

ACCELERATING INVESTMENT 12 - 14 May 2025 | Paris, FR

Rethinking Membrane Manufacturing

Presentation by

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Reverse Osmosis Membranes Today



How These Membranes are Made

GLOBAL WATER







This method has been the primary method for making RO membranes for over four decades.

The materials have stayed the same as have the methods of fabrication

In that time, various limitations have been identified

Uncontrolled Thickness







 $\begin{array}{ccc} 100000 \times & 1\,\mu m \\ & \text{Increased roughness} \\ & \text{increasing susceptibility to} \\ & \text{fouling} \end{array}$

Limited Chemistries



Little control over selectivity





Polyamide formation is selflimiting and essentially uncontrolled.

New Material Platforms for Membranes

55588

Antifouling membranes

Membrane protein or artificial

channel based membranes





Hinds, B.J., "Aligned Multiwalled Carbon Nanotube Membranes, *Science* 303, 2004, 62-65.



Gao, Y. "Reverse Osmosis Membranes with guanidine and amine enriched surface for biofouling and organic fouling control" Desalination 430, 2018, 74-85.



Cell membranes

Shen, Y., "Biomimetic membranes: A review", Journal of Membrane Science 454, 359-381.

Amorphous *sp*²-hybridized carbon sheets



Zhang, Y. "Fit-for-purpose block polymer membranes molecularly engineered for water treatment", *npj clean water 1, 2018.*

Zeolite Nanoparticle Barrier Layer (Fully Crosslinked Aromatic Polyamide) Microporous Support (Polysulfone)

Jeong B.H. "Interfacial polymerization of thin film nanocomposites: A new concept for reverse osmosis membranes". Journal of Membrane Science. 294, 2007.



Griggs, C.S., Medina, V.F., "Graphene and Graphene Oxide membranes for Water Treatment"

Small micropores
(Apertures)Micropores
(Galleries)Koh, D. "Reverse osmosis molecular

differentiation of organic liquids using carbon molecular sieve membranes" *Science* 353, 804-807.

Membrane Innovation Pip

- Large numbers of papers published on new membrane materials
- Very few papers published on membrane modules and processes

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Beuscher, U., Kappert, E.J., Wijmans, J.G. "Membrane research beyond materials science", *Journal of Membrane Science*, 643, 2022, 119902

Membrane Innovation Pipeline and Value Chain





Discover a new selective material

Synthesize the new material



Characterize the new material



Make it into a membrane at the lab <u>scale</u>



Verify membrane performance at <u>l</u>ab scale



End of life



Integrate and use in a process



Verify module performance



Assemble the modules







Manufacture the material at relevant scales

Other Options for Making Polyamide TFC Membranes



Zhou, Z. et al., 2022, Sep. And Pur. Tec., 288, 120648

Layer-by-layer deposition _o



Gu, J. Et al., 2013, Advanced Materials, 25, 4778-4782.

Ultrathin and smooth

TFC membranes

Molecular/Atomic Layer Deposition



Welch, B.C. et al., 2024, Chem. Mater., 36, 1362-1374.

Support Free Interfacial Polymerization



Park, S., et al., 2017, Journal of Membrane Science, 526, 52-59.





Scalable Thin Film Manufacturing with Electrospray







Winner of the 2019 Water Technology Idol **Competition at Global** Water Summit





Ostwal, M., Wazer, E., Pemberton, M., McCutcheon, J.R., Journal of Membrane Science Letters, 2022, 100035.

The presenter is an equity owner of a faculty affiliated company at the University of Connecticut that is seeking to commercialize technology related to some of the work described in these slides

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Where do we Find Game Changing Innovations in Desalination?

- Think about where innovation has stalled.
- A good place to start is looking at technology that has changed little in nearly a half-century: Materials and Manufacturing
- What opportunities to advance new materials have we missed because we have been reliant on a legacy manufacturing approach for reverse osmosis membranes.





10