

Supporting Information

Embedding Metal Foam into Metal-Organic Framework Monolith for Triggering the Adsorbed Atmospheric Water to Be Highly Efficiently Released by Localized Eddy Current Heating

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Experimental Section

Synthesis of powdered MOFs:

All reagents and solvents were commercially obtained from Aladin (China) and used without further purification.

MIL-101(Cr) was synthesized according to a previous one-pot solvothermal approach [S1]. Typically, 6.0 g of chromium nitrate nonahydrate ($\text{Cr}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$), 3.76 g of terephthalic acid (H_2BDC) and 0.75 mL hydrofluoric acid (HF) were added in 75 mL of deionized (DI) water. The mixture was then transferred into a 200 mL Teflon-lined autoclave and heated to 220 °C, where it was kept for 9 h. After the reaction, the autoclave was slowly cooled to room temperature. The obtained suspension of MIL-101(Cr) was filtered through a stainless steel mesh screen (with a diameter of 0.044 mm) to eliminate the re-crystallized H_2BDC and repeatedly washed with DI water to remove excess monomers. Finally, the green products were activated under vacuum at 150 °C overnight.

UiO-66 was synthesized according to the previously reported method [S2]. In a typical reaction, 1.00 g of ZrCl_4 , 0.71 g of 1,4-benzenedicarboxylic acid (BDC), and 8.3 g of benzoic acid were dissolved in 167 mL of dimethylformamide (DMF) and 8.3 mL of deionized water. After the reaction proceeded at 120 °C for 24 hours, the resulting UiO-66 nanoparticles were collected by centrifugation, followed by a thorough washing with DMF and drying at 120 °C under vacuum for 24 h.

Al-fumarate was synthesized according to a previously reported procedure [S3]. In a typical reaction, 0.67 g of fumaric acid and 1.4 g of $\text{AlCl}_3 \cdot 6\text{H}_2\text{O}$ were dissolved in

100 mL of KOH aqueous solution (0.086 M). The resulting mixture was then incubated in an oven at 100 °C for 12 hours, resulting in the precipitation of white Al-fumarate crystals. The resulting Al-fumarate was washed three times with fresh water and twice with methanol and dried at 50 °C in vacuum for 8 hours.

MIL-100(Fe) was synthesized according to previously reported method [S4]. Trimesic acid (0.42 g) and iron(III) nitrate (0.48 g) were dissolved in 60 mL water. The resulting solution was then transferred into a Teflon lined steel autoclave to allow a hydrothermal reaction at 200 °C for 8 h. After being cooled down to room temperature, the light orange solid product was collected by centrifugation and sequentially washed with ethanol, DMF and water. The purified solid was finally dried at 80 °C under vacuum for 20 h.

Preparation of MF@MOF monoliths:

Nickel metal foam (MF, 98% of porosity) was purchased from Longshengbao Co. Ltd (Jiangsu, China) and pre-cut into desired size with a scalpel. Prior to the preparation of MF@MOFs, MFs were cleaned by thorough rinses with acetone. To prepare MF@MIL-1, a MF ($1 \times 1 \times 0.5 \text{ cm}^3$) was placed in the centre of a PTFE mould ($1.5 \times 1.5 \times 1 \text{ cm}^3$), followed by infilling the mould with a 1.7 mL of MIL-101(Cr)/SA aqueous slurry (150 mg/mL, MIL-101(Cr):SA=7.5:1, w/w). Thereafter, the resulting mould was immersed into a 50 mL of calcium chloride aqueous solution (2.0 wt%) for 1 h. After thorough washing with DI water and a freeze-drying treatment for 24 h, MF@MIL-1 monolith was prepared. Following the same procedures, merely regulating MOF/SA content of the aqueous slurry to 105 and 70 mg/mL would produce

MF@MIL-2 and MF@MIL-3 monolith. Instead of MIL-101(Cr), the use of different type of MOFs (UiO-66, Al-fumarate, and MIL-101(Fe)) while remaining the other conditions unchanged would result in the production of different MF@MOF monoliths (MF@UiO-66, MF@Al-fumarate, and MF@MIL-101(Fe)).

Characterizations:

The microstructures of samples were analyzed using a Hitachi S-4800 SEM. TEM observation was carried out on a JEOL JEM-2100Plus Electro microscope. TEM samples were prepared by dispersing samples into ethanol solvent assisted with sonication, followed by dropping the resulting dispersion on a carbon-coated copper grid. The XRD pattern was collected in the 2θ range of $5-60^\circ$ in steps of 0.02° and a counting time of 2 s step^{-1} . Low pressure nitrogen and water adsorption were measured using a BELSORP-max II gas sorption analyzer. N_2 adsorption measurements were performed at 77 K in a liquid nitrogen bath and 298 K. Based on N_2 adsorption isotherms, surface area measurements were calculated using a Brunauer-Emmett-Teller (BET) method at relative N_2 pressures of 0.01-0.3. To investigate LECH capability of MF@MOFs, the monolith samples were loaded in the copper coil of a magnetic induction heater (SPZ-45, Shenzhen Shuangping) in ambient conditions, followed by recording their matrices and surfaces temperature with resolution of $0.1 \text{ }^\circ\text{C}$ using a fluorescence temperature detector (TMEAS, FM-07) and an infrared camera (Testo, 871), respectively. The comparative hot-plate heating experiments were performed on a commercial hot-plate (DB-XWJ, LICHEN, Shanghai).

LECH-triggered water desorption capacity of MF@MILOFs was initially assessed on BELSORP-max II gas sorption analyzer equipped with a magnetic induction heater. The water desorption efficiency of MF@MILs was calculated based on the difference of water vapor adsorption capacity of MF@MILs between with and without a magnetic field applied. If water adsorption capacity of the sample at 60% RH with and without a magnetic field applied were x and y g g^{-1} , the water desorption efficiency of the sample at 60% RH was calculated as $(100*(y-x)/y)\%$.

Atmospheric water adsorption and LECH-triggered water desorption:

The atmospheric water capture experiments were conducted in a Constant Humidity Chamber (HWHS-100L, Kaice Shanghai) with a constant humidified air environment (60% RH) and at 298 K. The water capture process was monitored by the mass change of the samples. After the adsorption phase, the samples were transferred into the copper coil of the magnetic induction heater. With the magnetic field applied, LECH-triggered water desorption process was initiated at ambient conditions (298 K and 60% RH). The water desorption process was monitored by the mass loss of the samples and terminated until the sample weight reached constant. Following the same method, the comparative water-desorption experiment was carried out on a traditional hot-plate.

Assembly and operation of atmospheric water harvester:

The water harvester was assembled with a magnetic induction heater and a customer-made PMMA chamber (Figure 4a). The copper coil part of the induction heater was enclosed in the chamber. MF@MIL-1 monoliths were fully dehydrated at

135 °C under vacuum for 12 h and then packed in the copper coil separated from each other with 2 mm of spacings. The harvester was continuously operated for 24 h in controlled laboratory conditions. The ambient temperature and RH were recorded with a Temperature/Humidity Meter (L95-8, Shanghai Fatai). In each WHC, the water adsorption phase was proceeded for 2 h and 20 mins. Right after that, water desorption phase was initiated by switching on a 5.5 mT of magnetic field. After 40 mins, the water desorption phase was terminated by switching off the magnetic field. The produced liquid water in each WHC was collected and measured by weight.

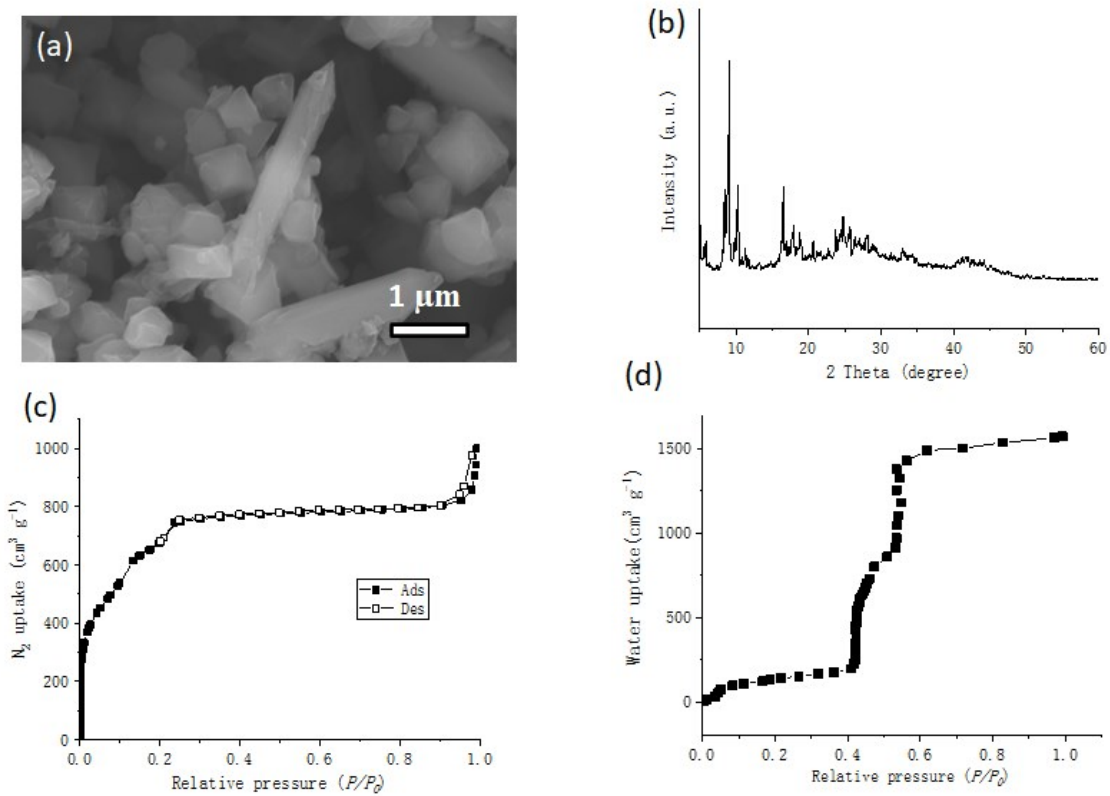


Figure S1. SEM image (a), XRD pattern (b), nitrogen adsorption isotherm at 77 K (c), and water vapor adsorption isotherm at 298 K (d) of powdered bare MIL-101(Cr).

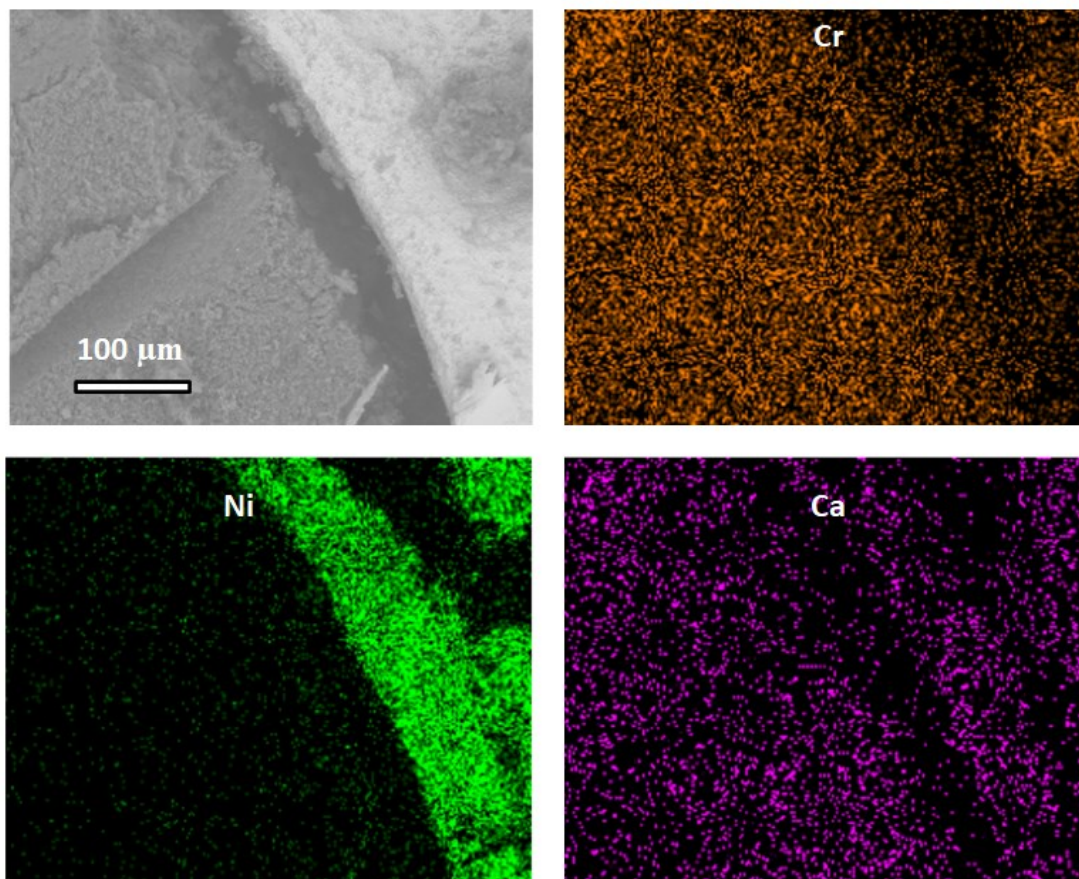


Figure S2. Back scattered SEM image and elemental mapping images of MF@MIL-1.

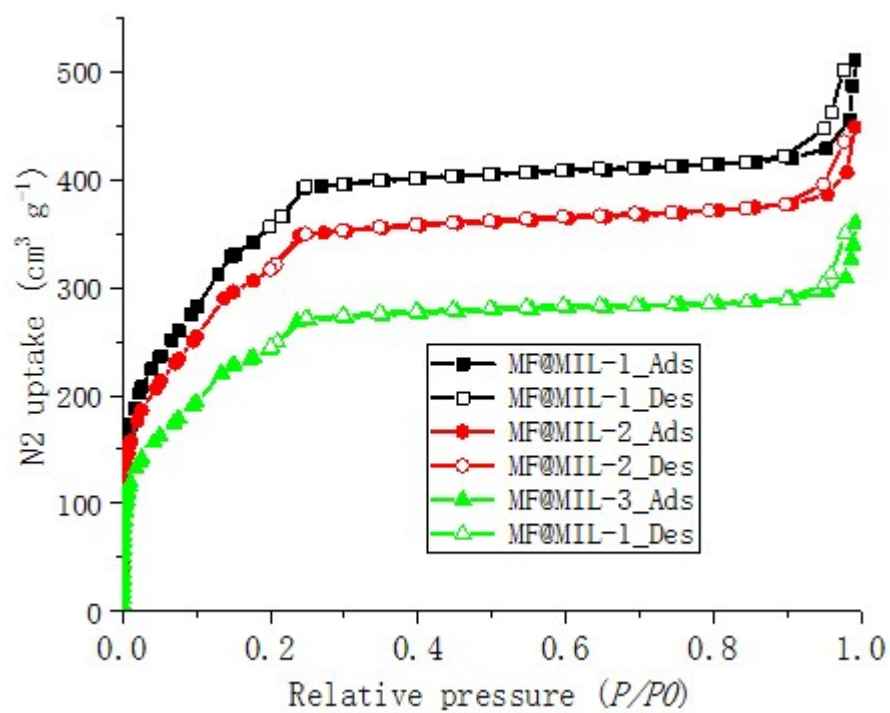


Figure S3. N₂ adsorption isotherms of MF@MILs at 77 K.

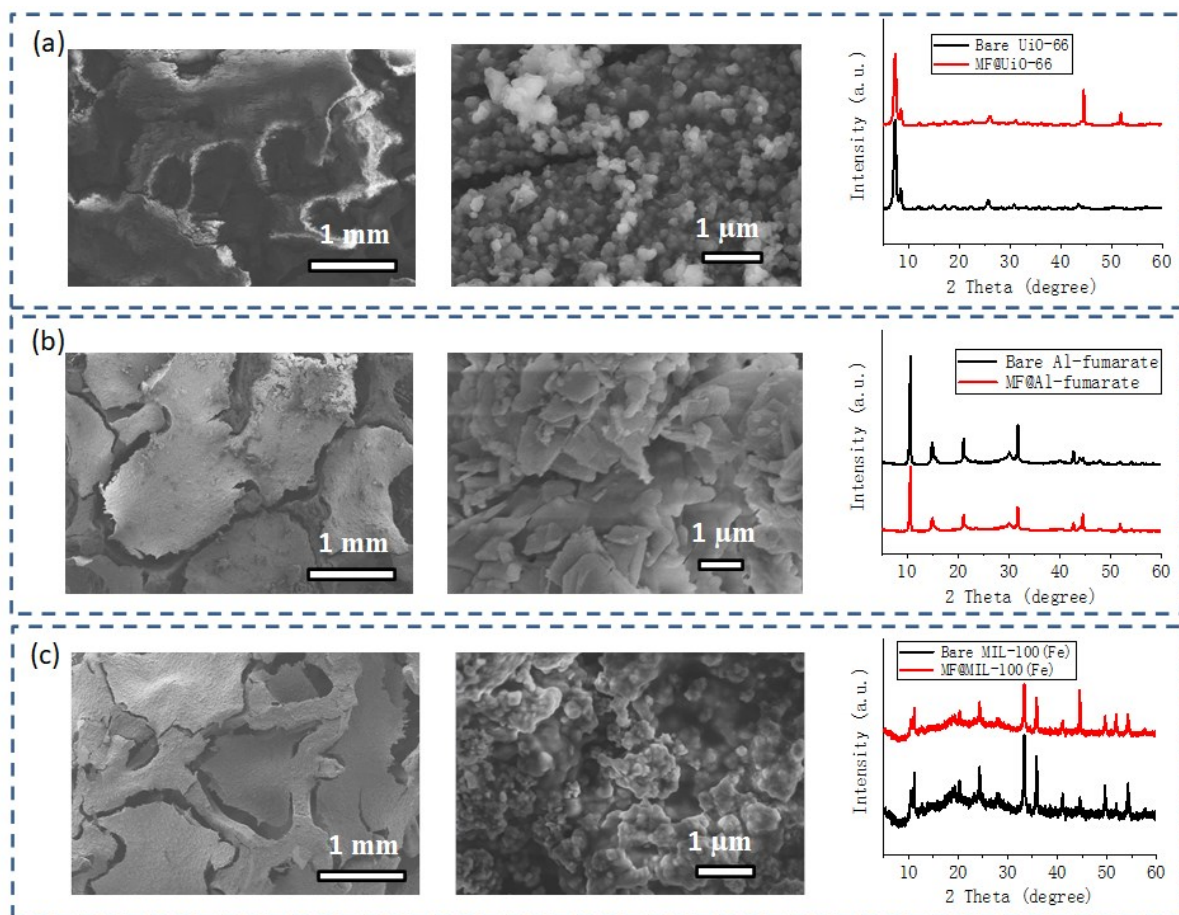


Figure S4. SEM image and XRD spectra of MF@MOF monoliths: MF@UiO-66 (a), MF@Al-fumarate (b), and MF@MIL-100(Fe) (c). The XRD peaks at 44.4° and 51.8° in all the XRD patterns corresponded to the (111) and (200) planes of nickel MFs.



Figure S5. Set-up for measuring water vapor adsorption capacity of MF@MIL-1 when LECH was applied during the measurement.

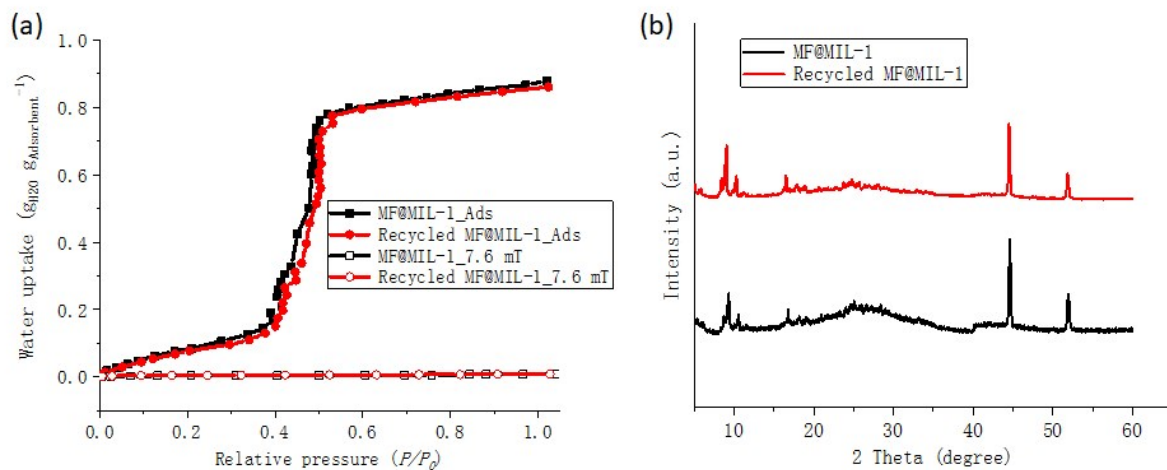


Figure S6. Water vapor adsorption isotherms of MF@MIL-1 before (black line) and after 5 cycles' reuse (red line) with (hollow symbol line) and without (solid symbol line) 7.6 mT of magnetic field applied (a); XRD patterns of MF@MIL-1 before and after 5 cycles' reuse (b).

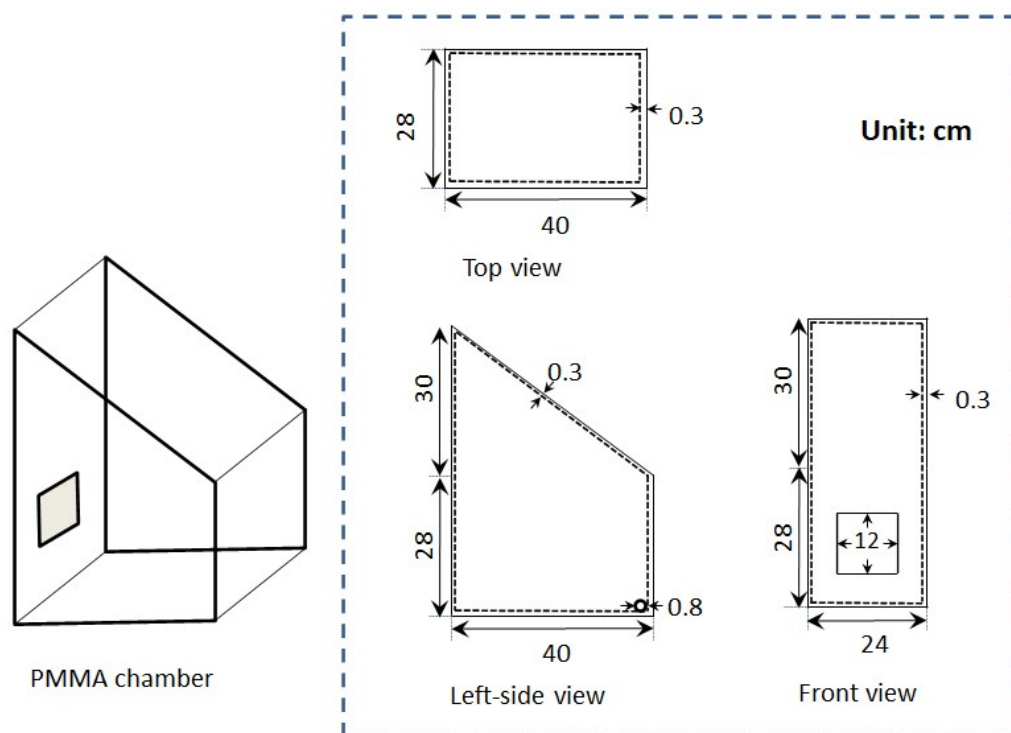


Figure S7. The design of PMMA chamber for constructing the atmospheric water harvester.

Reference

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- [S3] N. Hanikel, M. S. Prévot, F. Fathieh, E. A. Kapustin, H. Lyu, H. Wang, N. J. Diercks, T. G. Glover, *ACS Cent. Sci.* **2019**, *5*, 1699.
- [S4] N. M. Mhamoodi, J. Abdi, M. Oveisi, M. A. Asli, M. Vossoughi, *Mater. Res. Bull.* **2018**, *100*, 357.