Supporting Information

Patterned Surfaces for Solar Driven Interfacial Evaporation

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2. Steady-state evaporation heat and mass transfer model:

2.1 The energy balance of the evaporation process and evaporation efficiency based on the analysis of heat loss

Mass changes and IR images of different samples were recorded when samples were illuminated by simulated solar light. In this work, a simple steady-state model is developed for analyzing the evaporation performance of PAP interfacial evaporation system. This model describes the working mechanism of the PAP evaporation system and the parameters that affect evaporation. A generic device comprising a solar absorber that transfers heat to water at the air-liquid surface and causes the water molecules to evaporate is shown schematically in Figure S13. In the model, we assume that the device is perfectly insulated on the bottom and side. The length and width of the sample are also assumed to be much larger than the thickness of the sample. So that all heat transfer processes in the sample are one-dimensional in the vertical direction.

The energy conversion equation can be expressed as

\[ A_b q_b + A_w q_w = A_{total}(q_{rad} + q_{conv} + q_{cond} + q_{evap}) \]  

(S1)

where, \( q_b \) and \( q_w \) are the absorbing heat flux of the BP and the WP, respectively; \( A_b \) and \( A_w \) are the area of the BP and WP, respectively; \( q_{rad} \) is the radiation heat loss of the absorber; \( q_{conv} \) is the convection heat loss of the absorber; \( q_{cond} \) represents the conduction heat loss from the EPE foam to the underlying water; \( q_{evap} \) is the heat flux for interfacial evaporation of the absorber. \( A_{total} \) is the total area of the absorber, \( A_{total} = A_b + A_w \). \( q_b, q_w, q_{rad} \)
\( q_{\text{conv}}, q_{\text{cond}} \) in Eq. (S1) can be expressed as

\[
q_b = a_b q_s, \quad \text{(S2)}
\]
\[
q_w = a_w q_s, \quad \text{(S3)}
\]

\[
A_{\text{total}} q_{\text{rad}} = \varepsilon_b A_b \sigma (T_b^4 - T_\infty^4) + \varepsilon_w A_w \sigma (T_w^4 - T_\infty^4), \quad \text{(S4)}
\]

\[
A_{\text{total}} q_{\text{conv}} = h_{\text{conv}} A_b (T_b - T_\infty) + h_{\text{conv}} A_w (T_w - T_\infty), \quad \text{(S5)}
\]

\[
A_{\text{total}} q_{\text{cond}} = \frac{k_{\text{EPE}} A_{\text{EPE}}}{d_{\text{EPE}}} (T_{\text{top}} - T_{\text{down}}), \quad \text{(S6)}
\]

where, \( q_s \) is the solar flux, 1000 W/m\(^2\); \( \alpha_b \) and \( \alpha_w \) are the absorber absorption of the BP and WP, respectively; \( \varepsilon_b \) and \( \varepsilon_w \) are the emissivities of BP and WP, respectively; \( \sigma \) is the Stefan-Boltzmann constant, 5.67\times10^{-8} \text{ W/(m}^2 \text{ K}^4\)); \( T_b \) and \( T_w \) represent the average surface temperature of the BP and the WP, respectively; \( T_\infty \) is the ambient temperature; \( h_{\text{conv}} \) is the convection heat transfer coefficient; \( k_{\text{EPE}} \) is the EPE foam thermal conductivity (~0.03 W/(m K)), and \( d_{\text{EPE}} \) is the EPE foam thickness (2.52 cm); \( A_{\text{EPE}} \) is the cross area of the EPE; \( T_{\text{top}} \) and \( T_{\text{down}} \) are the average temperatures for top and bottom surfaces of EPE, respectively. The evaporation efficiency \( \eta_h \) can be calculated using the following equation:

\[
\eta_h = \frac{q_{\text{evap}}}{q_s} \cdot 100\% = \frac{A_b q_b + A_w q_w - A_{\text{total}} (q_{\text{rad}} + q_{\text{conv}} + q_{\text{cond}})}{A_{\text{total}} q_s}, \quad \text{(S7)}
\]

In the Eq. (S1)-(S6), the unknown variables are \( T_b, T_w, T_{\text{top}}, \) and \( T_{\text{down}} \). These unknown temperatures can be obtained from the experiment results. Based on the analysis of the heat loss, the evaporation efficiency of 1-stripe can be estimated to be 61.3%

2.2 Evaporation efficiency based on the analysis of mass flux
According to the calculated evaporation rate in the experiment, the heat flux for water evaporation $q_m$ can be expressed as below:

$$q_m = m h_{lv} = c m (T_v - T_\infty) + m \Delta H,$$

(S8)

$$\eta_m = \frac{q_m}{q_{m\text{total}}},$$

(S9)

where, $m$ is the interfacial mass flux, $h_{lv}$ is the total enthalpy of liquid-vapor phase change (sensible heat and latent heat), $c$ is the specific heat capacity, $T_v$ is the vapor temperature, $T_\infty$ is the ambient temperature, $\Delta H$ is the phase-change enthalpy. Based on the analysis of mass flux, the evaporation efficiency of 1-stripe can be estimated to be 62.0%. The results derived from mass flux match well with these calculations derived from heat loss.

### 2.3 Lateral thermal conductivity

The effect of the stripe width (the stripe number) on the temperature of patterned surface and lateral thermal transfer, which can be analyzed by cross-section schematics as shown in Fig. 5a-b in the main text. The heat transfer process involves the heat conduction between the BP and WP. The heat conduction within the BP can be expressed as

$$q_{b,\text{cond}} = 1/R_b \ast (T_b - T_i),$$

(S10)

The heat conduction within the WP can be expressed as

$$q_{w,\text{cond}} = 1/R_w \ast (T_i - T_w),$$

(S11)

where, $q_{b,\text{cond}}$ and $q_{w,\text{cond}}$ are the conduction heat transfer of the BP and WP, $R_b$ is the thermal resistance of the carbon black in the BP, $R_w$ is the thermal resistance of the air-laid
paper in the WP, $T_b$ is the average temperature of the BP, $T_i$ is the interfacial temperature between the BP and the WP, $T_w$ is the average temperature of the WP. $R_b$ and $R_w$ can be expressed as,

$$R_b = l_b/(k_{b,eff}A_{cond}),$$

(S12)

$$R_w = l_w/(k_{w,eff}A_{cond}),$$

(S13)

where, $l_b$ and $l_w$ are the half width of the white and black stripe, respectively; $k_{b,eff}$ and $k_{w,eff}$ are the effective conductivity of the carbon black and air-laid paper, respectively; $A_{cond}$ is the cross-sectional area of the stripe.

The effective thermal conductivity of the black and white porous wick can be expressed as

$$k_{eff} = k_f \frac{k_f+k_s(1-\gamma)(k_f-k_s)}{k_f+k_s+(1-\gamma)(k_f-k_s)},$$

(S14)

where, $k_f$ is the thermal conductivity of the liquid ($0.61 \text{ W m}^{-1} \text{ k}^{-1}$), $k_s$ is the thermal conductivity of the solid (air-laid paper: $0.03$-$0.05 \text{ W m}^{-1} \text{ k}^{-1}$, carbon black: $0.30 \text{ W m}^{-1} \text{ k}^{-1}$)$^{2,3}; \gamma$ denotes the porosity (air-laid paper: 0.62, carbon black: 0.31), According to the equation S14, we can calculate the $k_{b,eff}$ and $k_{w,eff}$. 
3. References