Center for Molecular & Engineering Thermodynamics Seminar

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TUFTS UNIVERSITY

"NEXT GENERATION MEMBRANES THROUGH POLYMER SELF-ASSEMBLY"

Polymer self-assembly is a crucial tool for scalable manufacturing of nano-scale features and for controlling surface chemistry and reactivity. Asatekin lab focuses on new polymeric materials designed to self-assemble to impart improved and/or new functionality to separation membranes. Our work aims to develop new membranes for generating fresh water and treating wastewater, and for chemical separations in many industries. We focus on preventing membrane fouling and controlling membrane selectivity while maintaining high flux and simple, scalable manufacturing methods.

Membrane fouling is the loss of membrane permeability upon the adsorption and accumulation of feed components (e.g. biomacromolecules in wastewater) on the membrane surface. It is one of the most significant obstacles to wider and more reliable use of membranes in many applications. Zwitterions, defined as functional groups with equal numbers of positive and negative electrostatic charges, strongly resist biomacromolecular adsorption due to their high degree of hydration. Zwitterionic groups also easily self-assemble due to their strong intra- and inter-molecular interactions. One of the objectives of our group is to better understand how zwitterion-containing amphiphilic copolymers self-assemble, and utilize their behavior to develop membranes with improved capabilities. In one research direction, we have prepared high flux, fouling resistant, size-selective membranes whose selective layers are made of random copolymers of zwitterionic and hydrophobic monomers. Membranes made using random copolymers exhibit high flux, and size-based selectivity with a cut-off around 1 nm. This pore size closely matches the size of self-assembled zwitterionic nanochannels we documented using transmission electron microscopy. Depending on the zwitterion chemistry, these membranes can be exceptionally fouling resistant, showing little to no flux decline and complete flux recovery with a water rinse upon the filtration of foulants such as protein solutions and oil suspensions. Well-designed membranes show no flux decline even in week-long fouling experiments with oil suspensions. Similar polymers can also be blended with a commodity polymer such as polyvinylidene fluoride (PVDF) during membrane manufacture by non-solvent induced phase inversion (NIPS) to prevent fouling. We have found design rules to direct the selection of best polymer structures and architectures for this use. For example, we found that copolymers with large zwitterion contents easily phase separate from the PVDF, leading to poor performance. In contrast, as little as 5 wt% of zwitterionic copolymer additive may be sufficient to prevent fouling and increase the membrane permeance by up to 6 times without a significant decline in rejection.

We are also interested in developing new membranes that can separate small molecules of similar size in the liquid phase based on their chemical properties. As an initial system, we developed membranes capable of charge-based separation through electrostatic interactions. We built layers with 1-5 nm functionalized pores by depositing micelles formed by random copolymers that combine highly hydrophobic fluorinated repeat units of trifluoroethyl methacrylate with ionizable repeat units of methacrylic acid on a porous support membrane. The gaps between the micelles act as nanochannels functionalized with carboxylic acid groups. The membrane showed charge-based selectivity between organic dye molecules, efficiently rejecting negatively charged solutes while allowing the passage of neutral solutes. Furthermore, the carboxyl groups can be post-functionalized to alter the selectivity of the membrane for desired separations. We believe these approaches will eventually lead to novel membranes that are capable of new separations and can replace more energy intensive methods such as distillation or extraction.

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CMET SEMINAR
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366 Colburn Lab

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BIOGRAPHY

AYSE ASATEKIN is an assistant professor at Tufts University's Department of Chemical and Biological Engineering. She received her Ph.D. in Chemical Engineering from the Program in Polymer Science and Technology at the Massachusetts Institute of Technology (MIT) in 2009. She completed B.S. degrees in Chemical Engineering and Chemistry at the Middle East Technical University (METU) in Ankara, Turkey. Prior to joining the faculty at Tufts, she worked at Clean Membranes, Inc., a start-up she co-founded to commercialize fouling resistant membranes she developed during her doctoral work. She received the NSF CAREER Award and the Turkish American Scientists and Scholars Young Scholar Award in 2016. She was also named John A. and Dorothy M. Adams Faculty Development Professor. Her research interests are in developing novel membranes for clean water and energy-efficient separations. She is also interested in multi-functional membranes, controlling surface chemistry for biomedical applications, polymer science, and energy storage.