Supplementary Information for

Ultrafast transformation of metal-organic frameworks into advanced oxygen evolution electrocatalysts with good universality and scalability

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1. Experimental Section

Chemicals. Iron (III) nitrate nonahydrate [Fe(NO₃)₃·9H₂O, 98%, J&K Scientific], nickel (II) nitrate hexahydrate [Ni(NO₃)₂·6H₂O, 98%, Analytical Reagent], cobalt (II) nitrate hexahydrate [Co(NO₃)₂·6H₂O, 99%, Aladdin], copper (II) nitrate trihydrate [Cu(NO₃)₂·3H₂O, analytical pure, Sinopharm Chemical Reagent Co., Ltd.], manganese (II) nitrate tetrahydrate [Mn(NO₃)₂·4H₂O, analytical pure, Sinopharm Chemical Reagent Co., Ltd.], cadmium (II) nitrate tetrahydrate [Cd(NO₃)₂·4H₂O, analytical pure, Sinopharm Chemical Reagent Co., Ltd.], zinc (II) nitrate hexahydrate [Zn(NO₃)₂·6H₂O, analytical pure, Sinopharm Chemical Reagent Co., Ltd.], zinc (II) nitrate hexahydrate [Zn(NO₃)₂·6H₂O, analytical pure, Sinopharm Chemical Reagent Co., Ltd.], 2-methylimidazole (C₄H₆N₂, 98%, Aladdin), ruthenium dioxide (RuO₂, Alfa Aesar), iridium dioxide (IrO₂, Alfa Aesar), Nafion (117 solution, 5% wt, Aldrich), hydrochloric acid (HCl, 37%, RCI Labscan Limited), nitric acid (HNO₃, 65%, EMD Millipore Corporation), potassium hydroxide (KOH, 99.99%, Aladdin), and Ni foam (thickness: 1.6 mm) were used as received. Deionized (DI) water was used for the preparation of all aqueous solutions.

Synthesis of CoNi MOFs on Ni foam. CoNi MOFs were synthesized *via* a reported solution method.¹ Before reaction, a piece of commercial Ni foam $(2 \text{ cm} \times 5 \text{ cm})$ was cleaned by 3 M HCl, ethanol, and DI water for several minutes, respectively. Then we prepared two different aqueous solutions A and B, where A contains 40 mL of 0.04 M Co(NO₃)₂·6H₂O and 0.01 M Ni(NO₃)₂·6H₂O and B is 40 mL 0.4 M C₄H₆N₂. Afterwards, solution B was quickly added into solution A, and the cleaned Ni foam substrate was immediately immersed into the mixture solution. After 4 h of reaction at room temperature, the sample was taken out, cleaned with DI water, and dried at 60 °C overnight. The mass loading of CoNi MOFs on Ni foam is about 1.67 mg cm⁻². Other CoM MOFs (M = Cu, Mn, Cd, and Zn) were prepared in the same way only by

replacing $Ni(NO_3)_2 \cdot 6H_2O$ to $Cu(NO_3)_2 \cdot 3H_2O$, $Mn(NO_3)_2 \cdot 4H_2O$, $Cd(NO_3)_2 \cdot 4H_2O$, and $Zn(NO_3)_2 \cdot 6H_2O$, respectively.

Conversion of CoNi MOFs into Fe-CoNi MOFs. The Fe-CoNi MOFs catalyst was synthesized by a facile room-temperature method *via* an etching-redeposition growth mechanism. Specifically, one piece of the CoNi MOFs supported on Ni foam $(0.3 \text{ cm} \times 2 \text{ cm})$ was immersed into an aqueous solution containing 10 mL 0.1 M Fe(NO₃)₃·9H₂O for only 3 seconds, and then quickly removed from the solution. After dried in air, the catalyst can be used as an OER electrode directly. The mass loading of Fe-CoNi MOFs on Ni foam is about 4.92 mg cm⁻². To study the effect of Fe concentration, another three different concentrations of 0.05, 0.15, and 0.2 M Fe(NO₃)₃ were used. Other Fe-CoM MOFs (M = Cu, Mn, Cd, and Zn) were also prepared by this ultrafast transformation process by immersing the corresponding CoM MOFs into the solution.

Preparation of RuO₂ and IrO₂ electrodes on Ni foam. To prepare the benchmark RuO₂/IrO₂ electrode, 40 mg commercial RuO₂/IrO₂ and 60 μ L Nafion were dispersed in 540 μ L ethanol and 400 μ L DI water in a small sealed tube (2 mL). The mixture was ultrasonicated for 30 min, and then a piece of Ni foam (~1 cm²) was placed inside the tube and swayed several times. After being soaked in the dispersion for 2 h, the Ni foam was taken out and air-dried overnight.

Materials characterization. The morphology and crystal structure of the samples were investigated by scanning electron microscopy (SEM, JEOL JSM-6900) and transmission electron microscopy (TEM, FEI TF20) coupled with energy dispersive X-ray spectroscopy. The phase composition of the samples was characterized using X-ray diffraction (XRD, Rigaku SmartLab Xray diffractometer) with a Cu Kα radiation source. X-ray photoelectron spectroscopy (XPS, PHI-Vesoprobe 5000III) was performed using a Thermo ESCALAB 250Xi spectrometer equipped with an anode of Al Kα radiation (1486.6 eV) X-ray sources. Electron paramagnetic resonance (EPR)

spectroscopy was analyzed using a Bruker EMXnano instrument. *In-situ* Raman was conducted on HORIBA LabRAM Spectrometer with a laser of 532 nm. Fourier transform infrared spectroscopy (FTIR) was measured by a FTIR spectrometer (Nicolet iS 10). The X-ray absorption fine structure (XAFS) spectroscopy was measured at the X-ray absorption fine structure for catalysis (XAFCA) beamline of the Singapore Synchrotron Light Source (SSLS), Singapore.

Electrochemical tests. All electrochemical tests were performed on an electrochemical station (CHI 760D, CH Instruments, Inc., Shanghai) in 1 M KOH at room temperature in a standard threeelectrode set-up with the prepared sample as the working electrode, a graphite rod as the counter electrode, and a standard Hg/HgO electrode as the reference electrode. Before OER measurement, cyclic voltammetry (CV) sweeps between 0.923 V and 1.923 V vs. reversible hydrogen electrode (RHE) at a scan rate of 100 mV s⁻¹ were conducted to electrochemically activate the catalysts until a stable CV curve was obtained. The OER polarization curves were measured at a sweep rate of 5 mV s⁻¹ and stability testing was performed under constant current densities of 10 and 100 mA cm⁻². To calculate the double-layer capacitance (C_{dl}) , CV curves were recorded at different scan rates ranging from 5 mV s⁻¹ to 25 mV s⁻¹ with an interval point of 5 mV s⁻¹. Electrochemical impedance spectra (EIS) were carried out at an overpotential of 300 mV from 0.01 Hz to 100 kHz with an amplitude of 10 mV. Faradaic efficiency was calculated by detecting the produced O₂ amount at a constant current density of 100 mA cm⁻² in a gas-tight H-cell through a drainage method. Turnover frequency (TOF) was calculated according to the equation: $TOF = j \times A/(4 \times F \times n)$, in which j is the current density (A cm⁻²), A is the geometric surface area of each electrode (cm²), 4 represents a four-electron transfer process of OER, F is the Faraday constant (96485.3 C mol⁻¹), and n is the amount of active sites (mol), which was roughly determined by the C_{dl} .² All of the measured

potentials vs. Hg/HgO were converted to RHE. All of the curves are reported with 85% iR compensation unless otherwise stated.

AEM electrolyser test. We evaluated the performance of Fe-CoNi MOFs as an OER electrocatalyst (anode) for industrial water electrolysis and CO_2 reduction in an AEM electrolyser device in 6 M KOH at 60 °C. For water electrolysis, a commercial Pt mesh was used as a cathode, while for CO_2 reduction, an Ag on PTFE electrode was prepared as a cathode for CO_2 reduction reaction. An anion exchange membrane (Alkymer®, EVE Institute of New Energy Technology) was applied to separate the cathode and anode compartments of the electrolyser. For comparison, the OER benchmark of commercial IrO₂ supported on Ni foam was also assessed as an anode in the two electrolysers.

DFT calculations. All theoretical calculations were carried out by using the Vienna Ab-initio Simulation Package (VASP) in Material Studio based on density functional theory (DFT). The generalized gradient approximation (GGA) of Perdew-Burke-Ernzerhof (PBE) form was used to describe the exchange-correction potential. The optimized surface of CoNi oxyhydroxide with and without Fe atom incorporation (denoted as Fe-CoNiOOH and CoNiOOH, respectively) were built as computation models (Fig. S31). Plane wave truncation energy was 500 eV, and the convergence criteria of energy and force were set as 1×10^{-6} eV and -0.02 eV/Å, respectively. During the calculation, the bottom two layers of atoms are fixed. According to the OER cycle proposed by Nørskov,³ the alkaline OER follows a four-electron process, in which three OER intermediates of *OH, *O, and *OOH are sequentially generated (the symbol * represents an active site on catalyst surface), as illustrated in the following equations.

$$* + OH^{-} \rightarrow *OH + e^{-}$$

$$*OH + OH^{-} \rightarrow *O + e^{-} + H_{2}O$$
$$*O + OH^{-} \rightarrow *OOH + e^{-}$$
$$*OOH + OH^{-} \rightarrow * + O_{2} + e^{-} + H_{2}O$$

The free energy change (ΔG) of each elementary step was calculated based on the following formula⁴:

$$\Delta G = \Delta E + \Delta Z P E - T \Delta S$$

where ΔE , ΔZPE , and ΔS represent the change of electron energy, zero-point energy difference, and entropy difference, respectively. The theoretical overpotential (η) is then calculated by the following formula⁵:

$$\eta = \Delta G_{max}/e - 1.23 \text{ V}$$

where ΔG_{max} is the maximum free energy change of the four OER elementary steps.

2. Supplementary Figures



Fig. S1. Photograph of commercial Ni foam and CoNi MOFs grown on Ni foam.



Fig. S2. (a) Photograph of CoNi MOFs treated by HNO₃ solution in comparison with that treated by 0.1 M Fe(NO₃)₃ solution. (b, c) SEM images of CoNi MOFs after treating in a HNO₃ solution.



Fig. S3. XRD patterns of CoNi MOFs and Fe-CoNi MOFs.



Fig. S4. (a) FTIR spectrum, (b) TEM image, and (c) STEM image and corresponding elemental mapping of Co, Ni, N, and C for CoNi MOFs.



Fig. S5. (a) TEM image of Fe-CoNi MOFs showing the size of one nanoparticle and (b) corresponding SAED pattern.



Fig. S6. HRTEM image of Fe-CoNi MOFs showing the feature of nanopolycrystalline with high density of grain boundaries and defects.



Fig. S7. EPR spectrum of Fe-CoNi MOFs.



Fig. S8. SEM and corresponding EDS mapping images of CoCu MOFs.



Fig. S9. SEM and corresponding EDS mapping images of CoMn MOFs.



Fig. S10. SEM and corresponding EDS mapping images of CoCd MOFs.



Fig. S11. SEM and corresponding EDS mapping images of CoZn MOFs.



Fig. S12. SEM and corresponding EDS mapping images of Fe-CoCu MOFs.



Fig. S13. SEM and corresponding EDS mapping images of Fe-CoMn MOFs.



Fig. S14. SEM and corresponding EDS mapping images of Fe-CoCd MOFs.



Fig. S15. SEM and corresponding EDS mapping images of Fe-CoZn MOFs.



Fig. S16. High-resolution XPS spectra of (a) C 1s, (b) N 1s, and (c) O 1s for CoNi MOFs and Fe-CoNi MOFs.



Fig. S17. OER polarization curves of Fe-CoNi MOFs reported with and without iR compensation.



Fig. S18. (a) OER polarization curves and (b) corresponding overpotential comparison at 100 mA cm⁻² of Fe-CoNi MOFs catalysts prepared using different Fe(NO₃)₃ concentrations.



Fig. S19. OER polarization curves of different CoM MOFs and Fe-CoM MOFs (M = Cu, Mn, Cd, Zn) catalysts.



Fig. S20. Cyclic voltammograms of (a) CoNi MOFs and (b) Fe-CoNi MOFs at scan rates ranging from 5 mV s⁻¹ to 25 mV s⁻¹ with an interval point of 5 mV s⁻¹.



Fig. S21. Liner fitting of C_{dl} of the catalysts versus CV scan rate for the estimation of ECSA.

Calculation of ECSA for each catalyst:

ECSA = $C_{\rm dl}/C_{\rm s}$, where $C_{\rm s}$ is the specific capacitance for a flat surface (40 μ F cm⁻²).⁶

ECSA $_{CoNi MOFs} = 1.23 \text{ mF cm}^{-2}/40 \text{ }\mu\text{F cm}^{-2} = 30.75 \text{ cm}^{-2}$

ECSA $_{Fe\text{-}CoNi\;MOFs}$ = 2.36 mF cm^-2/40 μF cm^-2 = 59 cm^2



Fig. S22. ECSA-normalized polarization curves of CoNi MOFs and Fe-CoNi MOFs.



Fig. S23. TOF plots of CoNi MOFs and Fe-CoNi MOFs.

The most important parameter for TOF calculation is the number of active sites, which was determined by the C_{dl} from Fig. S21. We assume 40 μ F cm⁻² for a flat electrode provided by previous reports,⁶ and the surface sites of 2 × 10¹⁵ for the flat standard electrode was used for our calculation. Thus, the number of active sites is estimated to be the following values.

CoNi MOFs: $\frac{1.23 \times 10^3}{40} \times 2 \times 10^{15} \text{ surface sites/cm}^2 = 6.15 \times 10^{16} \text{ surface sites/cm}^2,$

Fe-CoNi MOFs: $\frac{2.36 \times 10^3}{40} \times 2 \times 10^{15}$ surface sites/cm² = 1.18 × 10¹⁷ surface sites/cm². After converting into mol, the final TOF was calculated as follows:

 $\frac{6.02 \times 10^{23}}{\text{CoNi MOFs:}} \frac{6.15 \times 10^{16} \times 4 \times 9.6485 \times 10^4}{5 \times 10^{-3} \, \text{s}^{-1}} = 0.0254 \, \text{j s}^{-1},$



Fig. S24. Contact angle of a KOH (1 M) droplet on the surface of (a1, a2) commercial Ni foam, (b1, b2) CoNi MOFs, and (c1, c2) Fe-CoNi MOFs.

As the contact angle results in Fig. S24 show, when an electrolyte droplet landed on the surface of Ni foam, it keeps a stable teardrop shape with a contact angle of \sim 128°, suggesting a hydrophobic surface of Ni foam. For CoNi MOFs grown on Ni foam, the electrolyte droplet can stably stand on the surface for \sim 1 s and then quickly disappeared. In a sharp contract, the electrolyte droplet immediately disappears once touching the surface of Fe-CoNi MOFs, and we can hardly

capture a stable droplet shape, demonstrating improved wetting ability with a highly hydrophilic surface after the ultrafast transformation.



Fig. S25. OER polarization curves of Fe-CoNi MOFs before and after 2000 CV cycles.



Fig. S26. (a) SEM, (b, c) TEM, (d) HRTEM, and (e) STEM images and corresponding elemental mapping of Fe, Co, Ni, and O for Fe-CoNi MOFs after OER stability testing at 100 mA cm⁻² for 100 h.



Fig. S27. XRD patterns of the Fe-CoNi MOFs catalyst before and after OER stability testing.



Fig. S28. High-resolution XPS spectra of (a) Co 2p, (b) Ni 2p, (c) Fe 2p, and (d) O 1s for the Fe-CoNi MOFs catalyst before and after OER stability testing at 100 mA cm⁻² for 100 h.

From the high-resolution XPS spectra of Co 2p in Fig. S28a, we can see that all characteristic peaks of Co $2p_{1/2}$ and Co $2p_{3/2}$ turn into Co³⁺ without Co²⁺, and the Ni 2p XPS spectra also reveal the peak shift from Ni²⁺ to Ni³⁺ after the OER stability testing (Fig. S28b). The peak shift observed in the high-resolution XPS spectra of O 1s in Fig. S28d further prove the high valent states of different metals in Fe-CoNi MOFs after the OER stability testing, suggesting *in-situ* surface oxidation during OER process.



Fig. S29. Diagram of the *in-situ* Raman cell.



Fig. S30. Normalized Fe K-edge XANES spectra of Fe-CoNi MOFs before and after OER stability testing at 100 mA cm⁻² for 100 h.



Fig. S31. Optimized atomic structures of (a) CoNiOOH and (b) Fe-CoNiOOH for DFT calculation.



Fig. S32. (a) Proposed OER pathway on Ni site of CoNiOOH surface model. (b) Free energy diagrams of OER on Ni site of CoNiOOH with and without applying a potential (U) of 1.23 V *vs*. RHE.



Fig. S33. Proposed OER pathway on Co site of Fe-CoNiOOH surface model.



Large-size Fe-CoNi MOFs on Ni foam

Fig. S34. Photograph of Fe-CoNi MOFs catalyst synthesized on Ni foam in a large scale of 10 cm \times 10 cm.

3. Supplementary Tables

Table S1. Detailed OER activity comparison between the Fe-CoNi MOFs catalyst in this work and other reported MOF-based and MOF-derived OER catalysts in 1 M KOH electrolyte. Here η_{10} corresponds to the overpotential at the benchmark current density of 10 mA cm⁻².

Catalyst	ŋ ₁₀ (mV)	Tafel slope (mV dec⁻¹)	TOF (s ⁻¹)	Stability	Reference
Fe-CoNi MOFs	230	53.7	0.389 s⁻¹ at ŋ = 300 mV 2.75 s⁻¹ at ŋ = 340 mV	100 h at 10 mA cm ⁻² 100 h at 100 mA cm ⁻²	This work
NiCoFe MOFs	215	64.1	NA	50 h at 100 mA cm ⁻²	Energy Environ. Sci. 2021, 14, 6546-6553
CoCu MOFs	271	63.5	0.326 s ⁻¹ at ŋ = 300 mV	100 h at 10 mA cm ⁻²	Angew. Chem. Int. Ed. 2021,60, 26397-26402
CoFe MOFs	238	52	NA	~14 h at ~18 mA cm ⁻²	Angew. Chem. Int. Ed. 2021, 60, 12097-12102
NiFe MOFs	215	49.1	0.493 s ⁻¹ at ŋ = 300 mV	40 h at 10 mA cm ⁻²	Adv. Funct. Mater. 2021, 31, 2102066
ZnCo MOFs	231	74	1.627 s ⁻¹ at ŋ = 600 mV	12 h at 10 mA cm-2	Chem Catal. 2022, 2, 84-101
Br-Ni-MOFs	306	79.1	0.051 s ⁻¹ at ŋ = 300 mV	100 h at 10 mA cm ⁻²	Sci. Adv. 2021, 7, eabk0919
NiCo MOFs	270	49	0.86 s ⁻¹ at ŋ = 300 mV	NA	Nat. Energy 2020, 5, 881-890
CoFe MOFs	256	54	NA	24 h at 10 mA cm ⁻² 24 h at 100 mA cm ⁻²	Nano Energy 2020, 68, 104371
NiMn MOFs	280	86	0.32 s ⁻¹ at ŋ = 300 mV	30 h at 10 mA cm ⁻²	Angew. Chem. Int. Ed. 2020, 59, 18234-18239
NiFe MOFs	221	56	NA	20 h at 10 mA cm ⁻²	Angew. Chem. Int. Ed. 2019 , 131,7125-7130
NiCoFe MOFs	257	41.3	NA	35 h at 10 mA cm ⁻²	Adv. Mater. 2019, 31, 1901139
NiFe MOFs	258	46	NA	100 h at 20 mA cm ⁻²	J. Am. Chem. Soc. 2018, 140, 11286-11292
Low-crystalline NiFe MOFs	260	35	0.36 s ⁻¹ at ŋ = 330 mV	10 h at 10 mA cm-2	ACS Energy Lett. 2019, 4, 285-292
Defective CoFe MOFs	178	51	0.034 s ⁻¹ at ŋ = 250 mV	80 h at 100 mA cm ⁻²	Nat. Commun. 2019, 10, 5048-5055
Defective NiFe MOFs	283	54	NA	25 h at 10 mA cm-2	Nat. Commun. 2019, 10, 2799-2807
MOF-derived FeCoSe	270	35	1.23 s ⁻¹ at ŋ = 300 mV	24 h at 10 mA cm ⁻²	Energy Environ. Sci. 2021, 14, 365-373
$MOF\text{-}derived\ Co_3O_4\text{-}Mo_2N$	220	87.8	0.25 s ⁻¹ at ŋ = 300 mV	20 h at 10 mA cm ⁻²	Adv. Funct. Mater. 2021, DOI: 10.1002/adfm.202107382
MOF-derived Co-Ni/Ni ₃ N	322	63	~0.09 s ⁻¹ at ŋ = 420 mV	20 h at 20 mA cm-2	InfoMat. 2021, DOI: 10.1002/inf2.12251
MOF-derived Co-Fe-N-C	~310	40	∼1 s ⁻¹ at ŋ = 300 mV	5 h at 5 mA cm ⁻²	Nat. Energy 2021, 6,1054-1066
$MOF\text{-}derived\ NiCo_{2\text{-}x}Fe_xO_4$	274	42	0.016 s ⁻¹ at ŋ = 300 mV	25 h at 10 mA cm ⁻² 25 h at 50 mA cm ⁻²	Angew. Chem. Int. Ed. 2021, 60, 11841-11846
MOF-derived CoNiO _x -P	246	60.5	NA	10 h at 10 mA cm ⁻²	Energy Environ. Sci. 2020, 13, 5097-5103
$MOF\text{-}derived\ Co_{2\text{-}x}Ni_xP_4O_{12}\text{-}C$	230	51.1	NA	12 h at 10 mA cm-2	Adv. Funct. Mater. 2020, 30, 1910498
$MOF\text{-}derived\ CoTe_2$	241	46	~0.09 s ⁻¹ at ŋ = 295 mV	24 h at 10 mA cm ⁻² 24 h at 250 mA cm ⁻²	ACS Nano 2020, 14, 6968-6979
MOF-derived N-CoS ₂ @graphene	205	65	NA	10 h at 10 mA cm ⁻² 10 h at 100 mA cm ⁻²	Appl. Catal. B: Environ. 2020, 268, 118449
MOF-derived FeCoOOH	231	42	0.35 s ⁻¹ at ŋ = 300 mV	30 h at 10 mA cm ⁻²	Angew.Chem. Int.Ed. 2020, 59,13101-13108
MOF-derived ZnCoOOH	235	34.7	NA	40 h at 20 mA cm-2	Nat. Energy 2019, 4, 329-338
MOF-derived FeNiP	250	68	0.25 s ⁻¹ at ŋ = 300 mV	72 h at 10 mA cm ⁻²	J. Am. Chem. Soc. 2019, 141, 19, 7906-7916
MOF-derived FeCoP	269	31	NA	100 h at 30 mA cm-2	Energy Environ. Sci. 2019, 12, 3348-3355
MOF-derived Mo ₂ N-Mo ₂ C	197	82	0.25 s ⁻¹ at ŋ = 300 mV	40 h at 20/50/100 mA cm ⁻²	Adv. Energy Mater. 2019, 9, 1803768
$MOF\text{-}derived\ Ni_3S_4$	257	67	NA	300 h at 50 mA cm ⁻²	Adv. Funct. Mater. 2019, 29, 1900315

4. References

- Y. Li, Z. Wang, J. Hu, S. Li, Y. Du, X. Han and P. Xu, Adv. Funct. Mater., 2020, 30, 1910498.
- L. Wu, L. Yu, B. McElhenny, X. Xing, D. Luo, F. Zhang, J. Bao, S. Chen and Z. Ren, *Appl. Catal. B: Environ.*, 2021, 294, 120256.
- I. C. Man, H. Y. Su, F. Calle-Vallejo, H. A. Hansen, J. I. Martínez, N. G. Inoglu, J. Kitchin,
 T. F. Jaramillo, J. K. Nørskov and J. Rossmeisl, *ChemCatChem*, 2011, 3, 1159-1165.
- M. Bajdich, M. García-Mota, A. Vojvodic, J. K. Nørskov and A. T. Bell, *J. Am. Chem. Soc.*, 2013, 135, 13521-13530.
- (5) Z. Lei, W. Cai, Y. Rao, K. Wang, Y. Jiang, Y. Liu, X. Jin, J. Li, Z. Lv and S. Jiao, *Nat. Commun.*, 2022, 13, 24.
- L. Wu, L. Yu, Q. Zhu, B. McElhenny, F. Zhang, C. Wu, X. Xing, J. Bao, S. Chen and Z. Ren, *Nano Energy*, 2021, 83, 105838.