Superstructure-enabled anti-fouling membrane for efficient photothermal distillation

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**Table S1.** Mean pore size distribution ($R_d$), porosity ($\varepsilon$), thermal conductivity ($\lambda$) and heat resistance ($r_m$) of the commercial and F-CB-x membranes.

<table>
<thead>
<tr>
<th>Sample</th>
<th>F-CB-0.5</th>
<th>F-CB-2.0</th>
<th>F-CB-3.5</th>
<th>Commercial</th>
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</thead>
<tbody>
<tr>
<td>$R_d$ (nm)</td>
<td>298</td>
<td>226</td>
<td>113</td>
<td>441</td>
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<tr>
<td>$\varepsilon$ (%)</td>
<td>53.1</td>
<td>52.7</td>
<td>48.4</td>
<td>55.8</td>
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<tr>
<td>$\delta$ (µm)</td>
<td>120</td>
<td>120</td>
<td>120</td>
<td>100</td>
</tr>
<tr>
<td>$\lambda$ (W m$^{-1}$ k$^{-1}$)</td>
<td>0.04357</td>
<td>0.04373</td>
<td>0.04364</td>
<td>0.06128</td>
</tr>
<tr>
<td>$r_m$ (kW$^{-1}$ m$^2$ k)</td>
<td>2.7542</td>
<td>2.7441</td>
<td>2.7498</td>
<td>1.6319</td>
</tr>
</tbody>
</table>

**Table S2.** Cost analysis of F-CB membrane synthesis.

<table>
<thead>
<tr>
<th>Material</th>
<th>Cost (Dollar m$^{-2}$)</th>
<th>Processing</th>
<th>Energy cost (kW h m$^{-2}$)</th>
<th>Cost (Dollar m$^{-2}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVDF membrane</td>
<td>40.038</td>
<td>Stirring</td>
<td>0.917</td>
<td>0.264</td>
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<tr>
<td>FTCS</td>
<td>4.367</td>
<td>Spraying</td>
<td>0.400</td>
<td>0.120</td>
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<tr>
<td>CB nanoparticles</td>
<td>0.007</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>n-hexane</td>
<td>0.120</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material cost</td>
<td>44.532</td>
<td>Processing</td>
<td>1.317</td>
<td>0.384</td>
</tr>
</tbody>
</table>

Total economic cost per 1 m$^2$ F-CB membrane 44.916
Figure S1. (a) Schematic of the MD module. (b) Photo of the experiment set-up. The insets show the actual MD module.

Figure S2. Water flux and efficiency with varying (a, b) feed flow rates and (c, d) distillate flow rates using natural seawater under different solar irradiation.
Figure S3. SEM images of the commercial (a), F-CB-0.5 (b), F-CB-2.0 (c), F-CB-3.5 (d) membranes (where the number stands for the different FTCS concentration). The inset in Figure a represents the optical image of the commercial membrane.
Figure S4. (a) Experimental transmission spectra of glass cover in the wavelength range of 200-2,500 nm. During the membrane distillation, the optical loss has been accounted for 1.5%, ensuring the correctness of experiments. (b) Experimental absorbance spectra of four kinds of feed water with thickness of 1 mm in the wavelength range of 200-2,500 nm.
**Figure S5.** XPS spectra of the commercial (a) and F-CB membranes (b). (c) The Si 2p spectrum of the commercial and F-CB membranes.
Figure S6. Structural attributes (a), heat resistance (b), wettability (c) and light absorption (d) of commercial (F-CB-0) and F-CB-x membrane (where x stands for the different FTCS concentration x%).

Figure S7. Pore size distribution (a) and porosity (b) of F-CB-2.0 membrane.
Figure S8. (a) Purified water flux obtained at an illumination of 1 kW m$^{-2}$ for varying FTCS concentrations. (b) Comparison of solar-water energy efficiency varied with different FTCS concentrations.
Fabrication of Hydrophilic Membrane. The CB nanoparticles were attached to the commercial PVDF membrane surface using polydopamine (PDA) as the binder while achieving the hydrophilic property. First, 0.5 mg CB nanoparticles were dispersed in 100 ml n-hexane and sonicated for 30 min using an ultrasonicator. Then, 5 mL of the CB suspension was poured onto the membrane surface, followed with the air-dry for 30 min. Then, The CB membrane was fully dipped in a 2 mg mL-1 dopamine solution (pH 8.5) for 1 h and the dopamine solution was prepared by adding dopamine hydrochloride to a Tris-HCl buffer. Finally, the as-prepared membranes were vacuum-dried overnight at 45 °C and denoted as H-CB.

![Figure S9](image)

(a) Optical images of F-CB and H-CB membranes. The insets are the water contact angles of two kinds of membranes. (b) Experimental absorption spectra of F-CB and H-CB membranes in the wavelength range of 200-2,600 nm. (c) Water flux and (d) salt rejection rate of F-CB and H-CB membranes with natural seawater.
Figure S10. (a) Water flux and (b) salt rejection rate of commercial PVDF and F-CB-2.0 membranes with oil contaminated water.

Figure S11. The oil size distribution curve showing oil contents are mostly 0.6 to 1.1 μm in sizes along with minority content with the sizes from 12 nm to 28 nm. The oil emulsion is prepared under vigorous stirring for 12 h.
Figure S12. The permeate water flux and salt rejection rate for salty brine (16.7 wt% of NaCl solution) at an illumination of 1 kW m$^{-2}$. 