Graphene Oxide Functionalization of PVDF Membrane for Enhanced Antifouling and Photothermal Performance

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Introduction. Membrane Distillation-Crystallization (MDCr) is emerging as a promising technology for hypersaline water desalination and brine resource valorization, crucial for advancing toward a Circular Blue Industry. However, its large-scale implementation is impeded by key problems such as energy-inefficient bulk feed heating and membrane fouling, which increase operating costs and reduce membrane lifespan [1,2]. A major limitation is temperature polarization (TP), primarily caused by latent heat dissipation in the feed water vaporization and the permeate vapor condensation, leading to inefficient energy utilization. Additionally, membrane wetting remains a critical bottleneck of the technology [3,4]. To address these issues, Photothermal membranes with localized heat-harnessing strategies have been proposed as a promising alternative, credited to their self-heating capabilities and mitigating temperature polarization. To this end, this study aims to develop a self-heating photothermal membrane with enhanced heat harvesting efficiency, antifouling properties, and tailored surface characteristics, for recovering valuable minerals from hypersaline brine solution.

Experimental: Photothermal membranes with different loadings of graphene oxide (GO) nanoparticles as photothermal nanofillers were fabricated by surface coating a hydrophobic polyvinylidene fluoride (PVDF) membrane. Comprehensive analytical characterizations were performed to assess the Physicochemical and structural properties of the membrane sample. Additionally, the membranes were systematically evaluated for their sunlight-to-heat conversion efficiency, water evaporation performance, membrane crystallization behaviors, and antifouling properties.

Results and discussion. Results indicated that membranes with uniformly distributed photothermal nanofillers and an optimized microstructure for MDCr applications were successfully fabricated. Water evaporation experiments showed that the membranes coated with 5 wt% of GO (PVDF-GO5) achieved an evaporation flux of 1.10 L m^{-2} h^{-1}, more than double that of the pristine membrane. This membrane demonstrated 75% thermal efficiency and enabled the recovery of NaCl crystals, with a 36% dispersion around the mean crystal size from a hypersaline brine solution. Moreover, the antifouling properties of the membranes were studied via comprehensive investigations using various fouling agents. Interestingly, PVDF-GO5 reduced biofilm formation by 60% - 90%, while also significantly minimizing protein fouling compared to the uncoated membrane. These findings proved the membrane's suitability for solar-powered membrane distillation applications. In conclusion, this study provides a new approach to designing membrane distillation systems that can effectively and simultaneously address both temperature polarization and fouling challenges.

References

1. Santoro, S. *et al. Energy* **2021**, **228**
2. Horseman, T. *et al. ACS ES and T Engineering* **2021**, 1
3. Han, F., Mao, J. & Wang, K. *J. Environ. Chem. Eng.***2022**, 10,
4. Pintossi, D., Saakes, M., Borneman, Z. & Nijmeijer, K.. *ACS Appl. Mater. Interfaces* **2021**, 13

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