Supporting Information

Investigation of non-precious metal cathode catalysts for direct borohydride fuel cells

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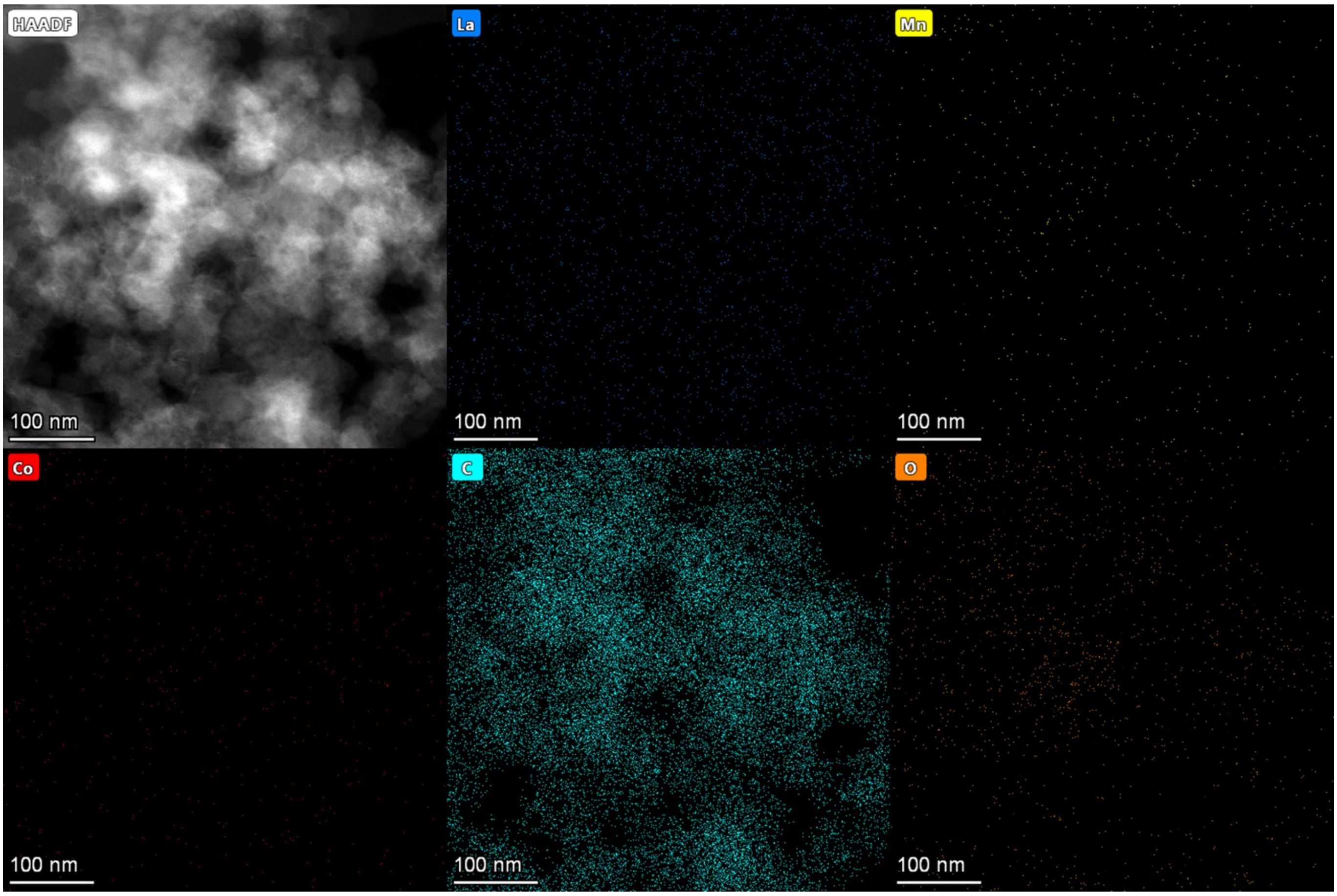

Figure S1. HAADF-TEM and EDS elemental mapping image of pristine LMCO electrode.

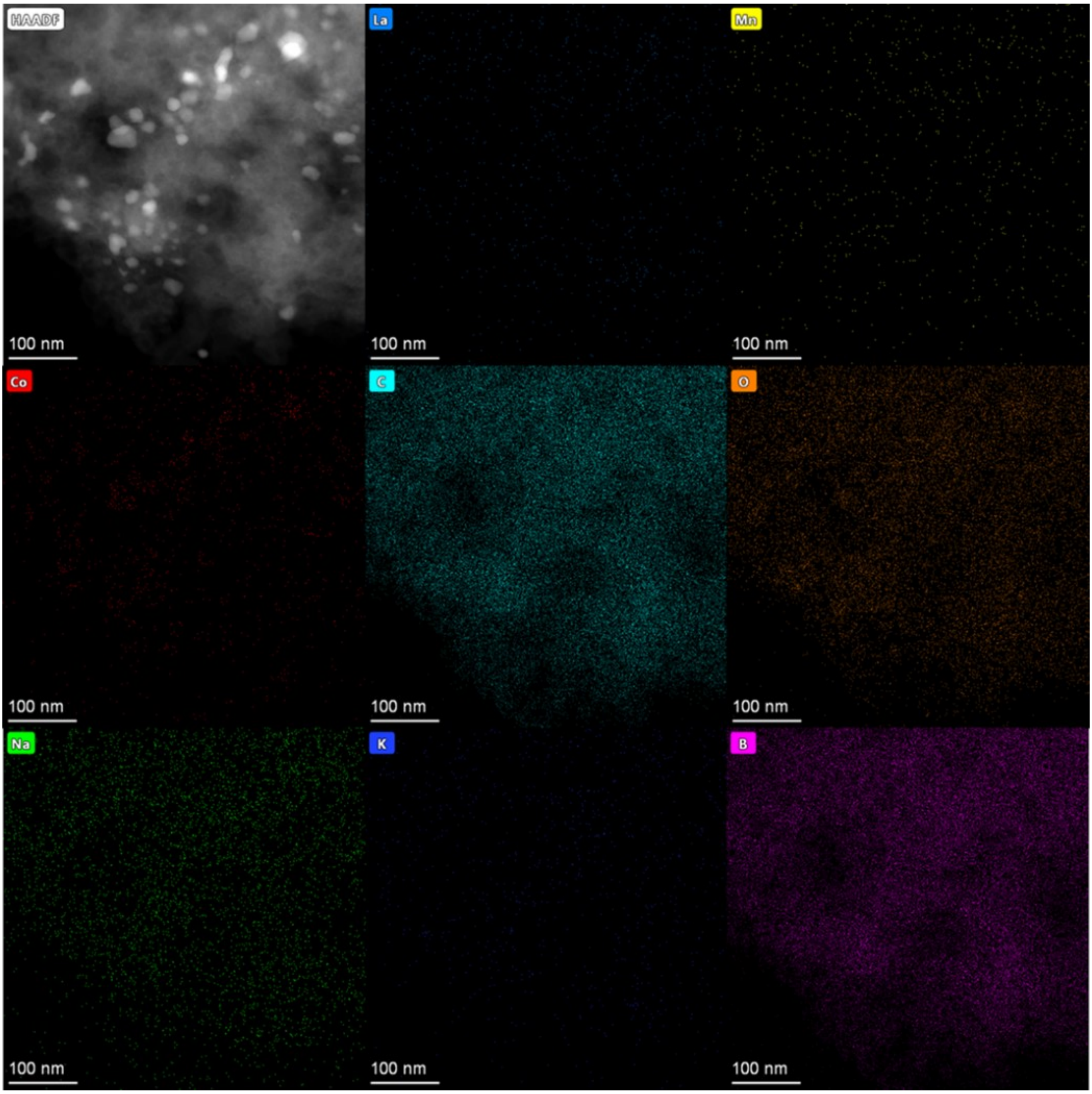

Figure S2. HAADF-TEM and EDS elemental mapping image of LMCO electrode after durability test.

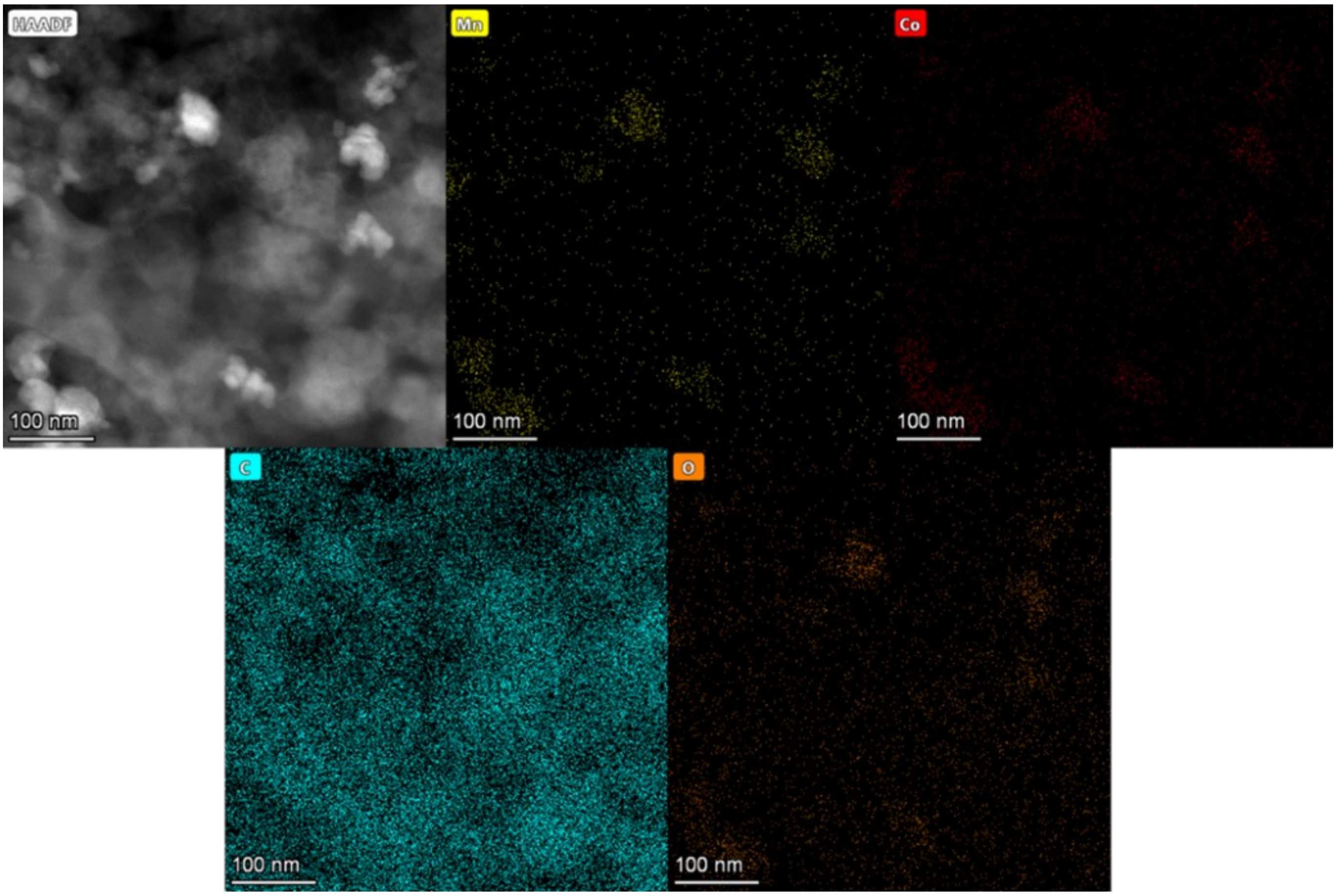

Figure S3. HAADF-TEM and EDS elemental mapping image of pristine MCS electrode.

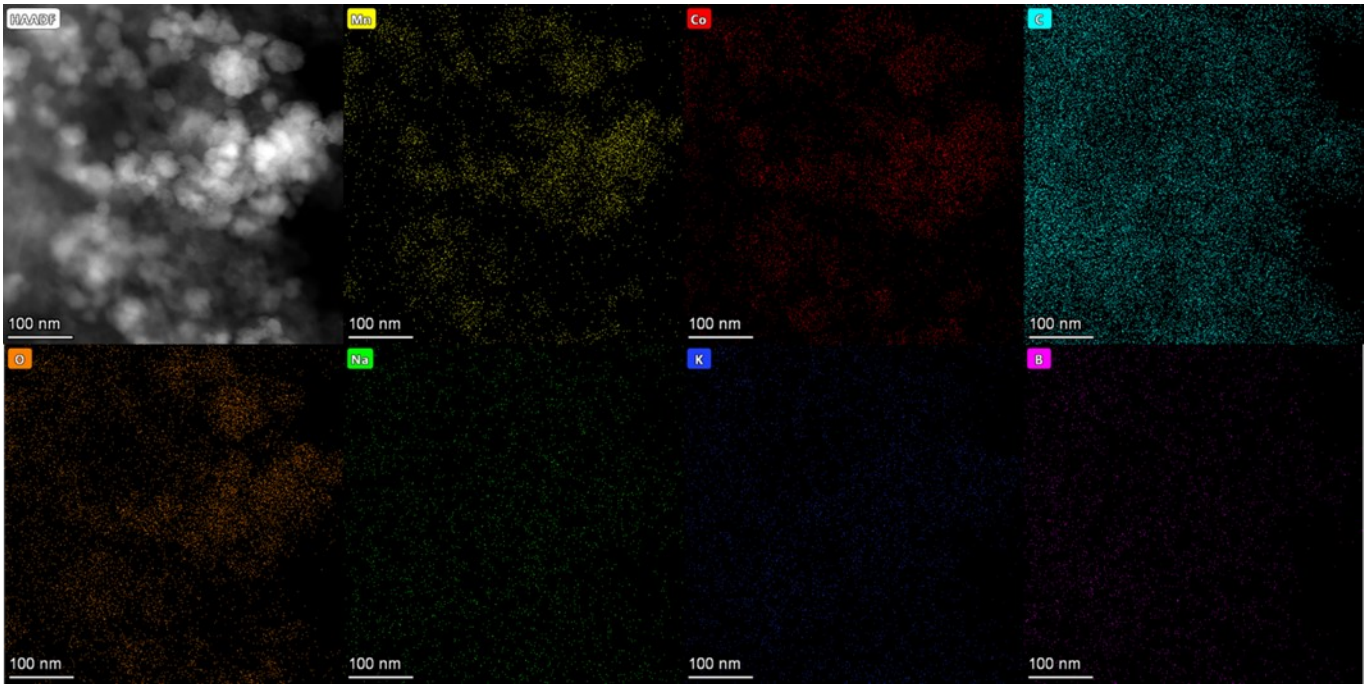

Figure S4. HAADF-TEM and EDS elemental mapping image of MCS electrode after durability test.

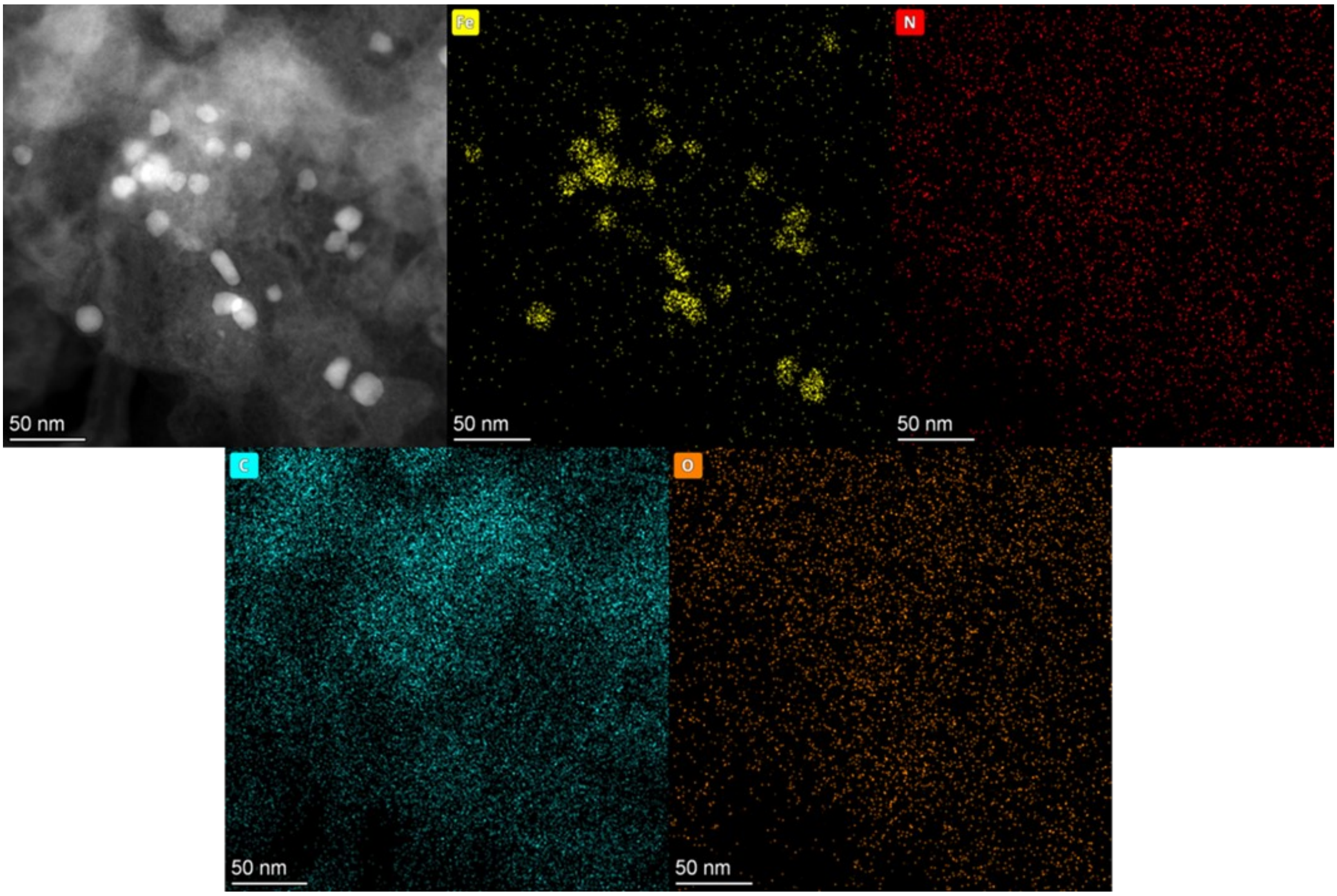

Figure S5. HAADF-TEM and EDS elemental mapping image of pristine Fe-N-C electrode.

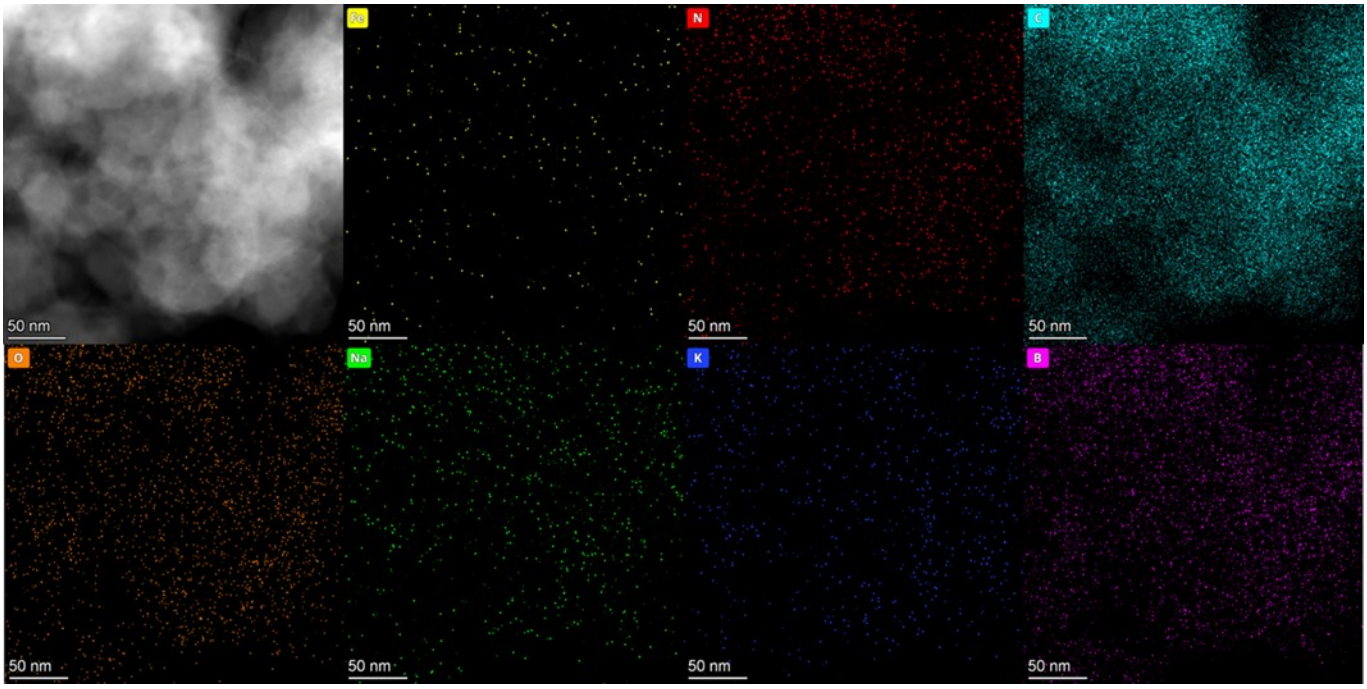

Figure S6. HAADF-TEM and EDS elemental mapping image of Fe-N-C electrode after durability test.

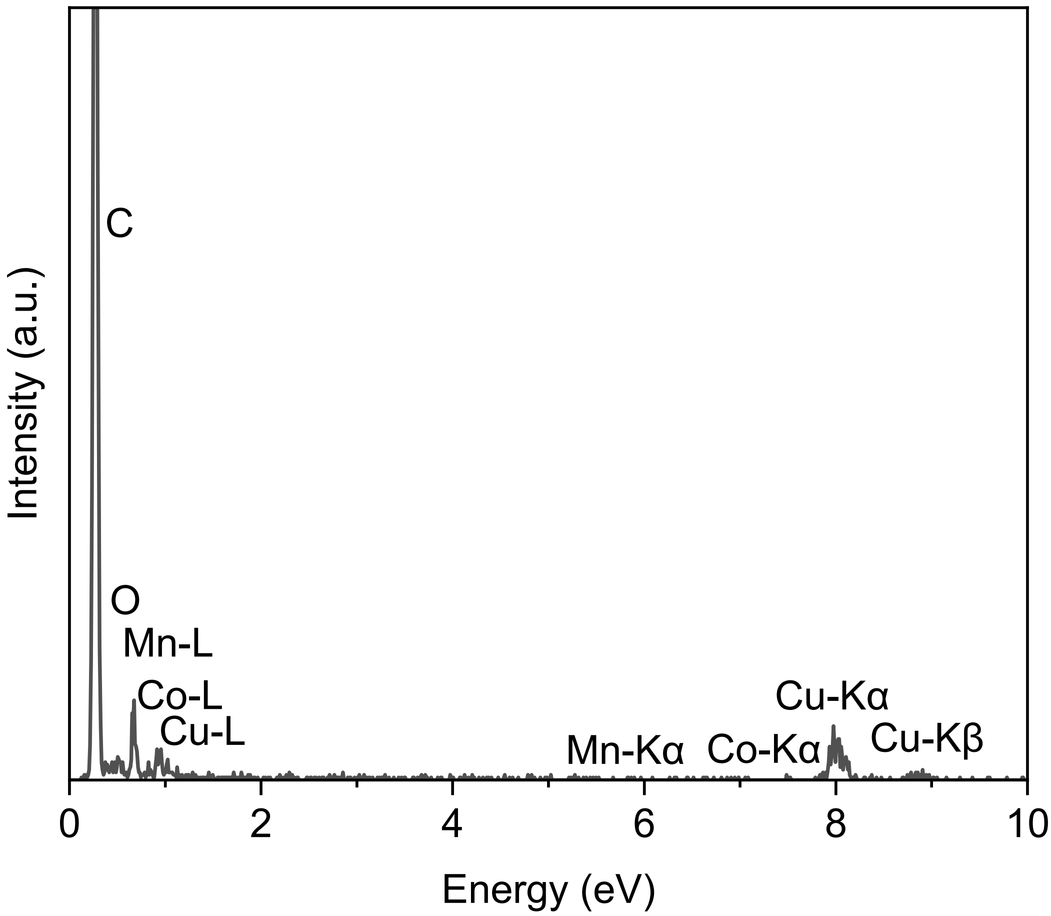

Figure S7. EDS elemental spectrum of pristine LMCO electrode.

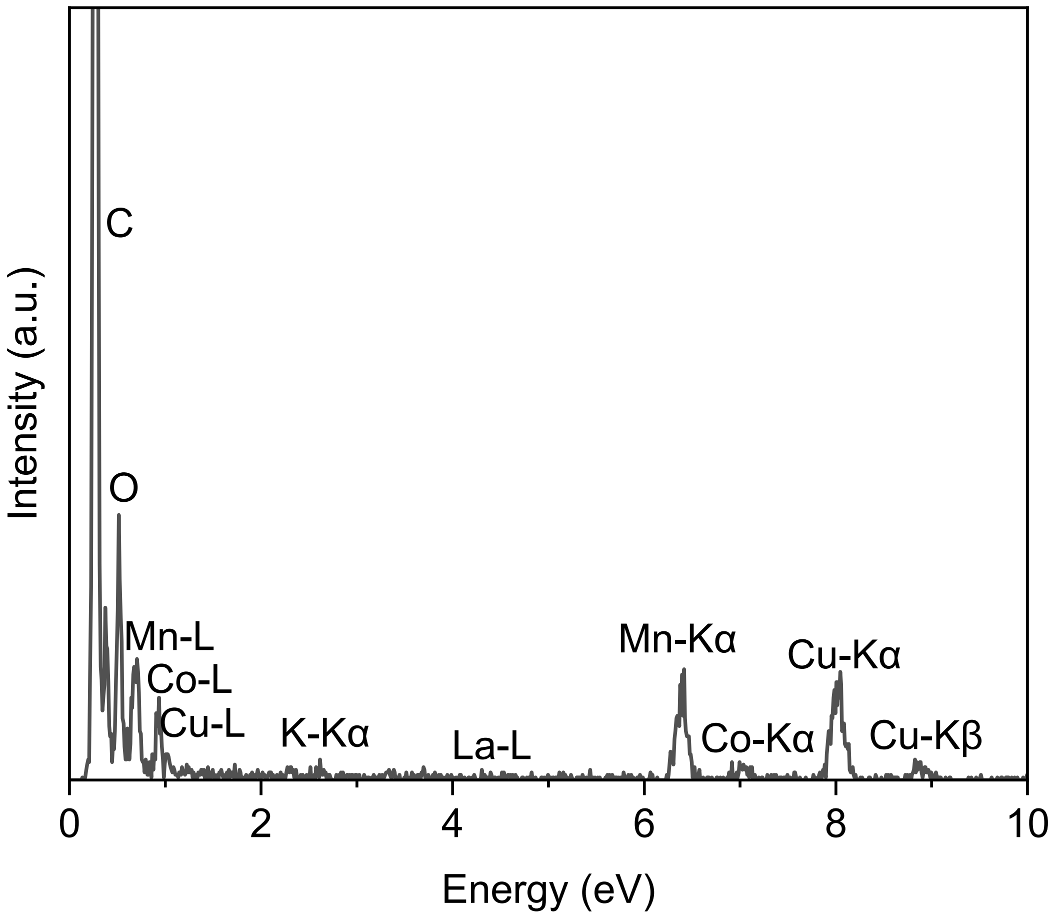

Figure S8. EDS elemental spectrum of LMCO electrode after durability test.

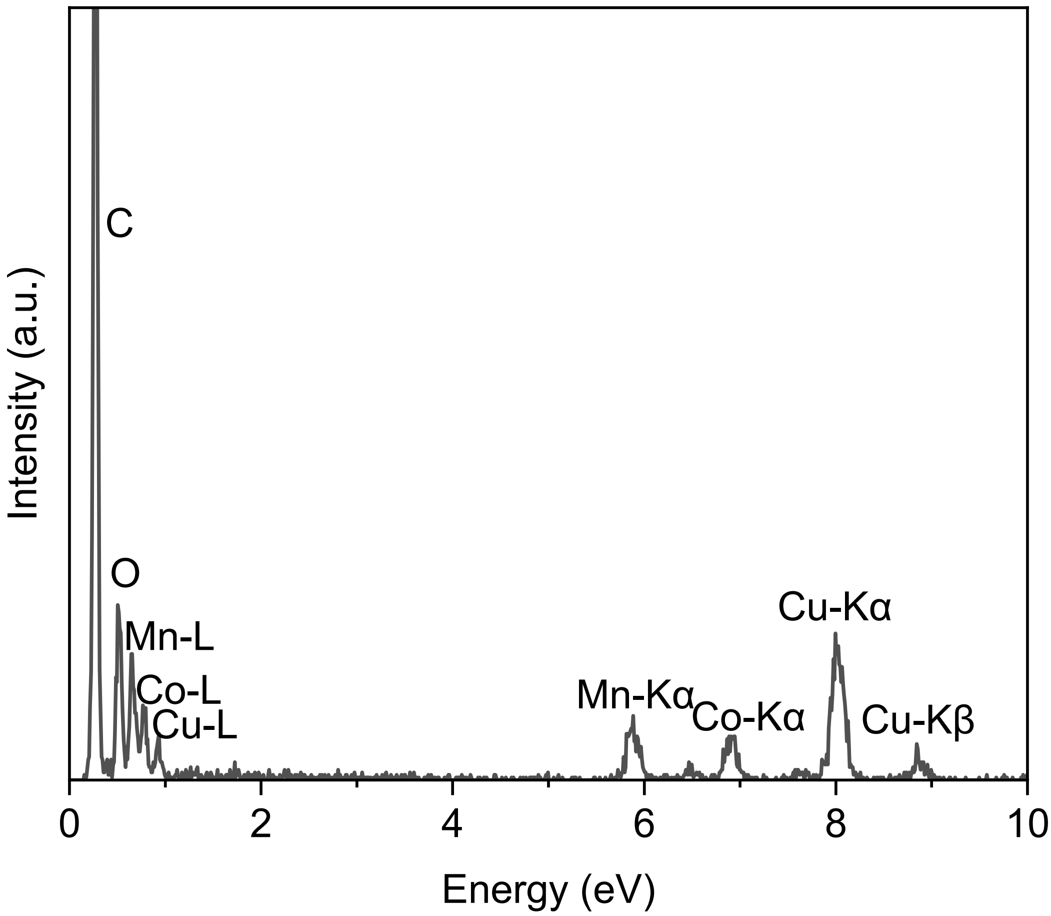

Figure S9. EDS elemental spectrum of pristine MCS electrode.

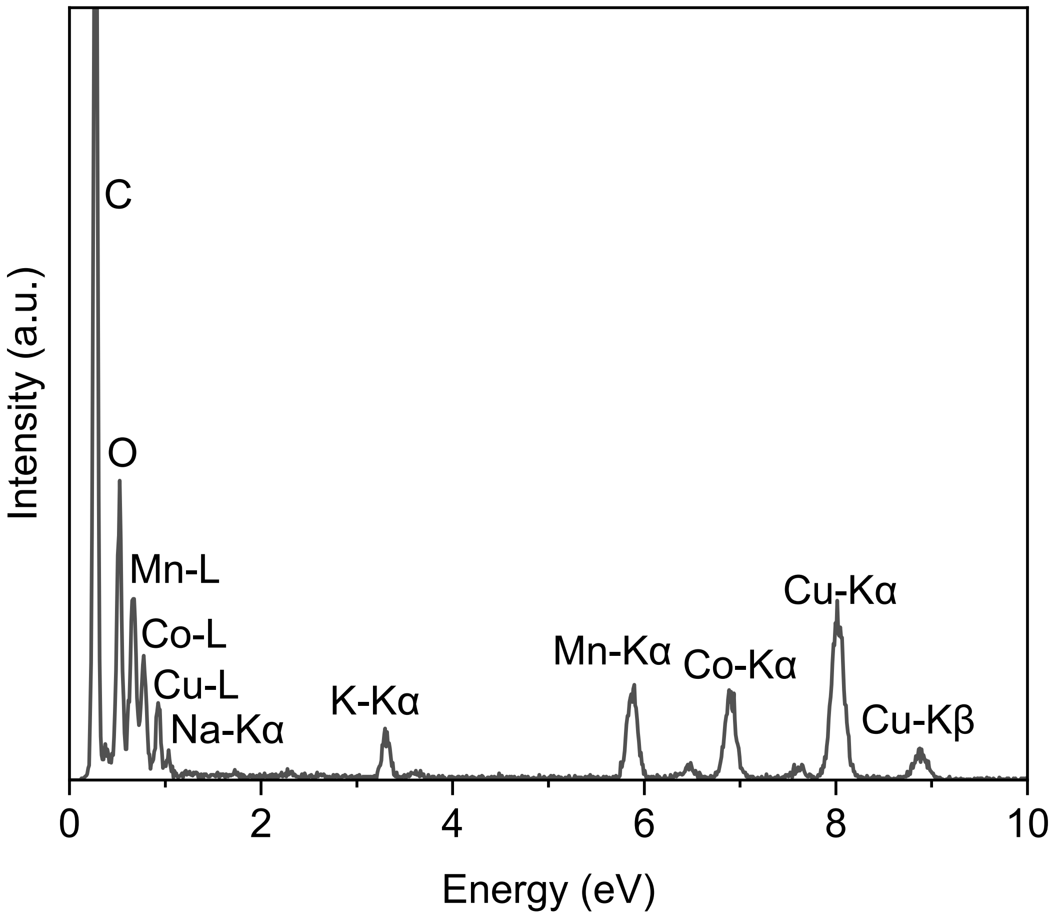

Figure S10. EDS elemental spectrum of MCS electrode after durability test.

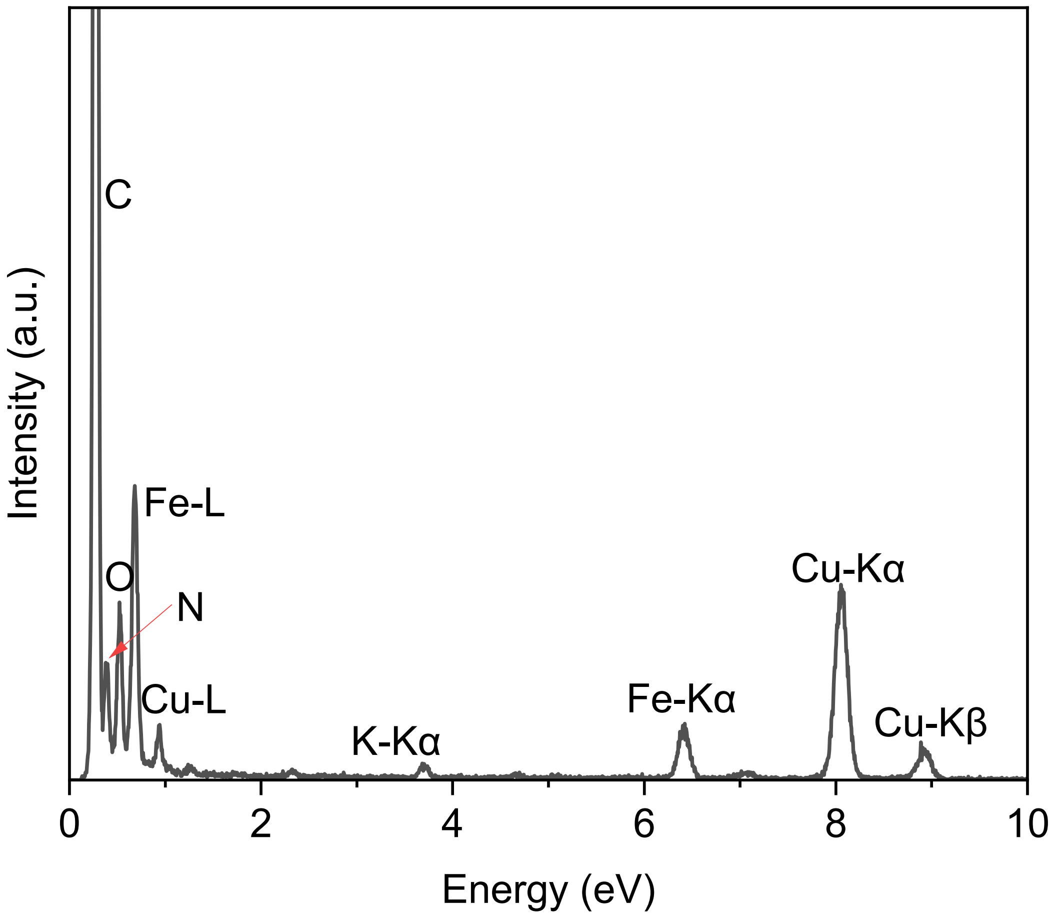

Figure S11. EDS elemental spectrum of pristine Fe-N-C electrode.

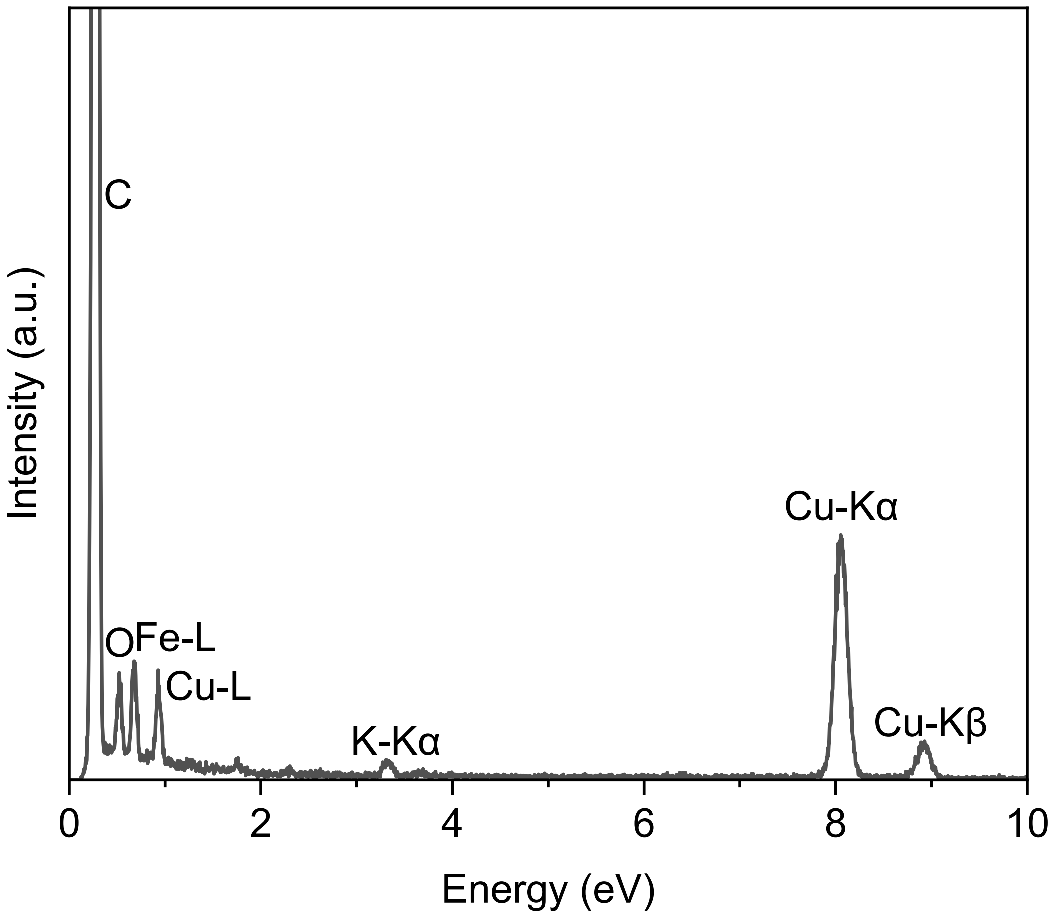

Figure S12. EDS elemental spectrum of Fe-N-C electrode after durability test.

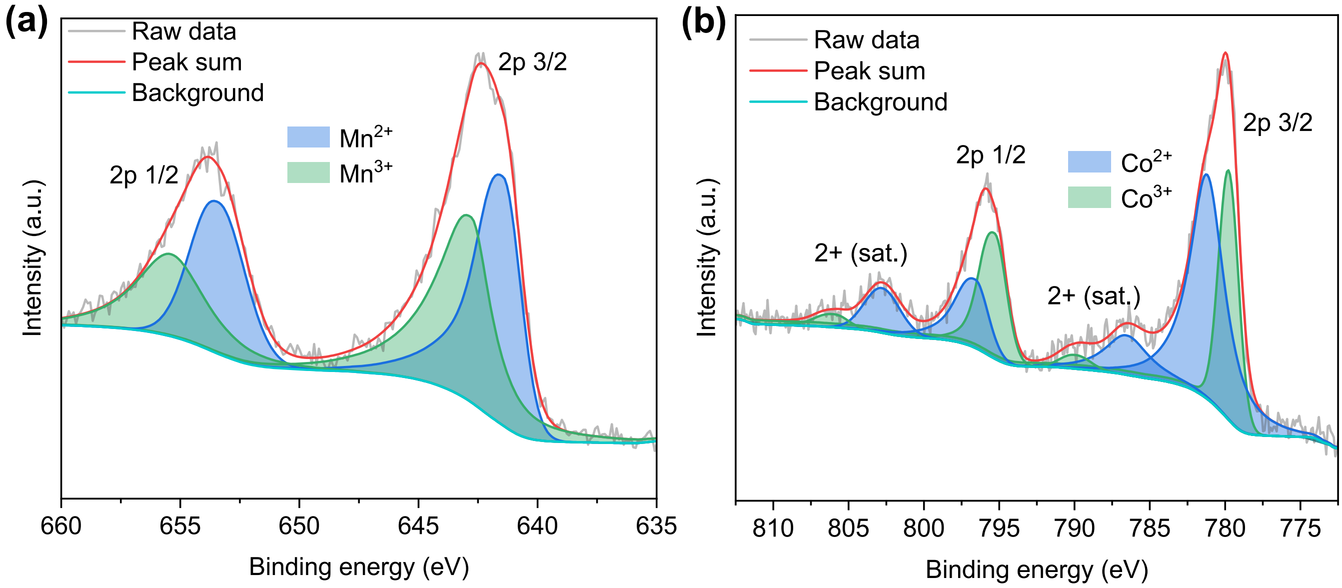

Figure S13. XPS high-resolution (a) Mn 2p, and (b) Co 2p spectra of pristine LMCO electrode.

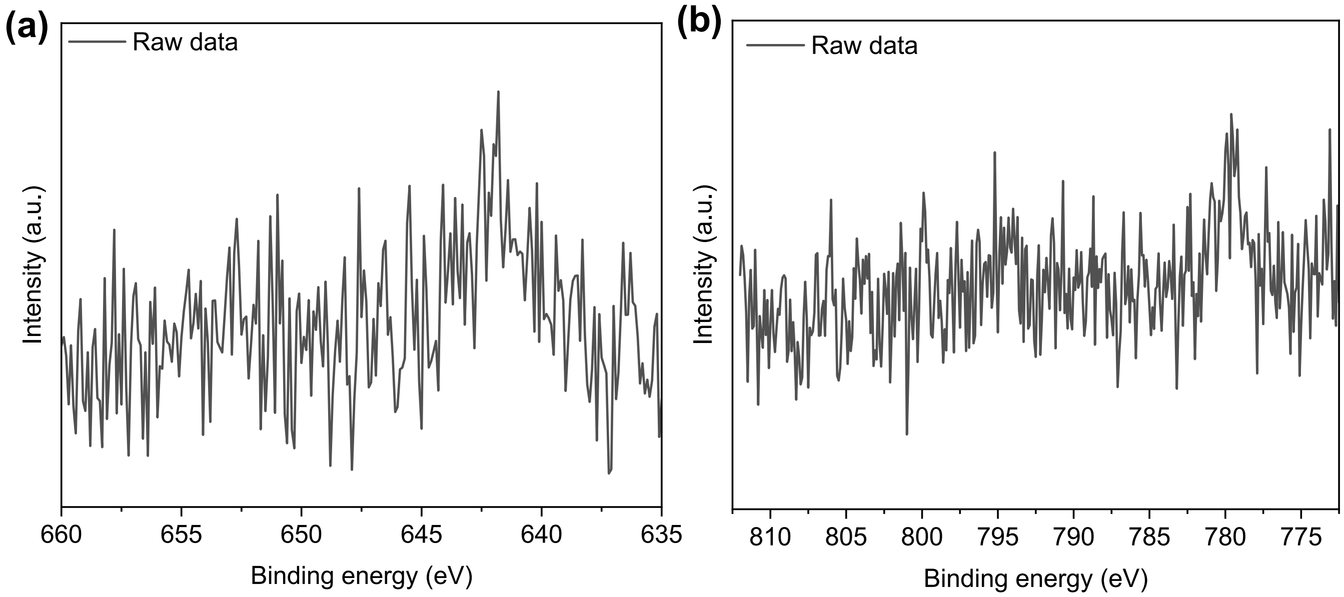

Figure S14. XPS high-resolution (a) Mn 2p, and (b) Co 2p spectra of LMCO electrode after durability test.

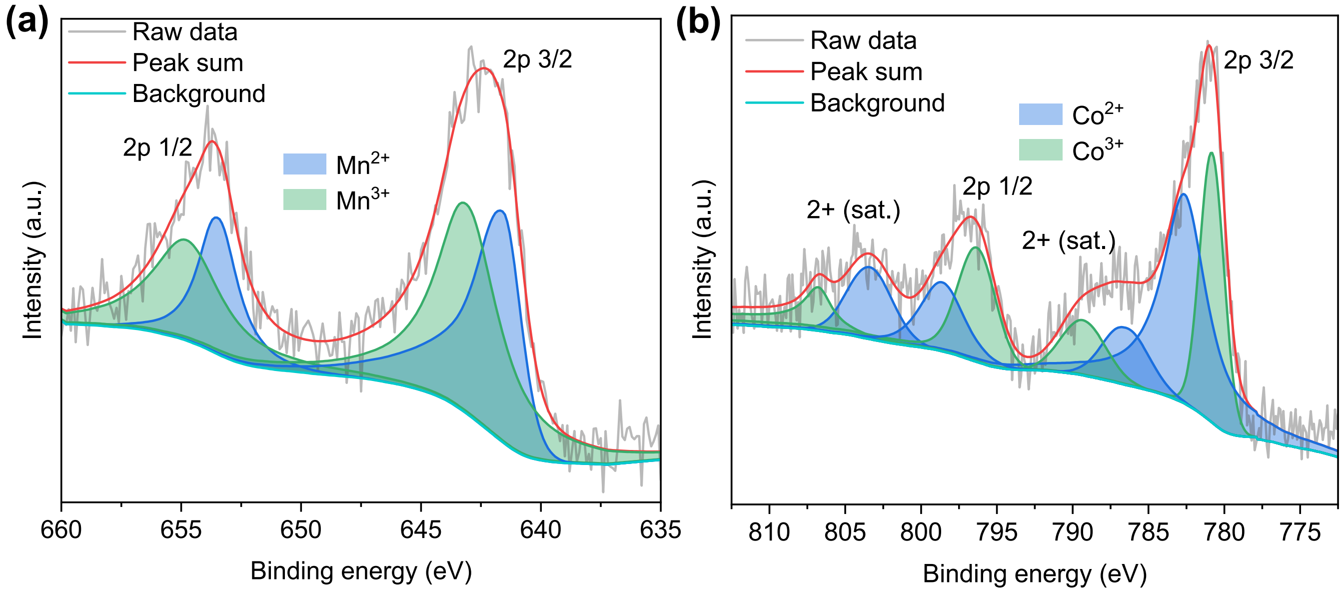

Figure S15. XPS high-resolution (a) Mn 2p, and (b) Co 2p spectra of pristine MCS electrode.

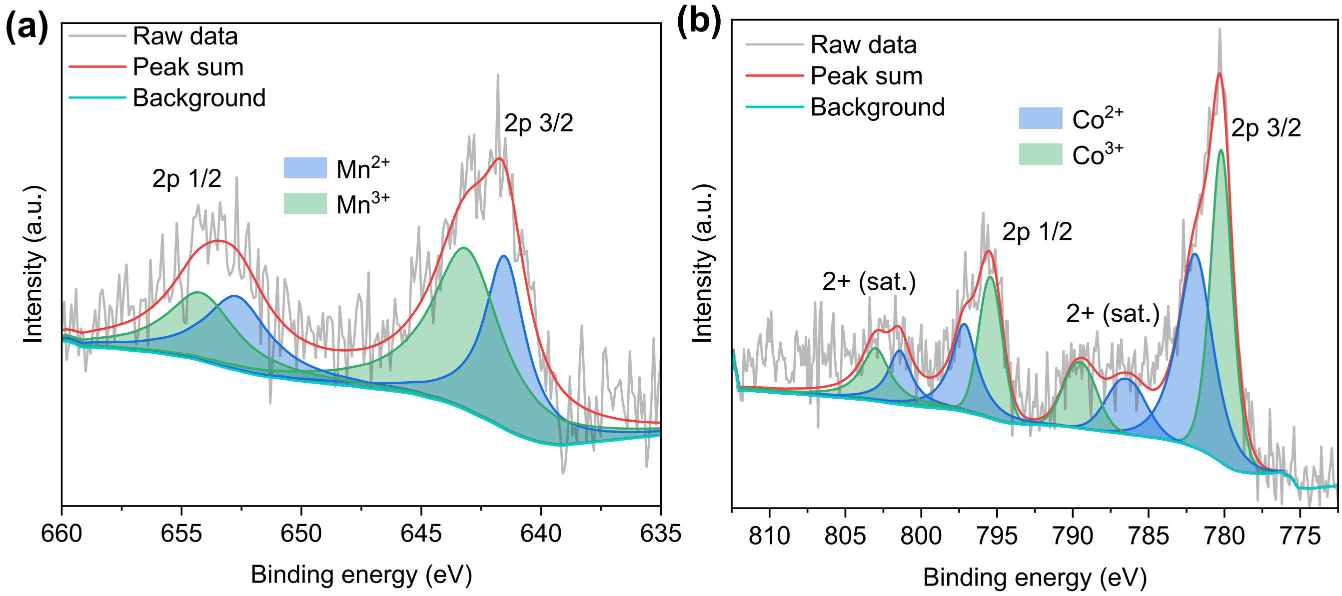

Figure S16. XPS high-resolution (a) Mn 2p, and (b) Co 2p spectra of MCS electrode after durability test.

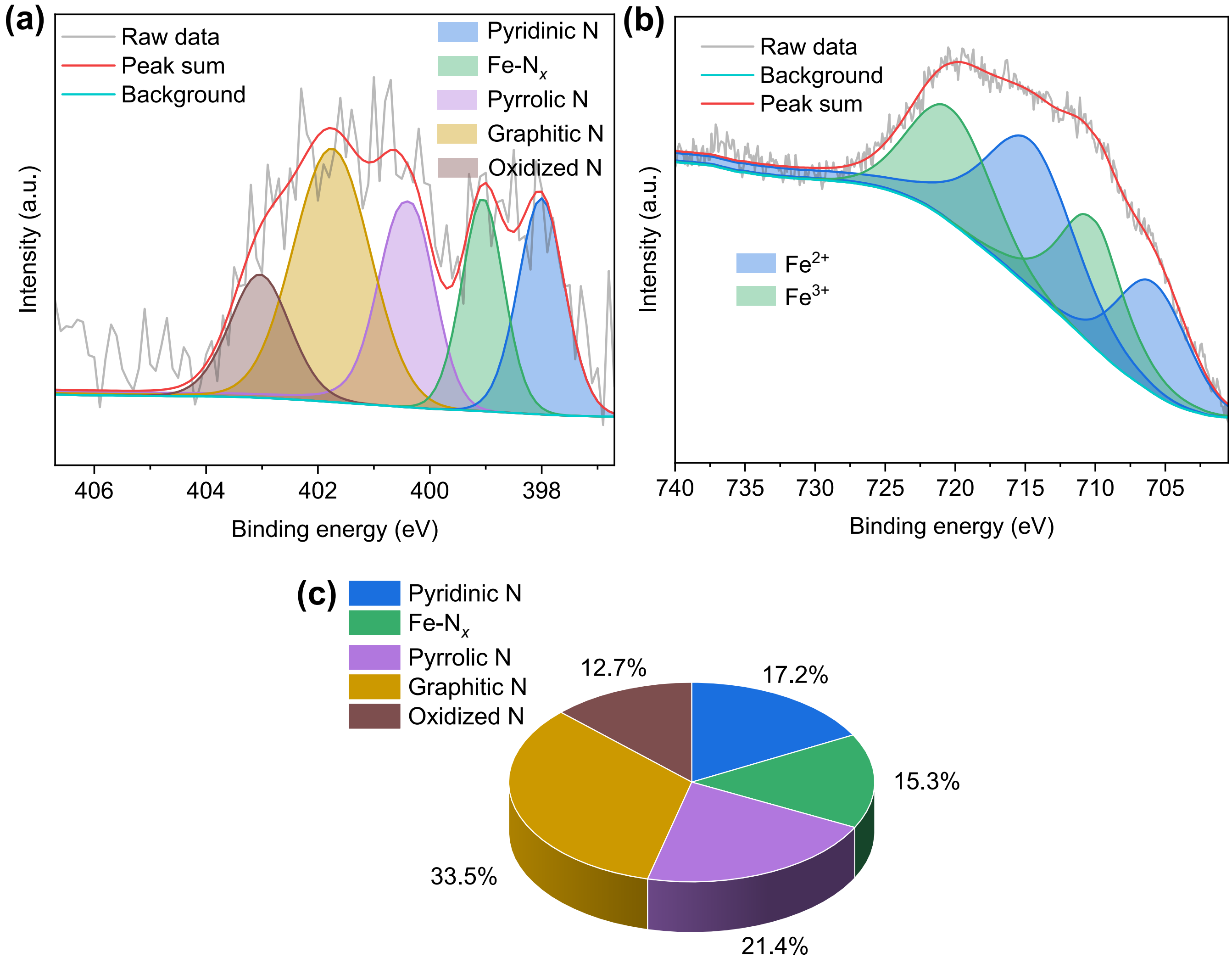

Figure S17. XPS high-resolution (a) N 1s, (b) Fe 2p spectra, and (c) comparison of different N species contents of pristine Fe-N-C electrode.

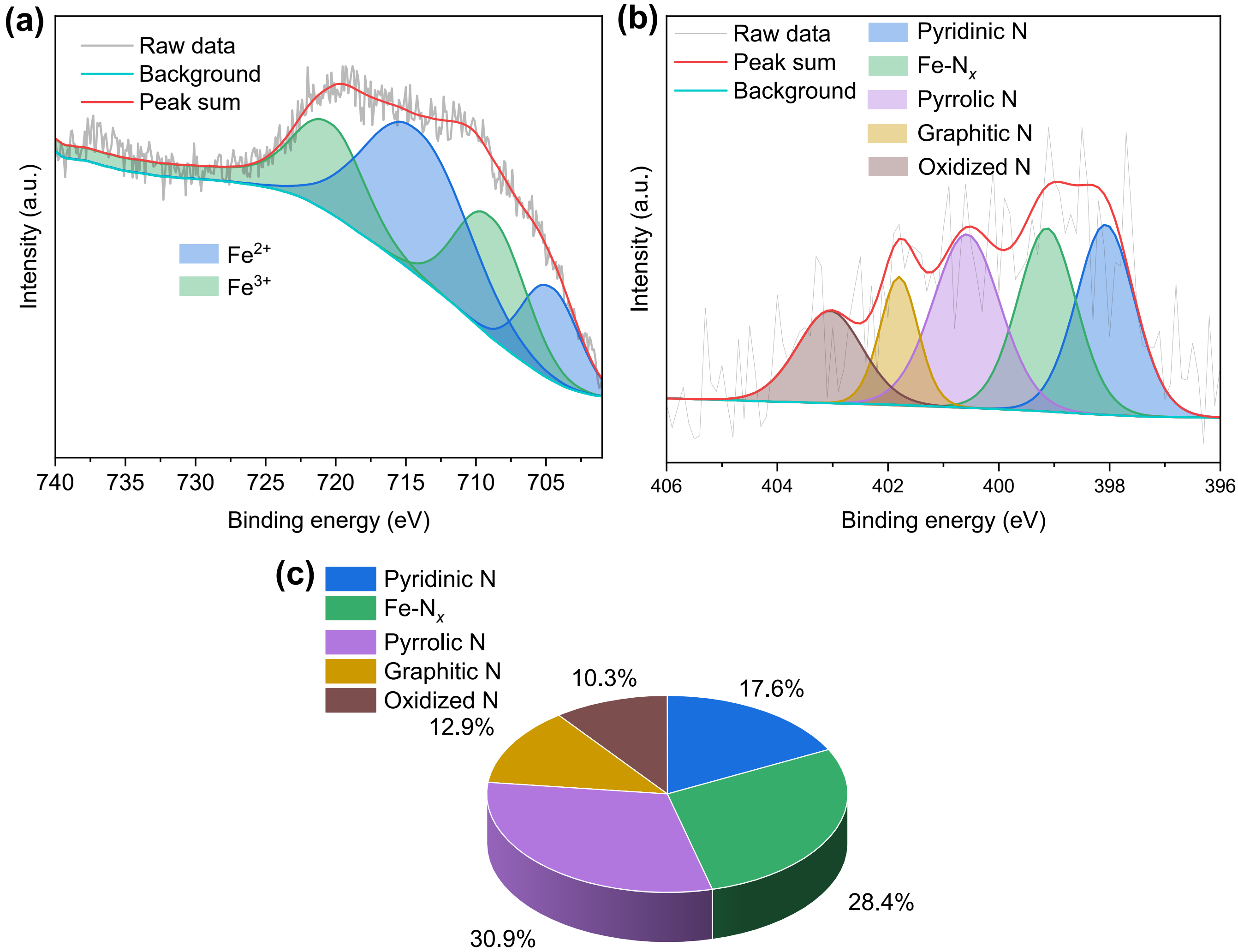

Figure S18. XPS high-resolution (a) N 1s, (b) Fe 2p spectra, and (c) comparison of different N species contents of Fe-N-C electrode after durability test.

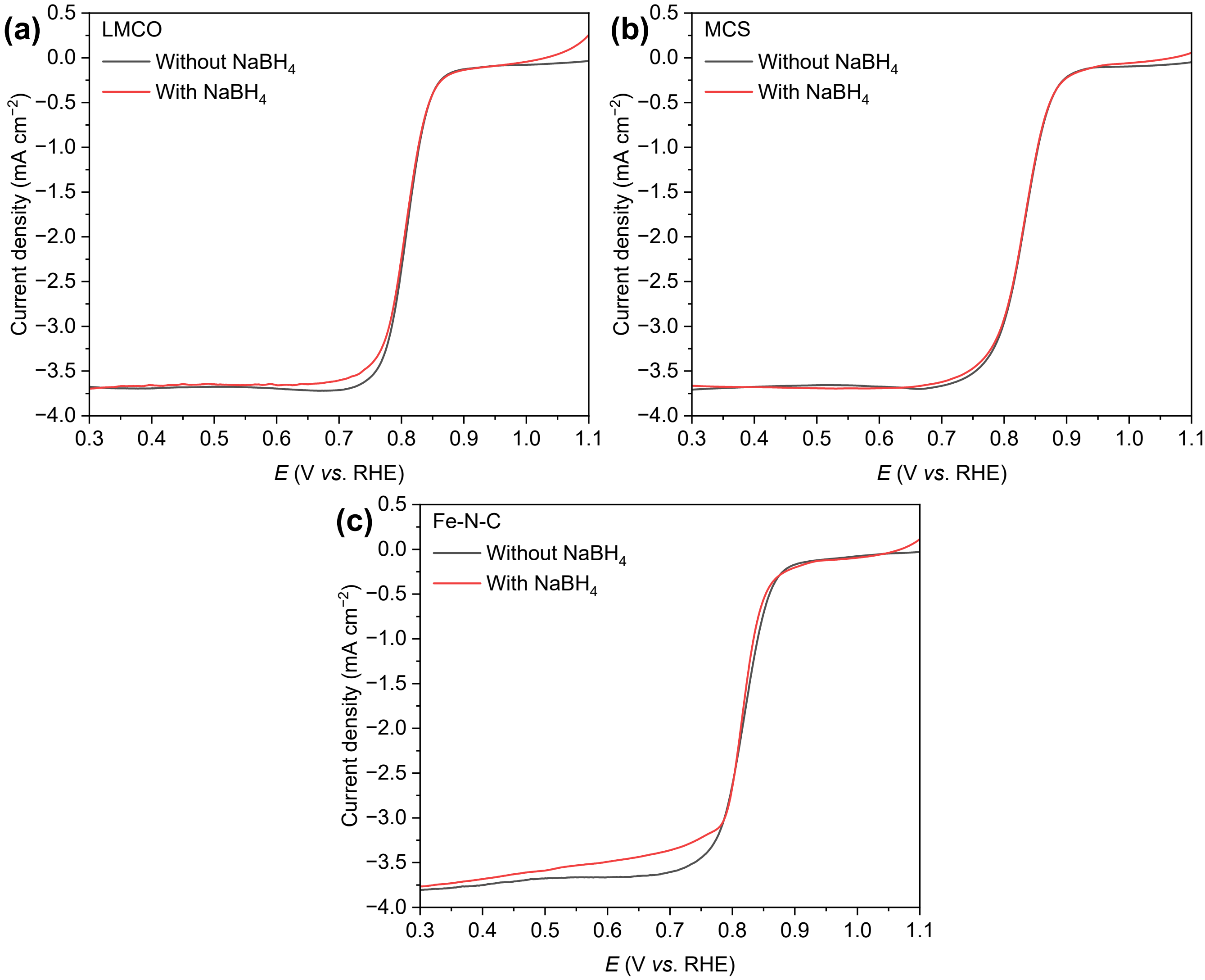

Figure S19. ORR polarization curves of (a) LMCO, (b) MCS, and (c) Fe-N-C at 25 °C, 20 mV s^{-1}, and 1600 rpm, in O_2-saturated 1 M KOH solution with or without 10 mM $NaBH_4$.

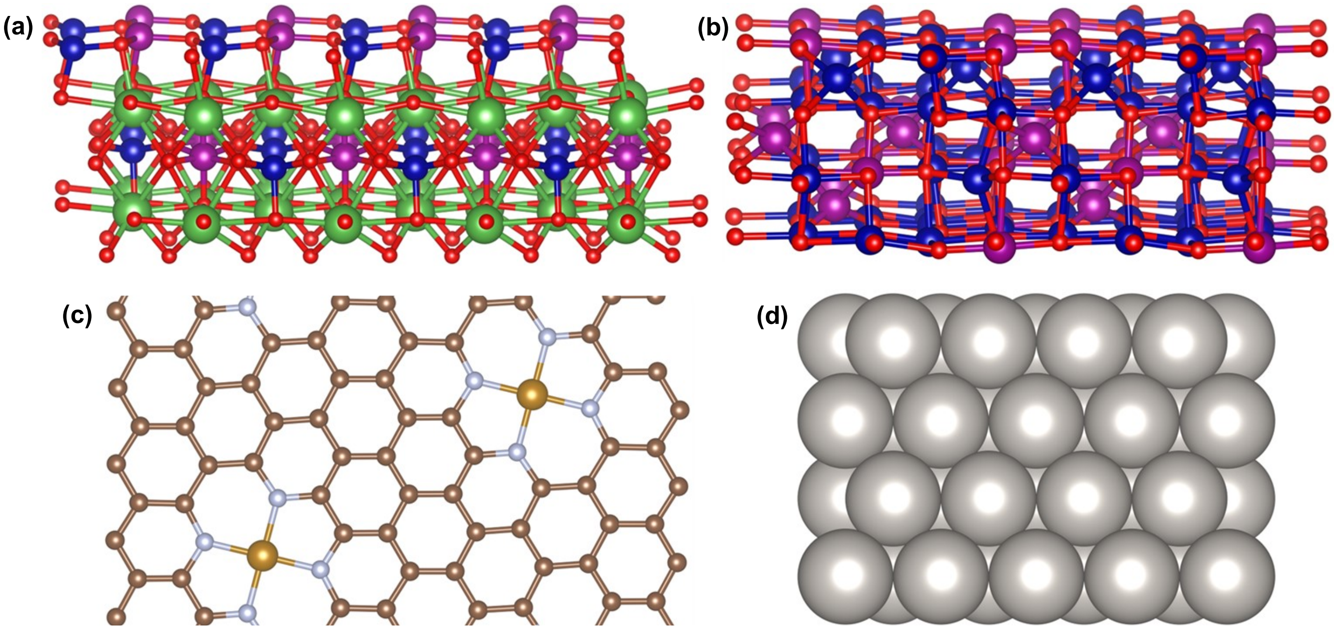

Figure S20. DFT optimized structure of (a) LMCO, (b) MCS, (c) Fe-N-C, and (d) Pt.

Table S1. Textural properties of the catalysts.

Sample	S_{BET} ($m^2\ g^{-1}$)	S_{micro} ($m^2\ g^{-1}$)	S_{meso} ($m^2\ g^{-1}$)	Total pore volume ($m^2\ g^{-1}$)
LMCO	1451	910	541	2.24
MCS	1538	985	553	2.59
Fe-N-C	734	427	307	0.61

Table S2. The comparison of the single cell performance of representative studies.

Anode catalyst	Membrane	Cathode catalyst	Oxidant	Peak power density (mW cm^{-2})	Ref.
Co-W-B	Membraneless	$LaNi_{0.9}Ru_{0.1}O_3$/CNT	Air	500	[1]
Pd/C + Ni	Nafion® 117	Pt/C	H_2O_2	630	[2]
Pd/C + Ni	Nafion® 117	Pt/C	H_2O_2	890	[3]
PdNi/C	Nafion® 117	Pt/C	H_2O_2	630	[4]
CoO	Nafion® 211	RuO_2	H_2O_2	425	[5]
Pd/C + Ni	Nafion® 117	Pt/C	H_2O_2	580	[6]
Pt/C	Nafion® 117	Pt/C	H_2O_2	800	[7]
PteAu/C	Nafion® 117	Pt/C	H_2O_2	345	[8]
Ni+Pd/C	Nafion®	Pt/C	H_2O_2	590	[9]
AB_5 alloy	Nafion® 117	Pt/C	H_2O_2	352	[10]
AB_5 alloy	Nafion® 117	Pd/C	H_2O_2	589	[11]
Ni particle on Ni felt	Nafion® 117	Pt/C	H_2O_2	446	[12]
Pd−Ni/N-rGO	Nafion® 117	Pt/C	H_2O_2	353.84	[13]
Core (Ni)-Shell (Pd)/rGP1	Nafion®	Pt/C	H_2O_2	339.1	[14]
Pt/[$TaOPO_4$/VC]	Nafion® 117	Pt/C	H_2O_2	360	[15]
nanoporous Au	Nafion® 212	nanoporous Au	H_2O_2	390	[16]
Au	Nafion®	Pd	H_2O_2	680	[17]
Au	Nafion®	Pd	H_2O_2	680	[17]
Au	Nafion®	Pd	H_2O_2	1500	[18]
Zn foil	Nafion® 117	Pt	H_2O_2	528	[19]
Ni + Pt/C	Nafion® 212	Pd	H_2O_2	665	[20]
Ni + Pd/C	Polymer electrolyte membrane	Pt/C	H_2O_2	810	[21]
Pt–Ru	Nafion® 115	Pd–Ir	H_2O_2	345	[22]
Pd/C	A-006 (AEM)	Fe–Co Hypermec™K14	O_2	890	[23]
Ni/C	Nafion® 212	Pt black	O_2	460	[24]
Pd/C + Ni	triphosphate chitosan hydrogel	Pt/C	O_2	685	[25]
Pd/C + Ni	cross-linked chitosan	Pt/C	O_2	450	[26]
Ni-based thin film	chitosan hydrogel (AEM)	Pt/C	O_2	429	[27]
Co–pyrrole/MPC	Nafion® 112	Pt/C	O_2	325	[28]
Pd decorated Ni–Co/C	AEM	Fe–Co/C	O_2	761	[29]

CoO	polymer fiber membrane	$LaNiO_3$	O_2	663	[30]
$Co(OH)_2$-PPy-BP	Nafion® 212	CoO Nanorods/C	O_2	410	[31]
$Co(OH)_2$-PPy-BP	Co-PVA & PVA bilayer (AEM)	$Co(OH)_2$-PPy-BP	O_2	327	[32]
$Co(OH)_2$-PPy-BP	AEM	$Co(OH)_2$-PPy-BP	O_2	500	[33]
NiFe-2	Nafion® 117	Pt/C	H_2O_2	540	[34]
Ni@NiP	Nafion® 117	Pt/C	H_2O_2	474	[35]
Pt/C	Alkymer®	Mn-Co Spinel	O_2	1518	This work

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