Ultrathin, Unsinkable, Janus-Faced Solar–Thermal Interfacial Evaporator for High-Throughput Seawater Distillation and Solar-Water Production

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Solar–thermal distillation offers immense and hitherto untapped potential for energy-efficient, sustainable freshwater production.[1] However, critical limitations in material and system design continue to hinder water-evaporation rate (R_w) and specific water productivity (SWP), posing significant roadblocks for scalable and stable solar desalination.[2] An ultrathin, porosity-tuned high internal phase emulsion polymer (polyHIPE, PH) scaffold is integrated with nanostructured hard-carbon florets (NCF) as a black-body absorber to create the thinnest interfacial evaporator, delivering best-in-class solar–thermal energy conversion (η-STC = 84%), rapid Rw (6.5 kg m^{-2} h^{-1}), and efficient SWP of 18 L m^{-2} day^{-1} from seawater.[3] The Janus-faced NCF@PH confines solar–thermal energy at the interface, which also promotes extensively convex water menisci, to deliver high R_w. The continuously interconnected 3D capillary channels within NCF@PH ensure continuous water transport and restructure hydrogen bonding in interfacial water, while their hydrophobic surfaces prevent salt deposition for robust long-term seawater distillation with high salt rejection (> 90 %). Furthermore, a system-level prototype termed SunSpring (SS) works to decouple the light-admitting, water-evaporation, and water-condensation steps to produce environmental protection agency (EPA)-standard freshwater (< 10 ppm salinity) from highly saline seawater (35 000 ppm) for over ≈ 225 h of real-time continuous usage. It is also estimated that SS has the lowest energy (< 3 W L^{-1}) and CO_2 (≈ 3 g L^{-1}) footprints, representing a paradigm shift in the water-energy nexus.[4]

References

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Figures

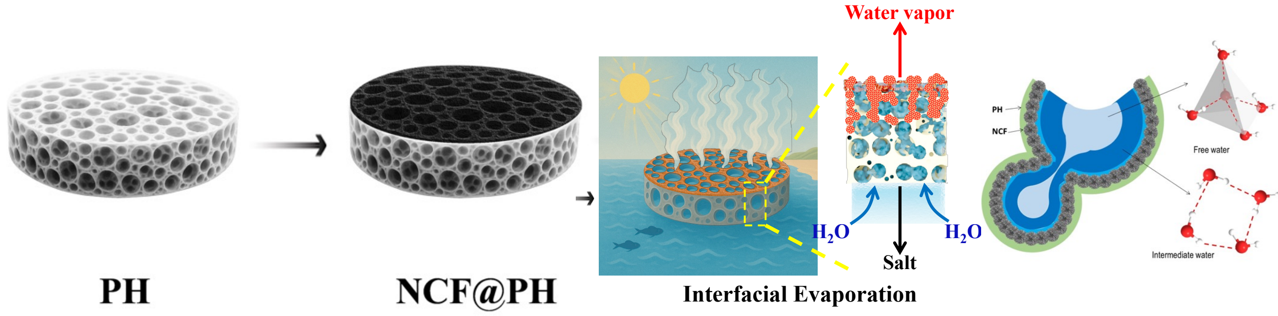

Figure 1: Schematic of Interfacial engineering of NCF@PH for solar-thermal desalination