenediamine. J. Membr. Sci. 353 (2010) 78-84.