Mechanical enhancement of thin-film composite membranes using helically-coiled carbon nanotubes for engineered osmosis

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The objective of this work is to enhance the mechanical robustness of thin-film composite (TFC) membranes and thereby improve their performance. Reverse osmosis (RO) and osmotically driven membrane processes (ODMP), namely forward osmosis and pressure-retarded osmosis often require a high pressure gradient across the membrane. Therefore, mechanical robustness is a required characteristic for a RO and ODMP membranes. Unfortunately, mechanical robustness commonly is inversely proportional to the water permeability of the membrane, which is a critical performance indicator of the membrane.

Previous works have used nano-engineered materials to cast membranes with improved properties, including mechanical strength. This contribution shows the effect on the mechanical strength of TFC membranes by the addition of never-before-tested helically-coiled carbon nanotubes (HCNT) in the membrane porous support. These membranes were fabricated by casting a support via phase inversion of a Matrimid 5218® solution with dispersed HCNT, followed by interfacial polymerization using m-phenylenediamine and trimesoyl chloride. Characterization and testing included compressive stress measurements using an INSTRON machine to evaluate the effect of HCNT content on the membrane mechanical strength. Water permeation and salt rejection tests using a direct flow cell in RO mode were done to compare the performance between the HCNT-TFC membranes and standard TFC membranes. Additionally, cross-sectional SEM images were taken before and after testing the membranes to evaluate the reversibility of the support compaction after testing due to the addition of the resistant HCNT. Finally, data also were compared to commercial RO membranes.

Results show a significant improvement on the mechanical strength compared to the standard TFC membranes and commercial RO membranes. Additionally, water permeation and salt rejection values were not affected by the addition of the HCNT relative to standard TFC membranes. The inclusion of HCNTs in the membrane support has potential for reducing support layer thickness, which is expected to yield higher water flux and generally better ODMP performance.

Keywords: thin-film composite membrane, carbon nanotubes, membrane mechanical resistance