Supplementary Information

From Binary to Ternary: NiFeM Alloys in Unified Electrodes for High Performance Anion-Exchange Membrane Water Electrolysis

Dae Hyun Lee[a,b,†], SungBin Park[c,†], Sungeun Heo[a,b], Min Seok Gi[d], Hyunjoon Lee[e], Eunwoo Seo[f], Junho Min[f], Heejin Lee[f], Jihun Cho[f], Ji Eun Park[d,*], Yung-Eun Sung[a,b]

[a]School of Chemical and Biological Engineering, Seoul National University, Seoul 08826, Republic of Korea

[b]Center for Nanoparticle Research, Institute for Basic Science (IBS), Seoul 08826, Republic of Korea

[c]Center for Hydrogen and Fuel Cells, Korea Institute of Science and Technology (KIST), Seoul 02792, Republic of Korea

[d]Graduate School of Convergence Technology and Energy, Tech University of Korea, Siheung-si, 15073, Republic of Korea

[e]Hydrogen Research Department, Korea Institute of Energy Research (KIER), Daejeon 34129, Republic of Korea

[f]Department of Chemical Engineering and Biotechnology, Tech University of Korea, Siheung-si, 15703, Republic of Korea

* Corresponding authors: jepark91@tukorea.ac.kr (J. E. Park)

Table S1. The Loading Table.

Sample name	Loading (mg/cm^2)
UE-NiFeCo-1	0.651
UE-NiFeCo-2	0.708
UE-NiFeCo-3	0.846
UE-NiFeCo-4	0.971
UE-NiFeCo-5	1.063
UE-NiFeCu-1	0.869
UE-NiFeCu-2	0.937
UE-NiFeCu-3	1.028
UE-NiFeCu-4	0.948
UE-NiFeCu-5	0.937
UE-NiFeLa-1	1.063
UE-NiFeLa-2	1.166
UE-NiFeLa-3	1.406
UE-NiFeLa-4	1.68
UE-NiFeLa-5	1.92
UE-NiFe	0.651

Table S2. The comparison in atomic ratios (Ni: Fe: Co) of UE-NiFeCo-1, 2, 3, 4, and 5.

Sample name	Ni	Fe	Co
UE-NiFeCo-1	1	0.78	0.60
UE-NiFeCo-2	1	0.78	0.87
UE-NiFeCo-3	1	0.82	1.23
UE-NiFeCo-4	1	0.68	1.74
UE-NiFeCo-5	1	0.63	2.00

Table S3. The comparison in atomic ratios (Ni: Fe: Cu) of UE-NiFeCu-1, 2, 3, 4, and 5.

Sample name	Ni	Fe	Cu
UE-NiFeCu-1	1	0.84	0.64
UE-NiFeCu-2	1	0.91	0.96
UE-NiFeCu-3	1	0.97	1.28
UE-NiFeCu-4	1	0.96	1.67
UE-NiFeCu-5	1	0.87	2.03

Table S4. The comparison in atomic ratios (Ni: Fe: La) of UE-NiFeLa-1, 2, 3, 4, and 5.

Sample name	Ni	Fe	La
UE-NiFeLa-1	1	0.93	0.64
UE-NiFeLa-2	1	0.91	1.00
UE-NiFeLa-3	1	0.90	1.39
UE-NiFeLa-4	1	0.95	1.76
UE-NiFeLa-5	1	0.99	2.18

Table S5. The EIS fitting results.

Sample name	Rohm (Ω cm^2)	CPE-T	R (Ω cm^2)
AEMWE-NiFeCo	0.043204	0.3104	0.018598
AEMWE-NiFeCu	0.05847	0.64871	0.0992
AEMWE-NiFeLa	0.050265	0.17644	0.045912
AEMWE-NiFe	0.048692	0.21178	0.022761
NiFe-NP	0.09771	0.11919	0.0938

Figure S1. SEM–EDS elemental mapping images of the UE-NiFeCo sample. (a) Combined EDS mapping showing the overall distribution of O, Ni, Fe and Co. (b-e) Individual EDS elemental mappings of (b) O, (c) Ni, (d) Fe, and (e) Co.

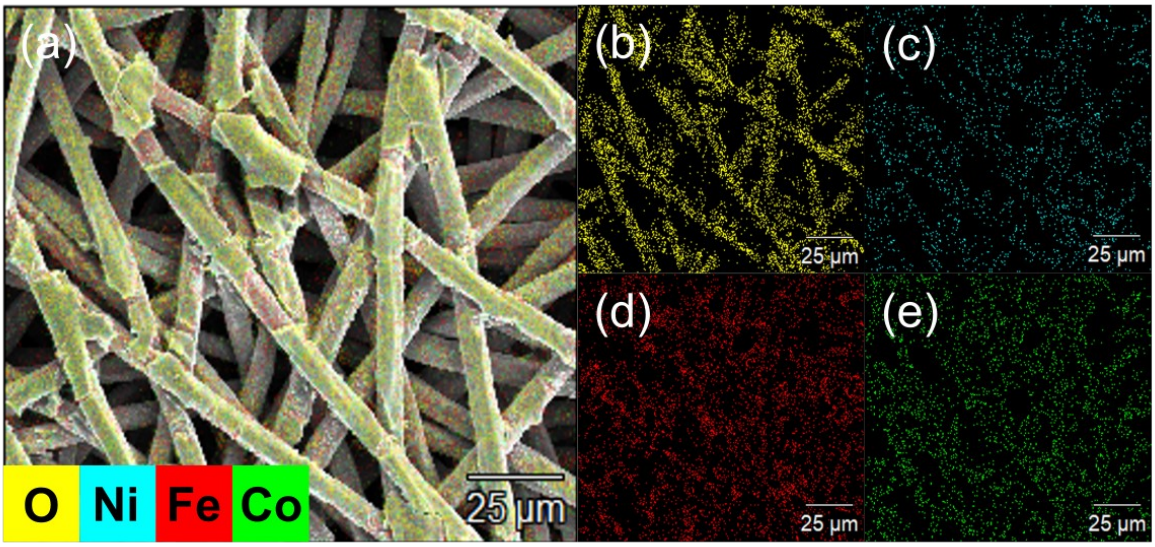

Figure S2. SEM–EDS elemental mapping images of the UE-NiFeCu sample. (a) Combined EDS mapping showing the overall distribution of O, Ni, Fe and Cu. (b-e) Individual EDS elemental mappings of (b) O, (c) Ni, (d) Fe, and (e) Cu.

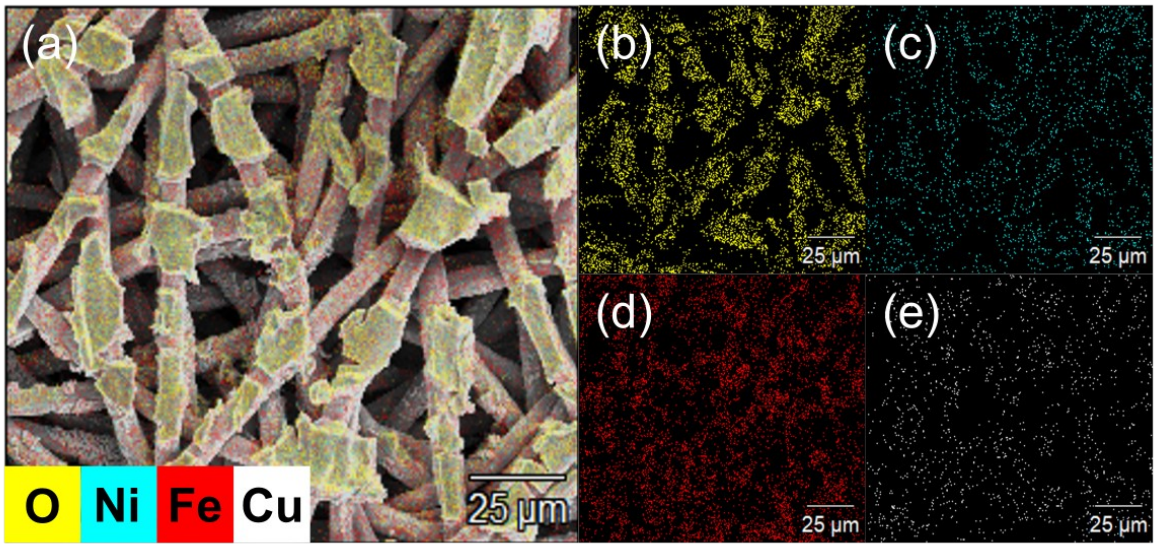

Figure S3. SEM–EDS elemental mapping images of the UE-NiFeLa sample. (a) Combined EDS mapping showing the overall distribution of O, Ni, Fe and La. (b-e) Individual EDS elemental mappings of (b) O, (c) Ni, (d) Fe, and (e) La.

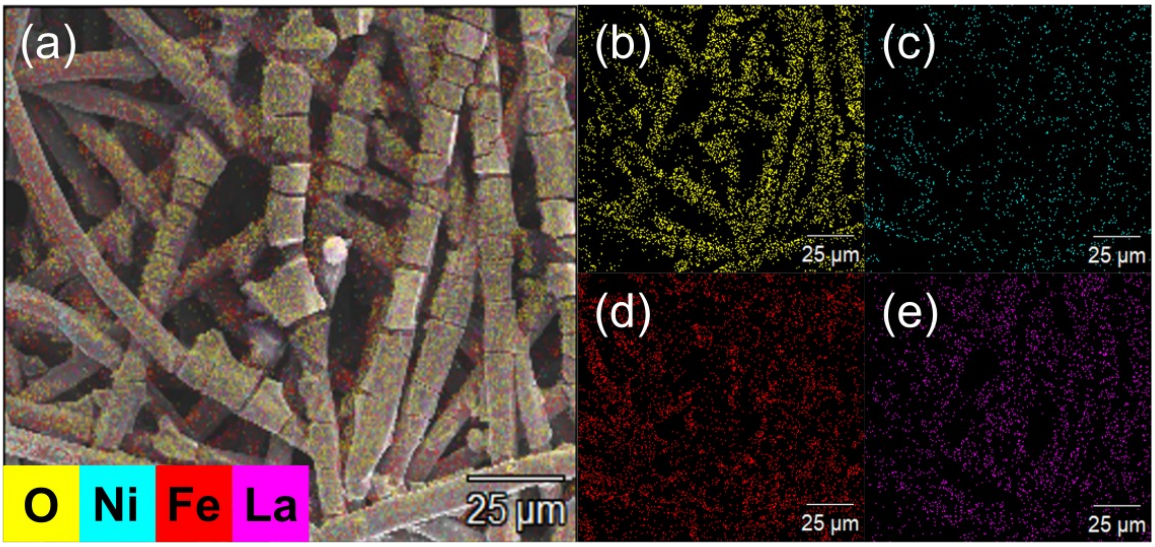

Figure S4. HR-TEM images of (a) UE-NiFeCo, (b) UE-NiFeCu, and (c) UE-NiFeLa.

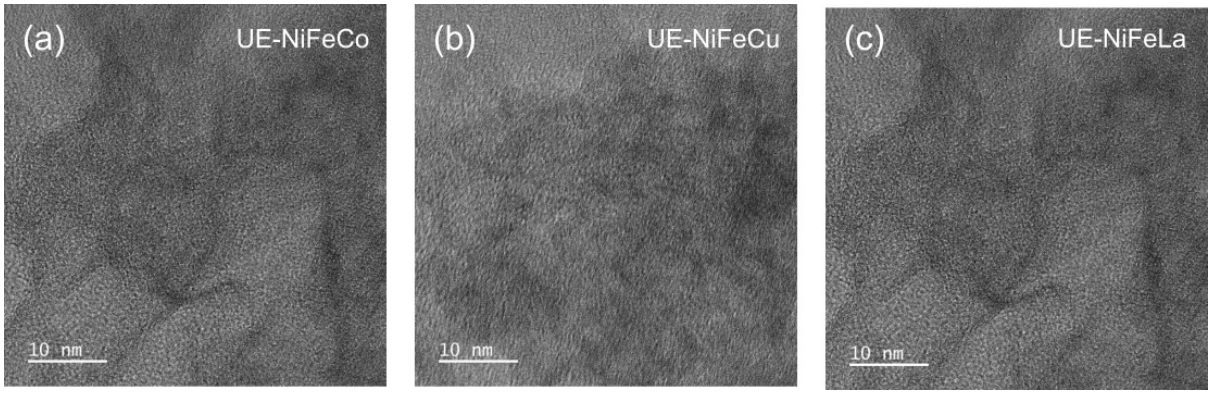

Figure S5. TEM-EDS elemental mapping images of the electrodeposited samples. (a) Combined elemental mapping of the UE-NiFeCo sample. (b-d) Individual elemental mappings of (b) Ni, (c) Fe, and (d) Co. (e) Combined elemental mapping of the UE-NiFeCu sample. (f-h) Individual elemental mappings of (f) Ni, (g) Fe, and (h) Cu. (i) Combined elemental mapping of the UE-NiFeLa sample. (j-l) Individual elemental mappings of (j) Ni, (k) Fe, and (l) La.

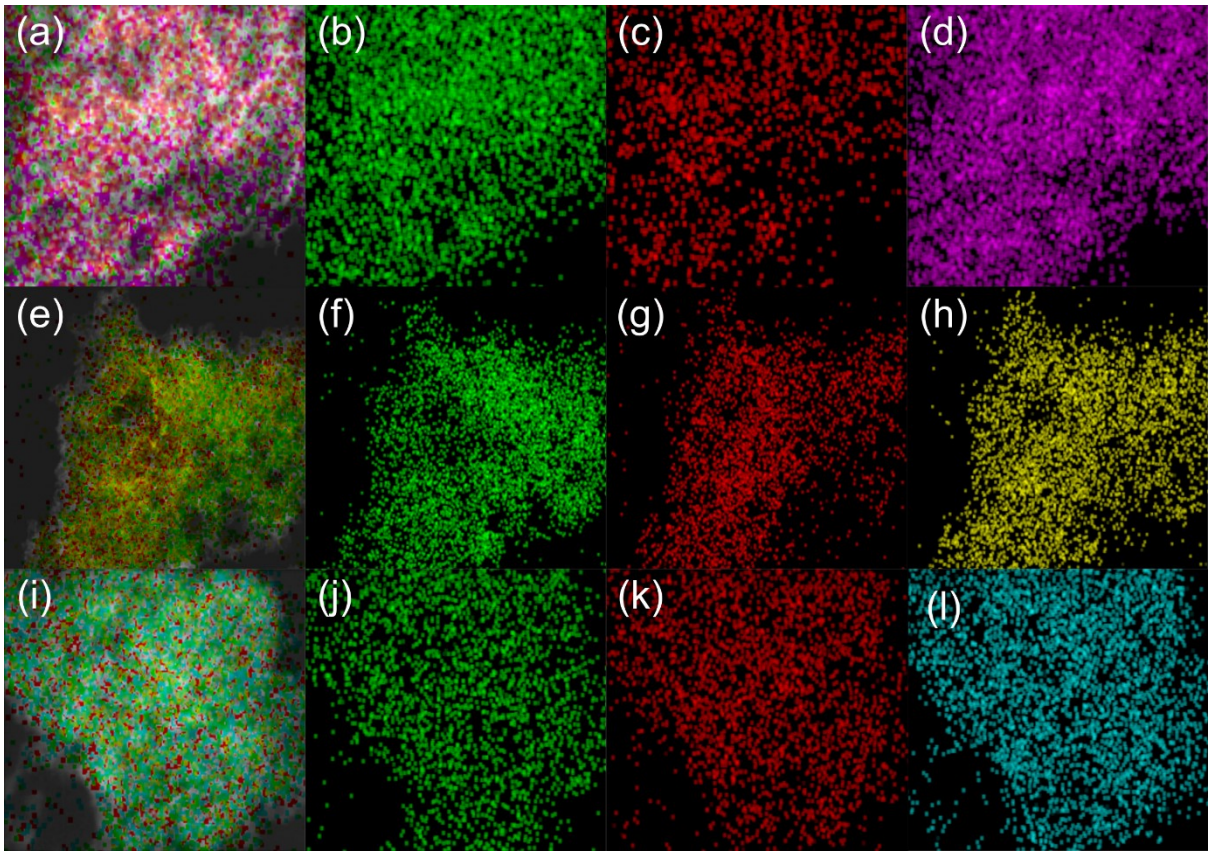

Figure S6. XRD spectra of the three electrodes (UE-NiFeCo, UE-NiFeCu, and UE-NiFeLa)

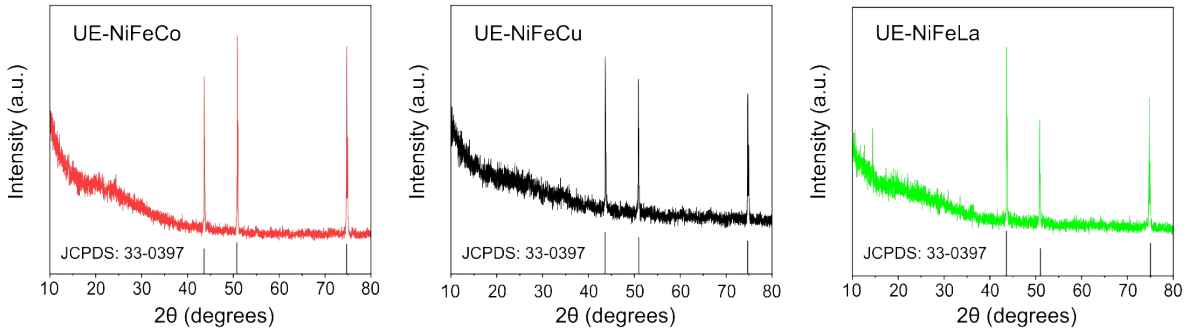

Figure S7. XPS O 1s spectra of (a) NiFeCo (b) NiFeCu (c) NiFeLa.

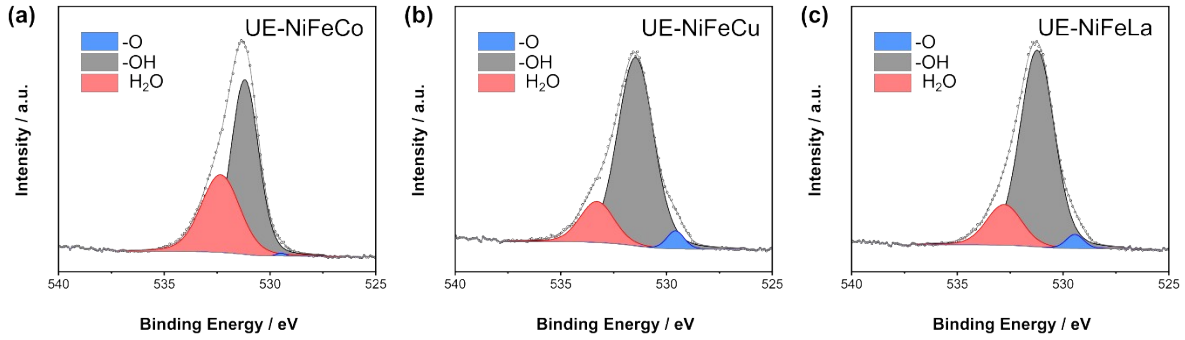

Figure S8. FE-SEM of UE-NiFe

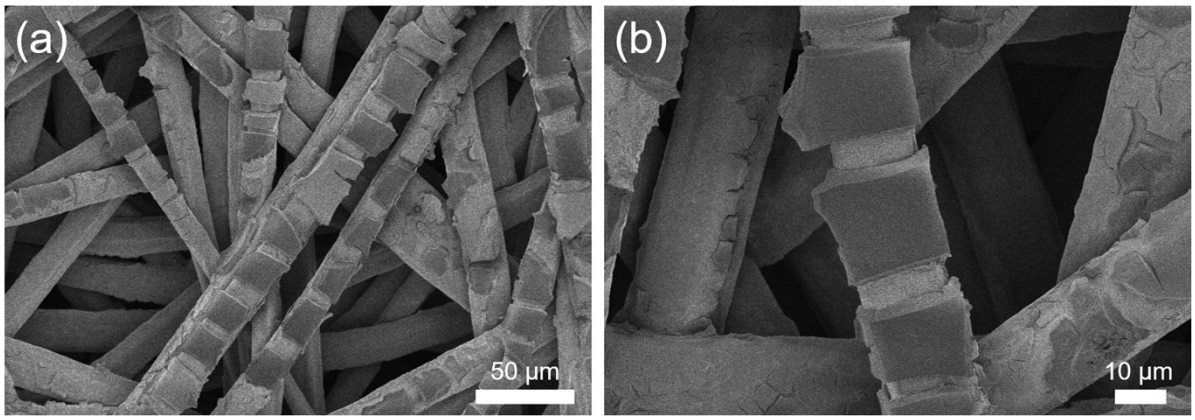

Figure S9. FE-SEM images of NiFe-NP

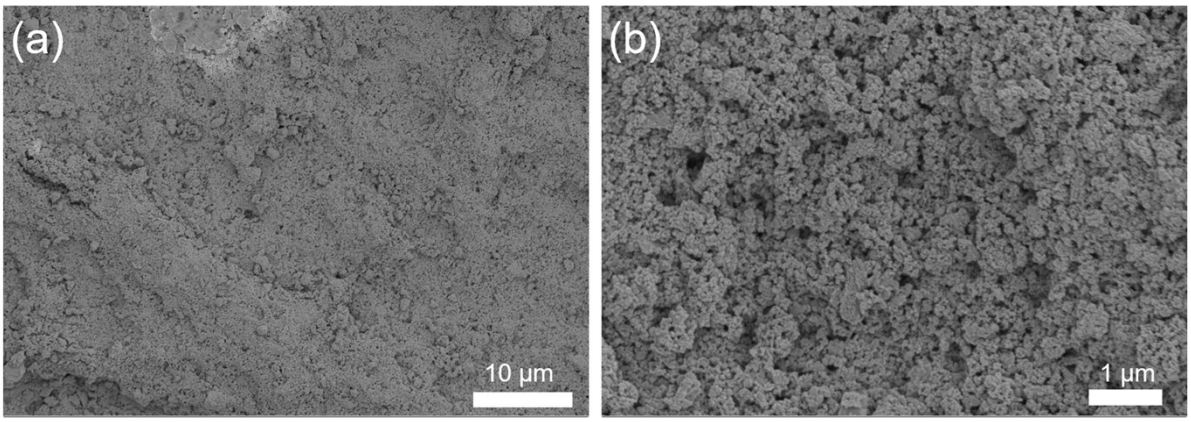

Figure S10. (a) The linear relation between the double-layer charging current and the scan rate. Cyclic voltammetry (CV) curves of (b) UE-NiFeCo, (c) UE-NiFeCu, (d) UE-NiFeLa, (e) UE-NiFe, and (f) NiFe-NP recorded at various scan rates ranging from 10 mV s^{-1} to 50 mV s^{-1}.

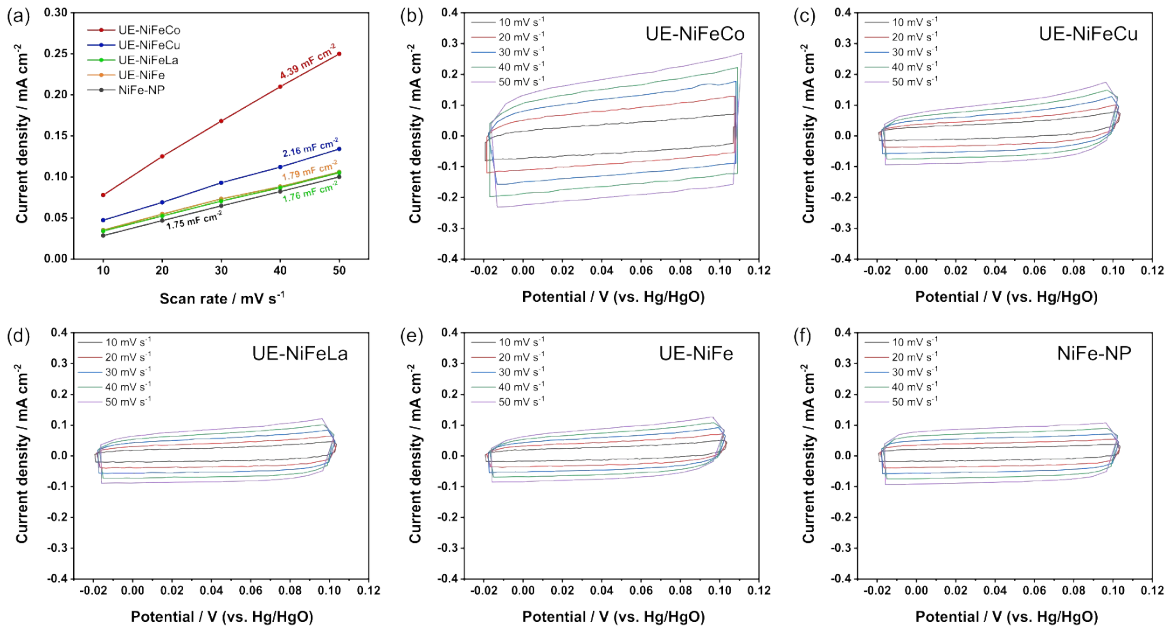

Figure S11 Stability test of UE-NiFeCo at a constant current density of 100 mA cm^{-2} for 1,000 h

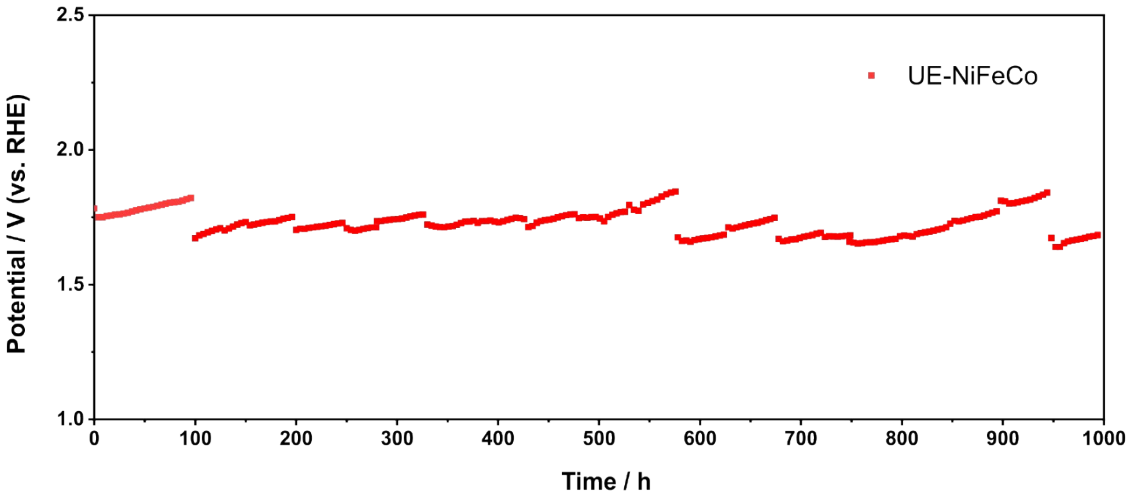

Figure S12. FE-SEM images of UE-NiFeCo after stability test conducted at a constant current density of 100 mA cm^{-2} for 1,000 h