Low Energy, Chlorine-Tolerant Desalination Membranes

Optimizing low-energy water production and recycling.

Sandia has developed chlorine-tolerant, biofouling-resistant, graphene oxide (GO)/polymer desalination membranes. These membranes improve desalination by treating water at lower energy and system operational costs.

Benefits of graphene oxide (GO)/polymer composite membranes

Chlorine-tolerant desalination membranes

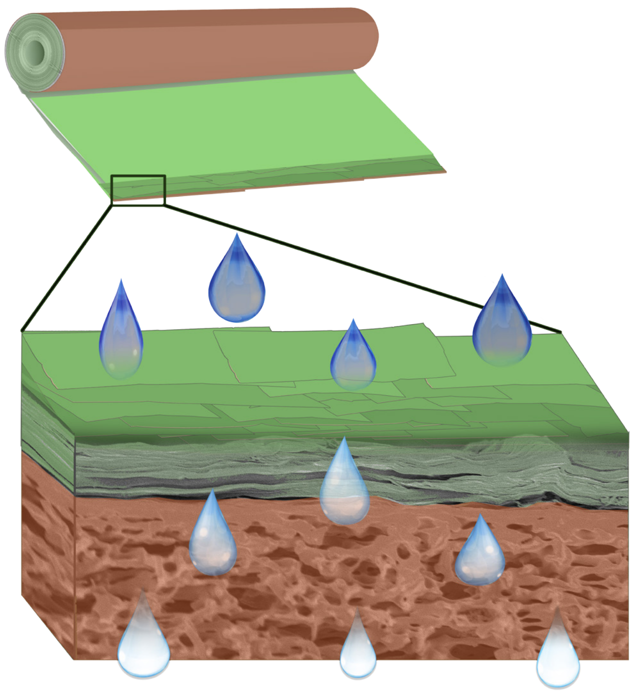
Laboratory tests show that GO/polymer membranes tolerate drinking water level chlorination (1-3 mg/L). This chlorine tolerance eliminates the need for energy-intensive de-chlorination processes used to pre-treat water for conventional thin-film composite reverse osmosis (TFC-RO) membranes, which are damaged by free chlorine levels >0.1 mg/L.

Combatting harmful biofilms

GO is an intrinsic contact-based biocide, which minimizes biofilm growth on GO/polymer membranes. After month-long exposure to fungi-contaminated waters, no spore growth was observed on the GO surface. In comparison, bacteria and spores grow readily in the dechlorinated feed water used for current TFC-RO membranes, forming harmful biofilms that decrease permeability and membrane lifetime. Current TFC-RO membranes must be regularly cleaned with strong acids and backflushed, increasing energy and operating costs.

Reduce the energy demands of desalination

The high density of water flow paths within the GO/polymer membranes provides for high flux membranes. The salt rejection is dynamically tuned by the applied driving pressure, allowing for optimum energy use and treat-to-need water quality.



Laminar GO (green) is covalently bound to a porous polymer support (brown), as shown in this false color scanning electron microscope image. At top, an artist's representation of a spiral-wound GO/polymer element.

Enable effective thermoelectric cooling tower water recycling

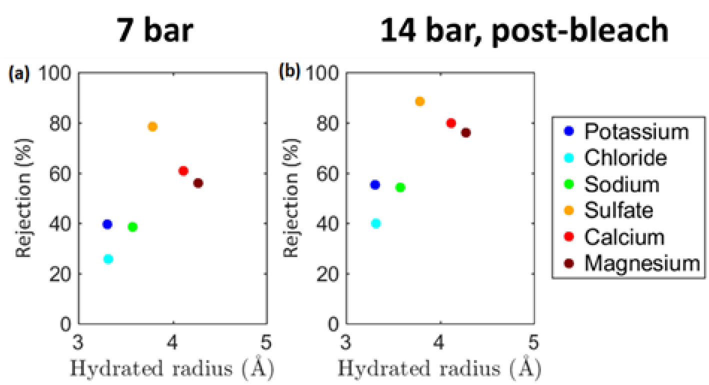
In partnership with the Electric Power Research Institute (EPRI) , Sandia has conducted month-long tests of these membranes against cooling tower blowdown water from thermoelectric power plants. The pressure-tunable rejection allows for energy optimization at varying water chemistries. At low pressure (150 psi), scale-forming divalent ions are rejected, while smaller, monovalent ions are only weakly rejected. Increasing the pressure to 300 psi nearly doubles the rejection of the monovalent ions. The GO/polymer membranes resisted biofilm and inorganic scaling; permeance (flux/pressure) remained constant.

Design and performance of GO/Polymer composite membranes

Our desalination membranes comprise a laminar graphene oxide film covalently bound to a porous polymer support. The laminar graphene oxide, covalent linker molecules and porous polymer support provide enhanced ion rejection, membrane integrity, and mechanical durability.

The intrinsic nanoscale properties of laminar GO/polymer membranes are optimum for desalination . The overlapping graphene oxide layers create a two-dimensional, high-flux pathway for water to flow around the individual GO sheets. The inter-sheet spacing of 0.7-1.1 nm allows water to flow under a high intrinsic capillary pressure while blocking the permeation of salt ions.

The rejection, determined by this inter-sheet spacing, is dynamically tuned by the applied driving pressure allowing for "treat-to-need" to decrease system operating costs. At low pressures scale-forming divalent ions are rejected while smaller, monovalent ions are only weakly rejected.



Treat-to-need rejection of salts in cooling tower blowdown water.

Following month-long rejection tests, no bio-film growth is observed on the GO/polymer membranes

Commercialization Path

To enable roll-to-roll processing of our GO/polymer membranes and eventual scale-up to spiral-wound membrane elements, a backing material must be integrated to the porous polymer support prior to assembly of the active graphene oxide layer.

We are seeking a partner with expertise in polymer membrane manufacturing and roll-to-roll material processing. To demonstrate commercial viability, we must integrate the GO/polymer membranes into spiral-wound membrane elements. With a collaborative partner, we will build small scale (eg: 12") GO/polymer desalination test elements.

Application spaces:

- Thermoelectric power generation: Increase cooling tower cycles of concentration; pre-treat brackish and waste water to diversify water supplies.
- Recycle produced water for productive reuse.

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