Supporting Information

Multilayered Co-Fc MOF/GO 3D evaporator for efficient solar-driven water generation and wastewater purification

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Keywords: Co-Fc MOF/GO 3D evaporator, Solar-driven water generation, Pollutant degradation, Photo-Fenton catalyst

Note. S1 Calculation of water evaporation rate and solar-vapor conversion efficiency

The water evaporation rate (m, kg m^{-2} h^{-1}) and solar-vapor conversion efficiency (η, %) were calculated as follow:

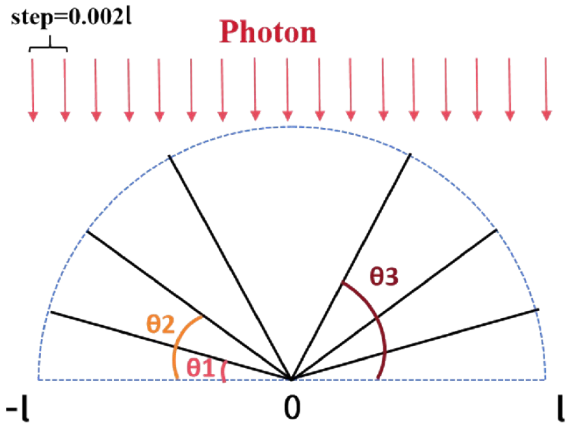
$$m = \Delta m/(S \times t) \quad (1)$$

$$\eta = (H_v + H_s) \times m_s/(3600 \times P_{in}) \quad (2)$$

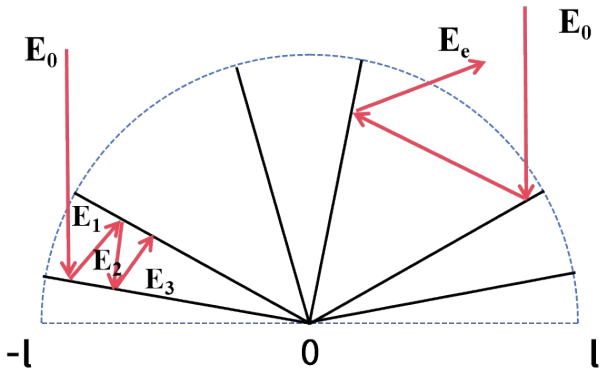
$$H_s = (c_{water} - c_{vapor}) \times (T_2 - T_1) \quad (3)$$

where Δm means the mass change of water within a certain time (kg), H_v is the heat of vaporization (2260 kJ kg^{-1}), H_s is the sensible heat of water. m_s represents the water evaporation rate after subtracting that under dark conditions (kg m^{-2} h^{-1}), and P_{in} means the irradiation intensity (kW m^{-2}). c_{water} and c_{vapor} are the specific heat of water and water vapor, T_2 is the boiling temperature, and T_1 is the measured surface temperature.

Note. S2 A home-made Python program was created to simulate the sunlight absorption of 3D CFG cones evaporators. The simulation is based on the following model：



Take a cross-section of the CFG-3 evaporator as the research object. The CFG-3 is composed of three CFG cones with different θ (θ_1, θ_2 and θ_3 correspond to the three CFG cones from outside to inside. The cone generatrix length of the cone is l. In the range of -l to l, photons fall vertically from the top of the evaporator with a step length of 0.002 l.



The initial energy of each photon is E_0. Each time a photon contact with the evaporator, it will be absorbed and reflected (the transmission can be ignored for black CFG membrane), and the absorptivity is α (measured by the UV-vis-NIR, α=0.917). The energy of a photon after one reflection is E_1 and the photon continues to move along the mirror reflection path. The energy of a photon after n reflections is E_n. E_1 and E_n can be interpreted as:

$$E_1 = (1-\alpha)E_0 \tag{3}$$

$$E_n = (1-\alpha)^n E_0 \tag{4}$$

When E_n is less than the threshold (0.0001 E_0), it is considered that the energy of the photon is completely absorbed.

Some photons exit from the evaporator after reflection, and their energy is lost to the air. This part of the energy is defined as E_e. E_e can be interpreted as:

$$E_e = E_0 - E_n \tag{5}$$

The sun absorptivity (A_s) can be interpreted as:

$$A_s = 1 - \frac{\sum E_e}{\sum E_0} \tag{6}$$

This program can simulate the corresponding A_s at any θ_1, θ_2 and θ_3 to determine the morphology of the evaporator for the best sun light absorption performance.

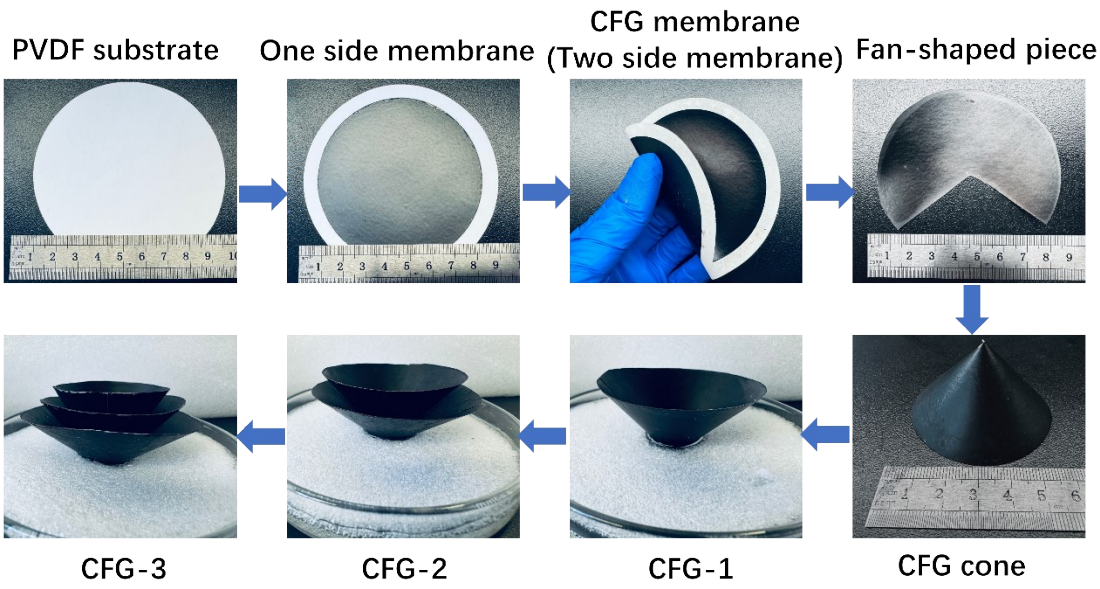


Fig. S1 Preparation process of 3D CFG-based evaporator.

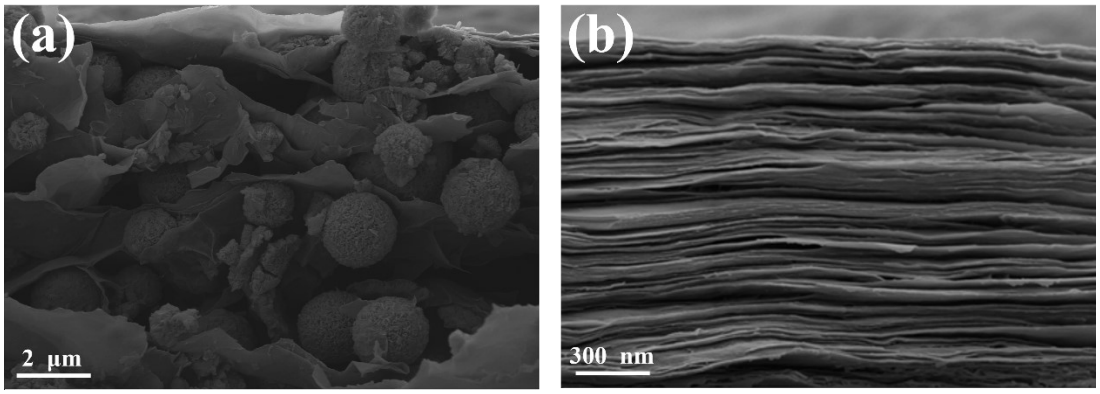


Fig. S2 SEM image of (a) CFG membrane and (b) GO membrane.

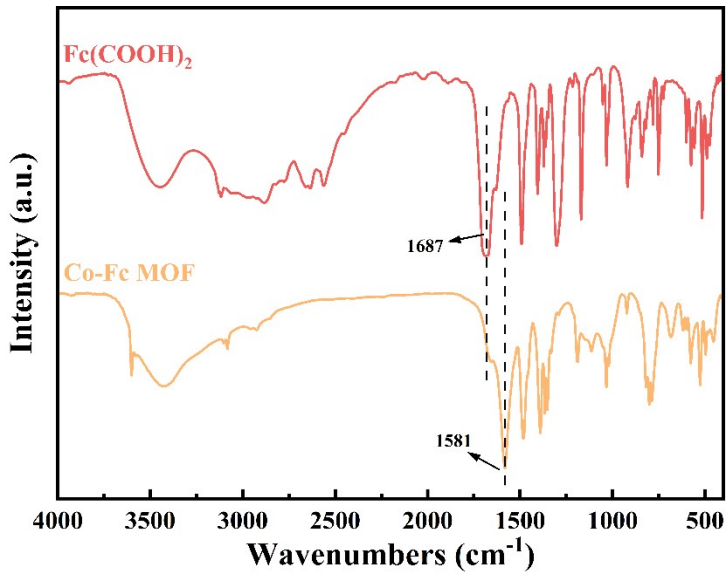


Fig. S3 FT-IR spectra of the $Fc(COOH)_2$ and Co-Fc MOF.

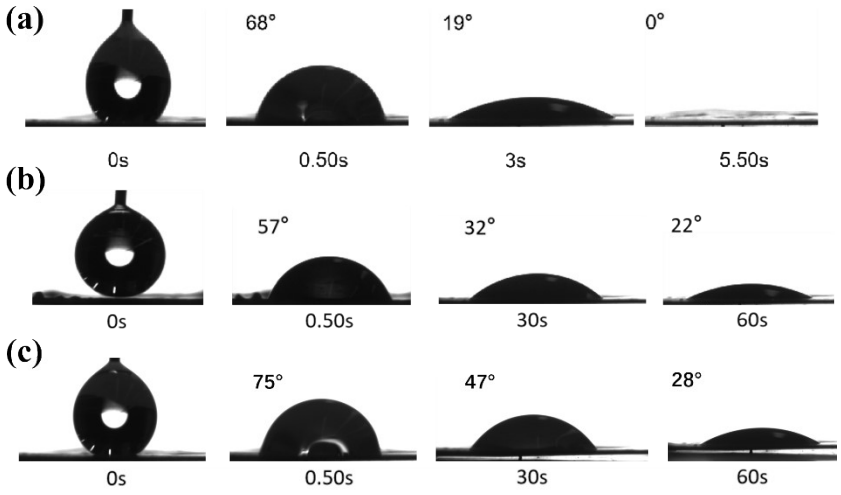


Fig. S4 Time evolution of water contact angles for (a) PVDF membrane, (b) CFG membrane, (c) GO membrane.

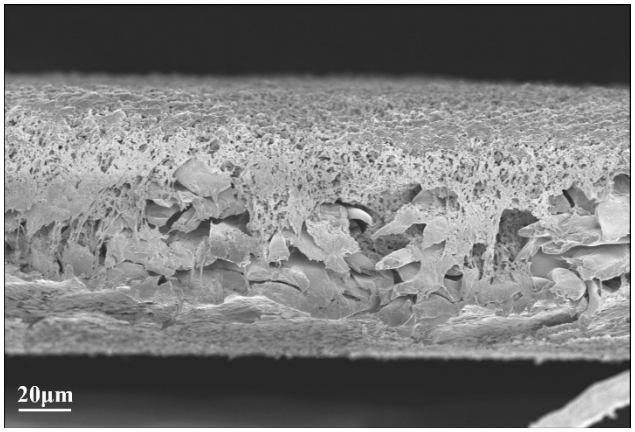


Fig. S5 SEM image of the cross-section for PVDF membrane.

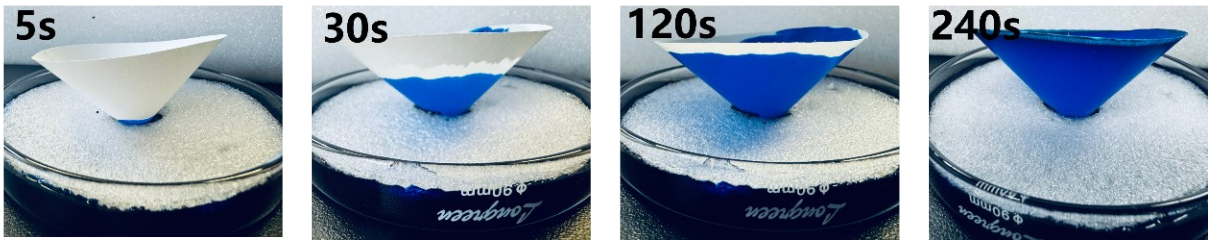


Fig. S6 Water climbing experiment of hydrophilic PVDF membrane (the solution used is MB solution).

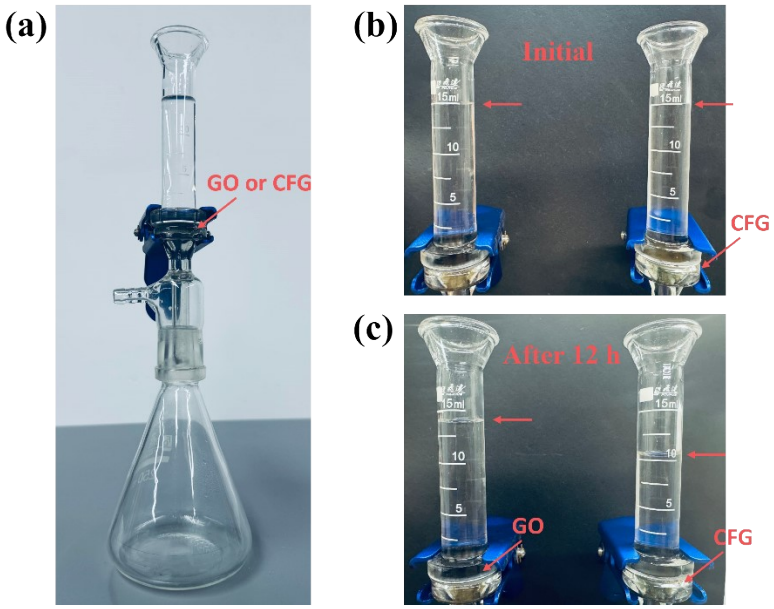


Fig. S7 (a) Water penetration experimental device. (b) Initial water level. (c) Water level after 12 h.

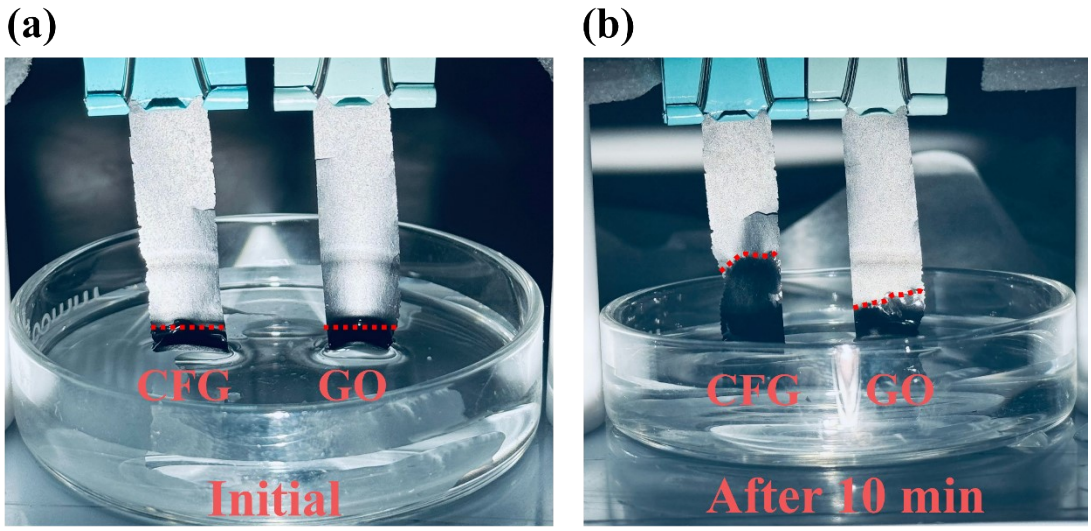


Fig. S8 Water climbing experiment of CFG and GO membrane

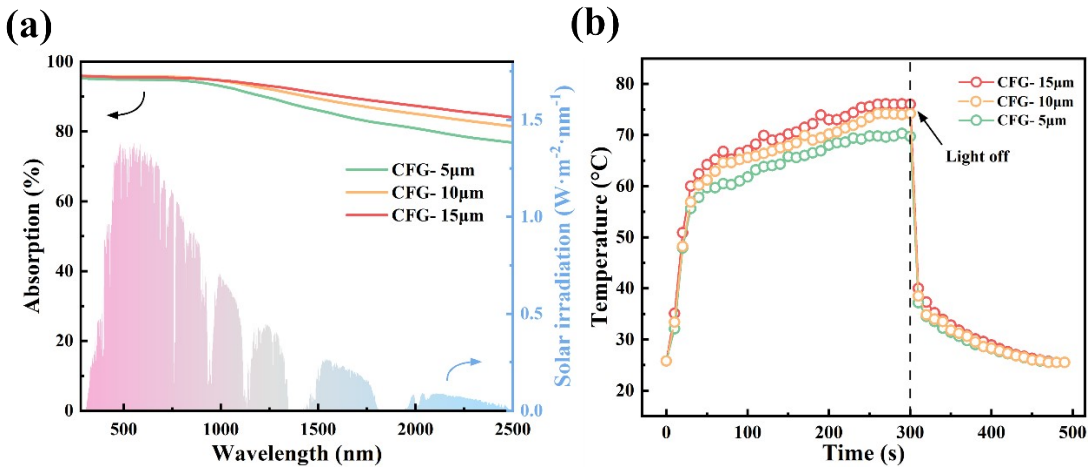


Fig. S9 (a) UV-vis-NIR absorption spectra of CFG membranes with different thickness. Background is the AM 1.5 solar light spectrum. (b) Changes in surface temperature of CFG membranes with different thickness (dry state) as a function of time under 1-sun illumination.

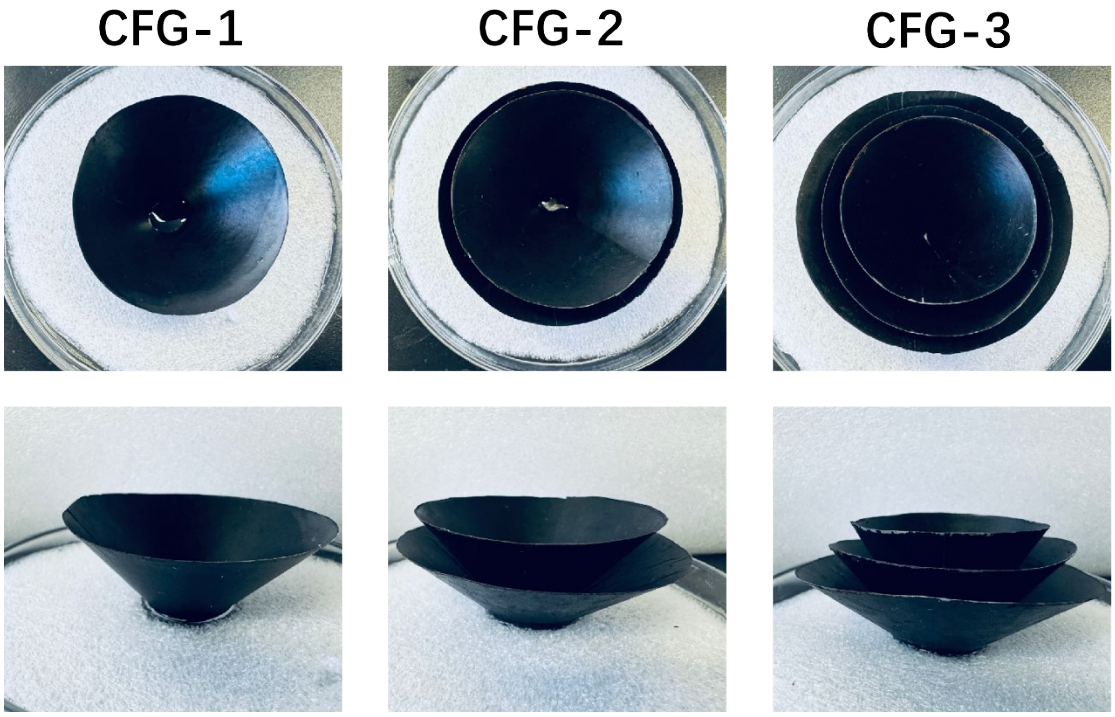


Fig. S10 Photos of 3D CFG inverted cones evaporators stacked by CFG cones with different layers.

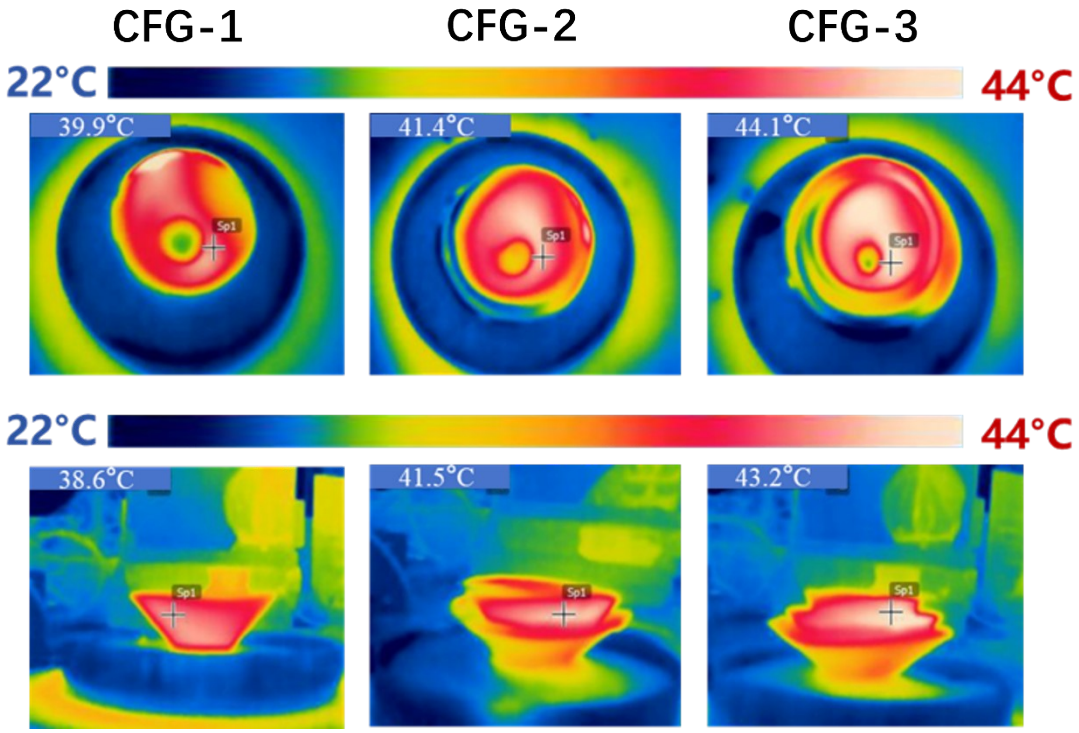


Fig. S11 Infrared images 3D CFG inverted cones evaporators.

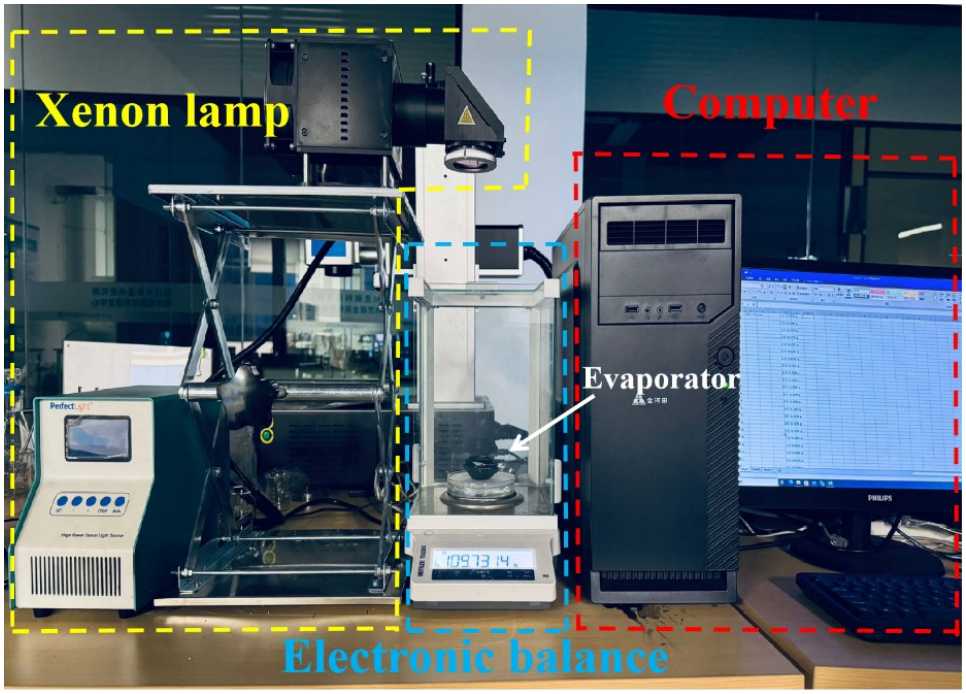


Fig. S12 Photo of the interfacial solar steam generation device.

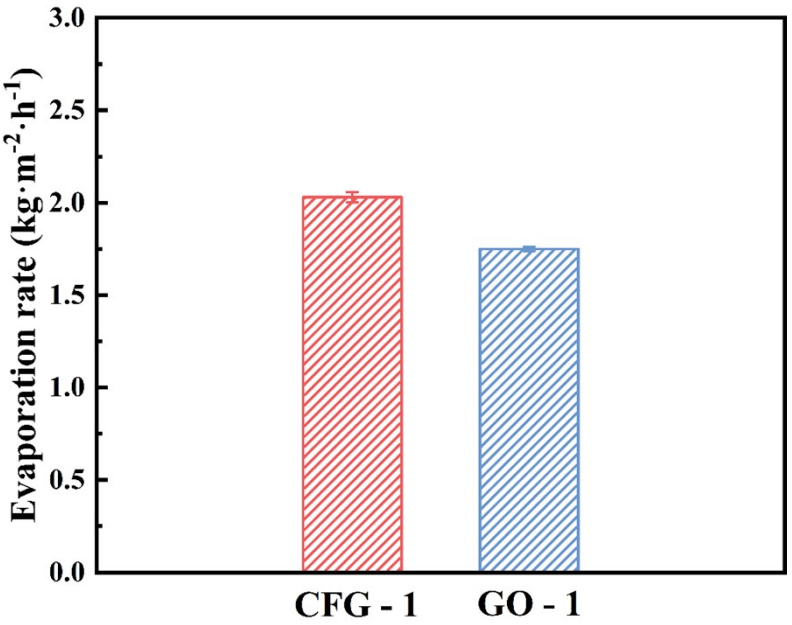


Fig. S13 Water evaporation rate of CFG-1 evaporator and GO-1evaporator.

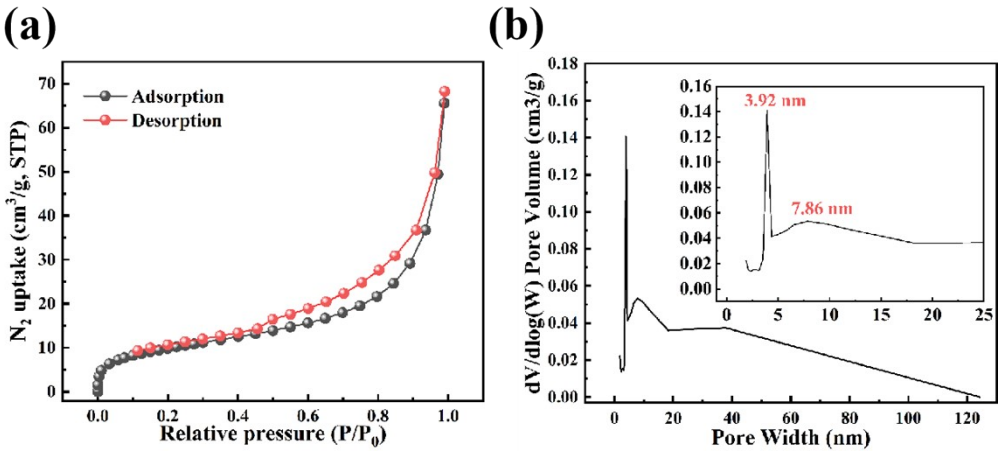


Fig. S14 Nitrogen adsorption–desorption isotherms at 77 K (a) and corresponding pore size distribution (b) were calculated using the DFT method for Co-Fc MOF.

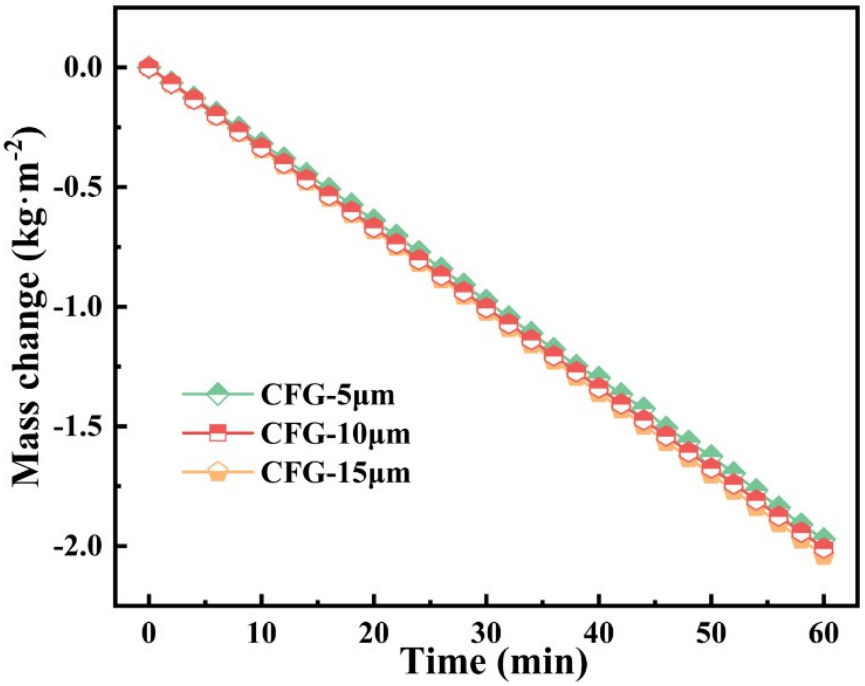


Fig. S15 Water evaporation rate of CFG-3 fabricated by different thickness of CFG membrane.

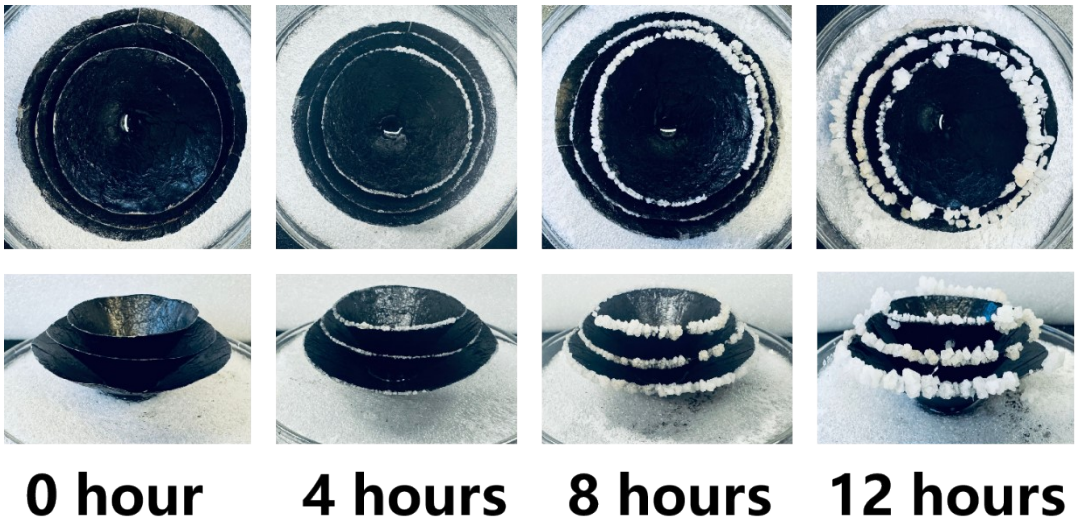


Fig. S16 NaCl crystallizes during the solar desalination.

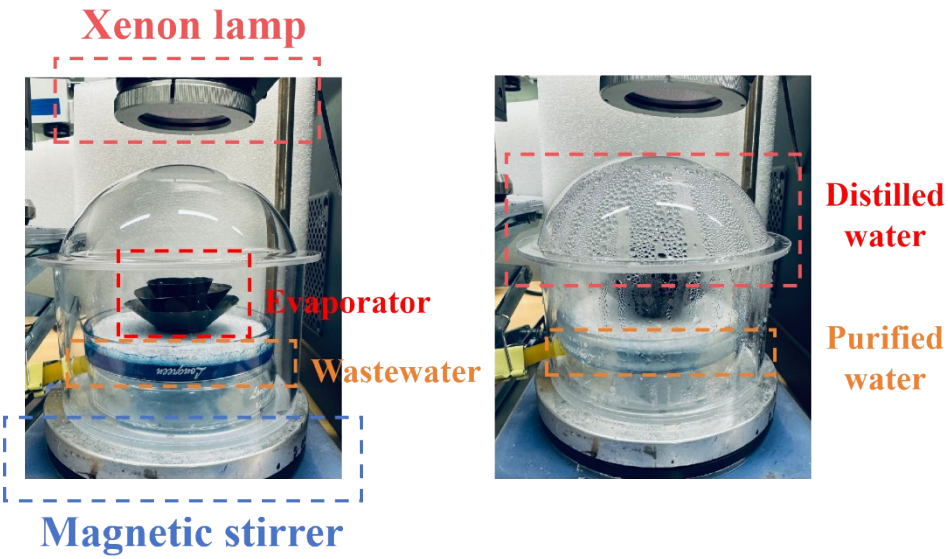


Fig. S17 The photo-Fenton catalytic system. (Distilled water refers to the water collected by condensing water vapor. Purified water refers to the wastewater that has been purified in the container.)

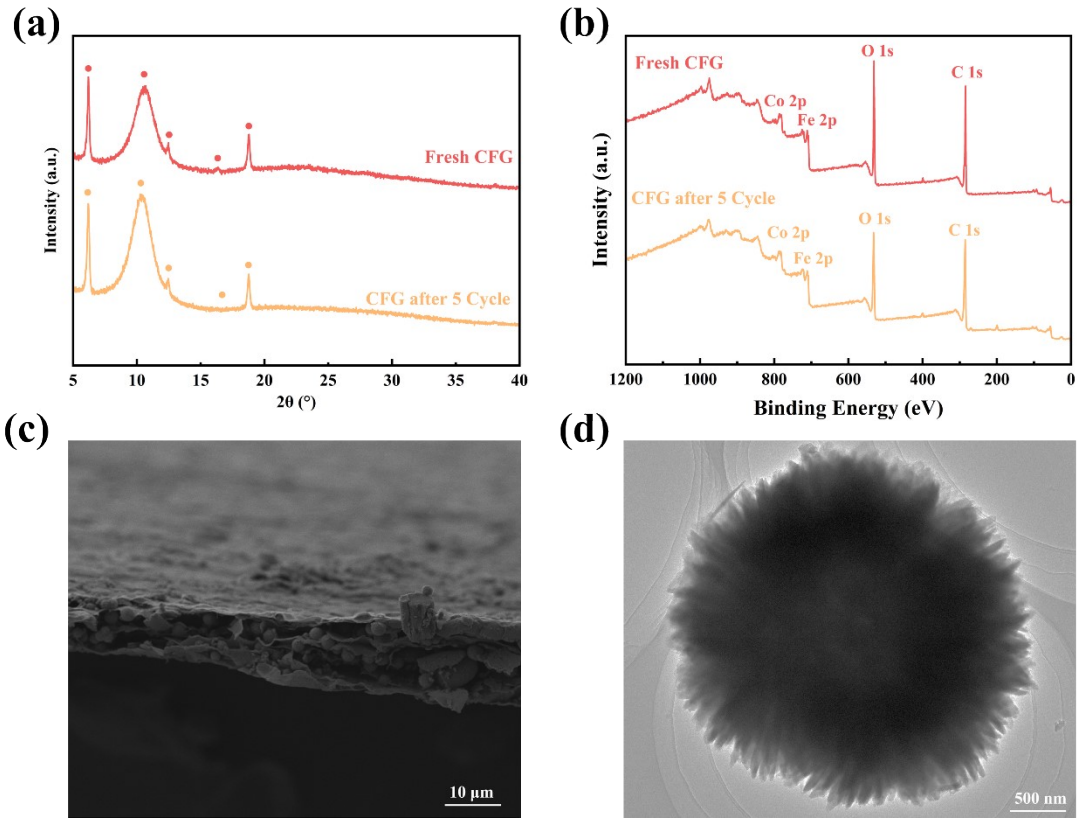


Fig. S18 XRD patterns (a) and XPS spectra (b) of fresh CFG membrane and 5 cycle reused CFG membrane. (c) SEM image of cycle reused CFG membrane. (d)TEM image of Co-Fc MOF in cycle reused CFG membrane.

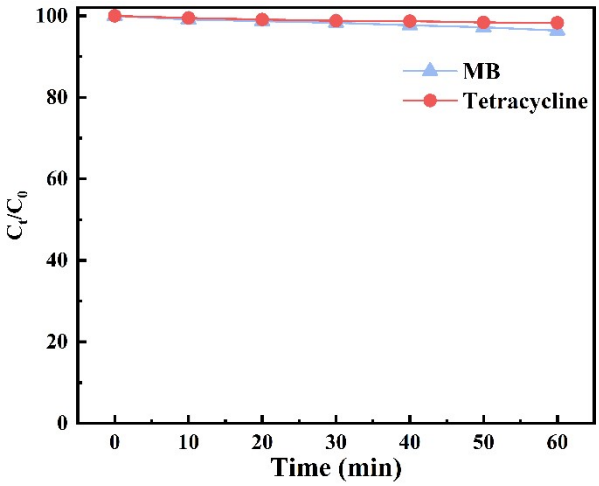


Fig. S19 The degradation of MB and tetracycline under pure light without the presence of evaporation and H_2O_2.

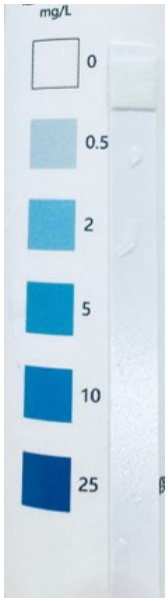


Fig. S20 H_2O_2 test paper and standard colorimetric card

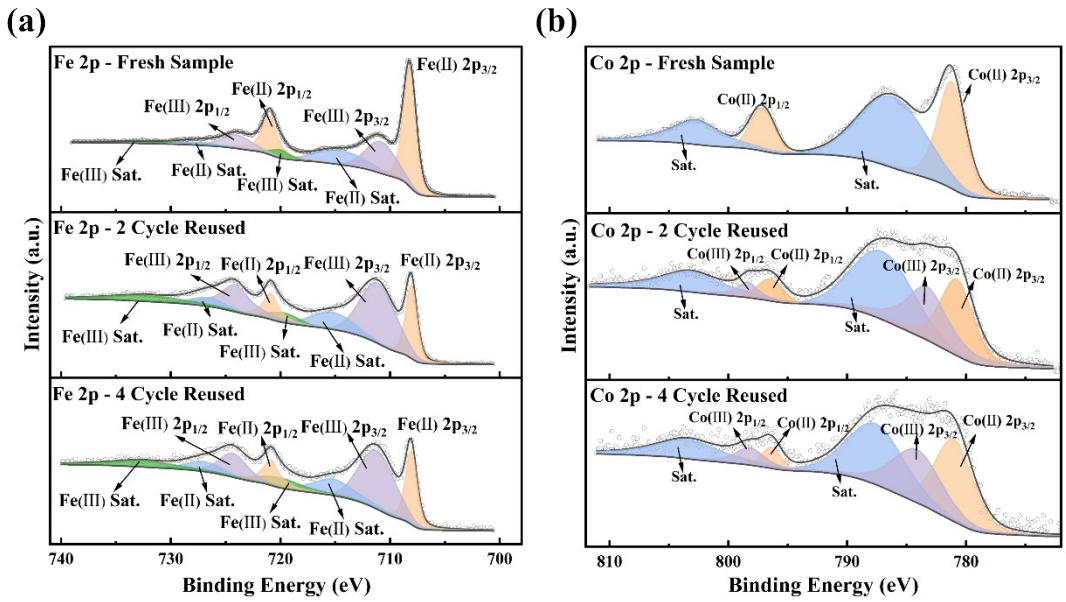


Fig. S21 XPS spectra of fresh CFG membrane and recycled CFG membrane after the Photo-Fenton catalytic degradation reaction: Fe 2p (a) and Co 2p (b).

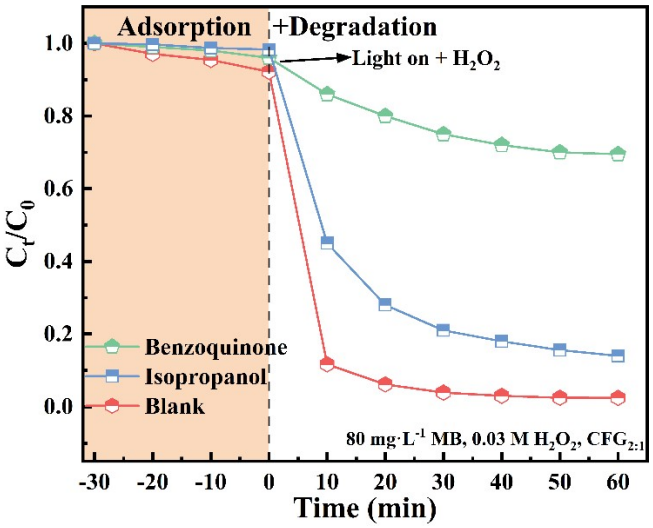


Fig. S22 Degradation rate of MB under different conditions: in the presence of isopropanol (50 mM), p-benzoquinone (5 mM) and blank.

Table S1 Solar-vapor conversion efficiency under different solar intensity.

Evaporator	Solar intensity	Evaporation rate ($kg\ m^{-2}\ h^{-1}$)	Efficient (%)
CFG-1	1 sun	2.03	88.4
CFG-2	1 sun	2.19	91.5
CFG-3	1 sun	2.28	94.8
CFG-3	1.5 sun	3.12	81.2
CFG-3	2 sun	4.32	69.1
CFG-3	2.5 sun	5.05	61.2

Table S2 Co and Fe element content in distilled water detected by ICP.

Cycle number	Co content (mg/L)	Fe content (mg/L)
1	Not detected	0.007
5	Not detected	0.011
10	Not detected	0.010

Table S3 Summary of the performance of the evaporators listed in Fig. 7f.

Ref	Evaporation rate ($kg\ m^{-2}\ h^{-1}$)	Pollutant	Concentration ($mg\ L^{-1}$)	Kinetic constant (min^{-1})	Evaporator or catalyst
This work	2.28	MB	80	0.136	CFG-3
[1]	1.53	MB	10	0.107	Zr-Fc/CNT
[2]	2.12	MB	5	0.051	TiO_2-PANI
[3]	1.43	MB	100	0.02	TiO_2/g-C_3N_4
[4]	1.88	MB	20	0.075	Ppy/cellulose
[5]	1.77	MB	50	0.22	Zr-MOF Carbon
[6]	1.42	MB	10	0.02	CA/PANI/CuS
[7]	1.49	MB	10	0.012	MXene/TiO_2
[8]	3.23	MB	10	0.02	TiO_2-PANI
[9]	1.64	MB	20	0.005	PPy/$BiVO_4$

Table S4 Degradation ratio in distilled water collected from CFG-3 evaporator detected by UV-vis-NIR and HPLC-MS

Characterization methods	Degradation ratio of MB (%)	Degradation ratio of TC (%)	Degradation ratio of Phenol (%)
UV-vis-NIR Spectroscopy	100	100	96.3
Mass Spectroscopy	100	100	95.0

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