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Highly Permeable and Selective Reverse Osmosis Membranes incorporating Artificial Water Channels

The current market of reverse osmosis (RO) membranes for desalination is dominated by thin-film composite membranes comprising an active layer of polyamide (PA) fabricated by interfacial polymerization (IP) of m-phenylenediamine with trimesoyl chloride, giving rise to fully aromatic films. However, these traditional PA membranes suffer from inherent limitations which reduce their performance. Biological membranes with highly selective pores can inspire the next-generation RO membranes that will overcome the current problems. However, producing defect-free bio-inspired membranes of large areas has been so far the most critical challenge.

We report the successful development of an approach to upscale the molecular/supramolecular artificial water channels (AWCs) systems to generate defect-free highly selective membrane materials readily applicable in RO applications [1-3]. Bio-inspired desalination membranes are prepared by using an IP approach, contacting an aqueous phase containing polyamine and alkyureido-imidazole monomers with an organic solution comprising an acyl halide. This procedure leads to the formation of PA-AWCs hybrid polymers, whose structures present the same microscale morphology of classic TFC-PA layers but with a different roughness and nano-structure that includes supramolecular aggregates of highly selective I-quartet AWCs.

Results demonstrate that bio-inspired AWCs-PA layers can enhance the selective water transport through the polymer. The performance of our membranes are evaluated by cross-flow filtration under RO conditions to desalinate solutions containing 3,500 and 35,000 ppm NaCl at 18 and 65 bar of applied pressure, respectively.
The thin layers embedding densely packed Å-scale bio-mimetic channels overcome the perm-selectivity trade-off of current commercial PA membranes, achieving a large improvement of 200% up in water permeance (up to 4.75 LMH/bar) while maintaining excellent NaCl rejection (observed rejection > 99.5%).

The proposed strategy represents a possible efficient route to further advance desalination strategies.