Electronic Supplementary Information

The porous size effect on water state and transport probed by ^{1}H LF-NMR relaxation: A case study of MF/PVA-Co_2C photothermal conversion materials

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1. Materials and Characterization

1.1 Materials

Commercial melamine foam was purchased from KELIN Co. Ltd., Beijing. Cobalt acetate ($Co(CH_3COO)_2 \cdot 4H_2O$, 99.9% metals basis) and potassium hexacyanocobaltate ($K_3(Co(CN)_6$, 99%) were purchased from Sigma–Aldrich. All reagents were used directly without further purification.

1.2 Characterization

Powder X-ray diffraction (XRD) patterns were measured using a Bruker D8 Discovery diffractometer with Cu Kα radiation (λ = 1.541 Å). Transmission electron microscope (TEM) and High-resolution transmission electron microscope (HRTEM) were performed on a JEOL-2100 microscope. X-ray photoelectron spectroscopy (XPS) measurements were carried on an Axis Ultra instrument (ESCALAB Xi^+, Thermo Scientific) under ultrahigh vacuum ($<10^{-8}$ torr) by using a monochromatic Al Kα (1486.6 eV) X-ray source. C 1s (284.7 eV) was chosen as the reference. Scanning Electron Microscopy (SEM) images were obtained on a field-emission scanning electron microscope (SU8010, Hitachi, Japan) using an accelerating voltage of 2.0 kV. All samples were pasted on the aluminum plate without a gold coating. Elemental analysis was analyzed by energy–dispersive X–ray spectroscopy (EDX, Oxford Instruments). Optical diffuse reflectance spectra of the fabrics were measured by a UV–vis-NIR absorption spectrophotometer (UV-3600, Shimadzu) in the range of 300–2500 nm attached to an integrating sphere (ISR-3100). Heat flow–temperature curves of the samples were measured using a differential scanning calorimeter (DSC, Setline, DSC-

21-0001) at a linear heating rate of 5 °C min^{-1}. The Optical microscope photographs were acquired by an inverted fluorescence microscope (Olympus IX 53). The ^{1}H relaxation time (*T*, ms) of pure water and containing different photothermal conversion materials was measured using Acron, XiGo nanotools operating at 13 MHz.

1.3 Relaxation LF-NMR measurement

The solvent relaxation LF-NMR measurements were performed in 100 MHz NMR tubes (5 mm O.D.) on an Acorn Area analyzer (XiGo Nanotools). Different amounts of MF and MF/PVA-Co_2C were weighed in the tubes and degassed water was added into the tube to obtain a series of materials to water ratios. The tubes were sealed with Teflon tape to prevent moisture loss. The tubes were sealed using Teflon tape to prevent water loss. A magnetic field perturbation was induced in the experiment, and then the corresponding response of the proton in the sample was detected. The transverse relaxation time (*T*2) was measured using the Carr–Purcell–Meiboom–Gill (CPMG) method. Signals were collected 9 times for each group of samples, and seven times of inversion data were arithmetically averaged as the final *T*2 data of the samples. A total of four tests were conducted for each sample with the masses of 0.24 g, 0.48 g, 0.72 g, and 0.96 g, respectively.

2. Calculation of solar water evaporation rate

The evaporation rate *Ve* (kg m^{-2} h^{-1}) is calculated by the following formula:

$$\boldsymbol{Ve = dm / (S \times dt)} \quad \textbf{(1)}$$

where dm is the mass change of water before and after evaporation (kg); S is the surface area of the prepared sample (m^2); dt is the time of evaporation under solar radiation (h). The changes in water weights were recorded in real-time by an electronic analytical balance with a resolution of 0.1 mg, connected to a computer.

3. Calculation of water enthalpy base on the dark evaporation

By conducting dark evaporation for 12 hours at 24 °C, the evaporation rate of pure water ($\dot{m}_0$) was measured as 0.0385 kg m^{-2} h^{-1}. Thus, the evaporation enthalpy of pure water at 24 °C was calculated to be 2440.67 J g^{-1}. Then, based on the formula $U_{in} = \Delta H_{equ}\dot{m}_g = \Delta H_{vap}\dot{m}_0$ and the dark evaporation rates measured with different PCMs ($\dot{m}_g$ = 0.0408, 0.0402, 0.0412, 0.0417, 0.0482, 0.0475, 0.0507 and 0.0526 kg m^{-2} h^{-1} for pure MF-0.5 cm-L, pure MF-0.5 cm-S, pure MF-1.0 cm-L, pure MF-1.0 cm-S, MF/PVA-Co_2C-0.5 cm-L, MF/PVA-Co_2C-0.5 cm-S, MF/PVA-Co_2C-1.0 cm-L and MF/PVA-Co_2C-0.5 cm-S, respectively.), the corresponding evaporation enthalpies were calculated to be 2303.08, 2337.46, 2353.38, 2380.72, 1949.5, 1978.23, 1853.21 and 1186.42 J g^{-1}，respectively.

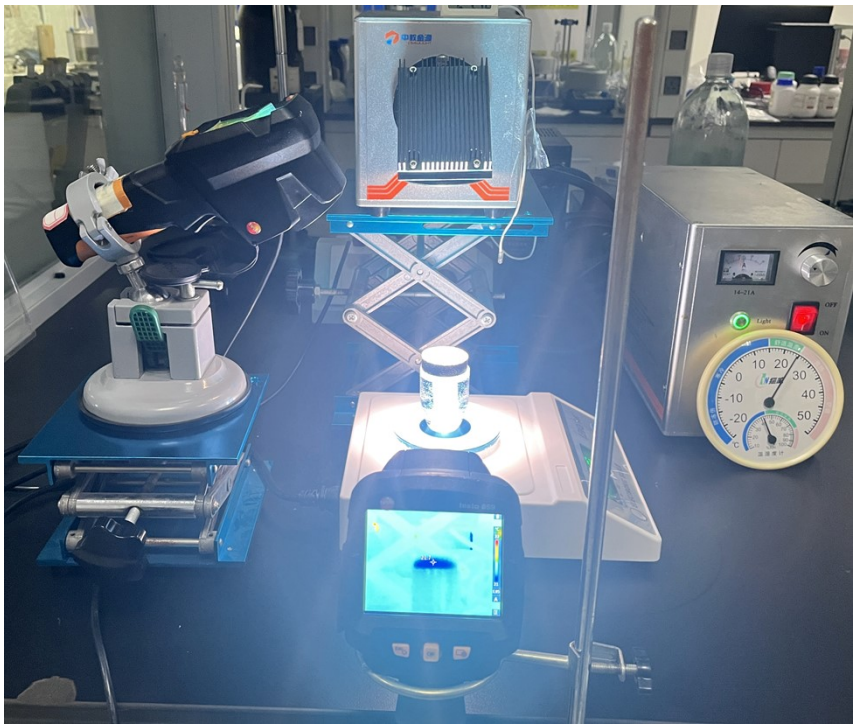

Figure S1. Overall photograph of the evaporator system.

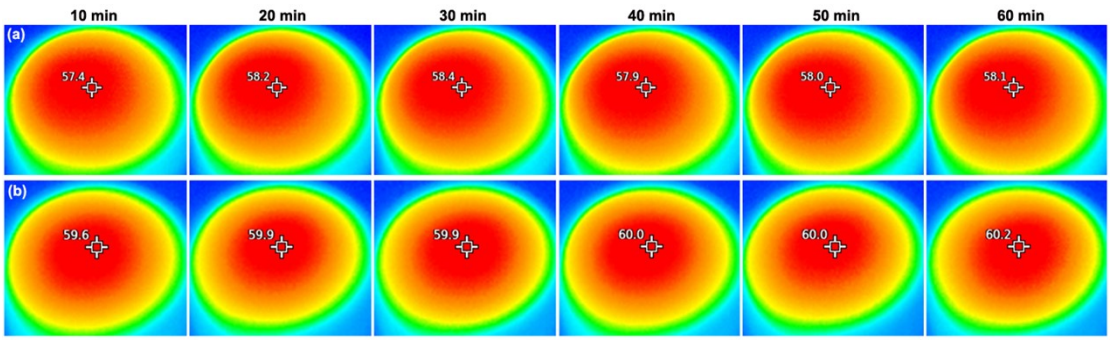

Figure S2. Surface temperatures under one solar light illumination during the ISVG process at different times. (a) MF/PVA-Co_2C-0.5 cm-L; (b) MF/PVA-Co_2C-0.5 cm-S.

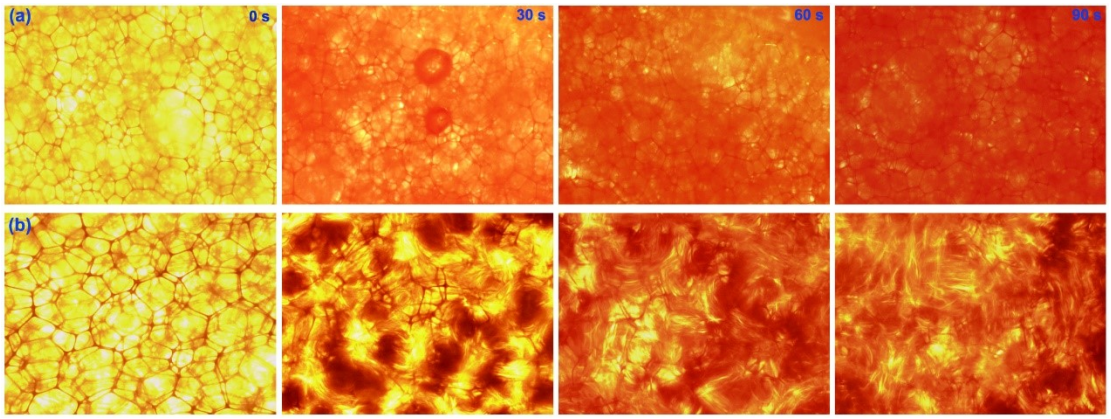

Figure S3. Optical microscope images of pure small pore and large pore MF impregnated in RhB solution at different times, respectively. (a) Small pore, (b) Large pore.

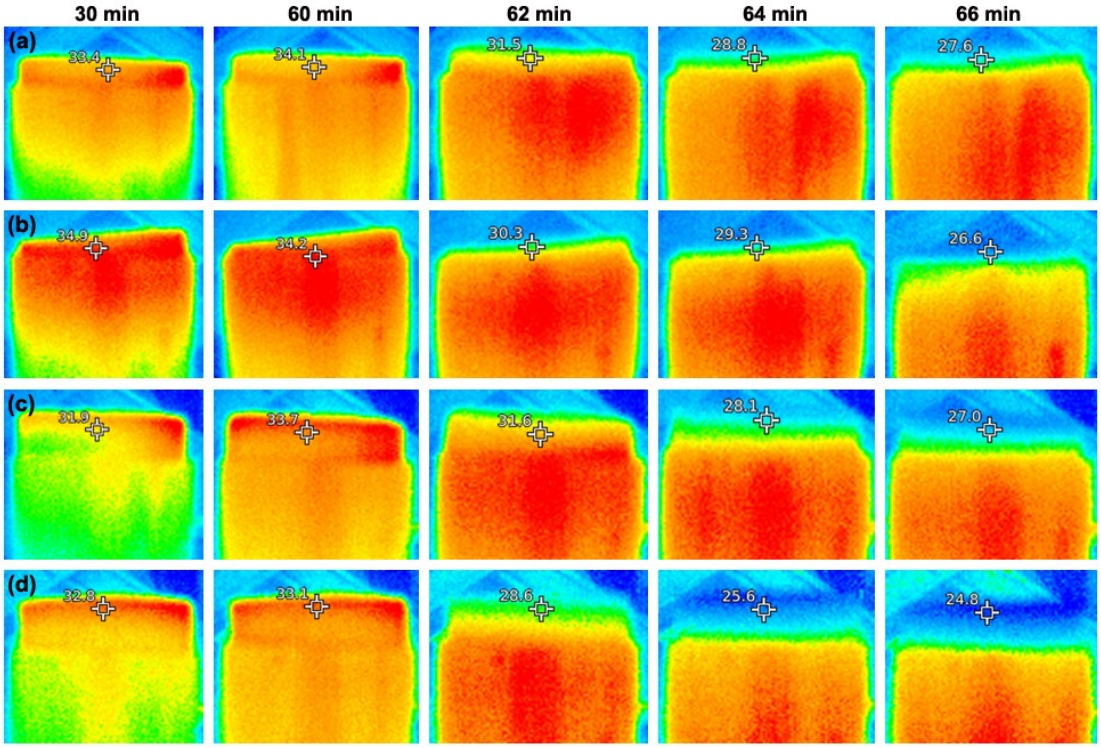

Figure S4. The lateral infrared images of different PCM during the photothermal conversion water evaporation process and after the light is stopped. (a) 0.5 cm-L. (b) 0.5 cm-S. (c) 1.0 cm-L. (d) 1.0 cm-S.

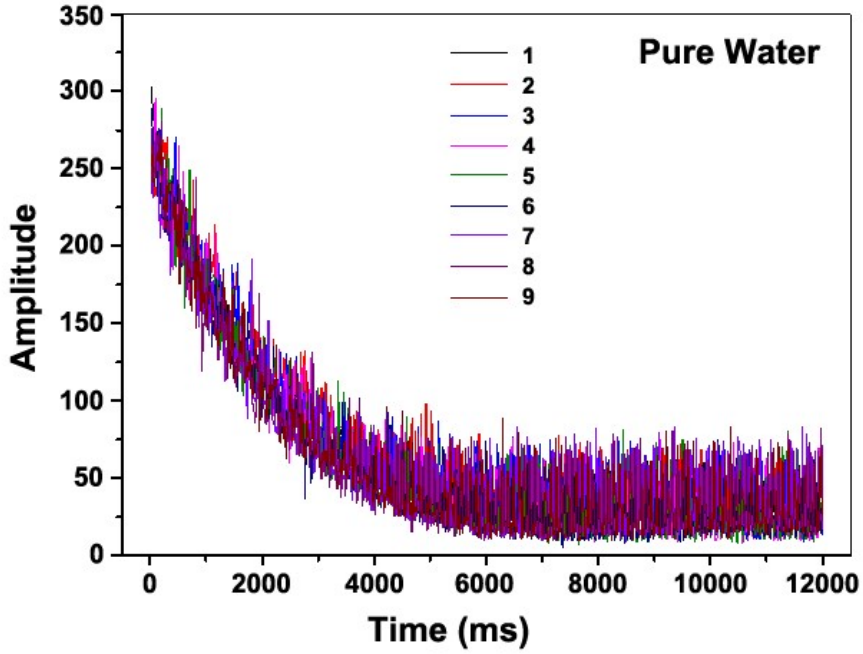

Figure S5. CPMG signals of pure water.

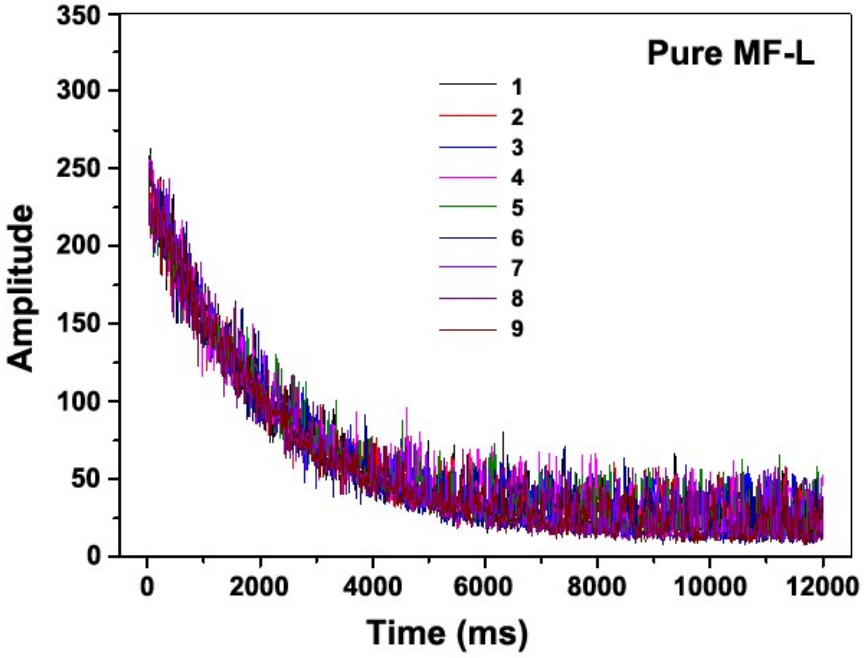

Figure S6. Carr-Purcell-Meiboon Gill signals of pure MF with large pore.

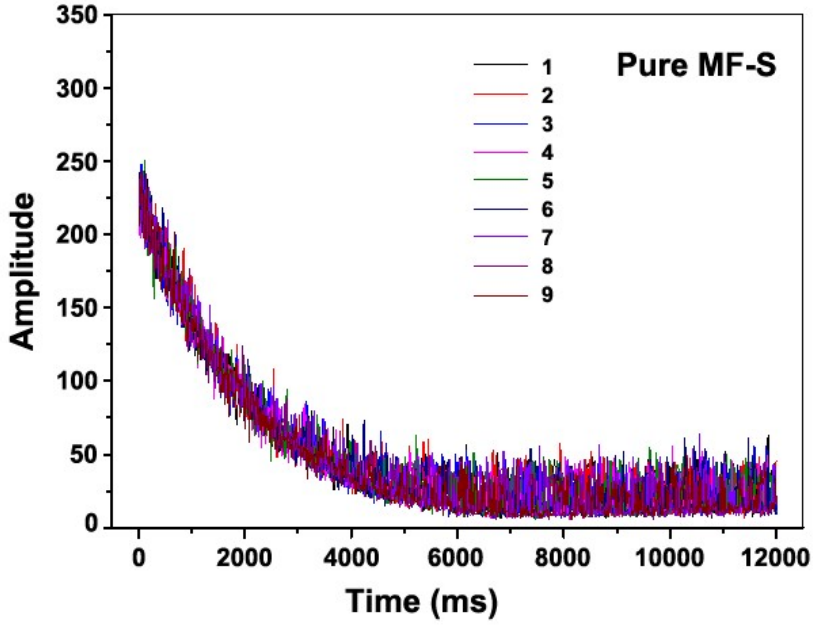

Figure S7. Carr-Purcell-Meiboon Gill signals of pure MF with small pore.

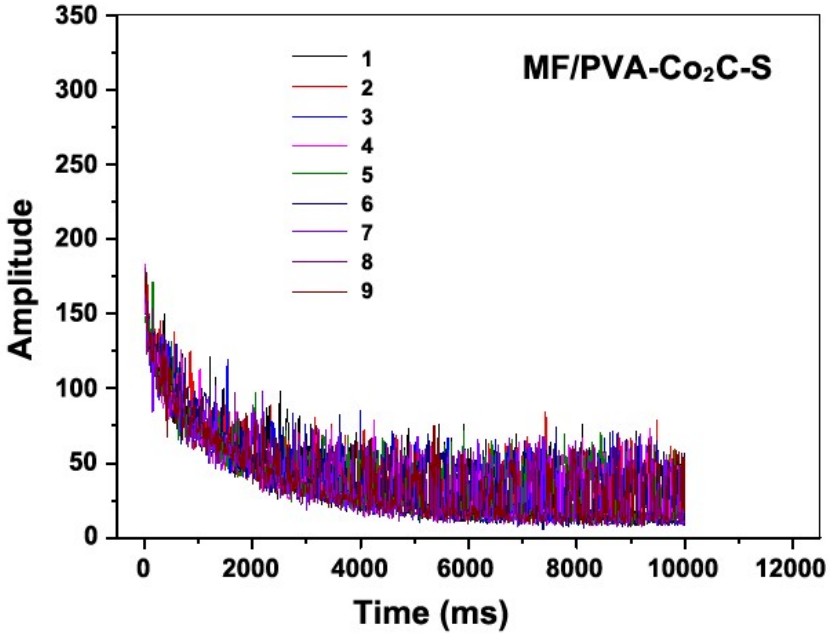

Figure S8. Carr-Purcell-Meiboon Gill signals of MF/PVA-Co_2C with small1 pore.

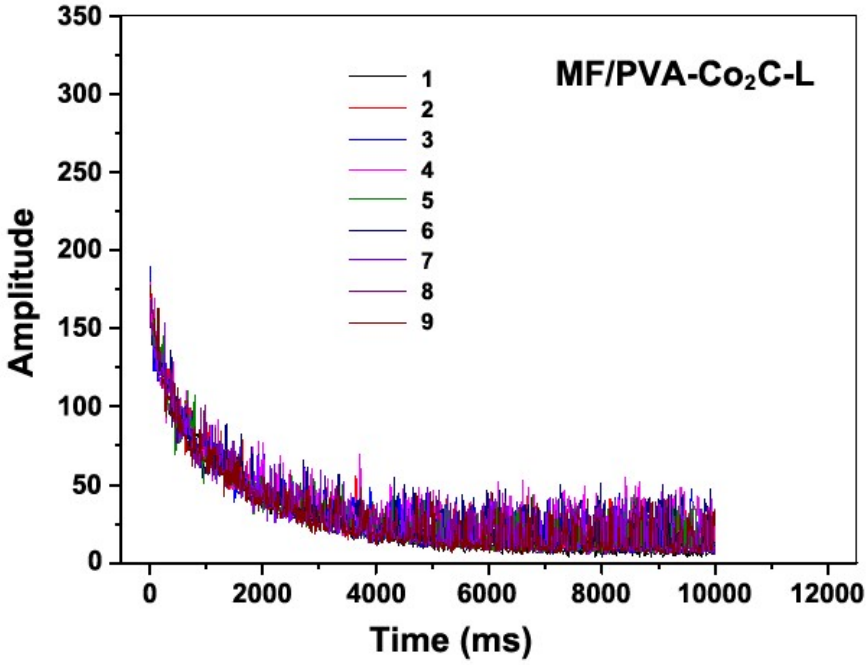

Figure S9. Carr-Purcell-Meiboon Gill signals of MF/PVA-Co_2C with large pore.

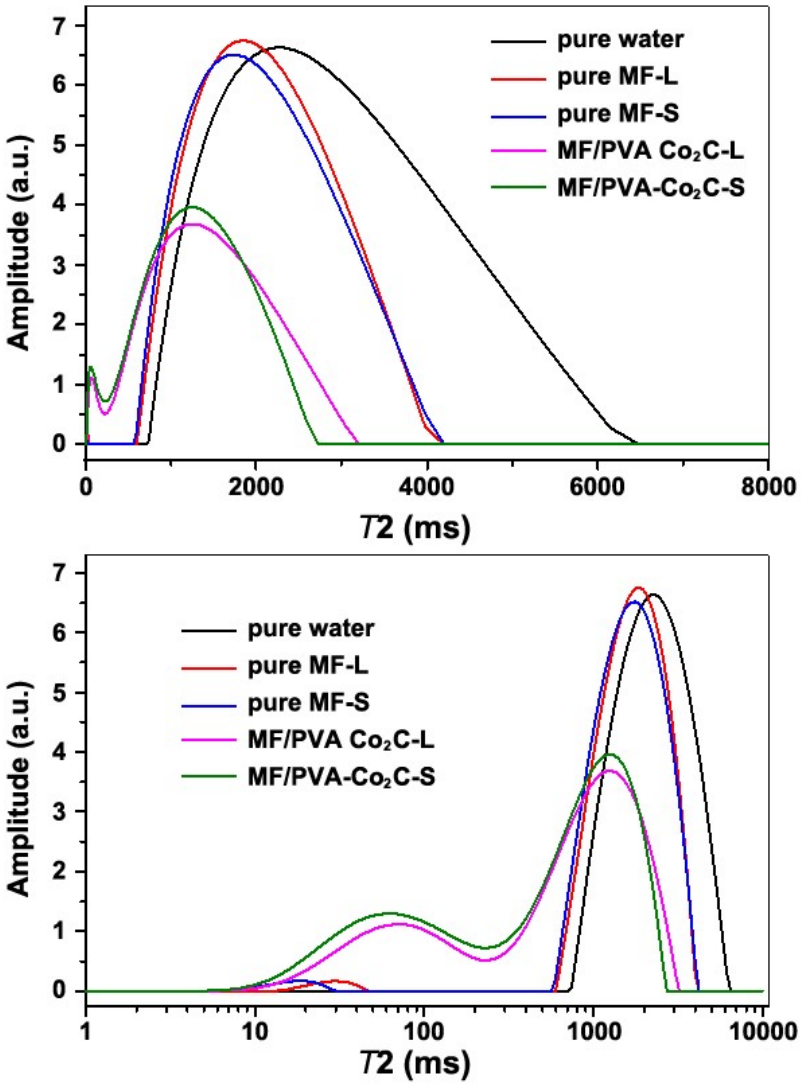

Figure S10. Time-resolved ^{1}H T_2 relaxation spectra at room temperature.

2025-07-17

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	时间	天气	温度	降水	风向	风力	风速	气压	湿度	云量	露点2m	短波辐射W/m²	直接辐射W/m²	散射辐射W/m²	直接正常辐照度W/m²
2	**17:00**	阴	31.8℃	0mm	北风	2级	6km/h	988hPa	46%	4%	20.9℃	340	146.9	193.1	273.6
3	**16:00**	晴	31.8℃	0mm	东北风	2级	8km/h	988hPa	44%	14%	20.3℃	527	281.2	245.8	400
4	**15:00**	晴	31.8℃	0mm	东北风	1级	5km/h	988hPa	46%	23%	19.5℃	660	356.6	303.4	426.6
5	**14:00**	多云	30.8℃	0mm	东北风	2级	6km/h	989hPa	51%	33%	19.5℃	731	369.5	361.5	399.3
6	**13:00**	晴	30.9℃	0mm	东北风	2级	7km/h	989hPa	49%	46%	19.7℃	760	380.7	379.3	394
7	**12:00**	多云	30.3℃	0mm	东北风	2级	10km/h	989hPa	53%	59%	20.2℃	760	383.6	376.4	401.5
8	**11:00**	晴	29.2℃	0mm	东北风	2级	11km/h	990hPa	54%	72%	20.7℃	716	380.3	335.7	425.6
9	**10:00**	晴	28.3℃	0mm	东北风	3级	14km/h	990hPa	59%	56%	21.2℃	617	341	276	434.5
10	**9:00**	晴	27.2℃	0mm	东北风	3级	12km/h	990hPa	61%	39%	21.7℃	467	246.1	220.9	386.5
11	**8:00**	多云	26.1℃	0mm	东北风	2级	9km/h	990hPa	67%	23%	21.9℃	303	137.7	165.3	299.5
12	**7:00**	雾	24.5℃	0mm	东北风	1级	4km/h	989hPa	81%	16%	21.8℃	161	58	103	218.8

2025-07-18

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	时间	天气	温度	降水	风向	风力	风速	气压	湿度	云量	露点2m	短波辐射W/m²	直接辐射W/m²	散射辐射W/m²	直接正常辐照度W/m²
2	**17:00**	晴	33.7℃	0mm	东北风	2级	11km/h	989hPa	40%	0%	20.7℃	340	147.3	192.7	274.9
3	**16:00**	晴	34.2℃	0mm	东北风	3级	13km/h	989hPa	37%	0%	20℃	539	297.7	241.3	424
4	**15:00**	多云	34℃	0mm	东北风	3级	12km/h	989hPa	39%	0%	18.7℃	692	402.5	289.5	482
5	**14:00**	晴	33.8℃	0mm	东北风	2级	6km/h	989hPa	42%	4%	18.2℃	790	453.9	336.1	490.8
6	**13:00**	阴	33℃	0mm	东北风	3级	13km/h	990hPa	45%	4%	18.2℃	834	486.5	347.5	503.8
7	**12:00**	多云	32.5℃	0mm	东北风	1级	5km/h	990hPa	46%	4%	18.7℃	824	475	349	497.6
8	**11:00**	多云	30.7℃	0mm	东北风	2级	6km/h	991hPa	52%	4%	19.5℃	754	435.5	318.5	488
9	**10:00**	晴	30.4℃	0mm	西北风	2级	9km/h	991hPa	56%	4%	21℃	636	368.5	267.5	470.2
10	**9:00**	多云	29.4℃	0mm	西南风	2级	6km/h	991hPa	63%	4%	22.3℃	475	257.2	217.8	404.8
11	**8:00**	晴	27.8℃	0mm	西南风	2级	7km/h	991hPa	68%	4%	22.8℃	305	140.5	164.5	306.7
12	**7:00**	晴	26.2℃	0mm	西南风	2级	7km/h	991hPa	75%	4%	22.4℃	160	57.6	102.4	218.8

Figure S11. Weather conditions in Lanshan District, Linyi City. Data source from the Internet (https://www.ip.cn/tianqi/shandong/linyi/lanshan/202507.html).

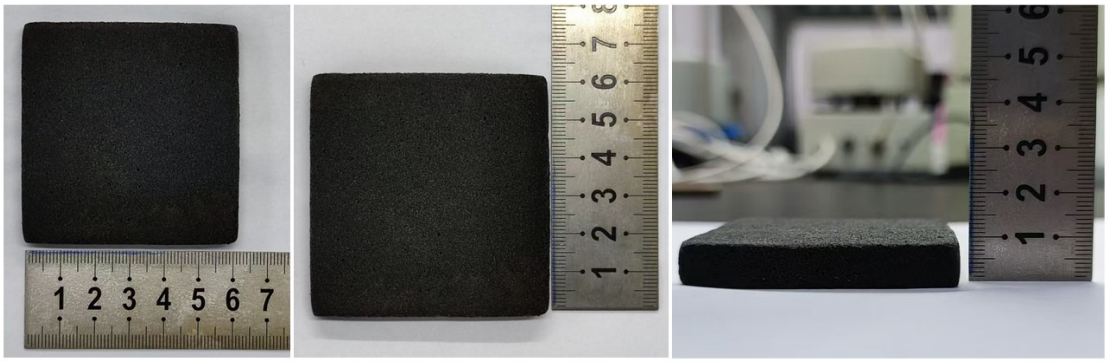

Figure S12. The size of the photothermal conversion material.

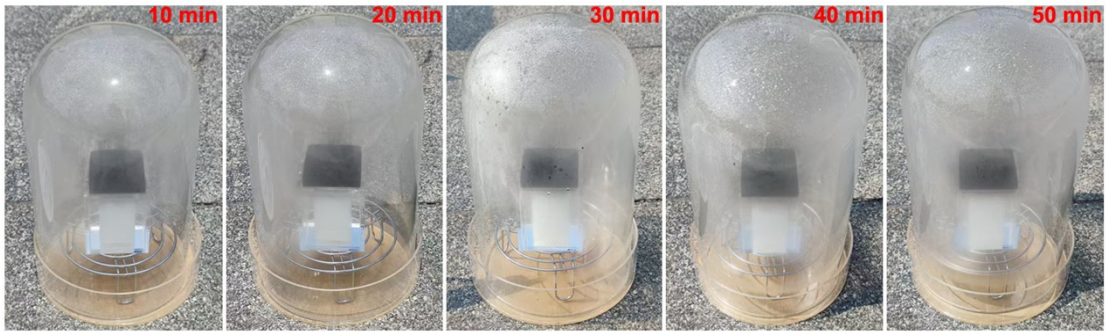

Figure S13. Photographs at different irradiation times under the outdoor sunlight.

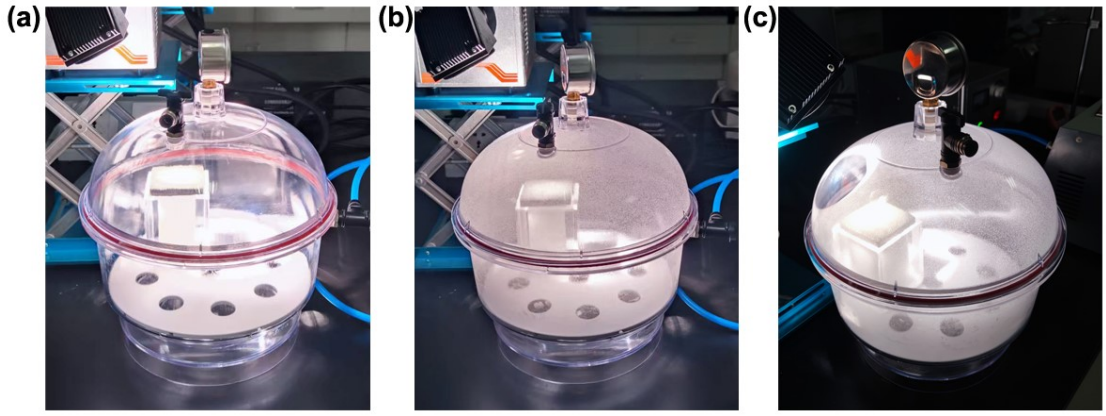

Figure S14. Photographs at different illumination times in a sealed space. (a) 0 min; (b) 20 min; (c) 40 min.

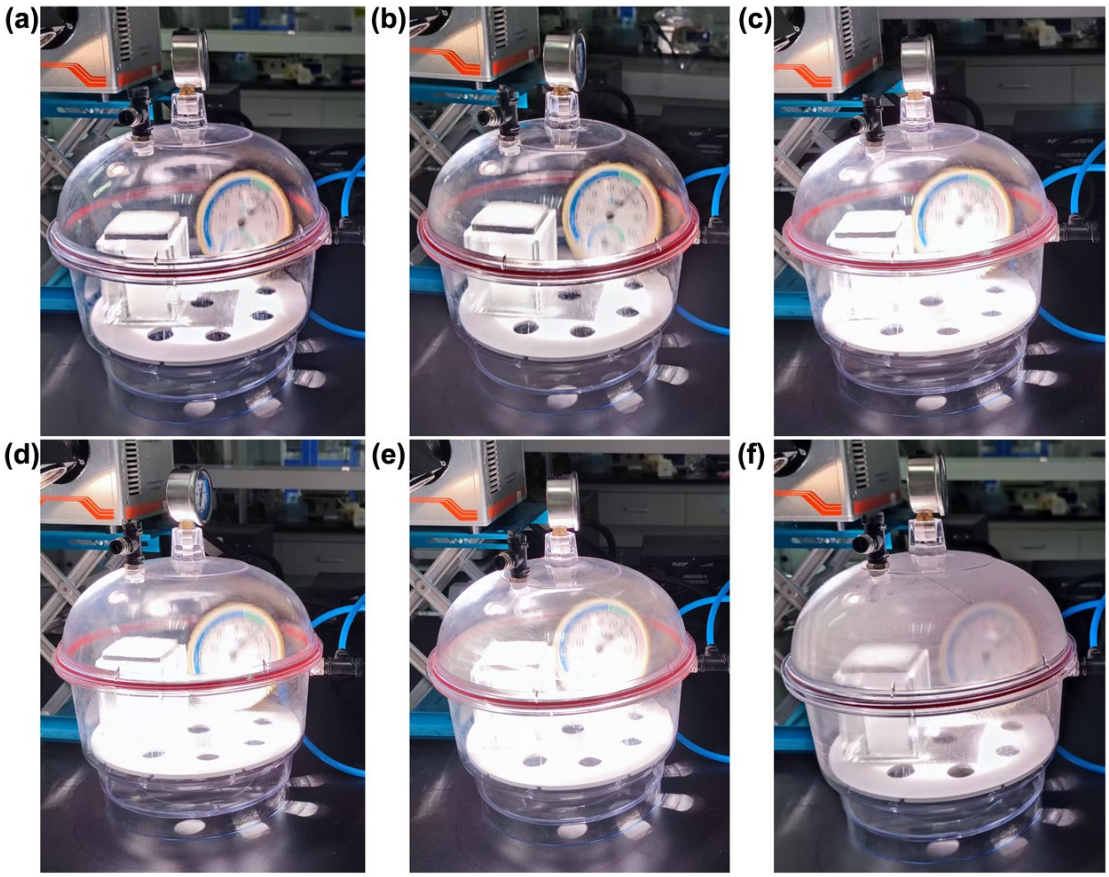

Figure S15. Photographs at different illumination times under evacuation. (a) 0 min; (b) 20 min; (c) 40 min; (d) 80 min; (e) 100 min; (f) 120 min.

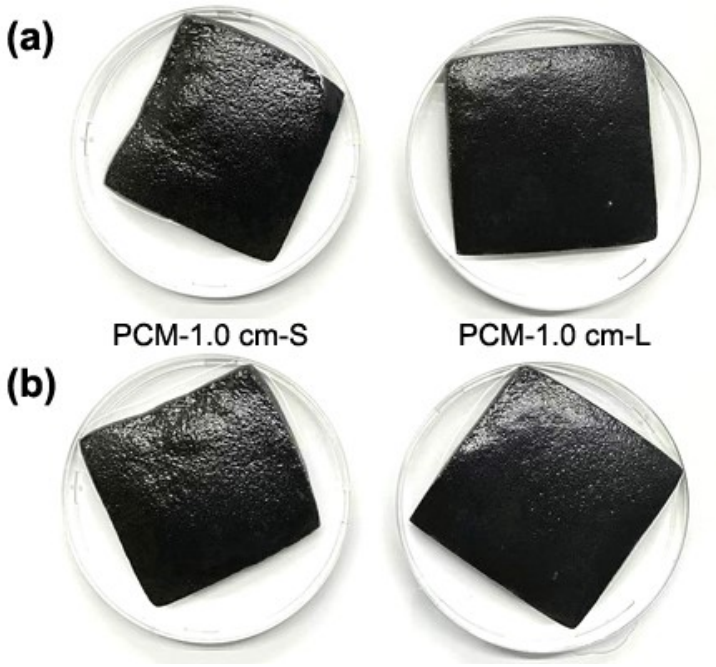

Figure S16. Photographs of prepared MF/PVA-Co_2C-1.0 cm-S and MF/PVA-Co_2C-1.0 cm-L composites immersed in water. (a) Just soaked, (b) After soaking for 10 days.