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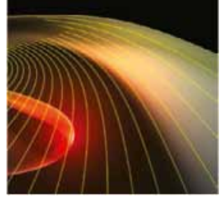

EDITORIAL

Editor's choice: Advancements in nanoconfined materials for osmotic power generation

In the quest for sustainable energy sources, osmotic power, or blue energy, that exploits the natural salinity gradient between freshwater and seawater has emerged as an interesting concept. It has seen significant advancements recently due to innovations in nanoconfined materials and their hierarchical structures that closely mimic natural systems to optimize ion transport and enhance power generation efficiency. Central to the success of these materials is the concept of nanoconfinement, where ion transport is influenced by the electrical double layer (EDL) within the pore channels of diameters ranging from 2 nm to 100 nm. Further, sub-2 nm channels exhibit unique ion dynamics due to selective attraction or repulsion by surface charges within the pores that facilitate unipolar ion transport. The paper by Zhong Lin Wang and Di Wei et al.[1] delves into the remarkable progress made in the field, focusing on one-dimensional (1D) nanopore materials, two-dimensional (2D) layered nanofluidic membranes, and three-dimensional (3D) self-assembled membranes. Their discussions of these topics are briefly summarized below:

1. 1D Nanopore Materials: 1D nanopores possess high ion selectivity, permeability, and output power density (22.5 kW m^{-2}). These attributes stem from precise control of the geometric and chemical properties of 1D nanopores in materials, achieved through ion-track-etching techniques. Despite their theoretical promise, practical applications are hindered by challenges such as polarization, high fabrication costs, and scalability issues. However, materials containing 1D pores provide a crucial foundation for understanding salinity gradient energy conversion principles.
2. 2D Layered Membranes: 2D layered membranes, including graphene oxide (GO) and MXenes, offer large specific surface areas and are easily modifiable, allowing for ion selectivity in nanoconfined channels. These membranes, typically fabricated by vacuum filtration, strike a balance between ease of production and high transmembrane resistance, though their output power density is limited to 15.7 W m^{-2}. The persistent challenge with membranes based on 2D materials is the trade-off between ion selectivity and permeability, which continues to be a critical area for improvement.
3. 3D Self-Assembled Membranes: 3D self-assembled membranes are promising for their low cost fabrication, scalability, and tunable surfaces. They are fabricated using layer-by-layer assembly and can achieve output power density of 210.1 W m^{-2} due to enhanced mass transfer and charge regulation. Their structural stability and scalability make them particularly promising for practical osmotic power generation applications.

The authors highlight that the overarching theme in the field is the necessity of designing nanostructures with optimized surface charges, pore geometries, and responsiveness to external stimuli such as temperature and pressure. By integrating hierarchical structures that promote mass transport and refined ion dynamics, the potential for high-efficiency osmotic power generation can be improved.

In sum, the convergence of nano science and strategic design of nanoconfined channels presents new approaches for overcoming current limitations in osmotic power generation. This paper highlights promising trajectories of nanoconfined materials for osmotic power generation, inviting further exploration.

REFERENCE

1. L. Yang et al., Osmotic power generation based on nanoconfined materials. MRS Energy Sustain. (2024). https://doi.org/10.1557/s43581-024-00104-3