Support Information

Synergistic Effect from Ru Nanoclusters on WC_{1-x} Anchored on N-doped Carbon Nanosheet Boosting High-efficient Alkaline Hydrogen Evolution

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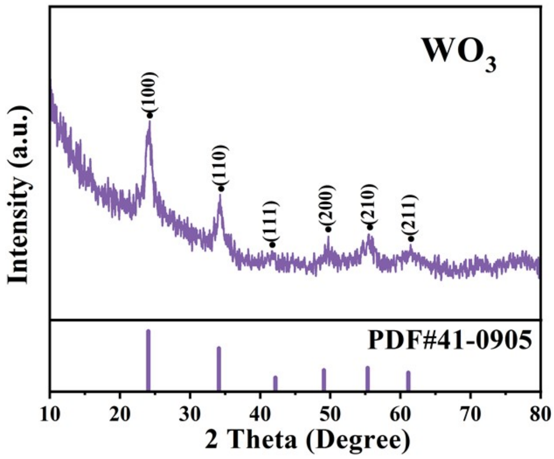

Figure S1 XRD pattern of the as-synthesized WO_3 nanosheets.

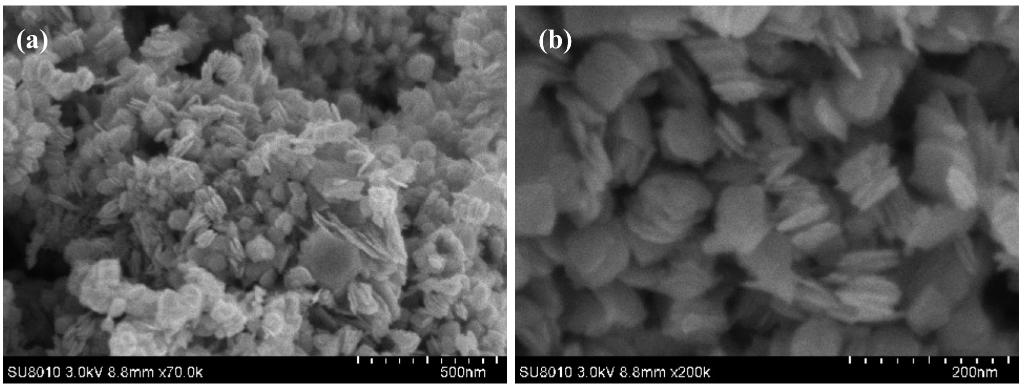

Figure S2 SEM images of the as-synthesized WO_3 nanosheets.

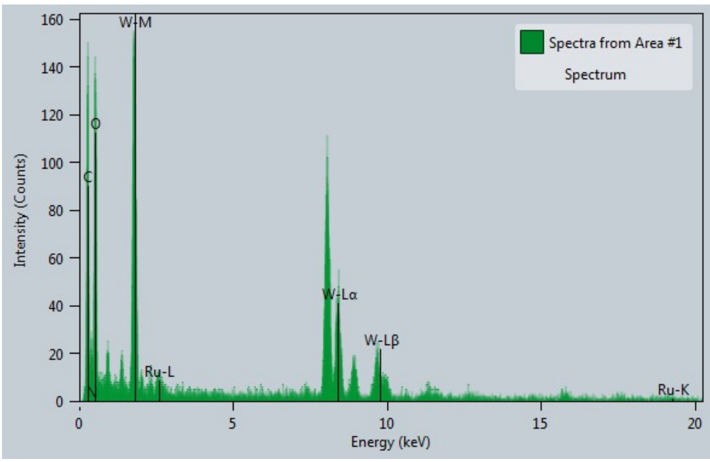

Figure S3 EDX patterns of the Ru/WC_{1-x}@NC hybrid.

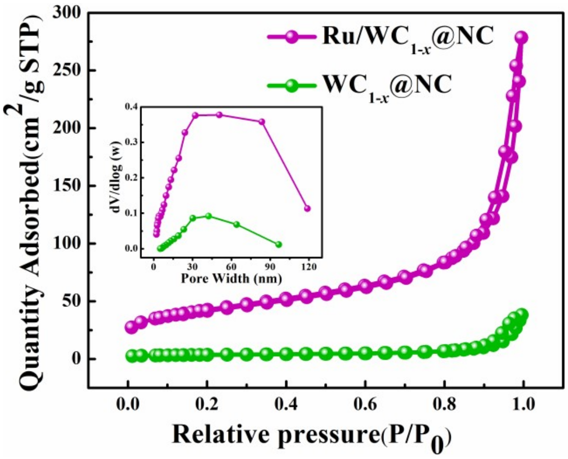

Figure S4 N_2 adsorption/desorption isotherms of Ru/WC_{1-x}@NC (the inset presents the corresponding pore size distribution).

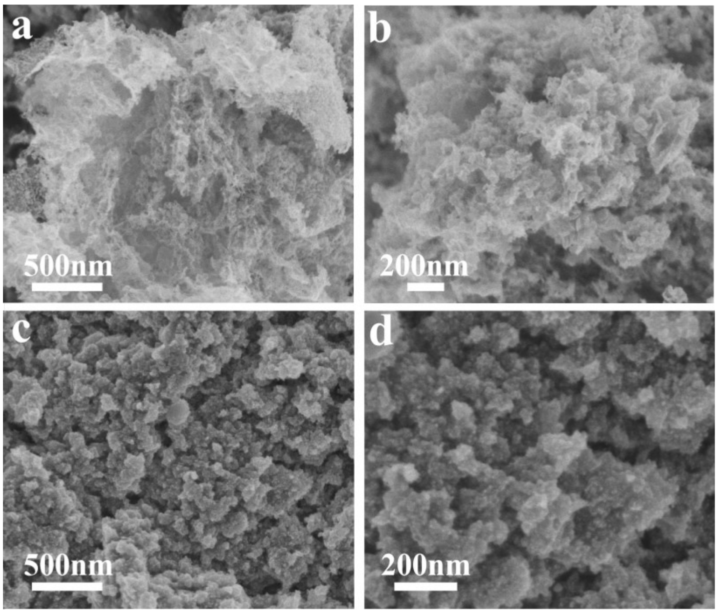

Figure S5 SEM images of the $WC_{1\text{-}x}$@NC (a-b) and Ru@NC (c-d) hybrids.

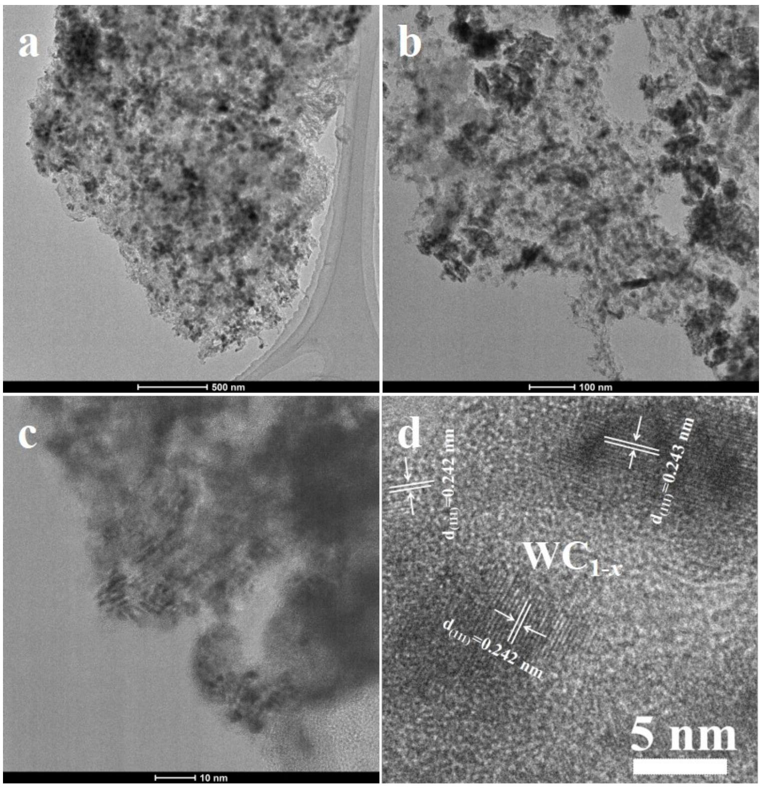

Figure S6 (a-c) TEM and (d) HRTEM images of the as-prepared WC_{1-x}@NC hybrid.

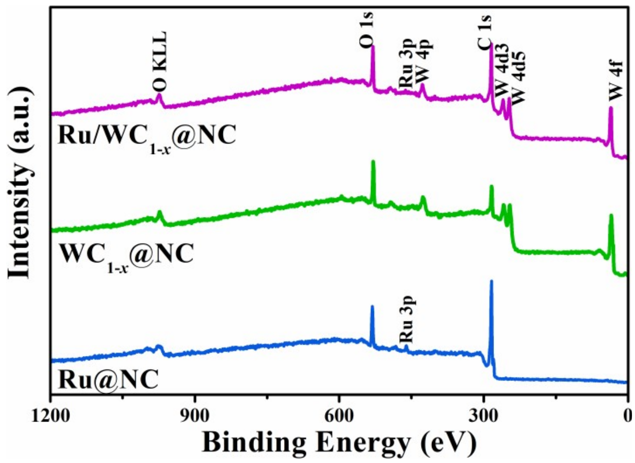

Figure S7 XPS surveys of the as-prepared Ru/WC_{1-x}@NC, WC_{1-x}@NC and Ru@NC hybrids.

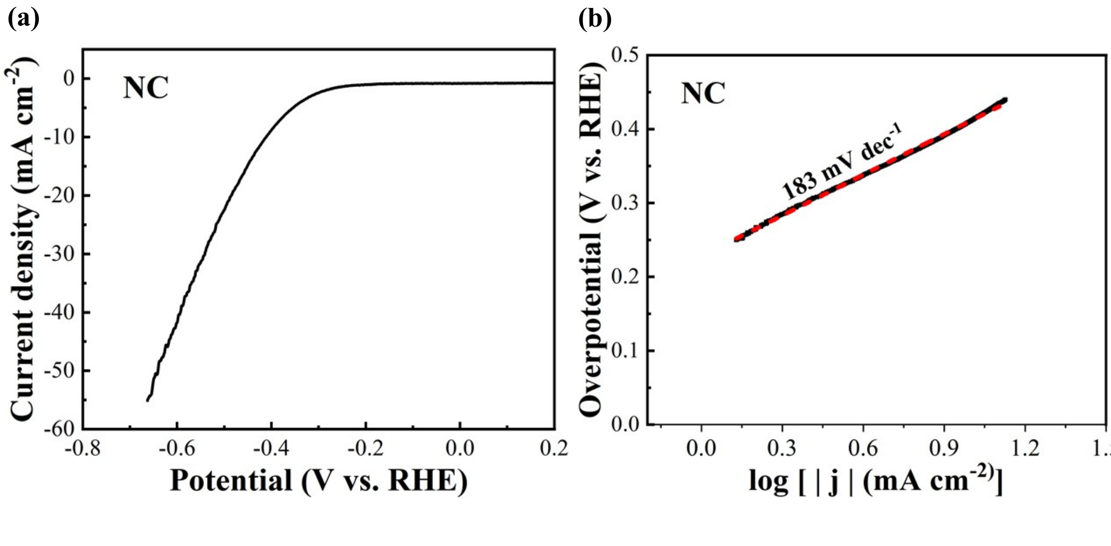

Figure S8 (a) LSV curve and (b) Tafel slope of nitrogen-doped carbon (NC) in 1 M KOH solution.

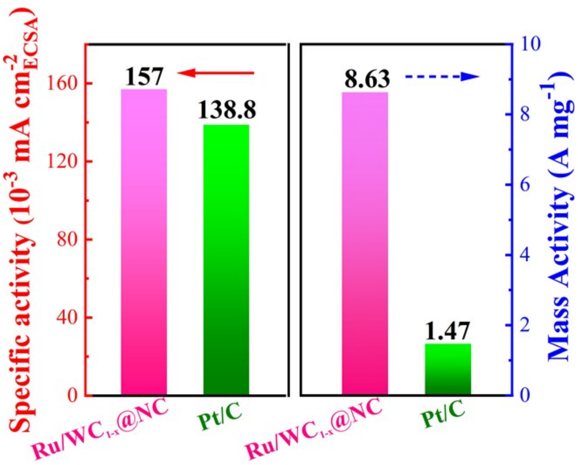

Figure S9. Specific activity and Mass activity of Ru/WC_{1-x}@NC hybrids at the overpotential of 100 mV, in comparison with the commercial Pt/C (20 wt.%).

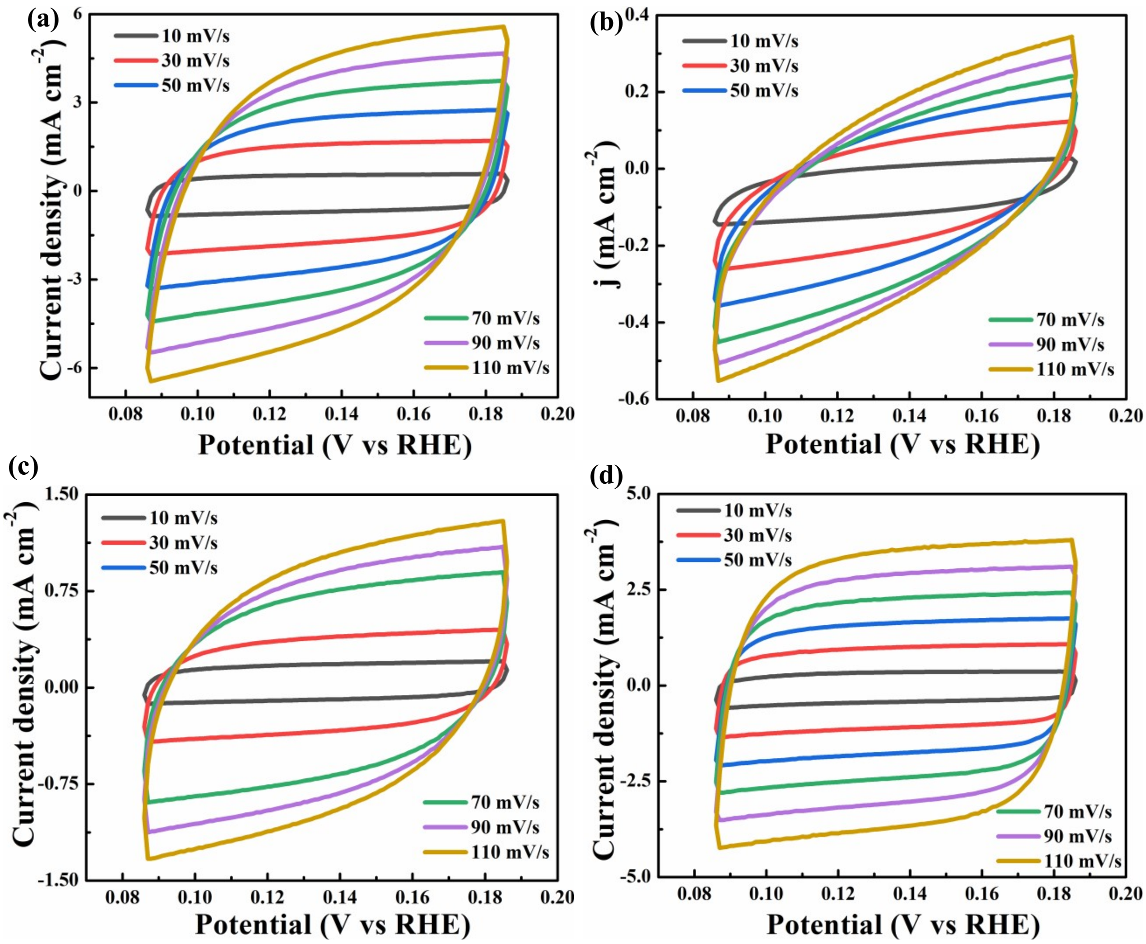

Figure S10 The CV curves measured at different scan rates in the nonfaradaic potential region (0.085-0.185 V vs. RHE) for (a) Ru/WC_{1-x}@NC, (b) WC_{1-x}@NC, (c) Ru@NC and (d) commercial Pt/C catalysts in 1 M KOH, respectively.

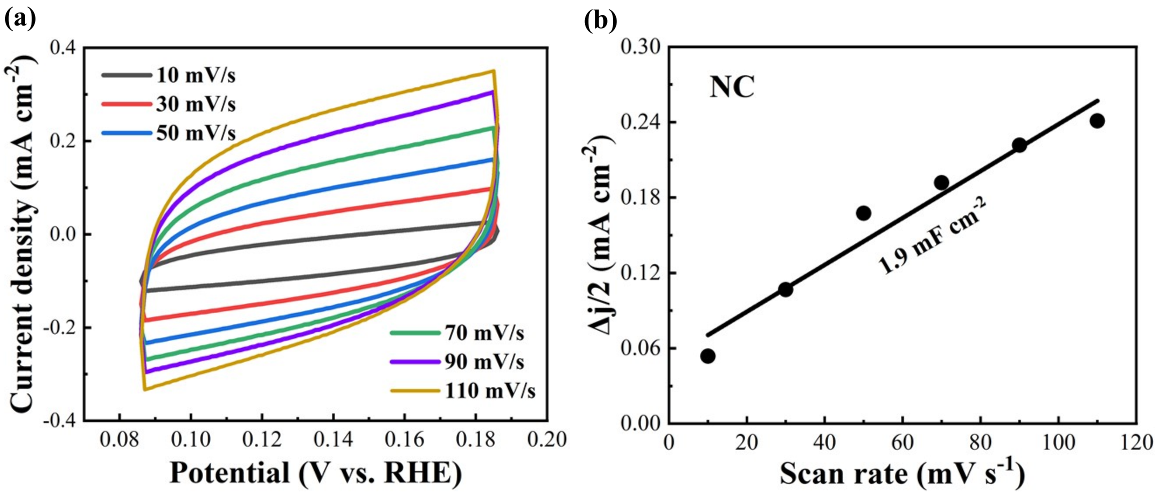

Figure S11 (a) The CV curves measured at different scan rates in the nonfaradaic potential region (0.085-0.185 V vs. RHE) and (b) the corresponding C_{dl} curve for NC support in 1 M KOH.

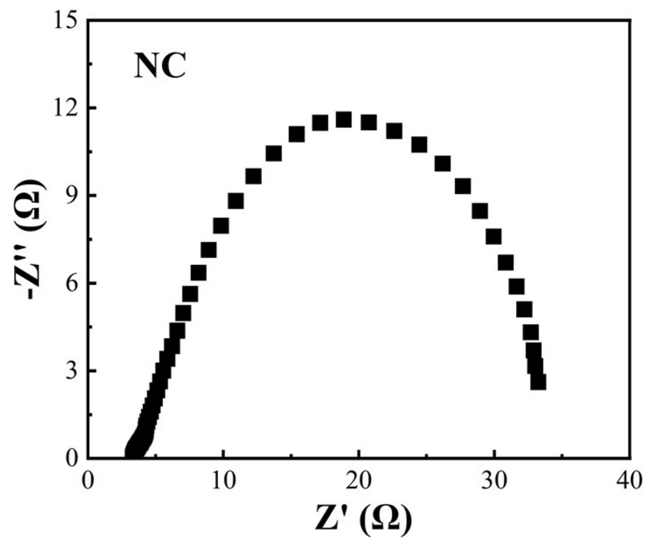

Figure S12. Nyquist plots of NC support in 1 M KOH solution.

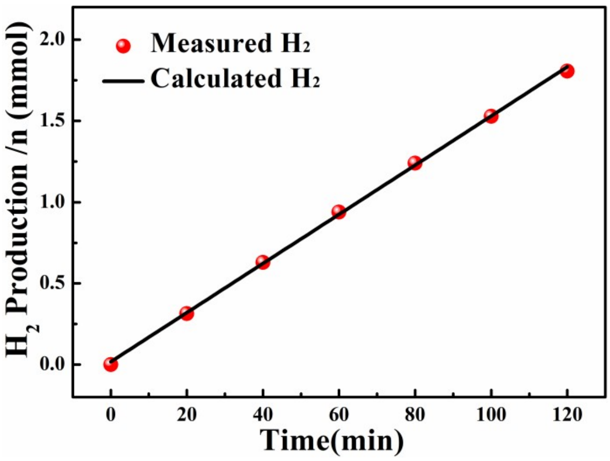

Figure S13. Comparison of the calculated and measured H_2 evolution amount of Ru/WC$_{1\text{-}x}$@NC hybrid at a period time.

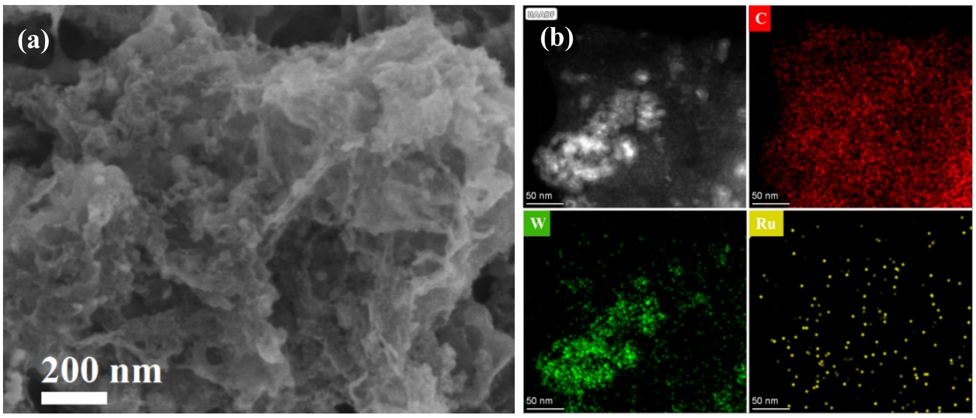

Figure S14. (a) SEM image and (b) EDX mapping spectra of Ru/WC$_{1\text{-}x}$@NC hybrid after 6000 CV cycles.

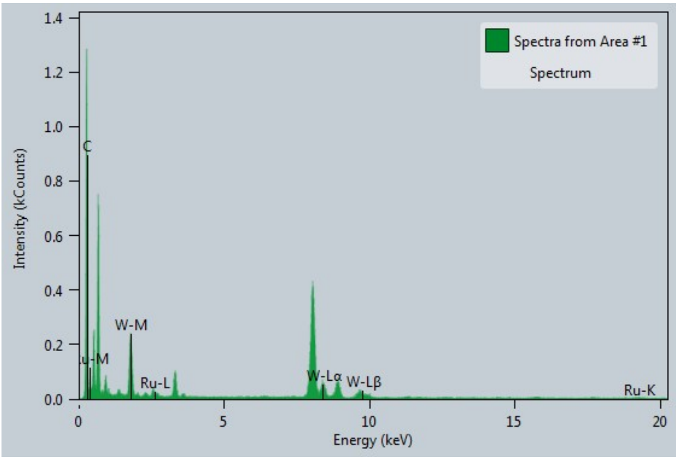

Figure S15. EDX patterns of the Ru/WC_{1-x}@NC hybrid after 6000 CV cycles.

Table S1. Ru content in the as-synthesized Ru/WC_{1-x}@NC hybrids measured through ICP-AES.

Samples	Ru content (wt.%)
Ru/WC_{1-x}@NC	2.5

Table S2 Comparison of Ru content in the resulted Ru/WC_{1-x}@NC hybrid in this work and the reported Ru-based catalysts in recent years.

catalysts	Ru content wt.%	measurement	Ref.
Ru/WC_{1-x}/NC	2.5	ICP-AES	This work
Ru_2P/WO_3@NPC	3.4	ICP-AES	[1]
(Ru-Co)O_x	28.4	ICP-AES	[2]
RuCo@NC	3.58	ICP-AES	[3]
Pyrite-type RuS_2	14.1	ICP-OES	[4]
Ru/Co_3O_4 NW	5.45	ICP-OES	[5]
Ru/g-C_3N_4	20	TEM-EDS	[6]
Ru NCs/BNG	14.25	TGA	[7]
RuP_2@NPC	23.3	ICP-AES	[8]

S-RP/C	21.4	TGA	[9]

Table S3 Comparison of HER activity of the resulted Ru/WC_{1-x}@NC hybrid in this work with reported WC_{1-x}-based or Ru-based electrocatalysts.

Electorcatalysts	**Electrolyte**	**Overpotential (η=10 mA cm^{-2})**	**Tafel slope**	**Ref.**
Carbon-encapsulated W_2C@WC_{1-x}	0.5 M H_2SO_4	240 mV	86 mV dec^{-1}	[10]
Pt(10 wt.%)/WC_{1-x}@C	0.5 M H_2SO_4	127 mV	32 mV dec^{-1}	[11]
W_2C@WC_{1-x}/Mo film	0.5 M H_2SO_4	58 mV	41 mV dec^{-1}	[12]
WC_{1-x} nanocrystals	1 M KOH	216 mV	122.2 mV dec^{-1}	[13]
Ru nanoparticles/WSe_2 nanosheets	1 M KOH	87 mV	118 mV dec^{-1}	[14]
Ru nanoparticles/CoO nanorods	1 M KOH	55 mV	72 mV dec^{-1}	[15]
Ru/TiO_2-VO@C hybrids	1 M KOH	64 mV	73 mV dec^{-1}	[16]
Ru nanoparticle/CeO_2 hybrids	1 M KOH	28.9 mV	53.2 mV dec^{-1}	[17]
Ru-doped Mo_2C nanoparticles/NC	1 M KOH	34 mV	80 mV dec^{-1}	[18]
Ru nanoparticles/N-doped carbon	1 M KOH	32 mV	53 mV dec^{-1}	[19]
Ru nanoclusers/WC_{1-x} nanosheets /NC	1 M KOH	24 mV	45 mV dec^{-1}	This work

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