

Supplementary information

FeCoNiRhPt High-Entropy Alloy Catalyst Synthesized via Atmospheric Plasma-Ionic Liquid Reduction for Efficient Oxygen Evolution Reaction

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Figure S2. Schematic Illustration of the wet plasma reduction strategy for the synthesis process of FeCoNiRhPt HEA NPs.

Figure S3. Cyclic voltammograms of FeCoNiRhPt and RuO₂ catalysts.

Figure S4. High-resolution X-ray photoelectron spectra (XPS) of the FeCoNiRhPt high-entropy alloy for (a) Fe 2p, (b) Co 2p, (c) Ni 2p, (d) Rh 3d, (e) Pt 4f, (f) O 1s, (g) C 1s, and (h) Cl 2p.

Tables S1 to S3

Structural characterization

The basic properties of the constituent metals Fe, Co, Ni, Rh, and Pt, which are required for calculating the thermodynamic parameters of FeCoNiRhPt nanoparticles, are provided in Tables S1 and S2

Table S1. Atomic properties of Fe, Co, Ni, Rh, and Pt

Metal	Atomic Radius (Å)	Electronegativity (Pauling)	Valence Electron Concentration
Fe	1.26	1.83	8
Co	1.25	1.88	9
Ni	1.24	1.91	10
Rh	1.34	2.28	9
Pt	1.39	2.28	10

Table S2. Enthalpy of Mixing of Metal Pairs among Fe, Co, Ni, Rh, and Pt

Metal Pair	Fe– Co	Fe– Ni	Fe– Rh	Fe– Pt	Co– Ni	Co– Rh	Co– Pt	Ni– Rh	Ni– Pt	Rh– Pt
ΔH_{mix} (kJ·mol ⁻¹)	-1.0	-2.5	-8.0	-7.0	-4.5	-11.0	-7.5	-8.0	-9.5	-5.0

Table S3. Correlation between valence electron concentration and crystal structures commonly observed in High-Entropy Alloys

VEC	Predicted Phase
> 8.0	FCC
< 6.87	BCC
< 3.0	HCP

Process operates

- Under atmospheric pressure
- Near room temperature
- Without any toxic chemicals



Parameters of Atmospheric Plasma Operation

- Ar gas flow rate: 5 lpm
- Substrate speed: 5 mm/s
- Gap distance: 2 mm
- Plasma Power: 225 W
- Treatment time: 15 min

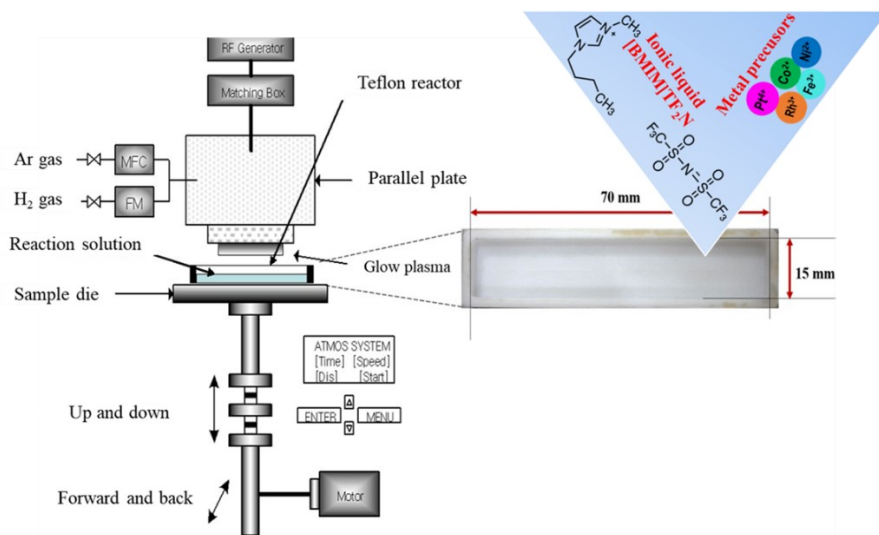


Figure S1. Schematic illustration of the plasma operation and the laboratory plasma equipment.

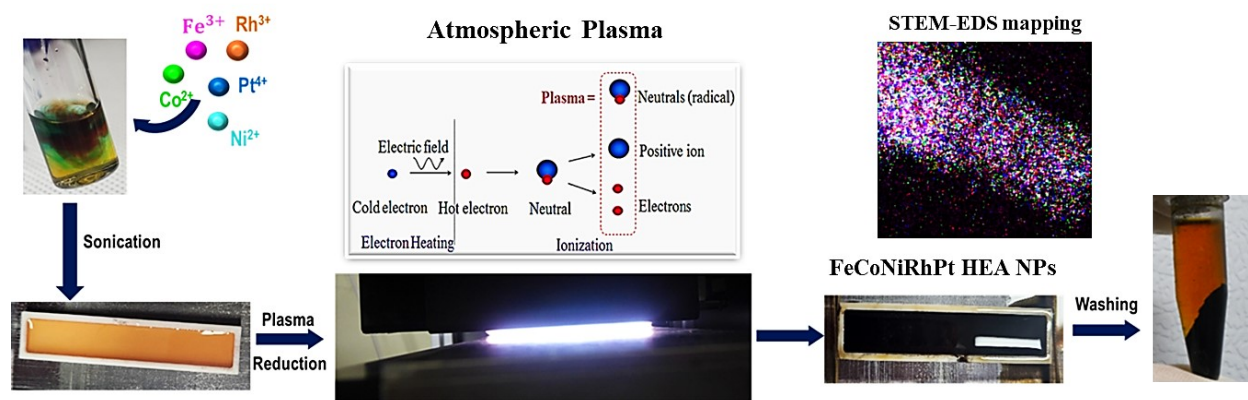


Figure S2. Schematic Illustration of the wet plasma reduction strategy for the synthesis process of FeCoNiRhPt HEA NPs

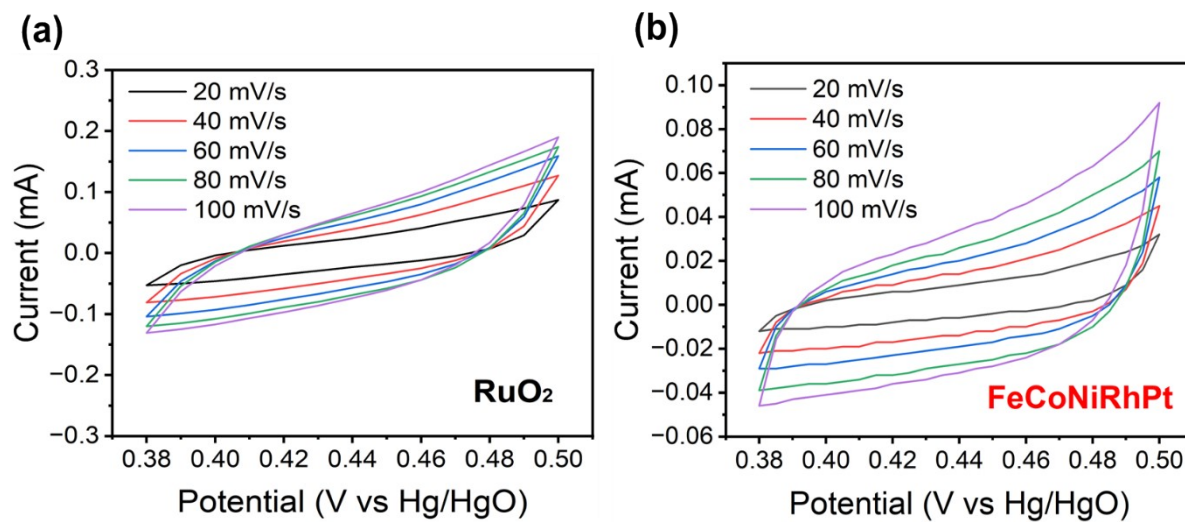


Figure S3. Cyclic voltammograms (CV) of FeCoNiRhPt catalyst (a) and RuO₂ catalyst (b) in the non-Faradaic region (0.38 to 0.50 V vs. Hg/HgO) at various scan rates ranging from 20 to 100 mV/s¹.

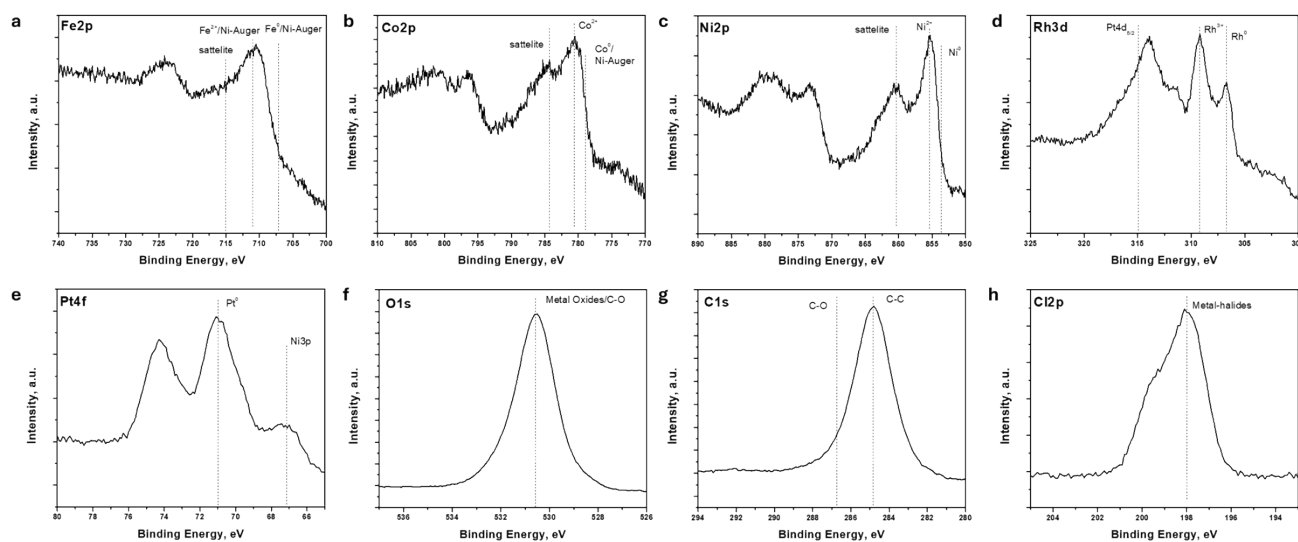


Figure S4. High-resolution X-ray photoelectron spectra (XPS) of the FeCoNiRhPt high-entropy alloy for (a) Fe 2p, (b) Co 2p, (c) Ni 2p, (d) Rh 3d, (e) Pt 4f, (f) O 1s, (g) C 1s, and (h) Cl 2p. The peak positions are referenced to the handbook of XPS [1].

XPS analysis of the FeCoNiRhPt HEA NPs (shown in Figure S4) reveals a predominantly mixed oxidized and metallic character of Fe, Co, Ni, and Rh, while Pt remains largely metallic. Due to significant overlap between core-level and Auger features inherent to the multi-component HEA system, quantitative deconvolution is limited; however, the data consistently indicate a mixed metallic/oxide surface state, which is typical for such nanoparticles under ambient conditions and relevant to their electrocatalytic behavior.

References:

[1] Chastain, Jill, and Roger C. King Jr. "Handbook of X-ray photoelectron spectroscopy." *Perkin-Elmer Corporation* 40.221 (1992): 25.

Structural characterization

The microstructure and morphology of the prepared samples were observed by a scanning electron microscope (SEM, Hitachi SU-70 FEG-SEM at 10 kV) and transmission electron microscopes (TEM, JEOL 2100F FEG TEM/STEM operated at 200 kV, and JEOL TEM/STEM ARM 200CF) equipped with high-angle annular dark field (HAADF) and annular bright field (ABF) detectors. High-angle annular dark field (HAADF) images were acquired using the JEOL ARM 200CF with a 90 mrad inner-detector angle. An Oxford X-max 100TLE window less X-ray detector was used to collect the energy dispersive spectra (EDS). The surface elemental composition and chemical states were analyzed using X-ray photoelectron spectroscopy (XPS; Thermo Fisher Scientific, Waltham, MA, USA) with a monochromatic Al K α excitation source.

