Shape-Selective Filtration Using Block Copolymer Membranes

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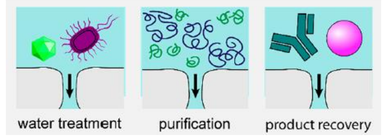
Background

Ultrafiltration (UF) membranes are used in different industries for water purification

UF membranes lack uniform pore sizes leading to poor selectivity[1]

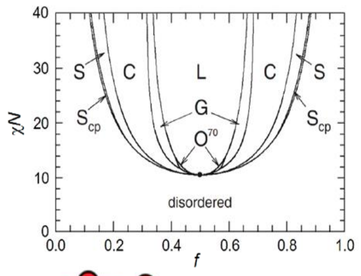
Major UF Applications



Block Copolymer (BCP) = Polymer A covalently bonded to Polymer B.

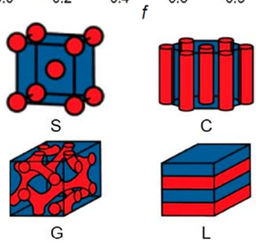
An example of a BCP is PS-b-PMMA.

BCP can self-assemble into well-defined uniform domains (morphology) of uniform pore size.



Most work done on vertical pores derived from cylindrical BCP membranes.

In this work, vertical lamellar BCPs are investigated for use as slit membranes.

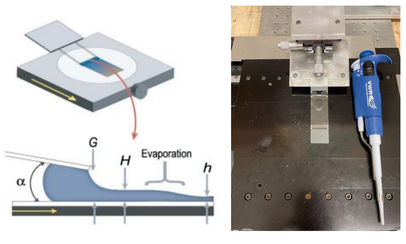


Different morphologies obtained by BCPs[1]

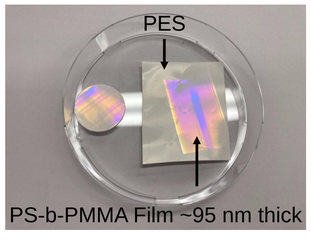
Experimental Methods

PS-b-PMMA (80k-80k) membranes were prepared in a 50:50 ratio of Toluene and THF solution giving 2.5% (wt/vol) with 10% Ionic Liquid (IL)

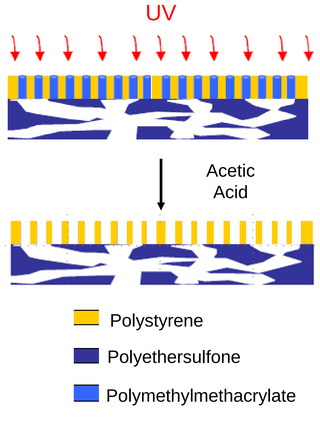
1. Flow Coat



2. Float Film



3. Etching PMMA Domain

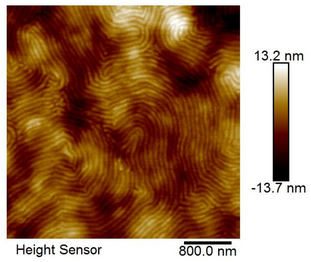


4. Ultrafiltration Pressure Cell

PS-b-PMMA 80k-80k Morphology

The morphology of the membranes were characterized by our Atomic Force Microscope (AFM).

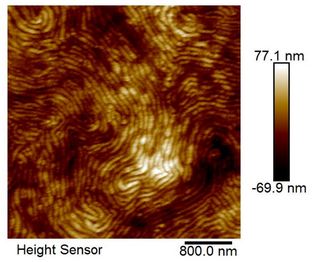
Before Etching



UV

Acetic Acid

After Etching



AFM scan of lamellar morphology of PS-b-PMMA (80k-80k) 50:50 Tol:THF 10%IL

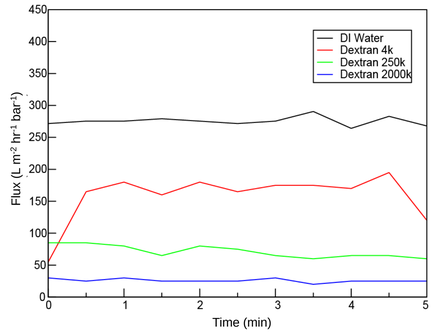
Flux and Filtration Results

Flux measurements at a pressure of 7.5 psi were recorded for different molecular weights (MW) of dextran as well for gold (Au) nanoparticles and nanorods.

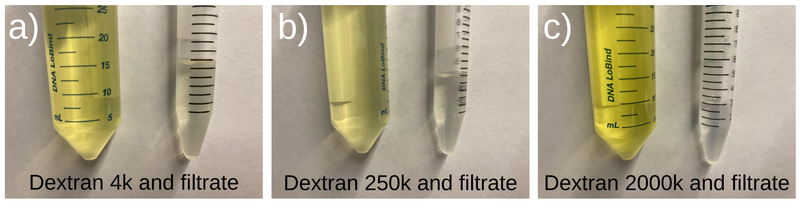
Dextran contains a fluorescein (dye) which aids in permeability tests.

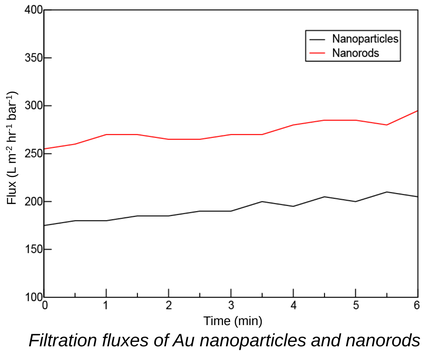
Dextran 4k, 250k, & 2000k solutions were filtered.

Flux for dextran 4k is higher relative to other MW.



Filtration fluxes of dextran



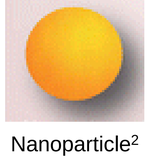


Filtration fluxes of Au nanoparticles and nanorods

Gold nanoparticles and nanorods solutions were filtered.

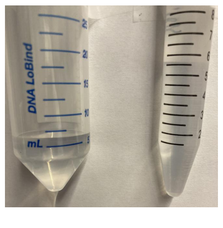
Flux for nanorods are higher than nanoparticles.

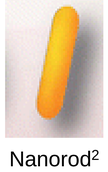
Au nanoparticles and filtrate



Nanoparticle[2]

Au nanorods and filtrate





Nanorod[2]

Rejection Analysis

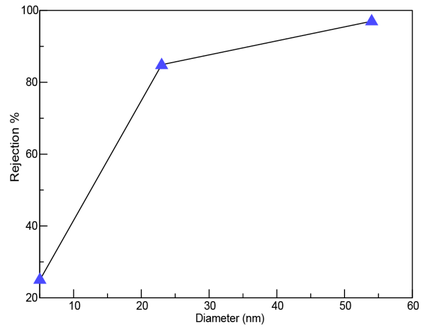
Section tool of Nanoscope Analysis Software was used to determine the slit width of our membrane: ~20 nm.

Rejection rates are determined via UV-vis Spectroscopy which measures how much a sample absorbs/reflects light.

The UV-vis spectra of feed and filtrate are compared to determine rejection percentage thus membrane efficiency.

Molecular Weight Cutoff (MWCO) is the lowest MW where 90% solute is rejected.[1]

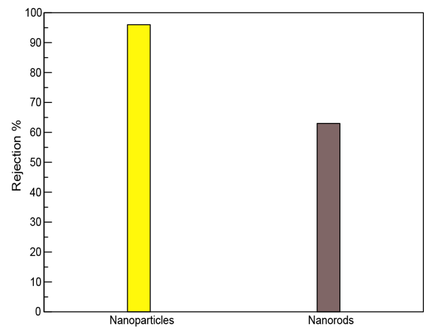
For Dextran rejection, cutoff size where 90% rejection is ~25 nm.



Cutoff Size of Different MW of Dextran

Molecular Weight of Dextran	Mean Diameter (nm)
4k	3
250k	23
2000k	54

MW of dextran relative to its mean diameter[3]



Rejection Rate of Nanoparticles and Nanorods

From the cutoff size, shape-selective filtration is investigated.

Majority of the nanoparticles were rejected due to their size.

Nanorods are highly selective compared to nanoparticles.

	Mean Diameter (nm)
Nanoparticle	40
Nanorod	10 (D) x 40 (L)

Conclusions and Future Work

Successful fabrication of BCP lamellar membranes.

Cutoff size was determined to be ~25 nm.

Lamellar slit membranes are more selective to nanorods compared to nanoparticles.

Extend shape-selective filtration to biological matter such as viruses, proteins, and pathogens.

References and Acknowledgements

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[1]Nicholas Hampu, Jay R. Werber, Wui Yarn Chan, Elizabeth C. Feinberg, and Marc A. Hillmyer* ACS Nano 2020, 14, 12, 16446–16471

[2]Onaciu, A et al, *Nanomedicine*, 2019, 14, 9

[3]Armstrong et al. *Biophysical Journal.* 2004, 87(6) 4259–4270