Electronic Supplementary Material (ESI) for Journal of Materials Chemistry A.

Electronic Supplementary Information

Photothermal and Fenton active MOF-based membrane for high-efficient solar water evaporation and clean water production

Xu Ma,[a] *Zheng Deng,*[a]* *Zhuoyi Li,*[a] *Danke Chen,*[a] *Xinyi Wan,*[a] *Xiaobin Wang,*[a] *Xinsheng Peng*[a]*

[a]State Key Laboratory of Silicon Materials, School of Materials Science and Engineering, ERC of Membrane and Water Treatment, Zhejiang University, Hangzhou 310027, People's Republic of China.

* Correspondence and requests for materials should be addressed to Z. D. (email: dengzheng@zju.edu.cn) and X. P. (email: pengxinsheng@zju.edu.cn).

The file includes:

SI-1 Detailed analysis of heat loss.

SI-2 Additional Figures and Tables.

SI-1 Detailed analysis of heat loss.

Appropriate thermal management is critical to localize heat at the air/water evaporative interface. The heat loss mainly includes conduction, radiation and convection during stable evaporation, and the detailed analysis is listed as follow: [S1-S5]

(1) Radiation

The heat radiation loss of ZSM is estimated by Stefan-Boltzmann Equation.

$$\varphi_{radd} = \varepsilon A\sigma\left(T_1^4 - T_2^4\right) \tag{S1}$$

where φ_{radd} is heat radiation flux, ε is the emissivity of the ZSG membrane, which is 0.965 in this work, A is the surface area, σ is Stefan-Boltzmann constant (5.67×10^{-8} W m^{-2} K^{-4}), T_1 is the surface temperature of ZSG membrane during evaporation (40.4 ℃) and T_2 is the ambient temperature upward the ZSG membrane (39.0 ℃). This temperature was estimated from the ~ 5 mm part above the sample surface by thermocouple. The relative high temperature of T_2 might be that, 1) in sun simulation system, the relatively short distance from Xe-lamp to the sample surface may induce the thermal radiation from the lamp to the ambient; 2) the water vapor is also carry heat. Therefore, the heat radiation loss is ~ 0.94% under 1 sun irradiation (1 kW m^{-2}).

(2) Convection

The heat convection loss of ZSG is calculated by Newton's law of cooling.:

$$\varphi_{conv} = hA\left(T_1 - T_2\right) \tag{S2}$$

where φ_{conv} is heat convection flux, h is the convection heat transfer coefficient (5 W m^{-2} K^{-1}). T_1 is the surface temperature of ZSG membrane during evaporation (40.4 ℃) and T_2 is the ambient temperature upward the ZSG membrane (39.0 ℃). Therefore, the convection heat loss is ~0.7% under 1 sun irradiation.

(3) Conduction

The heat conduction loss of ZSM is calculated by the following formula:

$$Q = Cm\Delta T \tag{S3}$$

where Q is conduction heat loss from membrane to bulk water, C represents specific heat of bulk water (4.18 J g^{-1} K^{-1}), m is the weight of bulk water (40g) and ΔT *(~0 K)* is the elevated bulk water temperature during evaporation. Therefore, the conduction heat loss is ~ 0% under 1 sun irradiation.

Based on equation S1, S2 and S3, the heat loss of this solar-driven interfacial water evaporation device is ~1.64%.

SI-2 Additional Figures and Tables.

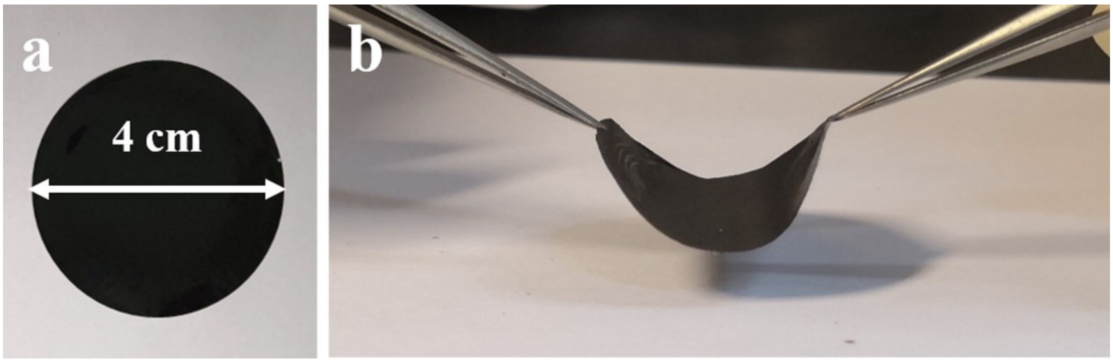

Figure S1. Digital images of a intact ZSG membrane on table (a) and the one (b) lifted by two pliers to show its flexibility.

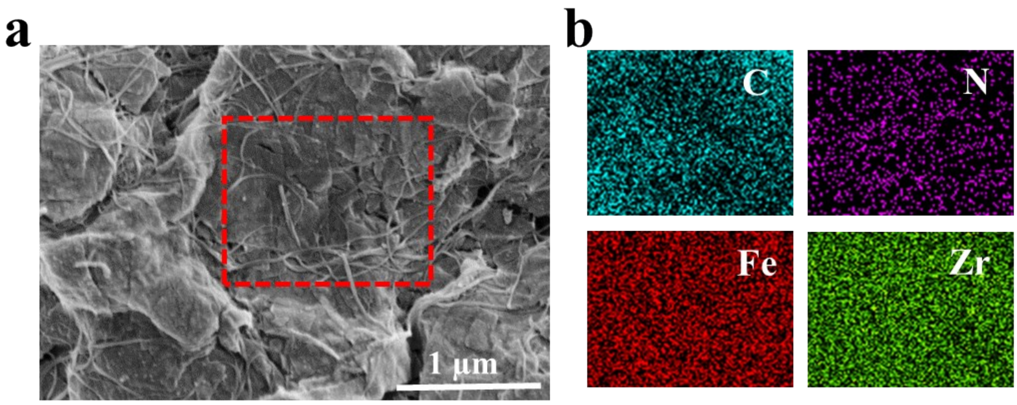

Figure S1 (a)SEM image of the upper surface of ZSG; (b) Elements mapping images of C, N, Fe and Zr elements in the selected area in (a)

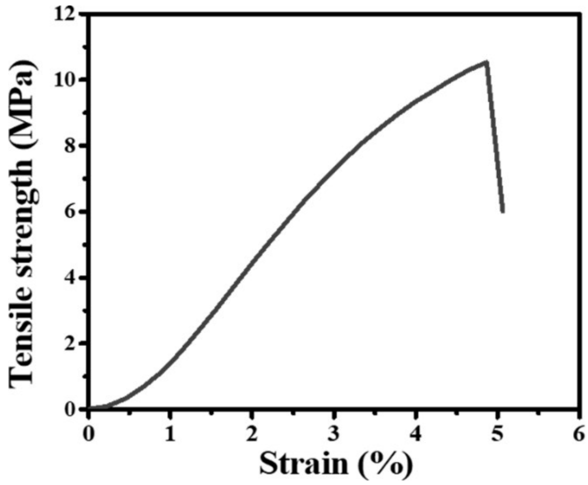

Figure S3. Stress-strain curve of ZSG membrane.

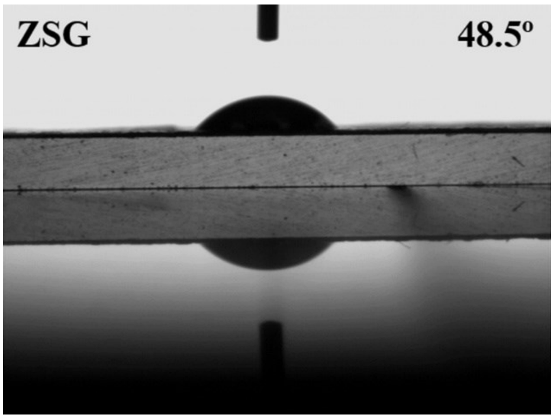

Figure S4. Water contact angle of ZSG membrane.

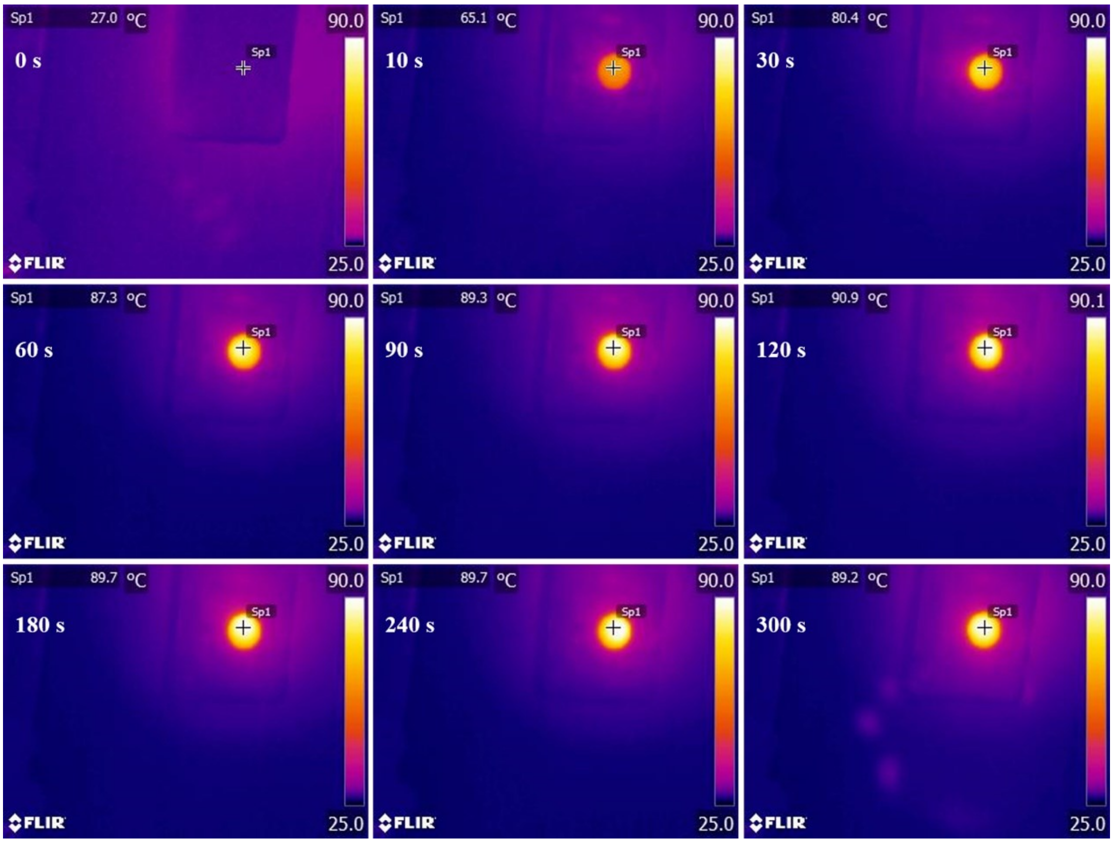

Figure S5. Infrared images of the dry ZSG membrane under 1 sun irradiation.

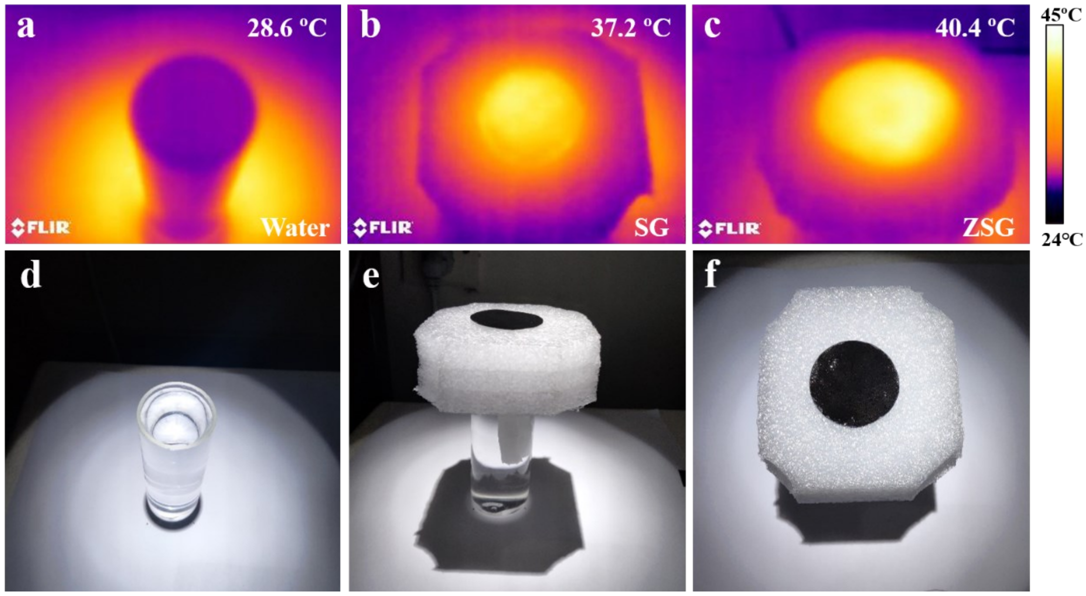

Figure S6. (a-c) Infrared images of water, SG and ZSG membrane during stable evaporation under 1 sun irradiation. (d-f) Digital images of the self-made water evaporation test device.

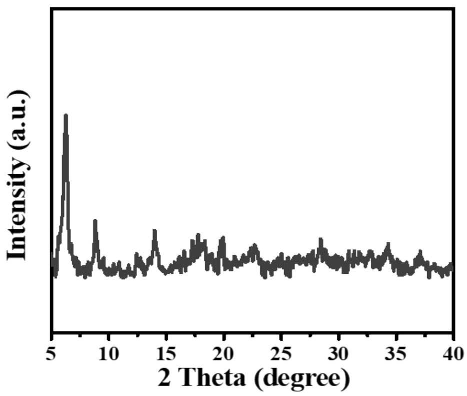

Figure S7. XRD patterns of ZSG membrane after long-term water evaporation test.

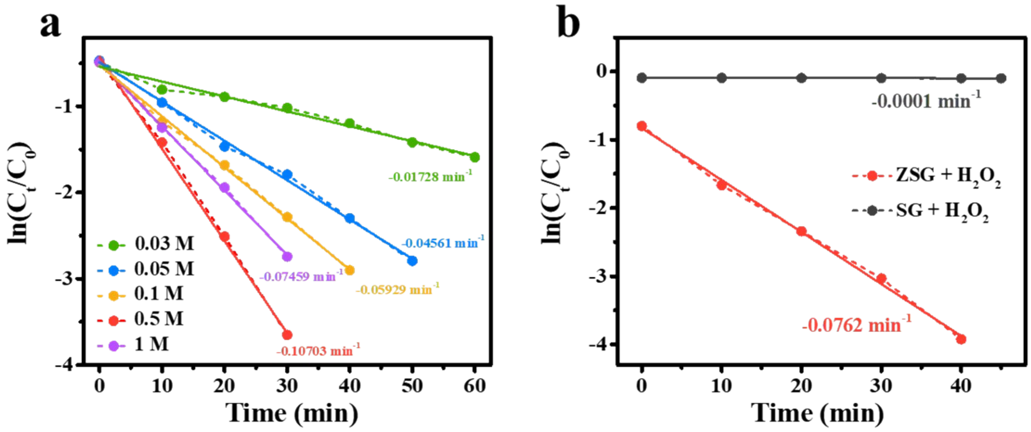

Figure S8. Degradation and the reaction kinetic study for MB under different conditions.

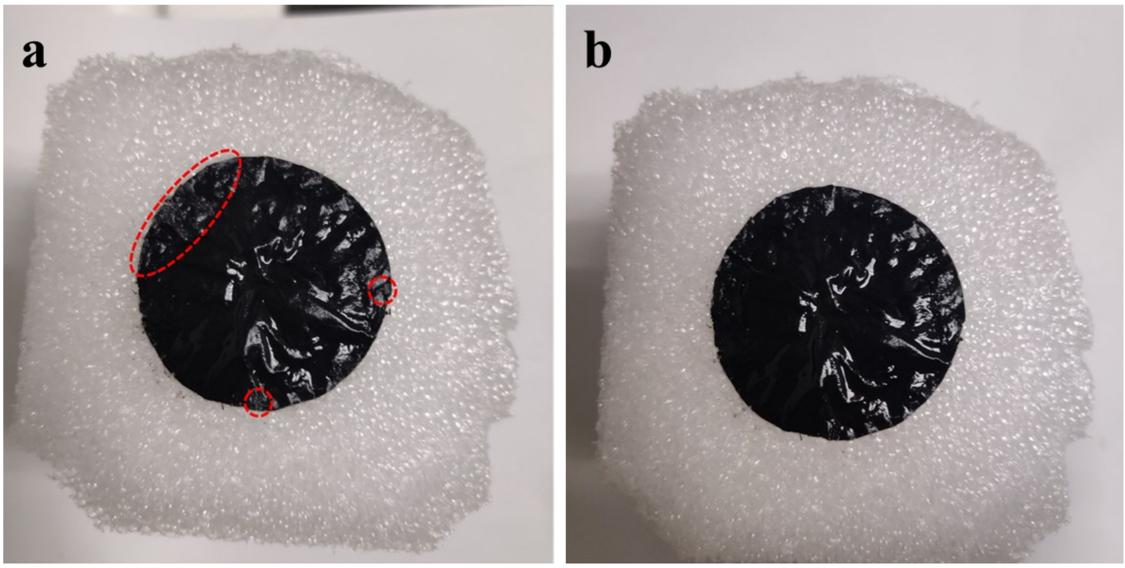

Figure S9. Digital images of (a) a small amount of salt precipitated on the surface of the ZSG membrane after 12 hours of solar irradiation; (b) the salt particles disappeared after 12 hours of standing at night.

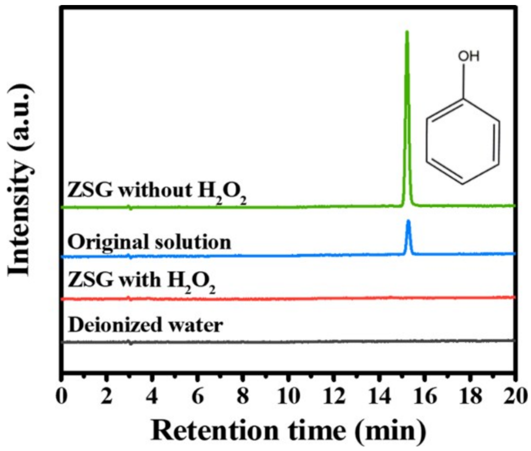

Figure S10. HPLC analysis of different samples using the mixture of ethanol and formic acid (0.1%) as mobile phase.

Table S1. The detailed calculation of solar-vapor efficiency.

	T_0 (°C)	T (°C)	ΔT (°C)	H_{sen} (Jg^{-1})	ΔH_{vap} (Jg^{-1})	h_{LV} (Jg^{-1})	Evaporation rate ($kgm^{-2}h^{-1}$)	$\dot{m}$ ($kgm^{-2}h^{-1}$)	Solar-vapor efficiency (%)
Pure water	25.0	28.6	3.6	15.1	2435.3	2450.4	0.48	0.37	25.2
SG	25.0	37.2	12.2	51.2	2418.3	2469.5	1.22	1.10	75.5
ZSG	25.0	40.4	15.4	64.7	2412.2	2476.9	1.53	1.39	95.6

Note: The *Hsen* is calculated by $Hsen = C \times (T-T_0)$ J/g, and the ΔH_{vap} is calculated by $\Delta H_{vap} = 1.91846\times103[T/(T-33.91)]^2$ J/g, where C is specific heat of water (4.18 J g^{-1} K^{-1}), T is the surface temperature during stable evaporation, and T_0 is the initial temperature of water, respectively [S2].

References

[S1] X. Ma, W. Fang, Y. Guo, Z. Li, D. Chen, W. Ying, Z. Xu, C. Gao and X. Peng, *Small*, 2019, **15**, e1900354.

[S2] X. Ma, W. Fang, W. Ying, D. Chen, Z. Li, Z. Deng, C. Gao and X. Peng, *Appl. Mater. Today*, 2020, **18**, 100459.

[S3] C. Chen, Y. Li, J. Song, Z. Yang, Y. Kuang, E. Hitz, C. Jia, A. Gong, F. Jiang, J. Y. Zhu, B. Yang, J. Xie and L. Hu, *Adv. Mater.*, 2017, **29**, 1701756.

[S4] T. Li, Q. Fang, X. Xi, Y. Chen and F. Liu, *J. Mater. Chem. A*, 2019, **7**, 586-593.

[S5] P. Zhang, Q. Liao, T. Zhang, H. Cheng, Y. Huang, C. Yang, C. Li, L. Jiang and L. Qu, *Nano Energy*, 2018, **46**, 415-422.