Supporting Information

A high-performance salt-rejecting and cost-effective superhydrophilic porous monolithic polymer foam for solar steam generation

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1 Experimental section

1.1 Materials

Styrene (ST) was obtained from Tianjin Fuchen chemical reagent Co., N,N'-Methylenebisacrylamide (MBA) was purchased from Shanghai Macklin Biochemical Co., Ltd. 1-vinyl-3-ethylimidazolium tetrafluoroborate ([VEIm]BF4) was purchased from Lanzhou Zhongke Kaite Industry &Trade Co., Ltd. 2,2'-Azobis(2-methylpropionitrile) (AIBN), Tetrahydrofuran (THF) and isopropanol alcohol (IPA) were purchased from Tianjin Fuyu chemical reagent Co., Ltd.. Phytic acid (PA, 50 wt% in water) was obtained from Aladdin Chemical Reagent Co., Ltd., all reagents were used directly. Pyrrole (Py) was purified by re-distillation just before use and obtained from Wuhan Pengo technology Co.

1.2 VMP hydrophilic porous polymers foam Preparation

VMP porous polymers foam was prepared by hydrothermal method, a certain amount of ST, [VEIm]BF_4, MBA and AIBN were dissolved in a mixed solution of THF and distilled water. The mixture solution stirred for an hour and then transferred into an autoclave at 65°C for 72h. After cooling to room temperature, the system was replaced with ethanol-water solution to remove unreacted monomers or initiators. The VMP monolithic foam was obtained after freeze-dried.

1.3 PPy-coated VMP foam Preparation

In a typical liquid phase interfacial reaction. The solution A was obtained by adding 0.548g ammonium persulfate into 10mL of DI water. 0.168 mL pyrrole and 5mL IPA were mixed together, followed by adding 0.368 mL phytic acid (50%, wt% in water)

and gentle shaking, the solution B was obtained. The solution A and B were rapidly cooled to roughly 0˚C. Then the cooled solution A and B were alternately sprayed on the upper surface of VMP directly. Repeated the above steps several times until the up surface of VMP completely became black, to make sure the PPy coating on VMP was complete and uniform. Finally, the foam was washed with DI water for several times and the PPy-coated VMP foam was obtained by natural drying.

2 Characterization

The morphology and microstructure of the samples were examined by field emission scanning electron microscopy (FE-SEM, Carl Zeiss-Ultra Plus, Germany) and Transmission electron microscope (TEM Tecnai G2TF20). The elemental composition was identified by scanning electron microscopy with energy dispersive X-ray (SEMEDX, JSM-6700F, JEOL, Ltd.). The surface wet ability of the samples was investigated by the contact angle meter (DSA100, Kruss). The thermal stability of the products was measured by a thermogravimetric analysis (TGA, Perkin Elmer) with a heating rate of 10 °C·min^{-1} under nitrogen atmosphere. Mercury intrusion was performed on AutoPore IV 9500 V1.09 equipment. The optical properties of the VMP and PPy-coated VMP were measured by ultraviolet–visible–near infrared spectrophotometer equipped with an integrating sphere (Lambda 900 UV/VIS/NIR PerkinElmer). Fourier transform infrared spectroscopy (FTIR) was recorded from in the range of 4000 - 400 cm^{-1} by using a Mexus 670 spectra instrument. The mechanical property was investigated by an electrical universal material testing machine with a 500 N load cell (EZ-Test, SHIMADZU) at a stress rate of 5

mm·min^{-1}. The camera photos were recorded at PhotronFastcamMini UX100 type high speed video camera.

3 Calculation of the energy conversion efficiency

We further investigated the solar thermal steam generation efficiency (η) of the PPy-coated VMP steam generators based on the measured evaporation rates.

$\eta = mh_{LV}/C_{opt}qi$

where m is the mass flux of steam (the rate of water evaporation under the dark environment is subtracted), C_{opt} is the optical concentration, qi is the nominal direct solar irradiation 1 kW m^{-2}.

h_{Lv} denotes total enthalpy of liquid-vapor phase change (including sensible heat and phase-change enthalpy), can be calculated as

$h_{Lv} = \lambda + C\Delta T$

where λ is latent heat of phase change (The latent heat varies from 2430 kJ/kg at 30 ˚C to 2265 kJ/kg at 100 ˚C), C is specific heat capacity of water (4.2 kJ kg^{-1} K^{-1}), and ΔT denotes the temperature increase of the water.

4 Solar steam generation tests.

The solar steam generation experiments was conducted at a lab-made, online, real-time measurement system which is composed by a solar light simulator (xenon arc lamp, CEL-S500, Ceaulight) with a solar filter (AM 1.5, Ceaulight), a test chamber with 80 mm in height 34 mm in diameter, an analytical balance (FA 2004), a computer to record the time-dependent mass change of water due to the stream generation, an infrared camera (Testo 869, Germany). Light intensity was measured

by a full spectrum optical power meter (CEL-NP2000-2, Beijing Education Au-light Co., Ltd.). During each test, the room temperature was maintained at 22-25 ˚C and the humidity was ranged from 25 and 32%.

5 The stability of PPy-coated VMP foam in wet-state or immersion in water.

The materials are stable in wet-state or immersion in water. No damage and crack appeared during the entire experimental process and test. As shown in **Fig.S1** A-B, there is no obvious crack presented in the surface of samples and no black PPy powder is observed after immersion in water for 4 months. The PPy-coated VMP foam can be removed and used conveniently (**Fig.S1** C-D). Generally, the foam has complete structure and good mechanical property in wet-state, which can fully apply in many kinds of measuring conditions.

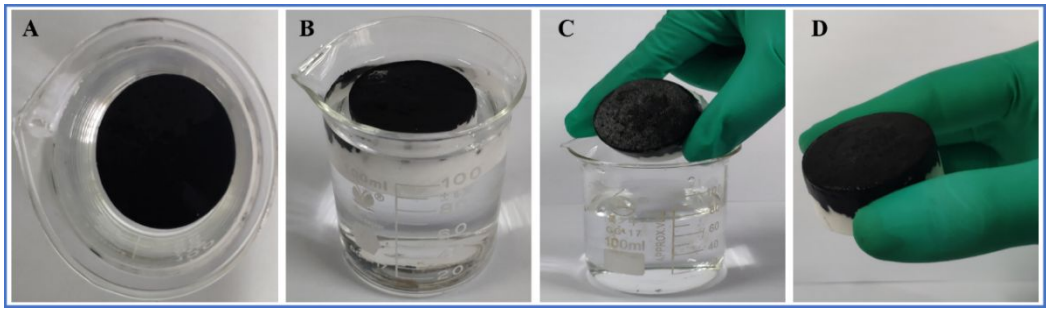

Fig.S1 (A-B) The PPy-coated VMP foam immersed in water for 4 months. (C-D) Removed PPy-coated VMP foam from water.

6 The FTIR and SEM of the top PPy layer.

FTIR and SEM characterization were used to analyse the chemical structure and microstructure of the PPy-coating. As depicted in **Fig.S2** A, the absorption peak at 1397 cm^{-1} and 1296 cm^{-1} are due to the vibrations of C-H bonds and the C-C stretching. The peak at 1552 cm^{-1} can be assigned to the in-ring stretching of C=C

bonds in the pyrrole rings. The characteristic peak at 1045 cm^{-1} could be ascribed to the in-plane deformation of the C-H bond and N-H bond. The formation of PPy could be confirmed by these characteristic absorption peaks. From the SEM image (**Fig.S2** B), we can find that the PPy coating is porous structure which composed of tiny and uniform particles. There are many pores of different diameters, which were formed inside the coating. Based on this structure, PPy coating could not fill pores of foam and not hinder the water evaporation.

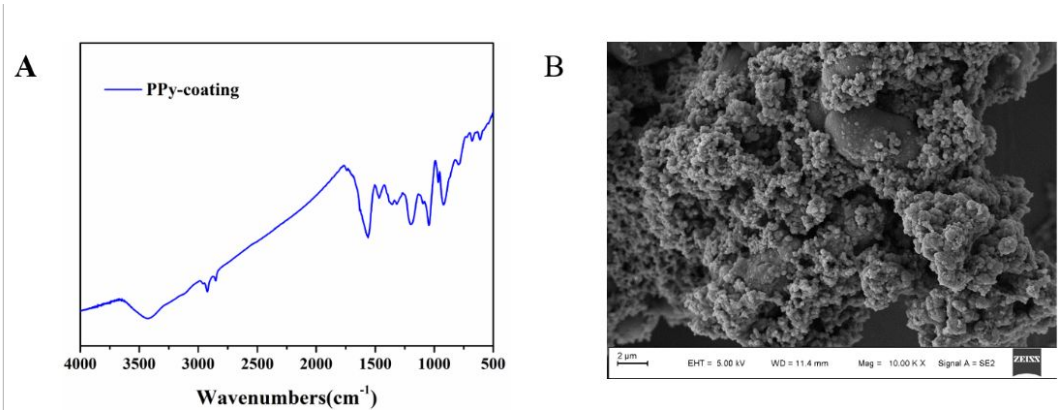

Fig.S2 A. The FTIR spectrum of the PPy-coating. B. SEM image of the top PPy layer.

7 The chemical stability of PPy-coated VMP foam after the test.

We have respectively configured 0.1mol/L HCl and NaOH solution, and then our PPy-coated VMP samples, which was immersed in DI water for 4 months after the test of solar steam generation, were placed in acidic and alkaline solutions for 24 hours to test their resistance in harsh environments. The experimental processes are shown in the **Fig.S3** A and B. The results show that the PPy-coated VMP samples are quite tenacious in an acidic (PH=1) and alkaline (PH=13) environment. Because our materials are polymers, they do not react with hydrochloric acid and sodium

hydroxide or other common inorganic compounds at normal temperature and pressure. So, our sample has great chemical stability during solar desalination.

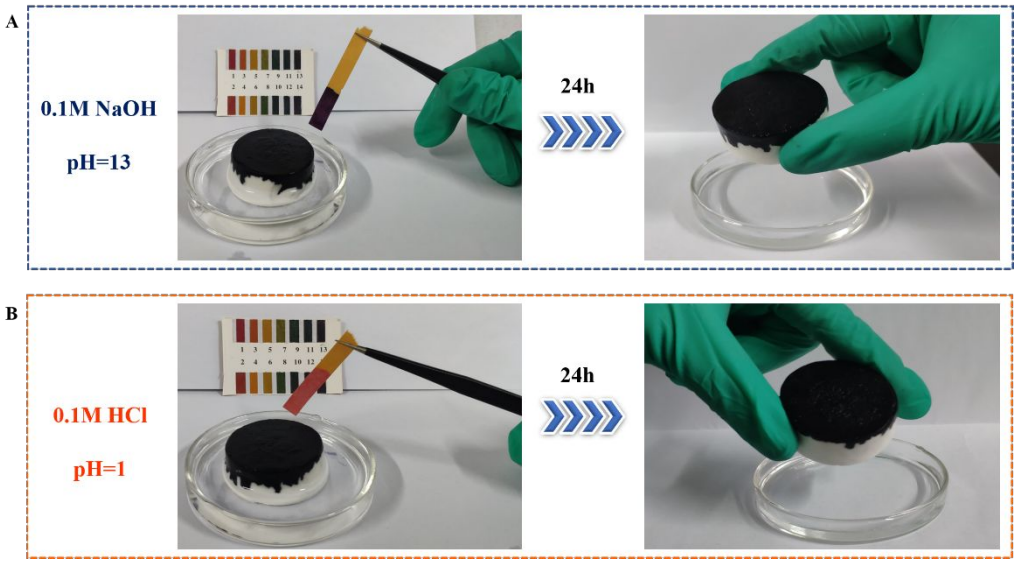

Fig.S3 Photographs of the PPy-coated VMP foam immersed in 0.1M HCl (A) and 0.1M NaOH (B) for 24h.

8 The outdoor solar seawater desalination experiments

Outdoor solar seawater desalination tests under natural sunlight are important measurement to demonstrate practical application potential of photothermal materials. The PPy-coated VMP foam floated on the simulated seawater and was placed in outdoor under nature sunlight. In addition, we also carried out a blank test for contrast (**Fig.S4** A). Two groups of experiments continuously evaporated 7h a day for three days under identical conditions. The outdoor experiment was carried out from 9:00 am to 4:00 pm, the ambient temperature range was from 11°C to 22.5°C and the humidity was ranged from 22 to 28%, which are relatively low in spring of the northwest China. The quantities of the simulated seawater daily evaporation were recorded and the results were shown in **Fig.S4** B. The mean evaporated mass of

simulated seawater with and without the PPy-coated VMP foam on it are 18.477g and 11.271g under natural light, respectively. It is worth noting that the difference of mass loss between two experimental groups is close to 7.3g (**Fig.S4** B), which indicates that our PPy-coated VMP foam can concentrate heat around itself and speed up the evaporation of seawater.

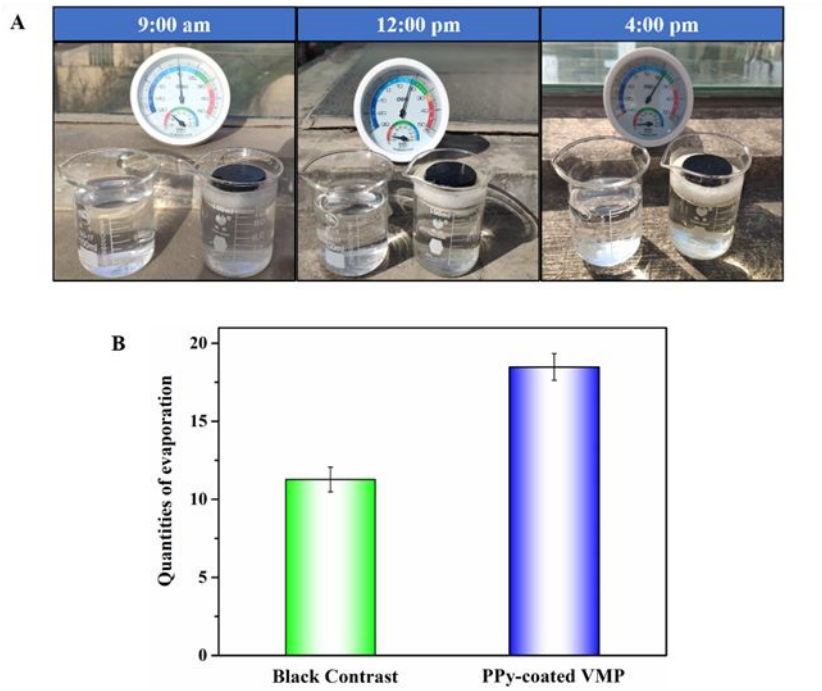

Fig.S4 A. Photographs of the outdoor solar seawater desalination contrast experiments (from 9 am to 4 pm). B. The quantities of the simulated seawater daily evaporation under natural sunlight.