Electronic Supplementary Material (ESI) for Sustainable Energy & Fuels.

Supplementary information

Cocoon-based 3D Solar Steam Generator for High-performance Saline Desalination

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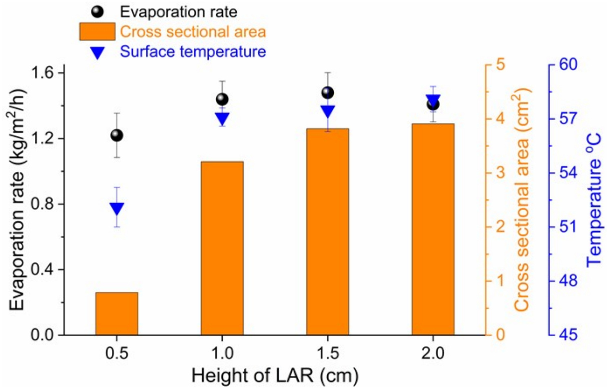

Fig. S1 Evaporation rate, cross sectional area and surface temperature during solar steam generation of generators with different height of LAR (the angle of incident light is 90 ^{o}).

As shown in Fig. R3, when the height changes from 0.5 to 1 cm, the cross-sectional area, surface temperature and evaporation rate all increase significantly, revealing that height can affect the light absorption area to tune water evaporation. However, due to the 3D structure of cocoon, the change of cross-sectional area is not obvious when the height continues to increase, leading to the surface temperature and evaporation rate tend to be stable. In consideration of cost and performance, 1 cm is chosen as the optimal height.

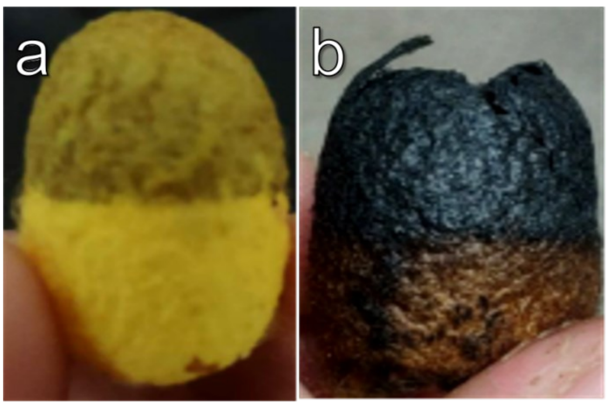

Fig. S2 Photos of (a) SC-Fe and (b) HSC-Fe-200.

HSC-Fe-200 is obtained by heating SC-Fe at 200 ^{o}C. When the temperature above

180 ^{o}C, the silk fibroin in the inner layer of the cocoon begin to break in air. Fig. S1b shows that HSC-Fe-200 is too fragile to use as generator.

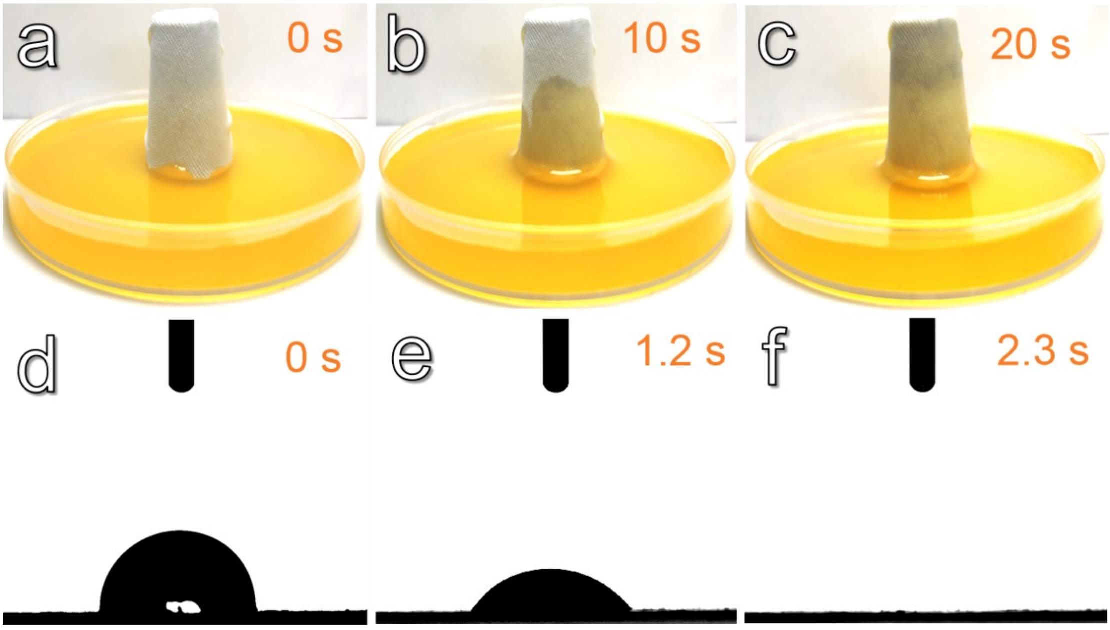

Fig. S3 (a-c)Water transport properties of gauze wrapped PS foam, (b) hydrophilicity of LAR.

PS foam, as a supporting substrate, can help the cocoon float on the water surface. Meanwhile, gauze wrapped on foam surface has a strong ability to draw water and transfers water from the bottom of the foam to its top in just 20 seconds. The cocoon possesses good hydrophilicity and water permeability. In less than 3 seconds, the water droplets completely wet and penetrate the cocoon.

Thus, It can ensure that the water can be quickly transferred from the bottom to the top of the cocoon, and the water vapor could easily escape during the process of solar evaporation.

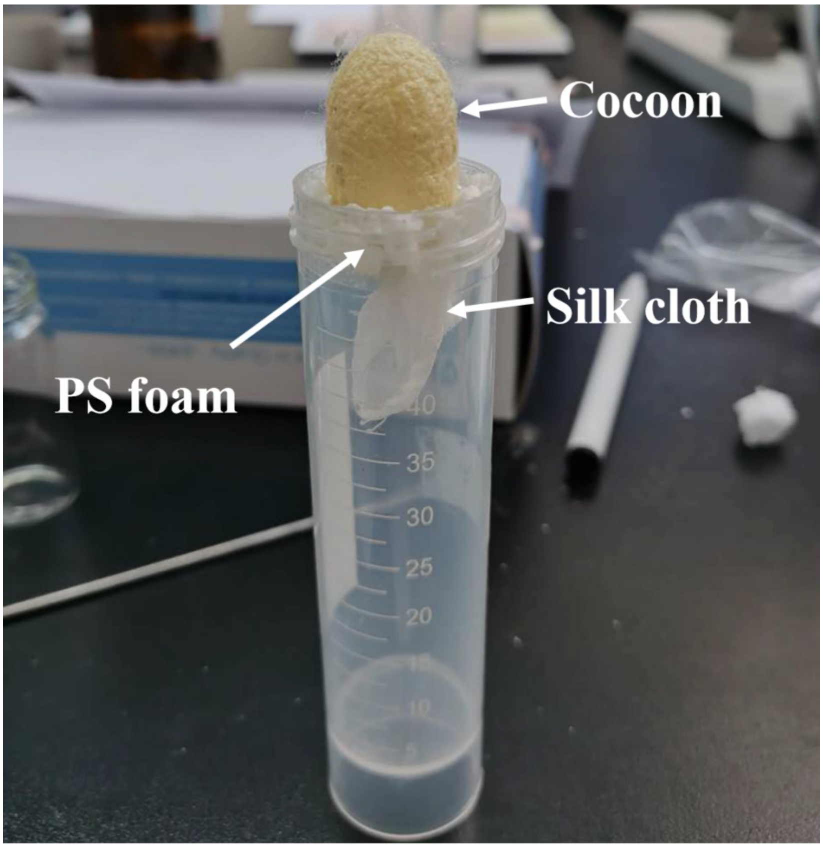

Fig. S4 Photos of steam generator.

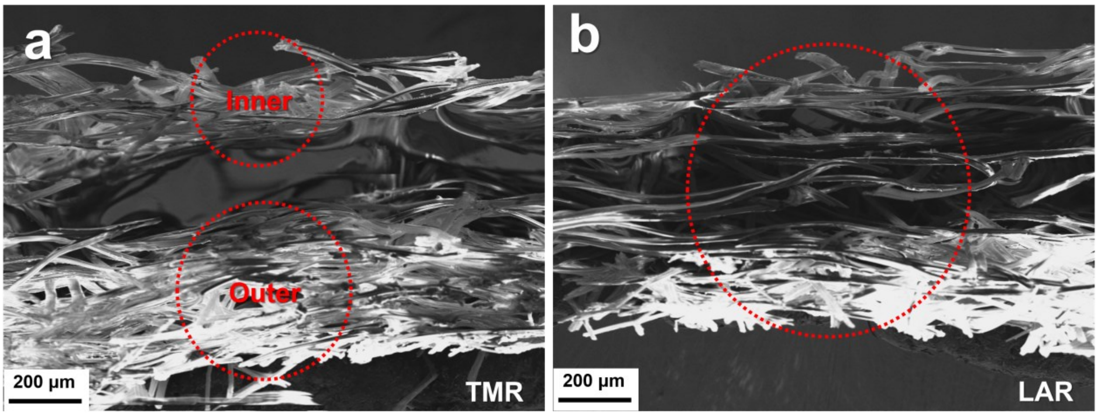

Fig. S5 SEM images of cross-section in (a) TMR and (b) LAR

As shown in Fig. S5, the inner layer can be observed (Fig. R5a), suggesting that the skeleton of outer layer will not be damaged at 180 ^{o}C and it also has a protective effect on the inner layer. Moreover, a large number of gaps can reduce the thermal conductivity of TMR to achieve excellent thermal management performance. For LAR (Fig. R5b), $FeCl_3$ promotes the degradation and crosslinking of peptide chain in heating process, and the inner and outer layers gradually combine to form a more dense light absorption layer.

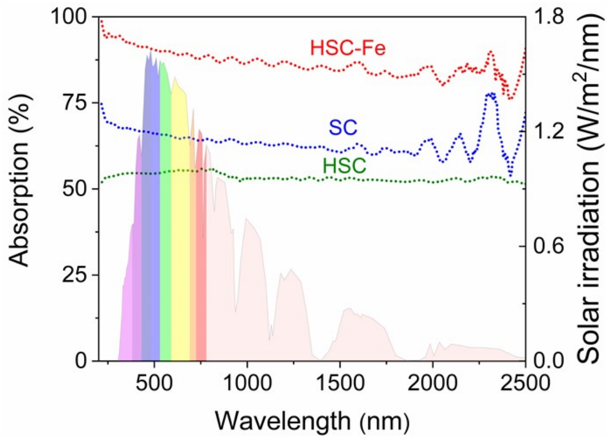

Fig. S6 UV-Vis-NIR absorption spectra of HSC-Fe, HSC and SC in wetting state.

Note 2:

The light absorption spectrum and calculated the overall light absorption using the following formula:

$$\alpha = \int_{200nm}^{2500nm} \frac{Is(\lambda)A(\lambda)d\lambda}{Is(\lambda)d\lambda}$$

Where λ is the wavelength, $A(\lambda)$ represents the measured absorption spectrum of the sample, $Is(\lambda)$ is the solar spectral radiation.

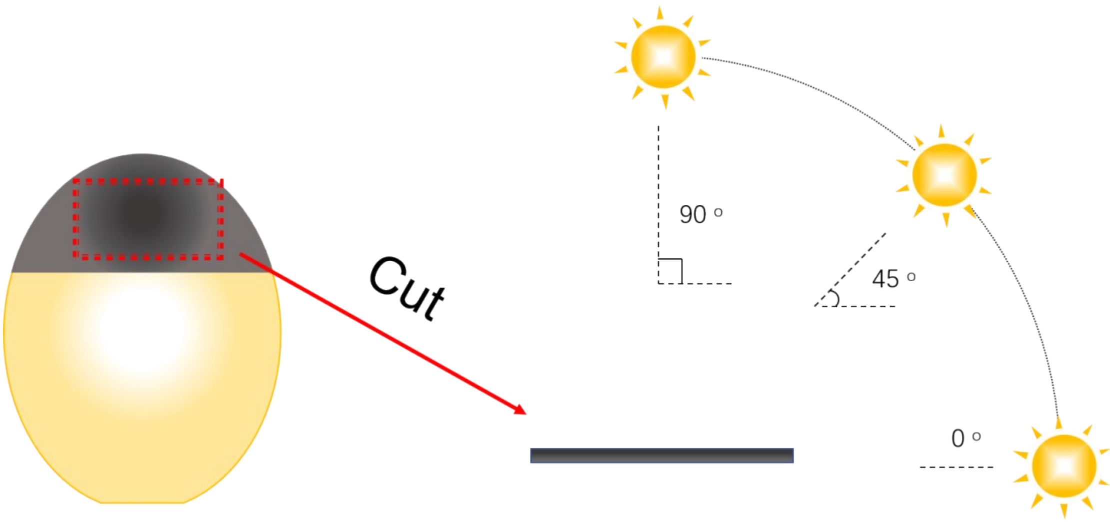

Fig. S7 Schematic illustration of 2D generator at different incident angles.

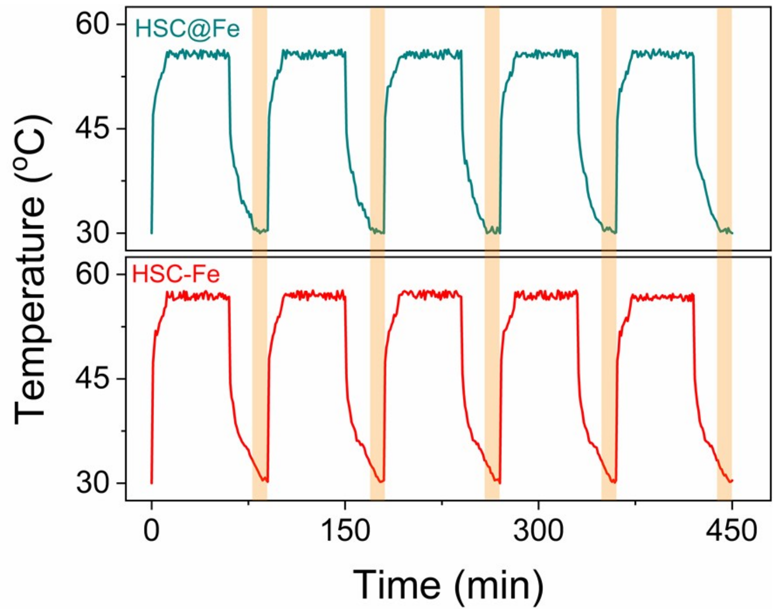

Fig. S8 Surface temperature of HSC-Fe and HSC@Fe under 1 kW/m^2 solar irradiation on the water.

Note 2:

Normally, the heat loss of water evaporation processes has three parts, i.e., radiation, convection and conduction. The calculation details of heat loss are shown below [1-3].

(1) Radiation

The heat radiation loss was calculated through Stefan-Boltzmann equation:

$$\Phi = \varepsilon A\sigma(T_1^4 - T_2^4) \quad \text{(R1)}$$

Where Φ represents heat flux, ε is the emissivity, and emissivity in the water evaporation processes is supposed has a maximum emissivity of 1. A is the effective evaporation surface area (ca. 400 mm^2). σ is the Stefan-Boltzmann constant (the value is 5.67×10^{-8} W/m^2/K^4). T_1 is the surface temperature of the as-prepared materials after stable steam generation under one-sun illumination, and T_2 represents ambient temperature upward the as-prepared materials (ca. 45 ^{o}C, or 318.15 K). According to Equation R1 in this file, the radiation heat flux of HSC-Fe and HSC@Fe are 0.035 W and 0.032 W. Therefore, the calculated heat radiation loss of HSC-Fe and HSC@Fe are 7.0% and 6.4%, respectively.

(2) Convection

The convection heat loss can be calculated by Newton's law of cooling as follows:

$$j = hA\Delta T \quad \text{(R2)}$$

Where j is the convection heat flux, h represents the convection heat transfer coefficient, which is approximately 5 $W/m^2/K$ in the early report [4]. ΔT is difference between the surface temperature of as-prepared carbon materials and the ambient temperature. Consequently, the connection heat loss of HSC-Fe and HSC@Fe are calculated through Equation R2, and the value are 0.0243 W (4.9%) and 0.0226 W (4.5%).

<u>(3) Conduction</u>

The conduction heat loss is due to that the heat was transferred from the as-prepared materials to water, which can be calculated by the following equation::

$$Q_{cond} = Cm\Delta T \tag{R3}$$

Where Q_{cond} is the heat energy, C represents the specific heat capacity of water (4.2 J/ ^{o}C/ g), and m denotes the weight of water (g). ΔT is the increased temperature of water (K). In this work, m = 10 g, $\Delta T_{\text{HSC-Fe}}$ = 30.4 ^{o}C - 30 ^{o}C = 0.4 ^{o}C, $\Delta T_{\text{HSC-Fe}}$ = 32.7 ^{o}C - 30 ^{o}C = 2.7 ^{o}C, $W_{solar} = P_{solar}t$ = 1800 J. Consequently, according to Equation S3, $Q_{\text{HSC-Fe}}$ = 16.8 J, $Q_{\text{HSC-Fe}}$ = 113.2 J, the calculated conduction heat loss of HSC-Fe and HSC@Fe are 0.9% and 6.3%.

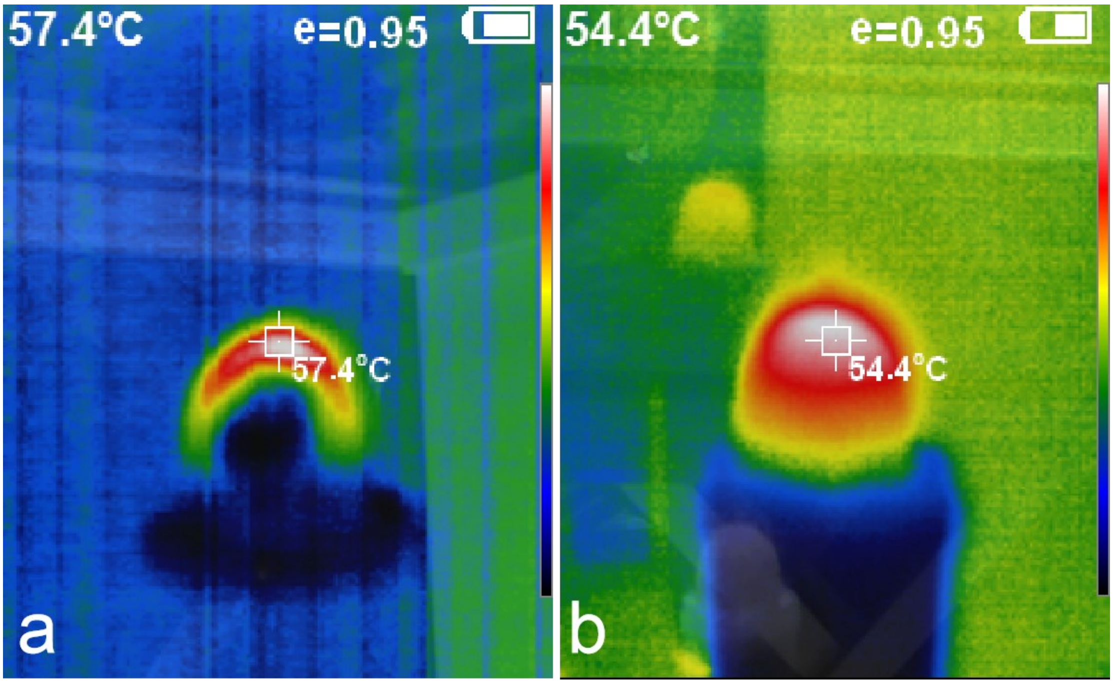

Fig. S9 IR image of (a) HSC-Fe and (b) HSC@Fe under 1 kW/m^2 solar irradiation on the water.

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[2] Xu N, Hu XZ, Xu WC, et al, Mushrooms as Efficient Solar Steam-Generation Devices. Adv Mater, 2017, 29: 1606762.

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[4] Hadi G, George N, Amy MM, et al, Solar steam generation by heat localization. Nat Commun 2014, 5: 5449–5455.