Electronic Supplementary Information

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

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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-S3

(1) Radiation

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

\[ \varphi_{rad} = \varepsilon A \sigma (T_1^4 - T_2^4) \]  

(S1)

where \( \varphi_{rad} \) is heat radiation flux, \( \varepsilon \) is the emissivity of the ZSG membrane, which is 0.965 in this work, \( A \) is the surface area, \( \sigma \) is Stefan-Boltzmann constant \( (5.67 \times 10^{-8} \text{ W m}^{-2} \text{K}^{-4}) \), \( T_1 \) is the surface temperature of ZSG membrane during evaporation \( (40.4 \text{ °C}) \) and \( T_2 \) is the ambient temperature upward the ZSG membrane \( (39.0 \text{ °C}) \). 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 \((1 \text{ kW m}^{-2})\).

(2) Convection

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

\[ \varphi_{conv} = h A (T_1 - T_2) \]  

(S2)

where \( \varphi_{conv} \) is heat convection flux, \( h \) is the convection heat transfer coefficient \( (5 \text{ W m}^{-2} \text{K}^{-1}) \). \( T_1 \) is the surface temperature of ZSG membrane during evaporation \( (40.4 \text{ °C}) \) and \( T_2 \) is the ambient temperature upward the ZSG membrane \( (39.0 \text{ °C}) \). 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:

\[ Q = Cm \Delta T \]  

(S3)

where \( Q \) is conduction heat loss from membrane to bulk water, \( C \) represents specific heat of bulk water \( (4.18 \text{ J g}^{-1} \text{ K}^{-1}) \), \( m \) is the weight of bulk water \( (40\text{g}) \) and \( \Delta T \) \( (~0 \text{ K}) \) 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%.
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.

<table>
<thead>
<tr>
<th></th>
<th>$T_0$</th>
<th>$T$</th>
<th>$\Delta T$</th>
<th>$H_{sen}$</th>
<th>$\Delta H_{vap}$</th>
<th>$h_L^\gamma$</th>
<th>Evaporation rate</th>
<th>$\dot{m}$</th>
<th>Solar-vapor efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pure water</td>
<td>25.0</td>
<td>28.6</td>
<td>3.6</td>
<td>15.1</td>
<td>2435.3</td>
<td>2450.4</td>
<td>0.48</td>
<td>0.37</td>
<td>25.2</td>
</tr>
<tr>
<td>SG</td>
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<td>37.2</td>
<td>12.2</td>
<td>51.2</td>
<td>2418.3</td>
<td>2469.5</td>
<td>1.22</td>
<td>1.10</td>
<td>75.5</td>
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<tr>
<td>ZSG</td>
<td>25.0</td>
<td>40.4</td>
<td>15.4</td>
<td>64.7</td>
<td>2412.2</td>
<td>2476.9</td>
<td>1.53</td>
<td>1.39</td>
<td>95.6</td>
</tr>
</tbody>
</table>

Note: The $H_{sen}$ is calculated by $H_{sen} = C \times (T - T_0) \ J/g$, and the $\Delta H_{vap}$ is calculated by $\Delta H_{vap} = 1.91846 \times 10^3 [(T/(T-33.91))^2] \ J/g$, 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