Mechanical & Industrial Engineering
UNIVERSITY OF TORONTO

MIE498H1: Research Thesis 2023-2024

Supervisor	Patrick Lee
Supervisor email	patricklee@mie.utoronto.ca
Number of Positions	1
Open to	Mechanical Engineering Students
Term Offered	Full-Year (Y)
Research Area	Materials
Research Topic	Deep insight into reverse osmosis membrane compaction and characterization using microscopy imaging techniques

Project Description

In the field of membrane technology, reverse osmosis (RO) is dominantly employed to reduce water usage and minimize the amount of hazardous waste generated from sustainable energy sectors. To adhere to "zero-liquid discharge" (ZLD) policies that mandate solid waste disposal, it is encouraged to employ highly effective processes that can handle very high salinity levels. High-pressure reverse osmosis (HPRO) membranes have emerged as a promising technology for the energy-efficient desalination of high salinity water, expected to consume roughly 10-fold lower energy input than widely used thermal methods. Nonetheless, RO membranes are not robust enough and suffer dramatic compaction (i.e., densification of the porous support) when exposed to high pressures. Although ongoing studies are investigating the performance of RO membranes, there is minimal understanding of (i) the actual pore structure changes during compaction and (ii) how the structure changes impact performance. Therefore, my current mission involves working towards the establishment of this correlation. Advanced Membranes Lab has developed a costume-made high-pressure setup, enabling testing membrane compaction at high pressures. And, the research lab will collaborate with SUEZ WTS, which is a world-class water-engineering firm that designs and manufactures membranes. With that being said, our research is expected to yield benefits and exert a positive impact on the country and the world as a whole. Objectives. We intend to compact the commercial HPRO membrane at various salinities of 0.1 - 2.7 M NaCl and pressures of 80 - 150 bar. Then, the membranes will be freeze fractured in liquid nitrogen, enabling image cross-section employing advanced visualization methodologies to capture 2D (Aim 1), 1st paper and 3D images (Aim 2), 2nd paper of the membrane support layer. This will allow for both quantitative and qualitative evaluation of pore structure densification. Scanning electron microscopy (SEM) will be used to obtain 2D images while emerging focused ion beam–scanning electron microscopy (FIB-SEM) will be utilized to capture 3D images. FIB-SEM involves taking SEM images after etching every ~4 nm and stitching the resulting layers to create a 3D reconstruction. Our end goal is to design experimental and computational tool for the analysis of pores using electron microscopy. This platform will be useful in the critical areas where pore analysis holds importance, for example, catalysts, batteries and fuel cells.

To analyze the membrane performance, water permeability will be monitored in-situ while compaction is happening (Aim 3), included in 1st paper. To further assess the membranes, we will conduct mechanical testing (Aim 4), 3 rd paper. This will allow investigation of the membrane microstructure effect on its strength.

Additional Information	N/A
Application Instructions	Please submit CV, unofficial transcript, to Prof. Patrick Lee (patricklee@mie.utoronto.ca)