Cellulose Nanofiber Composite Membranes for Water Purification

Nithinart Chitpong and Scott M. Husson

Department of Chemical & Biomolecular Engineering, Clemson University, Clemson, SC 29634

Global water demand continues to increase because of population growth, urbanization, and climate change. Since there are limited natural water resources, water purification systems play a critical societal role. Membrane technologies are used widely to improve water quality for beneficial use. Therefore, the development of new membranes is an active area of research in the water purification field.

In this project, high-performance, nanofiber-based ion-exchange membranes were prepared for removal of heavy metals from impaired waters. Our hypothesis was that such membranes would have high metal ion capacities resulting from large surface area-to-volume ratios and high water permeability relative to barrier-type membranes such as reverse osmosis and nanofiltration. The nanofiber membranes were produced by electrospinning cellulose acetate nanofiber mats, which were strengthened by thermal-mechanical annealing and then converted to regenerated cellulose nanofiber mats. Subsequent surface modification transformed the membranes into ion-exchange membranes for removal of trace metal ions in water.

Cellulose acetate was selected as the starting material because it has been used widely to electrospin fibers due to simple processing. The electrospinning formulation and conditions yielded fiber mats having a fiber diameter in submicron range and a thickness range of 160 to 330 μm. Following annealing, the nanofiber mats were converted to regenerated cellulose, which is a low-fouling material that can be modified using convenient surface chemistry to introduce the ion-exchange ligands.

Ion exchange using carboxylate anion ligands is a potential strategy to capture cadmium and nickel ions found in industrial wastewaters. Thus, the regenerated cellulose nanofiber mats were modified by grafting poly(itaconic acid) (dicarboxylic acid side groups) and poly(acrylic acid) (monocarboxylic acid side groups) to the surfaces of individual nanofibers that had been modified with epoxide groups by atom transfer radical addition of 1,2-epoxy-5-hexane. The success of poly(itaconic acid) and poly(acrylic acid) grafting was confirmed by attenuated total reflectance Fourier-transform infrared spectroscopy.

Direct-flow filtration measurements showed that the nanofiber membranes have water permeabilities of 2,000 $L/m^2/bar/h$, much higher than reverse osmosis or nanofiltration membranes. Results of metal ion static and dynamic ion-exchange capacities will be presented and compared to more traditional ion-exchange media.