From Materials to Impact: Graphene Membranes for Net-Zero Water Treatment

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Abstract
Two-dimensional (2D) membranes have emerged as a powerful platform for redefining the limits of molecular and ionic separations. Our work presents a comprehensive research programme focused on the design, control, and scale-up of graphene-based and related 2D membranes for desalination and advanced water treatment. By engineering angstrom-scale nanochannels with precisely tunable interlayer spacing and surface charge, we demonstrate controlled transport of water and ions that are fundamentally distinct from those governing conventional reverse osmosis separations.

The study encompasses electrically responsive and chemically adaptive membrane systems that enable dynamic regulation of ion sieving, stimulus-dependent permeation and exploring new driving forces in separation. These transport phenomena provide the foundation for new separation strategies, including selective salt partitioning, reaction-driven water transport, and coupling of desalination with resource recovery. Performance advantages include high water permeance, lower fouling propensity and engineering zero waste separation methods.

Scalable fabrication routes, including hollow-fibre architectures, are established to translate nanoscale transport control into practical modules suitable for desalination, wastewater treatment, solvent filtration, and industrial process streams. Collectively, this work advances 2D nanolaminate membranes from fundamental nanofluidic science to deployable technologies, positioning them as a transformative materials platform for energy-efficient separations and circular water–resource systems.

References

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