Supplementary Materials

CoFe$_2$O$_4$ nanoparticles as a bifunctional agent on activated porous carbon for battery-type asymmetrical supercapacitor

Qiang Qu[1,2], Zhuo Chen[1,2], Guo-Tao Sun[1,2], Ling Qiu[1,2], Ming-Qiang Zhu[1,2,*]

[1]College of Mechanical and Electronic Engineering, Northwest A&F University, Yangling 712100, Shaanxi, China.
[2]Northwest Research Center of Rural Renewable Energy Exploitation and Utilization of M.O.A, Northwest A&F University, Yangling 712100, Shaanxi, China.

[*]**Correspondence to:** Prof. Ming-Qiang Zhu, College of Mechanical and Electronic Engineering, Northwest A&F University, No. 3 Taicheng Road, Yangling 712100, Shaanxi, China. E-mail: zmqsx@nwsuaf.edu.cn

Supplementary Table 1. The electricity consumption and material use for preparing carbon products and discharging

Item	AC	140MAC24
Preparation of carbon products		
EUO Thumb (g)	20	20
85 wt% H_3PO_4 (g)	23.5	23.5
Activation time (h)	6	6
The power for Activation (kw)	2.5	2.5
N_2 (L)	5	5
HCl (mL)	5	5
$FeSO_4 \cdot 7H_2O$ (g)	0	4
$FeCl_3 \cdot 6H_2O$ (g)	0	7.834
$CoCl_2 \cdot 6H_2O$	0	10.47
NaOH (g)	0	8.128
Distilled water (mL)	56.5	256.5
Stirring time (h)	1	3
The power of stirring (kw)	0.6	0.6
Hydrothermal reaction time	0	24
The power of hydrothermal heating (kw)	0	2
Drying time (h)	12	24
The power for drying (kw)	1	1
Process of charging		
Activate material of electrode (mg)	4.2	4.2
Charging time (s)	310.39	685.20
The power of charging	0.5	0.5
KOH (g)	2.8	2.8
Distilled water (mL)	50	50

Supplementary Table 2. The price of electricity and material

Item	Price
EUO-wood (¥/g)	0.012
85% H_3PO_4 (¥/g)	0.050
Electricity (¥/kwh)	0.725
N_2 (¥/L)	0.024
Distilled water (¥/mL)	0.002
$FeSO_4·7 H_2O$ (¥/g)	0.022
$FeCl_3·6H_2O$ (¥/g)	0.053
$CoCl_2·6H_2O$	0.725
NaOH (¥/g)	0.026

Supplementary Table 3. The relative content of elements on the surface of MACs

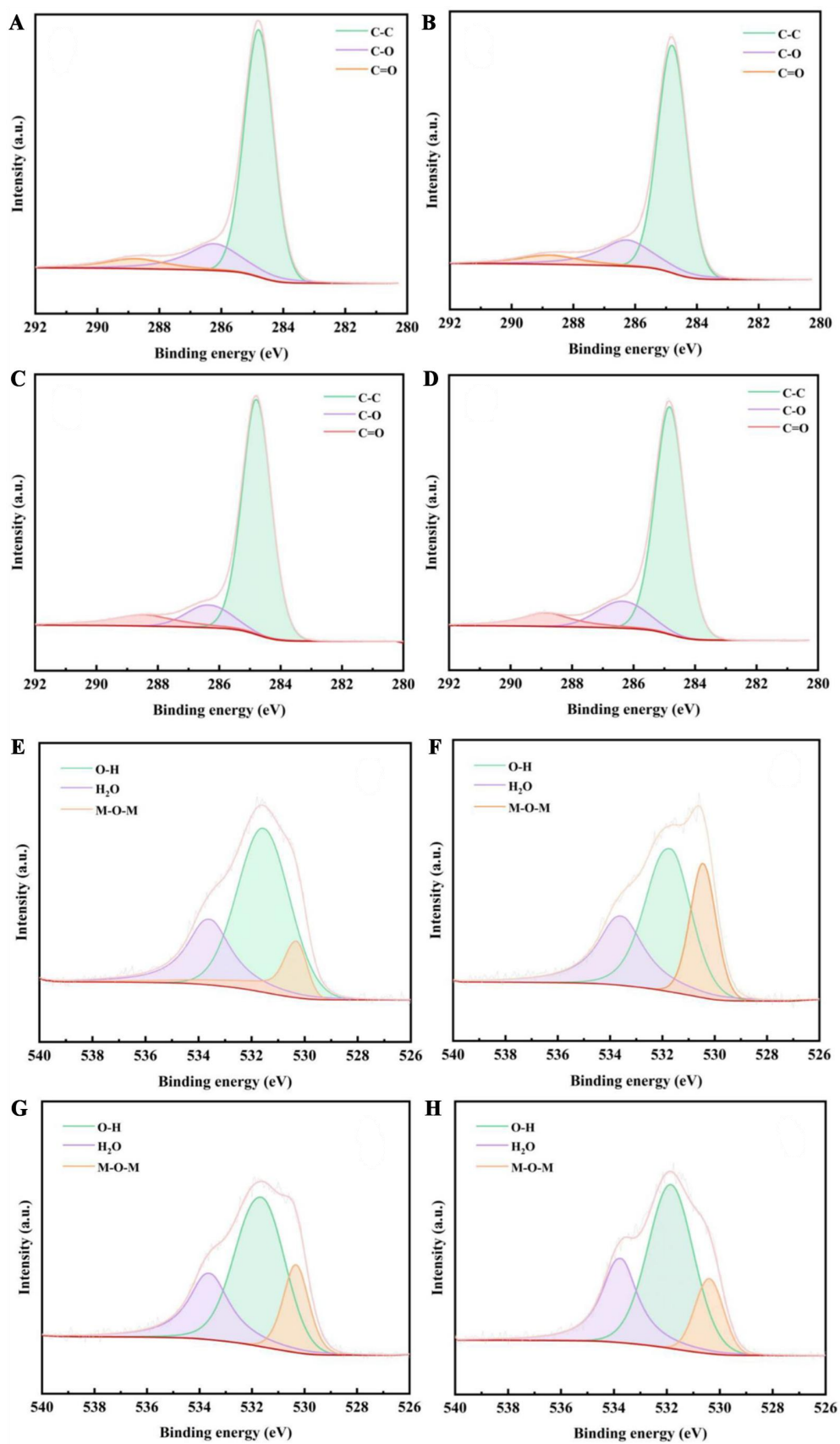|	C		O		Fe		Co	
	FWHM[a]	A.C.[b]	FWHM[a]	A.C.[b]	FWHM[a]	A.C.[b]	FWHM[a]	A.C.[b]
120MAC24	2.82	79.27	4.08	18.69	2.79	0.47	4.26	1.57
140MAC18	2.86	77.56	4.07	17.84	6.53	3.06	8.27	2.45
140MAC24	2.74	70.36	3.65	21.1	6.47	4.44	8.27	2.74
140MAC30	2.95	77.2	4.36	20.44	0.77	0.55	4.06	1.82
160MAC24	2.85	78.03	4.41	19.12	5.38	1.9	1.97	0.96

[a]full width at half mixima (eV); [b]relative atomic percent contents (%).

**Supplementary Table 4. The relative content of various groups on the surface of MACs**

	120MAC24	140MAC18	140MAC24	140MAC30	160MAC24
C					
C-C/C=C/C-H	75%	75%	73%	78%	75%
C-O	18%	18%	21%	12%	15%
C=O	7%	7%	6%	10%	10%
O					
H_2O	14%	25%	9%	18%	16%
O-H	60%	47%	66%	56%	56%
M-O-M	26%	29%	30%	26%	28%
Fe					
Fe(II)	21%	4%	14%	22%	22%
Fe(III)	13%	17%	8%	16%	0%
Sat.	19%	19%	26%	4%	8%
Fe(II)	14%	23%	21%	22%	28%
Fe(III)	32%	38%	31%	36%	41%
Co					
Sat.	14%	11%	10%	12%	16%
Co(II)	12%	13%	13%	15%	12%
Sat.	16%	13%	21%	14%	15%
Co(II)	29%	19%	22%	10%	23%
Co(III)	29%	45%	33%	49%	33%

Supplementary Table 5. The operation costs of discharging using electrode based on AC and 140MAC24

| Samples	Material cost for preparation of carbon products (¥)	Electricity cost for preparation of carbon products (¥)	Material cost for charging using electrode (¥)	Electricity cost for charging using electrode (¥)	The cost of discharge using electrode [¥/(specific capacitance F/g*h)]
AC	1.898	20.01	3.986×10^{-4}	0.031	5.540×10^{-5}
140MAC24	10.603	64.38	2.227×10^{-3}	0.067	2.753×10^{-4}

Supplementary Figure 1. The C 1s and O 1s spectra of (A and E) AC; (B and F) 120MAC24; (C and G) 140MAC18; and (D and H) 140MAC30.
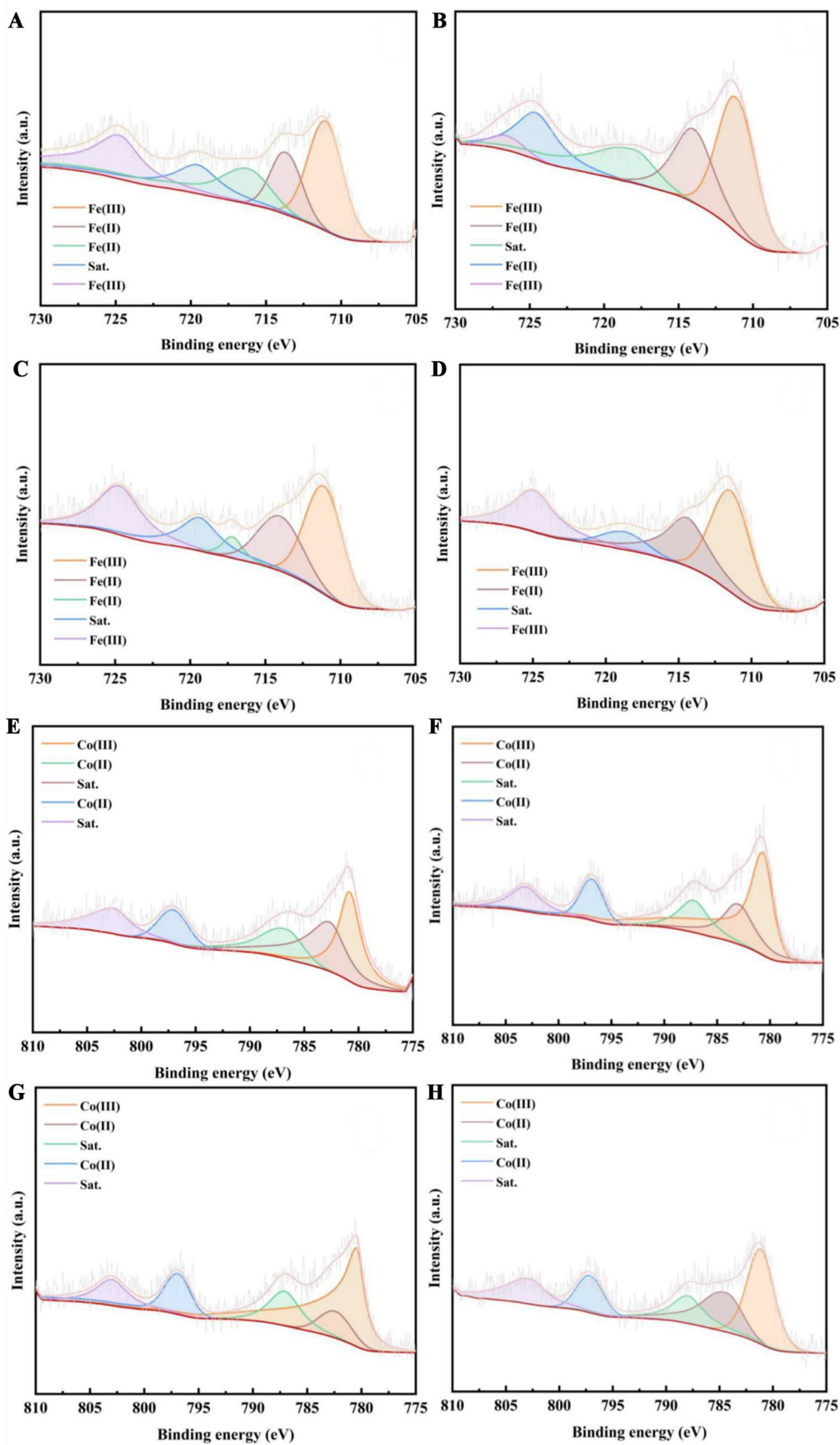
Supplementary Figure 2. The Fe 2p and Co 2p spectra of (A and E) AC; (B and F) 120MAC24; (C and G) 140MAC18; and (D and H) 140MAC30.
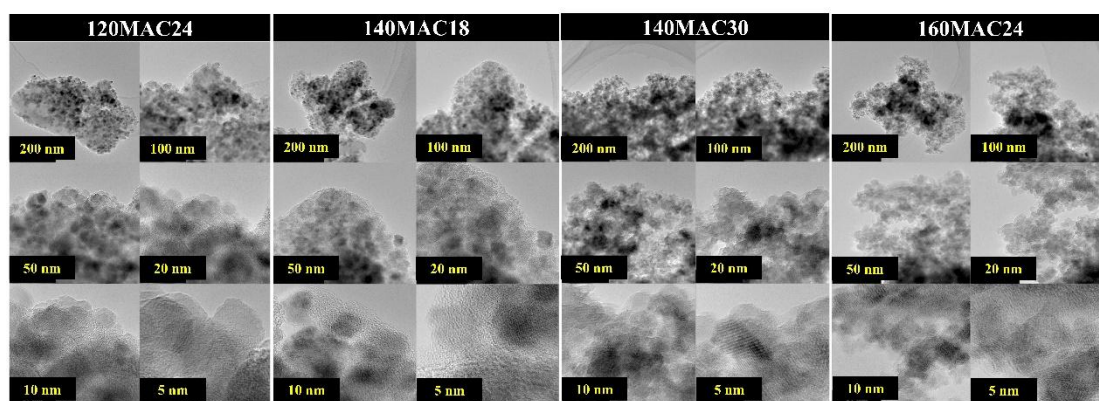
Supplementary Figure 3. The TEM images of 120MAC24, 140MAC18, 140MAC30, and 160MAC24.
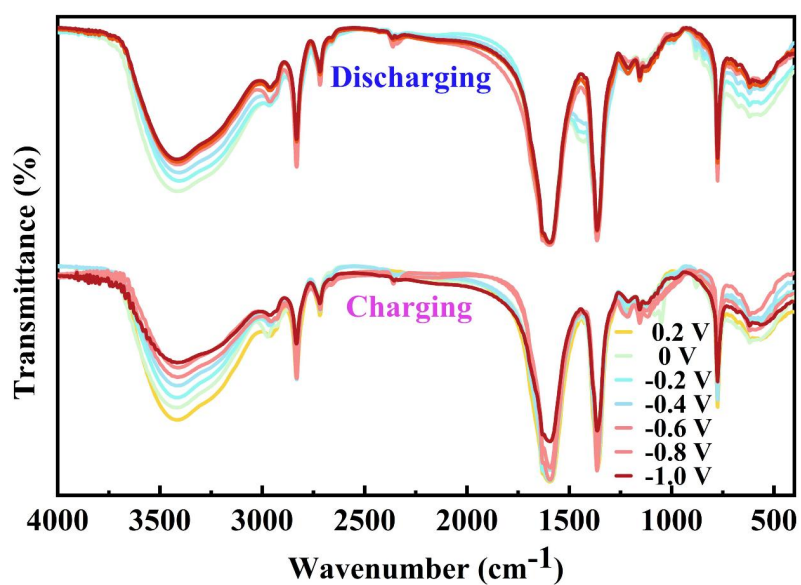
Supplementary Figure 4. The FTIR spectrum of 140MAC24 based electrode after charging-discharging for 10,000 cycles.