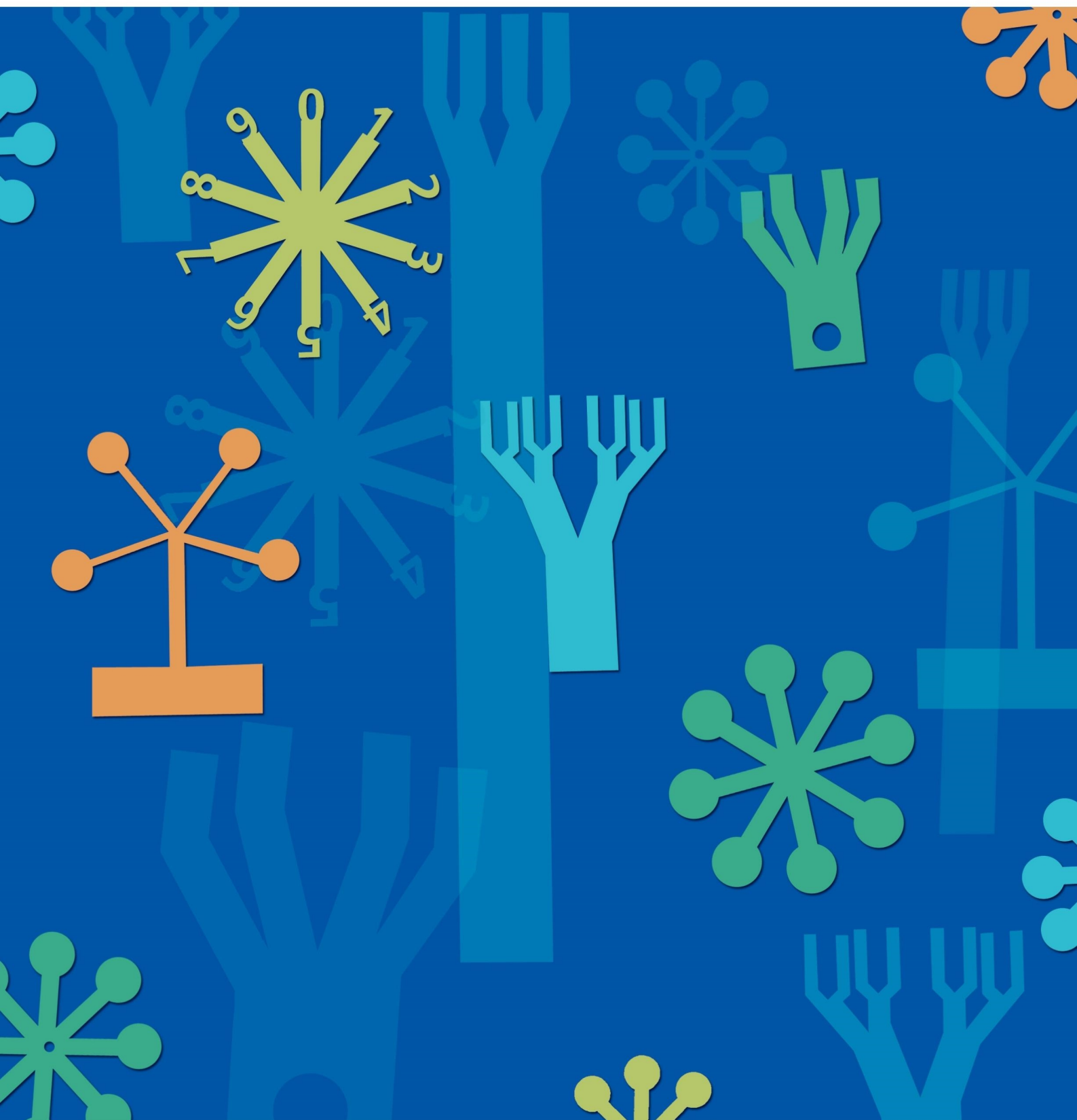


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Salt-Resistant Self-Floating Composite Hydrogel Foam Evaporator Enabled by Donnan Effect for Efficient Solar Interfacial Evaporation and Water Purification

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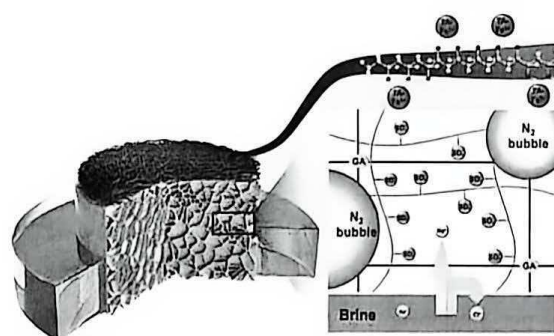
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ABSTRACT: Solar interfacial evaporation is a promising approach for desalination and wastewater treatment, yet practical evaporators remain challenged by limited water transport, interfacial heat loss, and salt deposition in high-salinity brines. Herein, a self-floating, salt-resistant composite hydrogel foam evaporator, PTF@PGAS-Foam, was developed by integrating an electrospun tannic acid-Fe³⁺ photothermal membrane with a polyelectrolyte double-network hydrogel foam. The upper photothermal membrane enables strong solar absorption and thermal localization, while the lower foam layer provides buoyancy, low thermal conductivity, and continuous three-dimensional water-transport pathways. Fixed sulfonate groups in the hydrogel induce the Donnan effect, suppressing salt-ion migration toward the evaporation interface and alleviating salt crystallization during continuous evaporation. Under 1 sun irradiation, PTF@PGAS-Foam achieved an evaporation rate of 2.61 kg·m⁻²·h⁻¹ and an efficiency of 92% in a 20 wt % NaCl solution, with stable performance during continuous and cyclic tests. The evaporator also adsorbed heavy metal ions, including Pb²⁺ and Cd²⁺, and cationic dyes. In outdoor scaled-up tests, a 15 cm diameter evaporator produced 20.35 kg·m⁻² of water per day. This multifunctional evaporator integrates solar absorption, heat localization, self-floating behavior, salt resistance, and adsorption, showing potential for solar desalination and wastewater purification.

KEYWORDS: self-floating, hydrogel foam, Donnan effect, solar interfacial evaporation, adsorption



INTRODUCTION

With the rapid advancement of global industrialization, water scarcity has become increasingly severe, prompting the urgent development of effective water purification strategies.^{1–3} To address this challenge, conventional technologies, including reverse osmosis, distillation, and chemical treatment, have been widely investigated and applied for water purification. Nevertheless, their practical implementation remains limited by high energy consumption, elevated operating costs, and potential secondary environmental impacts.^{4–8} Solar-assisted interfacial evaporation (SIE) has therefore emerged as a promising strategy for water purification because it utilizes renewable solar energy while offering low energy consumption and high evaporation efficiency.^{9–11}

Thermal localization and interfacial thermal decoupling are effective strategies for enhancing the evaporation performance of solar-driven evaporation systems.^{12–14} By concentrating photothermal materials at the evaporation interface and separating them from the bulk water, the heat generated during photothermal conversion can be localized at the evaporation surface, thereby reducing heat dissipation to the underlying water and

improving evaporation efficiency. Electrospinning is a versatile and scalable technique for fabricating polymer fibrous membranes with fiber diameters ranging from the nanometer to micrometer scale. Owing to their high specific surface area and porosity, electrospun membranes loaded with photothermal materials are considered promising candidates for solar-driven interfacial evaporation. Tian et al.¹⁵ prepared a superhydrophilic Cu/C porous fibrous evaporator through multi-fluid electrospinning followed by heat treatment. Under one-sun irradiation, the evaporator achieved an evaporation rate of 1.41 kg·m⁻²·h⁻¹ and an evaporation efficiency of 94.6%. Kumar et al.¹⁶ fabricated a solar steam generator based on an α -FeO/PAN nanofibrous membrane evaporator prepared by electrospinning, achieving a maximum evaporation rate of

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