Ultrafine CoRu alloy nanoparticles in situ embedded in Co_4N porous nanosheets as high-efficient hydrogen evolution electrocatalysts

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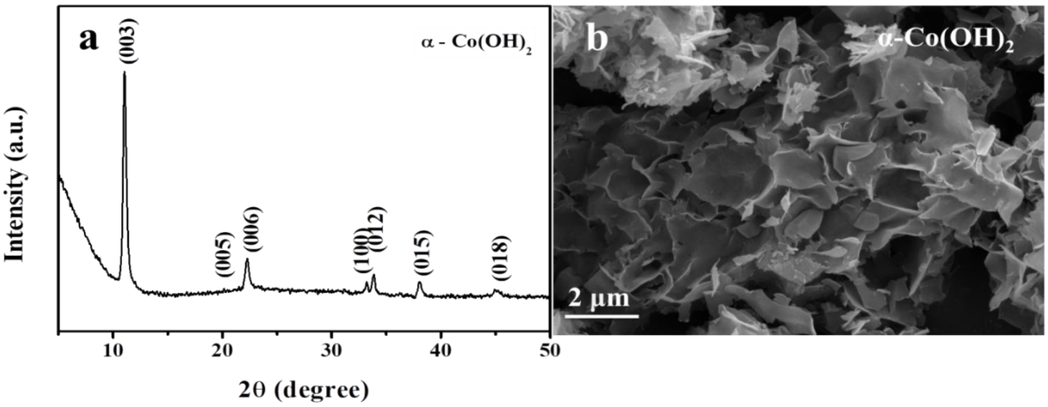

Fig. S1 XRD pattern and SEM image of α-$Co(OH)_2$.

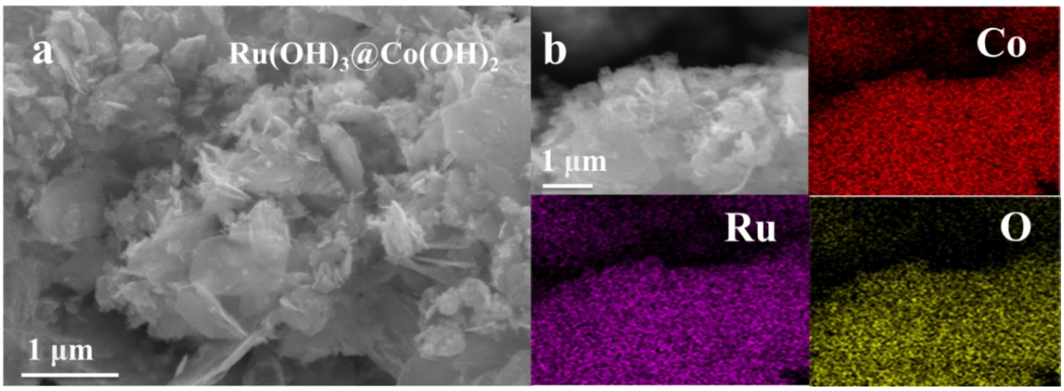

Fig. S2 (a) SEM image of $Ru(OH)_3$@$Co(OH)_2$ and corresponding (b) EDS mapping.

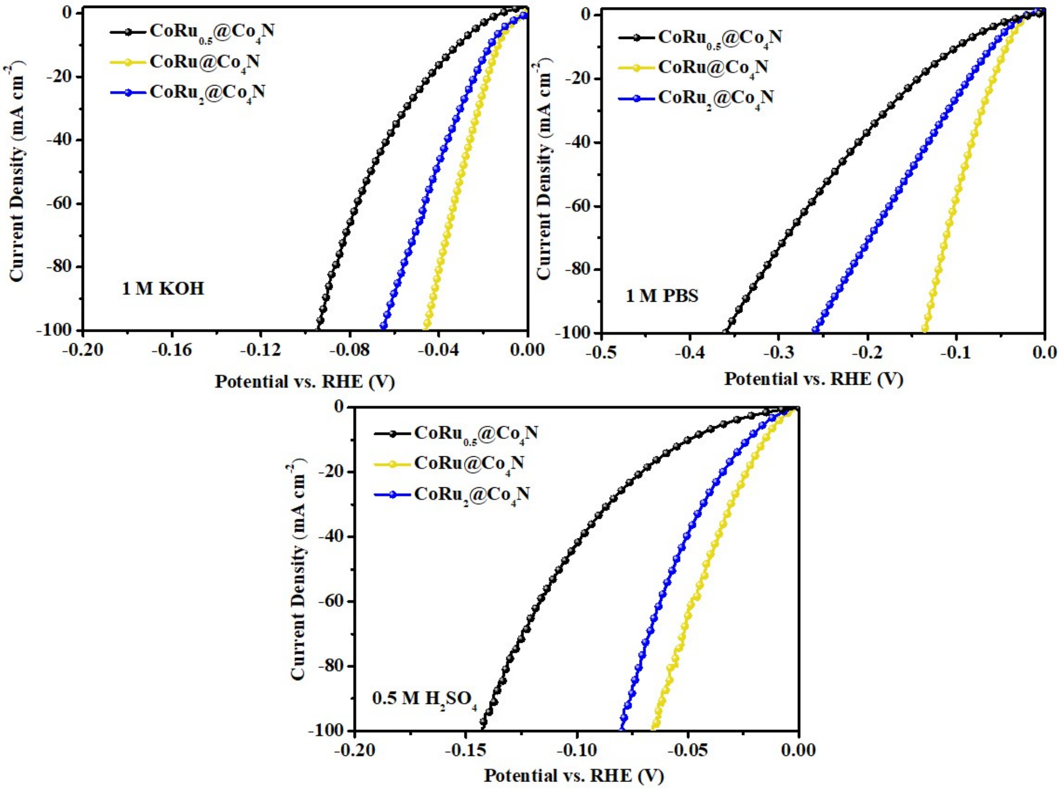

Fig. S3 LSV curves of $CoRu_{0.5}@Co_4N$, $CoRu@Co_4N$ and $CoRu_2@Co_4N$ tested in 1 M KOH, 1 M PBS and 0.5 M H_2SO_4.

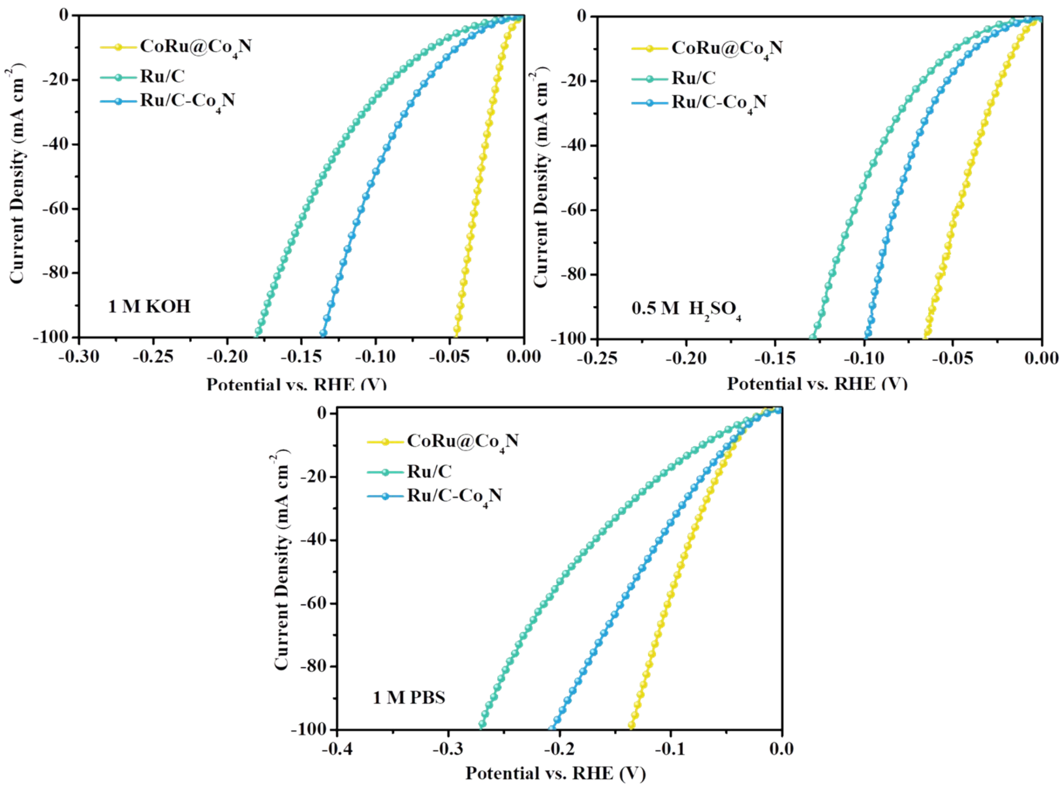

Fig. S4 LSV curves of $CoRu@Co_4N$, Ru/C and Ru/C-Co_4N tested in 1 M KOH, 1 M PBS and 0.5 M H_2SO_4.

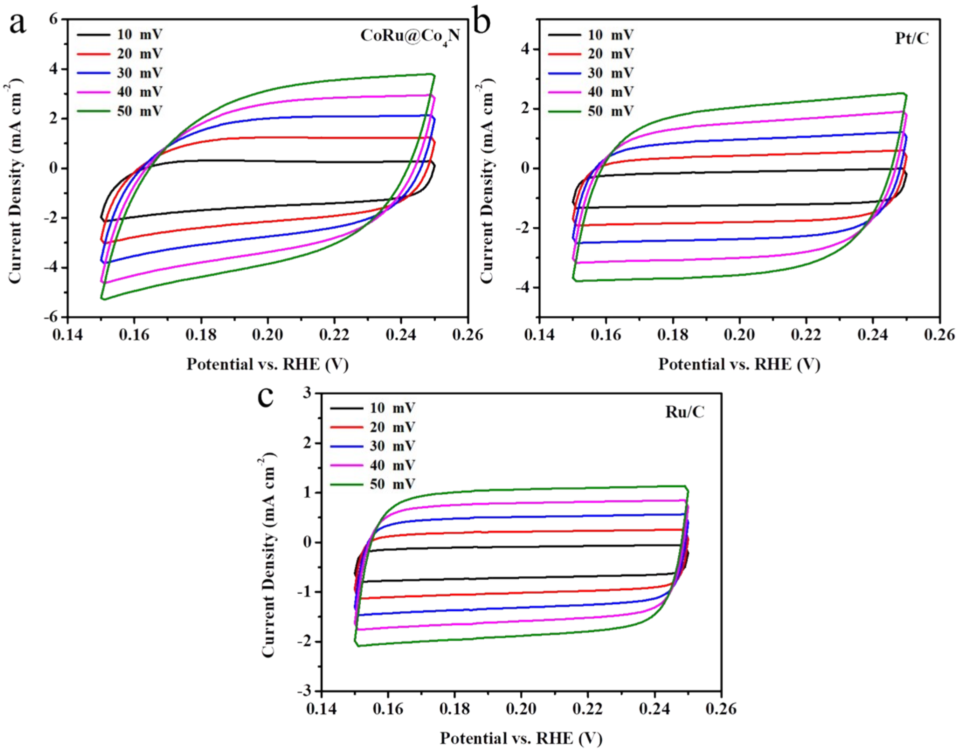

Fig. S5 CVs for HER in 1.0 M KOH.

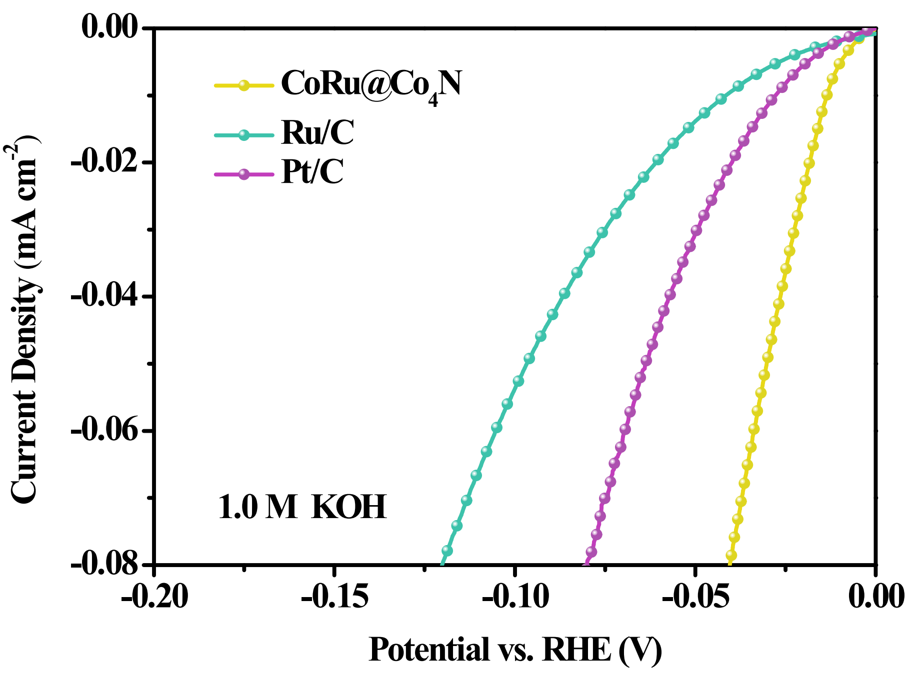

Fig. S6 ECSA-normalized LSV curves in 1.0 M KOH.

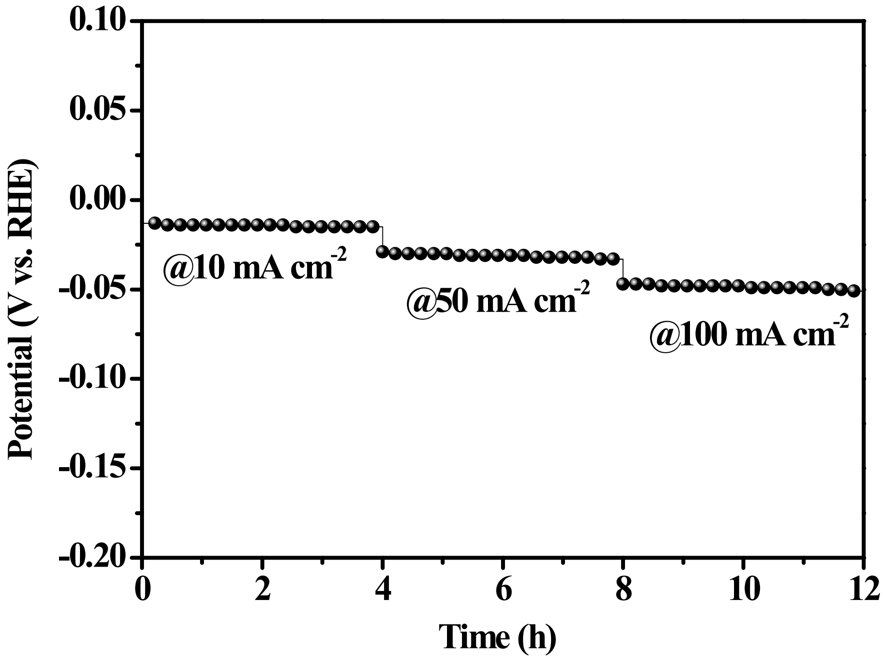

Fig. S7 Multi-current process of CoRu@Co_4N in 1.0 M KOH.

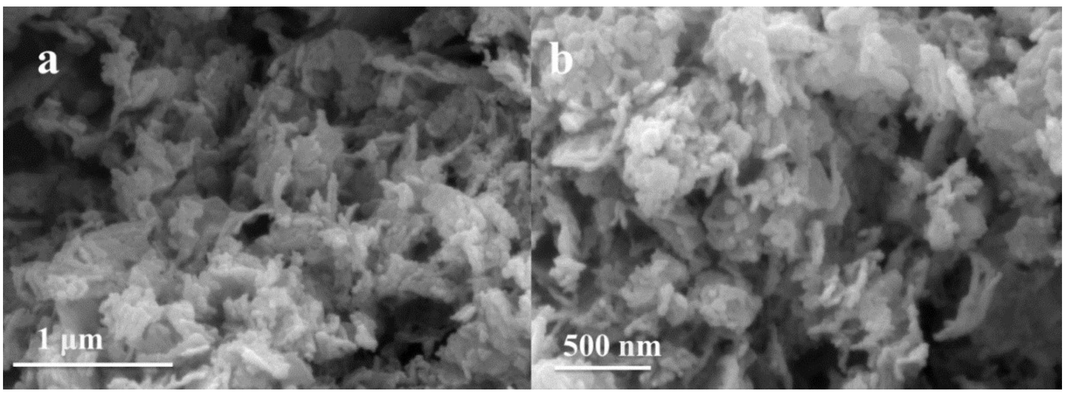

Fig. S8 SEM images of CoRu@Co_4N after stability test in 1.0 M KOH.

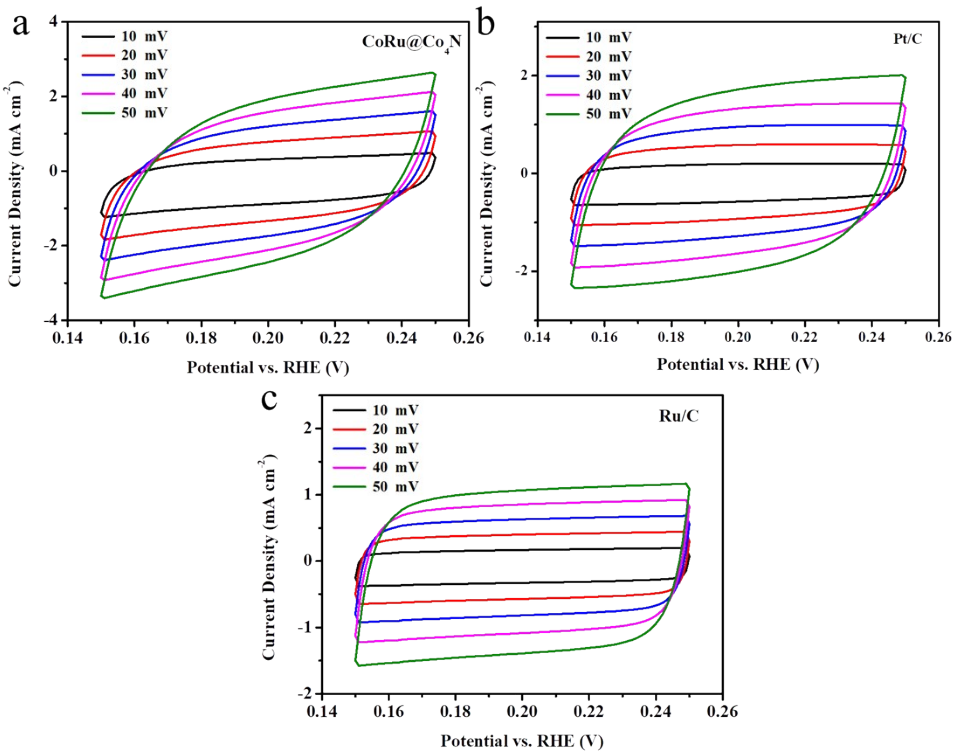

Fig. S9 CVs for HER in 1 M PBS.

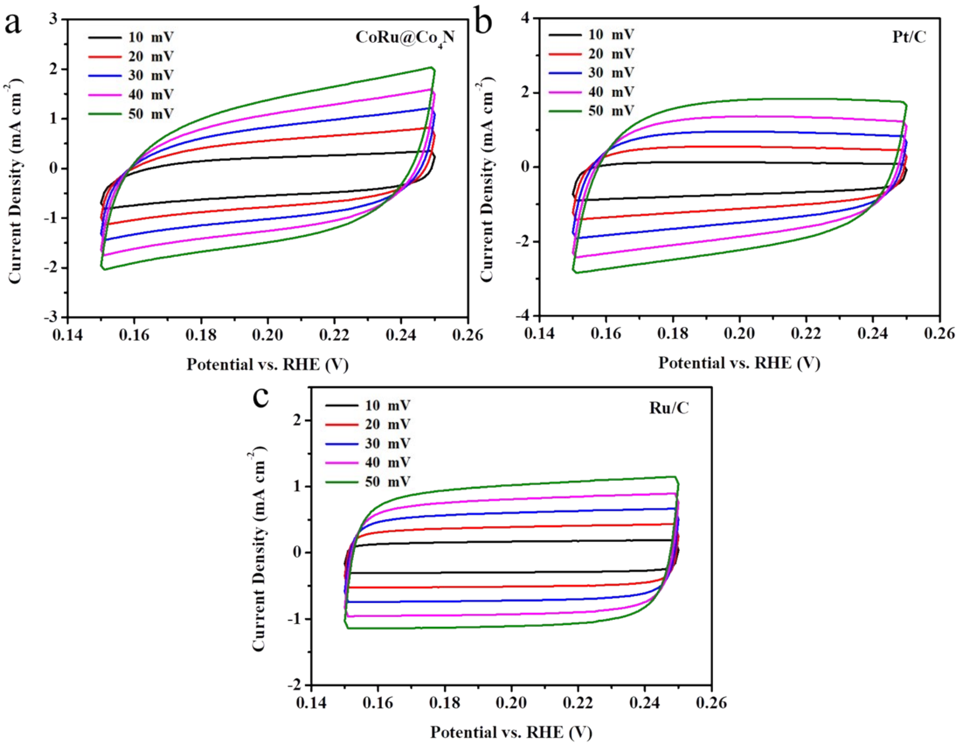

Fig. S10 CVs for HER in 0.5 M H_2SO_4.

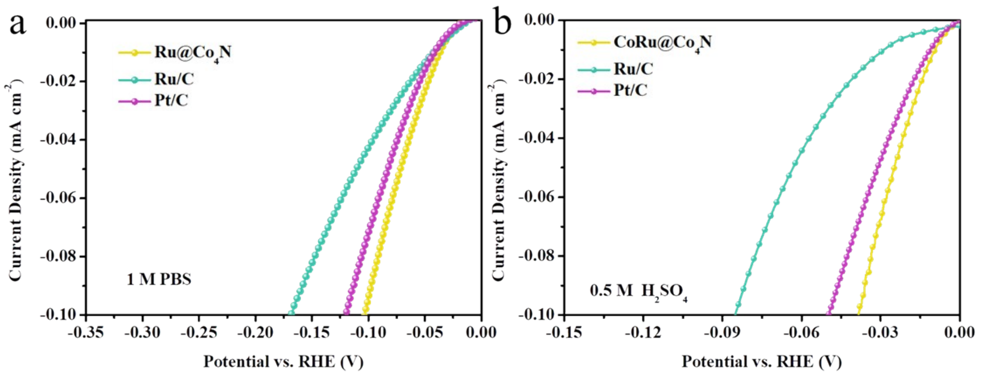

Fig. S11 ECSA-normalized LSV curves in 1M PBS and 0.5 M H_2SO_4.

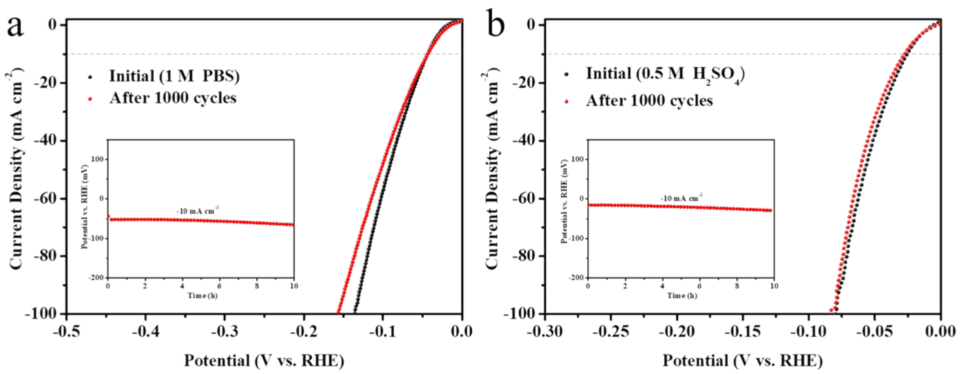

Fig. S12 ADT cyclic stability and time-dependent current density curve of CoRu@Co_4N in 1 M PBS and 0.5 M H_2SO_4.

Table. S1 A performance comparison of $CoRu@Co_4N$ to reported HER electrocatalysts recently.

Catalyst	Electrolyte	η_{10} (mV)	Reference
$CoRu@Co_4N$	**1 M KOH** **0.5 M H_2SO_4** **1M PBS**	**13** **15** **44**	**This work**
Ru@MWCNT	0.5 M H_2SO_4 1 M KOH	13 17	Nat. Commun., 2020, 11, 1278.
$RuP_2@NPC$	1 M KOH 0.5 M H_2SO_4 1M PBS	52 38 57	Angew. Chem. Int. Ed., 2017, 56, 11559-11564.
$Ru@C_2N$	1 M KOH 0.5 M H_2SO_4	17 13.5	Nat. Nanotechnol., 2018, 12, 441-446.
Co_1/PCN	0.5 M H_2SO_4 1 M KOH	151 89	Nat. Catal., 2019, 2, 134-141.
L-Ag	0.5 M H_2SO_4	32	Nat. Catal., 2019, 2, 1107-1114.
Ru-NC-700	0.5 M H_2SO_4 1 M KOH	29 12	Nat. Commun., 2019, 10, 631.
$Ru-MoO_2$	0.5 M H_2SO_4 1 M KOH	29 55	J. Mater. Chem. A, 2017, 5, 5475-5485.
Pt-GT-1	0.5 M H_2SO_4	18	Nat. Energy, 2018, 3, 773-782.
Ni-FeP/C	0.5 M H_2SO_4 1 M KOH	72 95	Sci. Adv., 2019, 5, eaav6009.
Pt@PCM	0.5 M H_2SO_4 1 M KOH	105 139	Sci. Adv., 2018, 4, eaao6657.
Ru/GLC	0.5 M H_2SO_4	35	ACS Appl. Mater. Interfaces, 2016, 8, 35132-35137.
$Ru/C_3N_4/C$	0.5 M H_2SO_4 1 M KOH	70 79	J. Am. Chem. Soc., 2016, 138, 16174-16181.
PtRu@RFCS	0.5 M H_2SO_4	20	Energy Environ. Sci., 2018, 11, 1232-1239.
RuCoP	0.5 M H_2SO_4 1 M KOH	11 23	Energy Environ. Sci., 2018, 11, 1819-1827.
Ru@CN-0.16	0.5 M H_2SO_4 1 M KOH	126 32	Energy Environ. Sci., 2018, 11, 800-806.
$Ru-MoO_2$	0.5 M H_2SO_4 1 M KOH	29 55	J. Mater. Chem. A, 2017, 5, 5475-5485.
L-RuP	0.5 M H_2SO_4 1 M KOH 1 M PBS	19 18 95	Adv. Mater., 2018, 30, 1800047.
PtNi-O/C	1 M KOH	40	J. Am. Chem. Soc., 2018, 140, 9046-9050.
$Ni@Ni_2P-Ru$	0.5 M H_2SO_4 1 M KOH	51 31	J. Am. Chem. Soc., 2018, 140, 2731-2734.