Seminar Announcement

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“Zwitterionic Copolymers for Fouling Resistant Ultrafiltration Membranes”

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“Chemoselective Nanoporous Membranes for Separation of Small Molecules”

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Science & Technology Center Room 136
“Zwitterionic Copolymers for Fouling Resistant Ultrafiltration Membranes”

Fouling is probably the most important obstacle to the use of membranes in many applications, especially those where the feed contains high concentrations of organics such as oil and biomacromolecules. Zwitterions, defined as molecules with equal numbers of positively and negatively charged functional groups, show excellent fouling resistance and hydrophilicity. These features can be incorporated into ultrafiltration (UF) membranes during their manufacture by blending a commodity polymer like polyvinylidene fluoride (PVDF) with a copolymer containing zwitterionic groups. This approach can be used directly in existing membrane production systems, with no need for post-processing. Research to date, however, does not provide any guidelines for designing or selecting a zwitterion-containing polymer for this purpose to achieve the best possible performance. In this work, we investigate the impact of different copolymer properties such as zwitterion chemistry, copolymer composition (i.e. zwitterionic/hydrophobic monomer ratio), and blend composition on the performance of membranes manufactured from their blends with PVDF. We report how changing these variables affect the morphology, selectivity, permeance and fouling resistance of membranes, and connect this data with design rules for selecting preferred copolymers for this use. Our study showed that, with well-selected zwitterion-containing copolymers, membranes with significantly higher permeance and remarkable fouling resistance could be attained even with very small amounts of zwitterionic additives.

Another objective in this research is designing polymeric materials that self-assemble into functional nanostructures that lead to the desired membrane functionality (e.g. selectivity, fouling resistance). Zwitterion-containing amphiphilic copolymers can be used as membrane selective layers, and derive their permeability and selectivity in addition to fouling resistance from the self-assembly of zwitterions by linking their pore size with their self-assembled nanostructure. We aim to uncover fundamental structure-property-function relationships that correlate polymer chemistry and architecture, self-assembled nanostructure, and function in membrane applications. We aspire to achieve this without forgoing key membrane properties for successful, energy efficient operation such as high flux, fouling resistance, and scalable manufacturing.

We also introduce a new self-cleaning, photoresponsive membrane that can remove pre-deposited foulant layers upon exposure to UV light, exhibit UV-triggered surface morphology changes, and sustain stable pore size and permeance throughout. Prior to any photo-treatment, the membrane surface consists mainly of hydrophobic groups that are susceptible to the adsorption of hydrophobic solutes on pore channel walls, reducing flow rate. Upon irradiation with UV light, the hydrophobic groups are converted to zwitterionic/hydrophilic groups that release the adsorbed molecules and permit water passage once again. This “self-cleaning” behavior is shown by measuring pre- and post-UV water permeability after fouling with model protein bovine serum albumin (BSA). We found that flux decline through a BSA-fouled membrane can be fully recovered back to its original value by a simple, non-mechanical intervention of exposure to UV light. The UV-induced zwitterionic form of the membrane surface is fouling resistant, indicated by no irreversible flux loss after two hours of protein filtration. In addition, the switch between hydrophobic and zwitterionic/hydrophilic states causes morphological changes on the membrane surface as documented by atomic force microscopy (AFM). Thus, self-cleaning is driven both by increased hydrophilicity, and by the motion of the membrane surface during this rearrangement, providing a mechanical push that enhances the removal of deposited foulants.
Membranes that can separate solutes by factors other than size (e.g. charge, hydrophobicity, chemical functionality) would enable the use of this energy-efficient, green technology in new applications. However, achieving membrane selectivity based on parameters other than size has been a challenge, especially when the molecules to be separated are small. Such membranes do not exist today, but if successful, can have great impact in broadening the applications where membranes are used. We will design novel membrane selective layer chemistries, analyze their selectivity between solutes of similar sizes but different chemical structures, and acquire a better understanding of how membrane selectivity can be controlled through the rational incorporation of functional groups, generation of self-assembled nano-scale features using scalable manufacturing methods.

We used two different manufacturing approaches as possible alternatives. We fabricated a selective layer with a network of functionalizable nanochannels through the assembly of micelles on a porous support. Incorporating nanostructures that confine permeation into membrane selective layers can significantly enhance selectivity. We investigated fundamental structure-property relationships and transport mechanisms to gain fundamental insight into how solute interaction with membrane pore walls influence membrane selectivity in the presence of a self-assembled nanostructure. We initially targeted charge-based separations, mediated by Coulombic interactions. We will then further convert the existing functional groups (carboxylic acid) to other functionalities for desired chemical interactions (i.e. aromaticity-based separation).

Alternatively, we developed a new manufacturing method for membranes with thin functional hydrogel selective layers, and studied how hydrogel chemistry controls selectivity. In this method, a thin hydrophilic membrane selective layer is formed by free-radical polymerization initiated at the organic solvent-water interface spanning the surface of a support membrane. We also studied fundamental relationships between manufacturing conditions, selective