Problem and Research Objectives:

Ultrafiltration (UF) membranes are widely considered the "state-of-the-art" material for water treatment and wastewater reuse; they can effectively remove emulsified oils, metal hydroxides, colloids, emulsions, dispersed material, suspended solids, and waterborne pathogens from drinking water. In Massachusetts, UF is used for direct filtration applications and synergistically as a pre-treatment for reverse osmosis systems. This project embarked on a new generation of UF membranes that are surface-functionalized with nanomaterials that do not affect the membrane's flux. We used surface topography as an environmentally benign approach to change the active layer of the membrane, and potentially, reduce biological fouling. Our specific aims were to systematically electrospin fibers from a robust polymer familiar to water purification membranes, polysulfone. In-house fabricated polysulfone UF membranes enhanced by a thin, porous, and robust layer of fibers were characterized for retention of high flux, molecular weight cut-off (MWCO), and biofouling. Our long term goal is to establish a "greener" antifouling strategy for high flux UF membranes.

Methodology:

In-house (hand-cast) polysulfone UF membranes and commercial control membranes were characterized and served as the base membranes. We enhanced the membranes using a thin, ultra-porous, and robust layer of fibers using a layering technique. Electrospun polysulfone fibers were first optimized to have an average fiber diameter of 1.0 μm. This was accomplished by varying the electrospinning pre-curser solution (polymer concentration, solvent) and electrospinning apparatus conditions (advance speed, separation distance, environmental parameters). All materials were characterized using scanning electron microscopy and contact angle. MWCO, pure water flux, and protein adsorption/rejection of the UF membranes (with and without nanofibers) were characterized.

Principal Findings and Significance:

To synthesize polysulfone nanofibers, an 18 wt% polysulfone solution in a 1:1 mixed solvent system of tetrahydrofuran and N-N-dimethylformamide was employed. These nanofibers exhibit a smooth cylindrical shape without beads and have an average fiber diameter of 1.0 ± 0.4 μm and a contact angle of 112 ± 5 °. The electrospinning time was optimized so that the nanofiber layer would be consistent, 48 ± 13 μm thick. Adding the nanofiber layer to the membranes did not affect their size selectivity; and a MWCO greater than 100 kDa was observed which is consistent with the values reported by the commercial supplier of the control membranes. Previously, the addition of polymers, nanoparticles, and polymer layers decreased this flux. The result with electrospun nanofibers is exciting as the addition of the nanofiber layer increased the membrane thickness but did not decrease the flux. Observing the nanofiber enhanced membranes, their permeability increased across all pressures tested. The pure water permeability was 561, and 830 L m^{-2} h^{-1} bar^{-1} for the control membranes and the nanofiber-enhanced membranes, respectively. This result suggests that the fiber morphology is playing a role in water transport. The functionality of the additional nanofiber layer was investigated under static and flow conditions using bovine serum albumin (BSA) protein. The BSA did not attach to the nanofiber layer and because the BSA is smaller than the MWCO of the membranes, it was able to quickly pass through the membranes. In sum, electrospun nanofibers can effectively be used to functionalize the surface of ultrafiltration membranes and importantly, size selectivity of the ultrafiltration membranes persists with the addition of the nanofiber layer. The full methods and results from this work are currently being prepared for submission to a peer-reviewed journal.