

Supporting Information

The Promotional Effect of Na on Ru for pH-Universal Hydrogen Evolution Reactions

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Table S1. Elemental content of Ru, Na measured by ICP-OES.

Catalysts	Ru (wt%)	Na (wt%)
Ru _{0.3} /C-800	0.81	0.36
Ru _{0.3} /C-900	0.25	0.30
Ru _{0.3} /C-1000	0.11	0.004
Ru _{0.3} /C-800-WF	0.28	0.03

Table S2. Ru⁰/Ruⁿ⁺ ratio of Ru_{0.3}/C-800, Ru_{0.3}/C-900, Ru_{0.3}/C-1000 and Ru_{0.3}/C-800-WF.

Catalysts	Ru ⁰ /Ru ⁿ⁺
Ru _{0.3} /C-800	1.68
Ru _{0.3} /C-900	1.23
Ru _{0.3} /C-1000	1.18
Ru _{0.3} /C-800-WF	1.20

Table S3. BET Surface Area (m²/g) of Ru_{0.3}/C-700, Ru_{0.3}/C-800, Ru_{0.3}/C-900, Ru_{0.3}/C-1000 and Ru_{0.3}/C-800-WF.

Catalysts	BET Surface Area (m ² /g)
Ru _{0.3} /C-700	66.6
Ru _{0.3} /C-800	592.0
Ru _{0.3} /C-900	202.7
Ru _{0.3} /C-1000	91.6
Ru _{0.3} /C-800-WF	362.9

Table S4. R_s and R_{ct} of Ru_{0.3}/C-800, Ru_{0.3}/C-900 and Ru_{0.3}/C-1000 in 1.0 M KOH.

Samples	Ru _{0.3} /C-800	Ru _{0.3} /C-900	Ru _{0.3} /C-1000
R_s (Ω cm ²)	1.29	1.91	2.04
R_{ct} (Ω cm ²)	21.80	50.14	116.00

Table S5. Summary of the recently reported HER catalysts.

Catalysts	1.0 M KOH - η_{10} (mV)	0.5 M H ₂ SO ₄ - η_{10} (mV)	Content (Ru)	References
Ru _{0.3} /C-800	29	83	0.81 wt%	this work
h-RuNP	75	90	/	<i>ACS Appl. Nano Mater.</i> 4 (2021) 8530–8538
Ru@NGT	75	/	28 wt%	<i>ACS Appl. Energy Mater.</i> 2 (2019) 7330–7339
2D-MoO ₂ /Ru/N C	25	68	18.22 wt%	<i>J. Phys. Chem. C.</i> 124 (2020) 10804–10814
Ru/C-H ₂ O/CH ₃ CH ₂ OH	53	35	58.22 wt%	<i>Appl. Catal. B Environ.</i> 258 (2019) 117952
MSOR ₁	43	197	4.09 wt%	<i>Adv. Funct. Mater.</i> 2210939 (2023) 1–12
RuP ₂ @NPC	52	38	23.3 wt%	<i>Angew. Chem. Int. Ed.</i> 56 (2017) 11559–11564
Ru@ENG	47	/	4.21 wt%	<i>Nano Energy.</i> 76 (2020) 105114
Ru@Co/N-CNTs	48	92	/	<i>ACS Sustain. Chem. Eng.</i> 8 (2020) 9136–9144

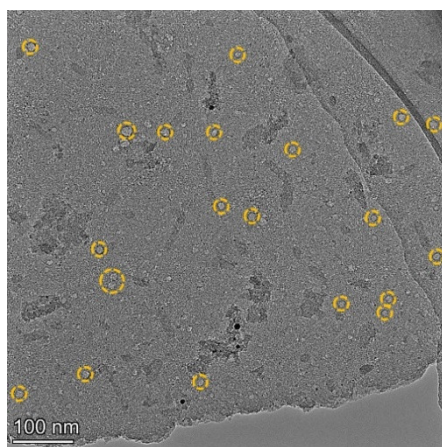


Figure S1. TEM image of $\text{Ru}_{0.3}/\text{C}-800$, the yellow circle is a pore structure, mainly mesopores.

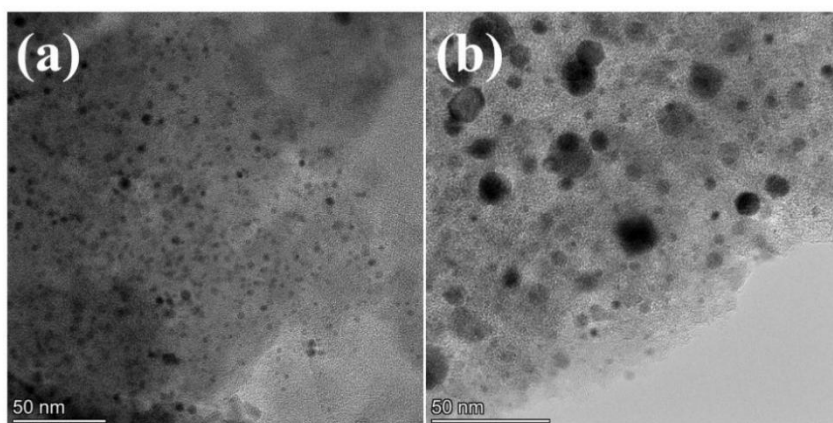


Figure S2. (a) TEM image of $\text{Ru}_{0.2}/\text{C}-800$. (b) TEM image of $\text{Ru}_{0.4}/\text{C}-800$.

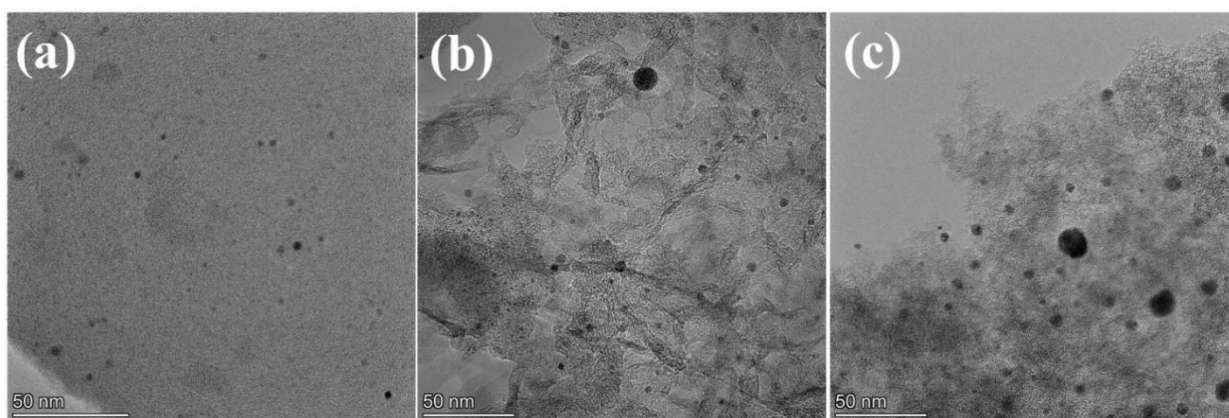


Figure S3. (a) TEM image of $\text{Ru}_{0.3}/\text{C}-700$. (b) TEM image of $\text{Ru}_{0.3}/\text{C}-900$. (c) TEM image of $\text{Ru}_{0.3}/\text{C}-1000$.

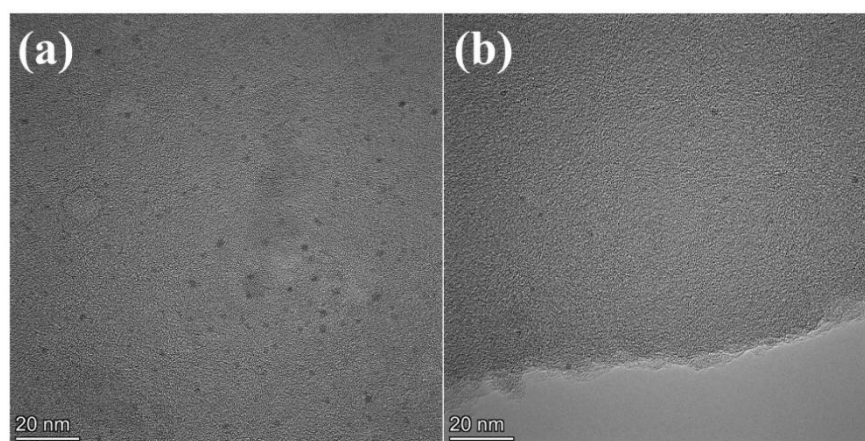


Figure S4. TEM image of (a) Ru_{0.3}/C-800 and (b) Ru_{0.3}/C-800-WF.

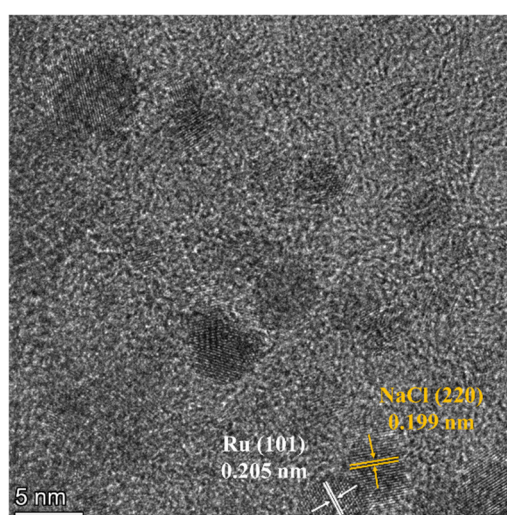


Figure S5. HRTEM of Ru_{0.3}/C-800.

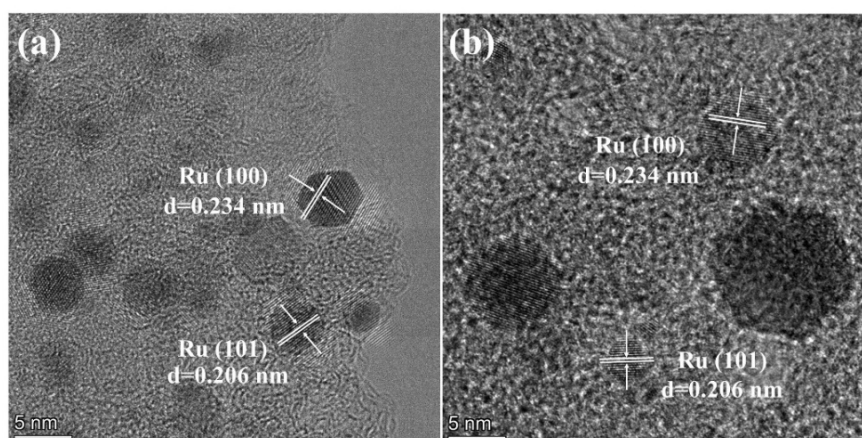


Figure S6. HRTEM image of (a) Ru_{0.3}/C-800 and (b) Ru_{0.3}/C-900.

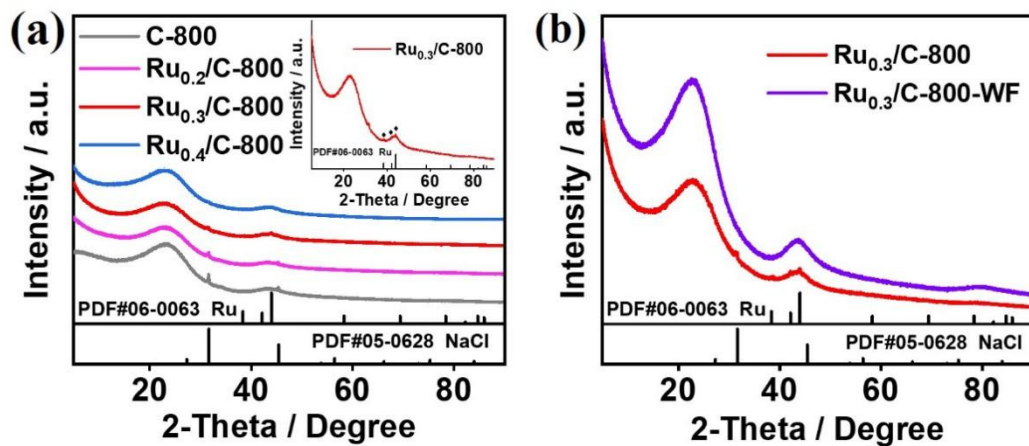


Figure S7. (a) XRD patterns of C-800, Ru_{0.2}/C-800, Ru_{0.3}/C-800 and Ru_{0.4}/C-800, inset: XRD enlargement of Ru_{0.3}/C-800. (b) XRD patterns of Ru_{0.3}/C-800 and Ru_{0.3}/C-800-WF.

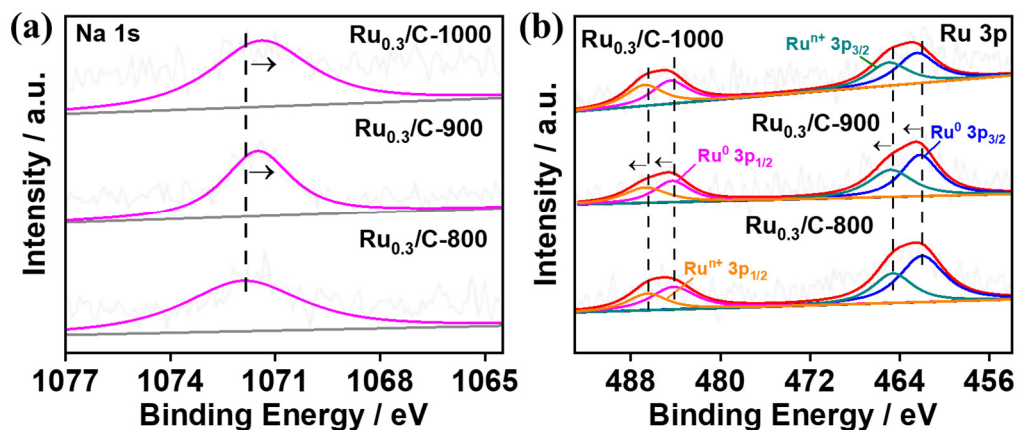


Figure S8. (a) High-resolution XPS spectra of Na 1s about Ru_{0.3}/C-800, Ru_{0.3}/C-900 and Ru_{0.3}/C-1000. (b) High-resolution XPS spectra of Ru 3p about Ru_{0.3}/C-800, Ru_{0.3}/C-900 and Ru_{0.3}/C-1000.

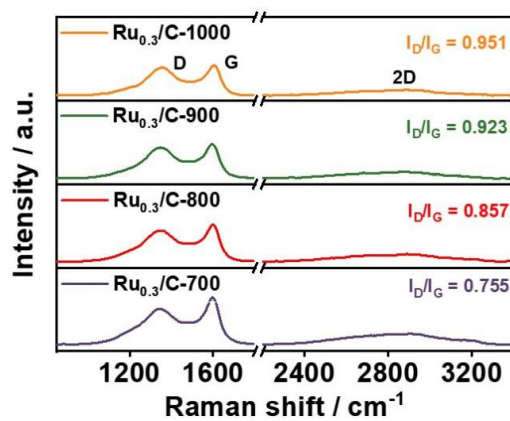


Figure S9. Raman spectra of Ru_{0.3}/C-700, Ru_{0.3}/C-800, Ru_{0.3}/C-900 and Ru_{0.3}/C-1000.

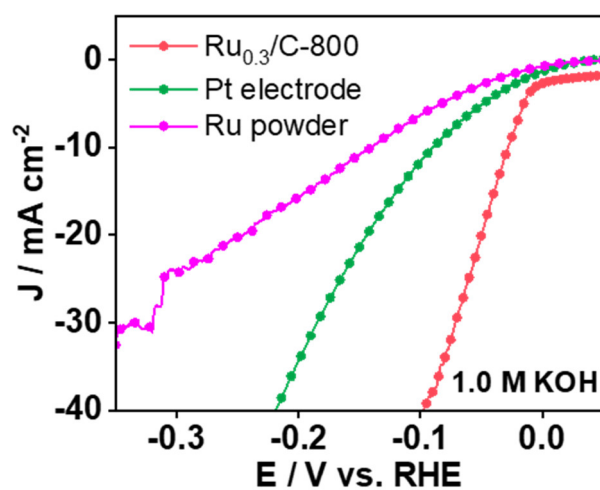


Figure S10. LSV curves of Ru powder, Pt electrode and Ru_{0.3}/C-800 in 1.0 M KOH.

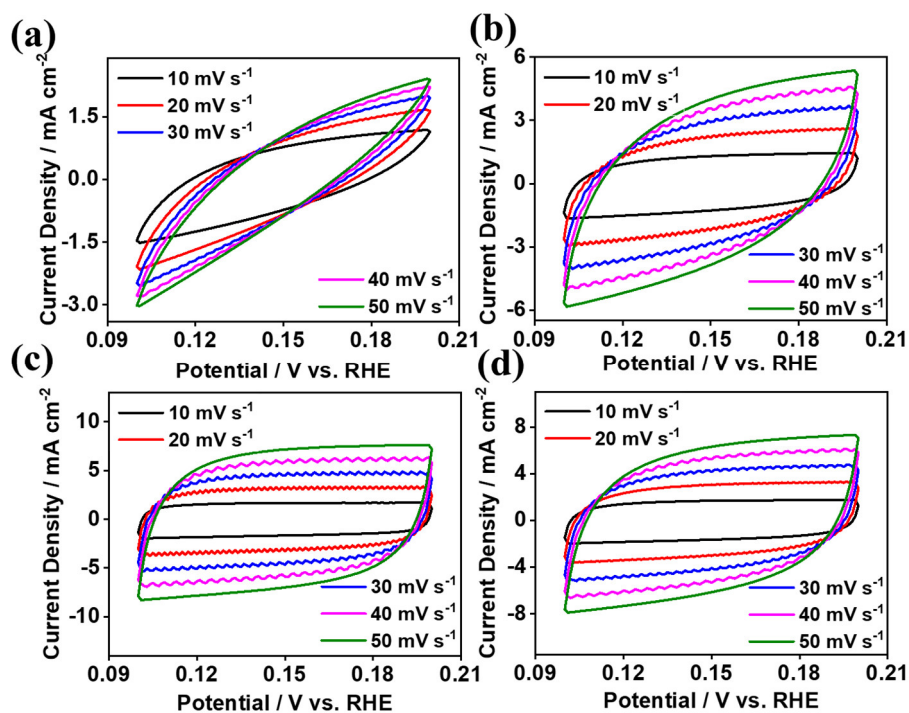


Figure S11. CV curves of (a) C-800, (b) Ru_{0.2}/C-800, (c) Ru_{0.3}/C-800 and (d) Ru_{0.4}/C-800 at different scan rates: 10, 20, 30, 40, 50 mV s⁻¹ in 1.0 M KOH solution.

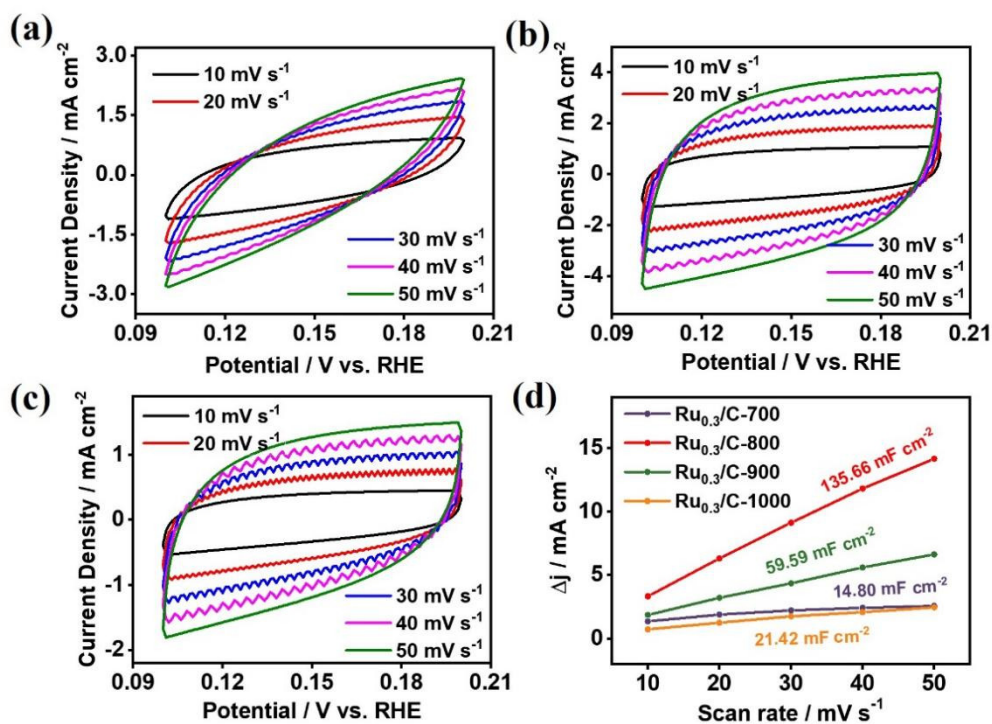


Figure S12. CV curves of (a) Ru_{0.3}/C-700, (b) Ru_{0.3}/C-900 and (c) Ru_{0.3}/C-1000 at different scan rates: 10, 20, 30, 40, 50 mV s⁻¹ in 1.0 M KOH solution. (d) The linear plot of the capacitive current versus the scan rate for determination of the C_{dl}.

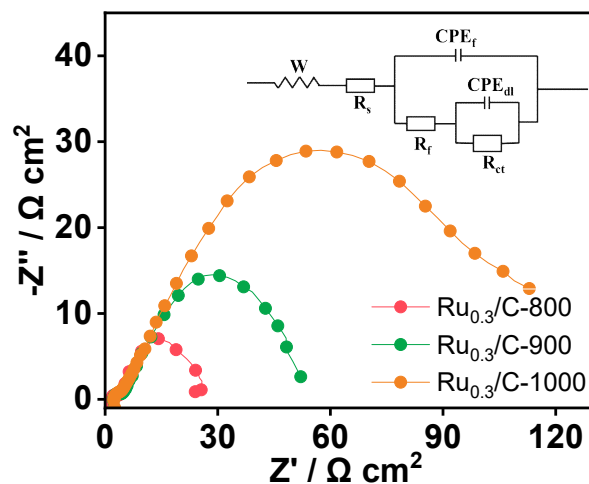


Figure S13. EIS spectra of Ru_{0.3}/C-800, Ru_{0.3}/C-900 and Ru_{0.3}/C-1000. Inset: equivalent circuit models used for fitting the EIS response of HER.

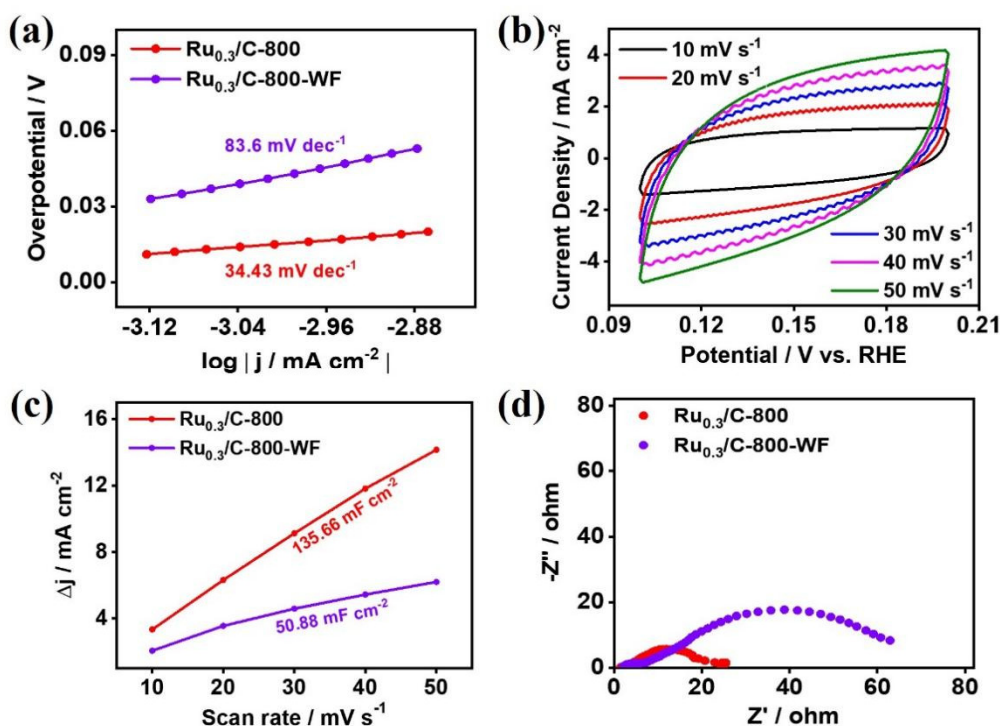


Figure S14. (a) Tafel plots of Ru_{0.3}/C-800 and Ru_{0.3}/C-800-WF. (b) CV curves of Ru_{0.3}/C-800-WF at different scan rates: 10, 20, 30, 40, 50 mV s⁻¹ in 1.0 M KOH solution. (c) The linear plot of the capacitive current versus the scan rate for determination of the C_{dl}. (d) Nyquist plots of Ru_{0.3}/C-800 and Ru_{0.3}/C-800-WF.

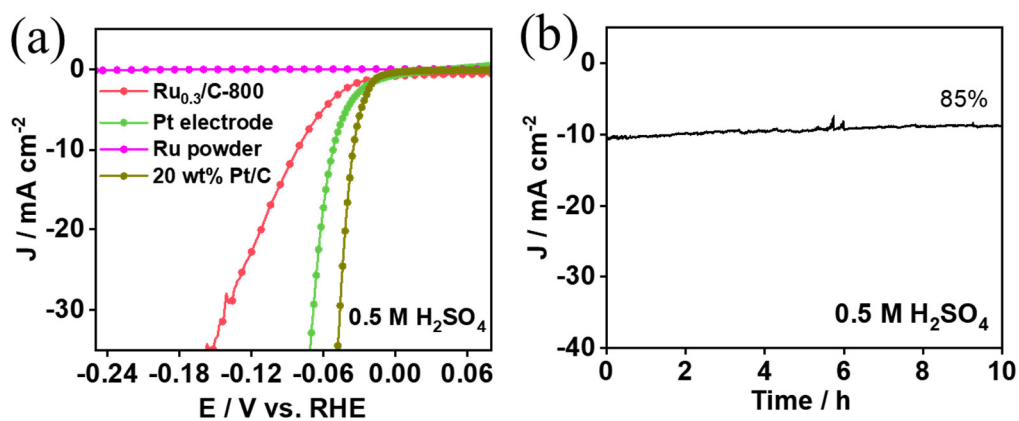


Figure S15. (a) LSV curves of Ru_{0.3}/C-800, Ru powder, Pt electrode and 20 wt% Pt/C in 0.5 M H₂SO₄. (b) The i-t curve of Ru_{0.3}/C-800 in 0.5 M H₂SO₄.

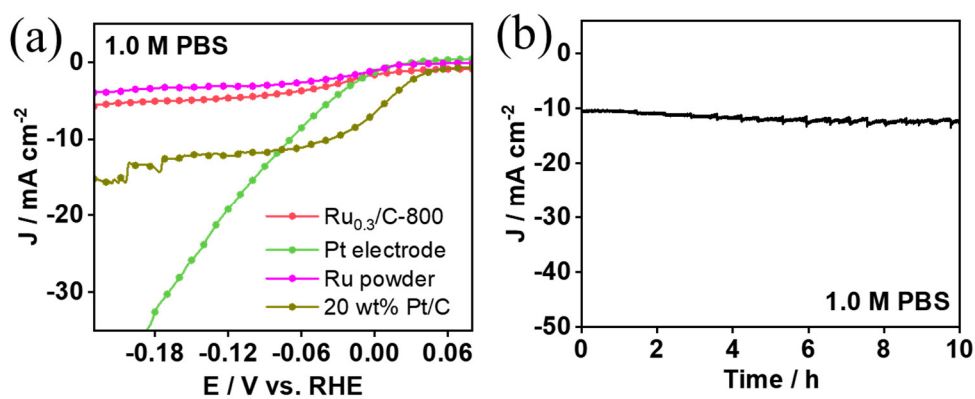


Figure S16. (a) LSV curves of Ru_{0.3}/C-800, Ru powder, Pt electrode and 20 wt% Pt/C in 1.0 M PBS. (b) The i-t curve of Ru_{0.3}/C-800 in 1.0 M PBS.