Supporting Information

A simple method for the preparation of nickel selenide and cobalt selenide mixed catalyst to enhance bifunctional oxygen activity for Zn-air battery

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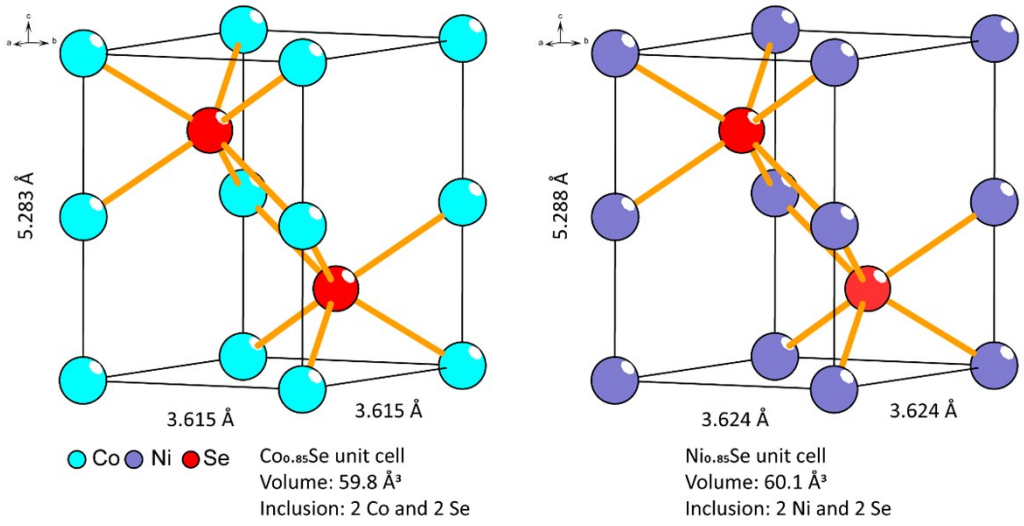


Fig. S1 The unit cell of $Ni_{0.85}Se$ and $Co_{0.85}Se$

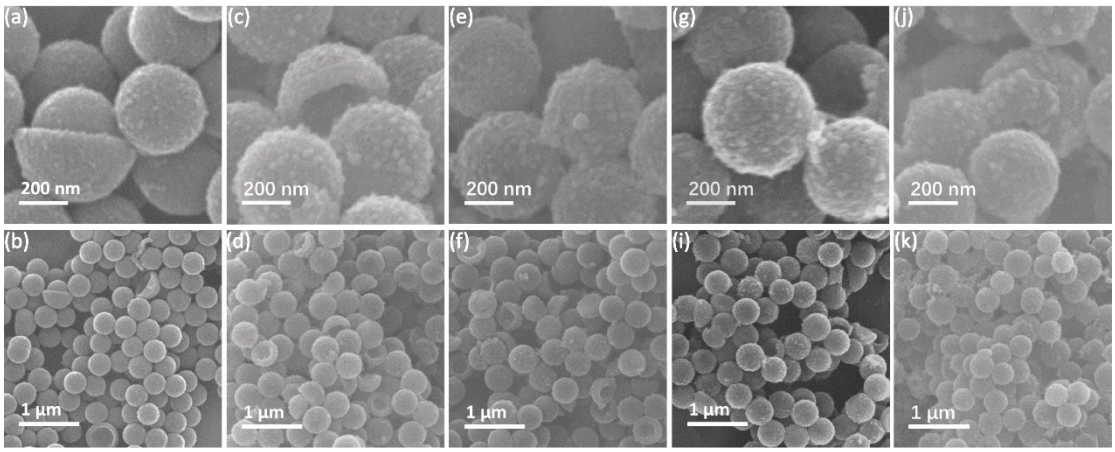
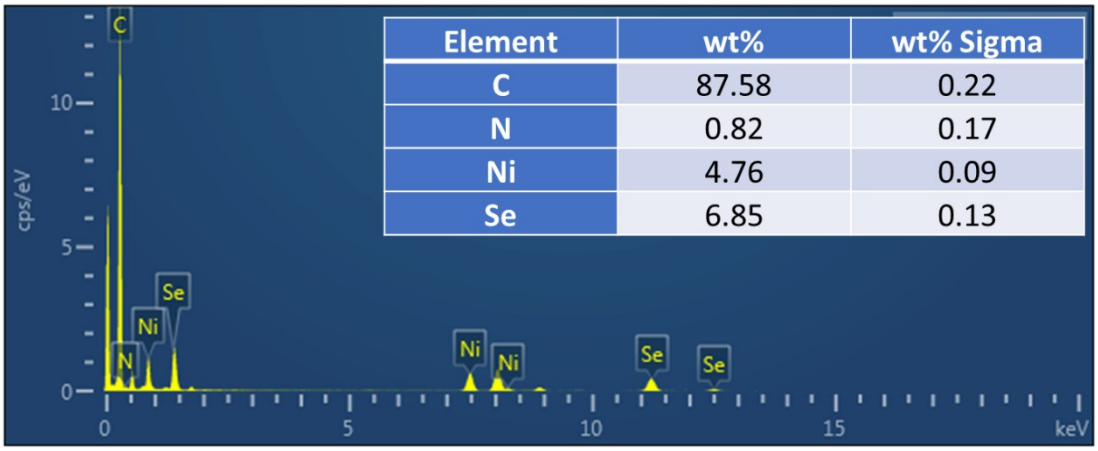


Fig. S2 SEM of (a, b) NHCS, (c, d) $Ni_{0.85}Se$-NHCS, (e, f) $Co_{0.85}Se$ -NHCS, (g, i) $Ni_{0.85}Se/Co_{0.85}Se$-NHCS-2, and (j, k) 50% Ni-$Co_{0.85}Se$-NHCS



Element	wt%	wt% Sigma
C	87.58	0.22
N	0.82	0.17
Ni	4.76	0.09
Se	6.85	0.13

Fig. S3 EDX of $Ni_{0.85}Se$-NHCS and corresponding element content

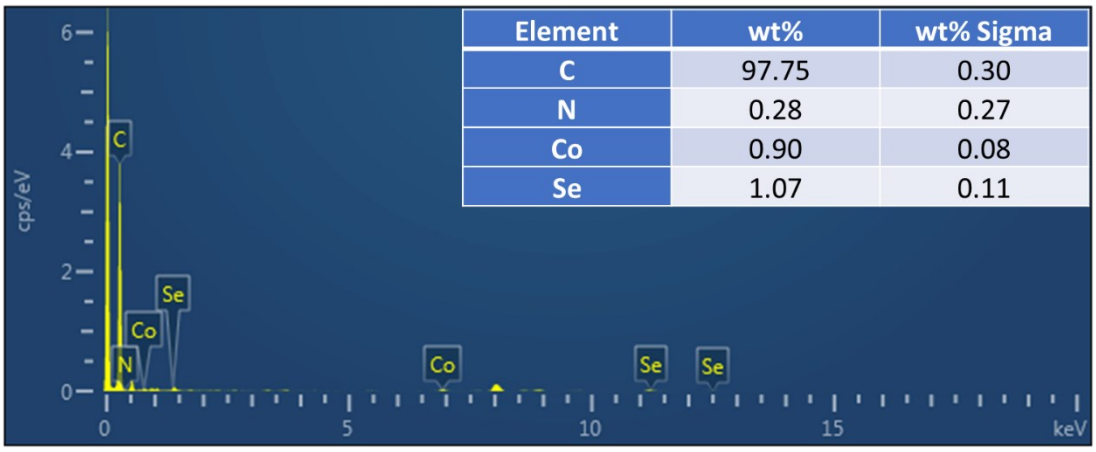


Fig. S4 EDX of $Co_{0.85}Se$-NHCS and corresponding element content

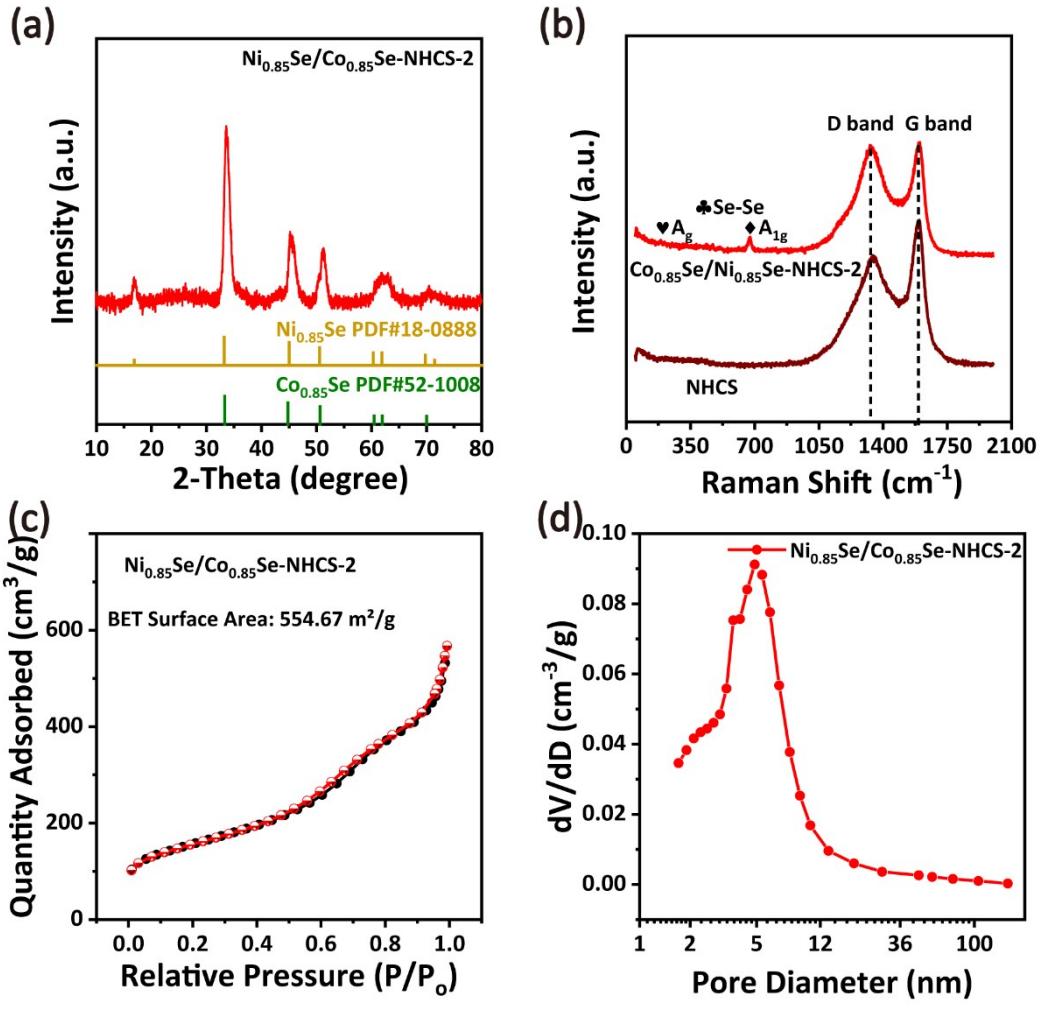


Fig. S5 (a) the XRD patterns of $Ni_{0.85}Se/Co_{0.85}Se$-NHCS-2 and (b) Raman patterns of $Ni_{0.85}Se/Co_{0.85}Se$-NHCS-2 and NHCS, (c) N_2 adsorption/desorption isotherms and (d) corresponding pore size distributions curves of $Ni_{0.85}Se/Co_{0.85}Se$-NHCS-2.

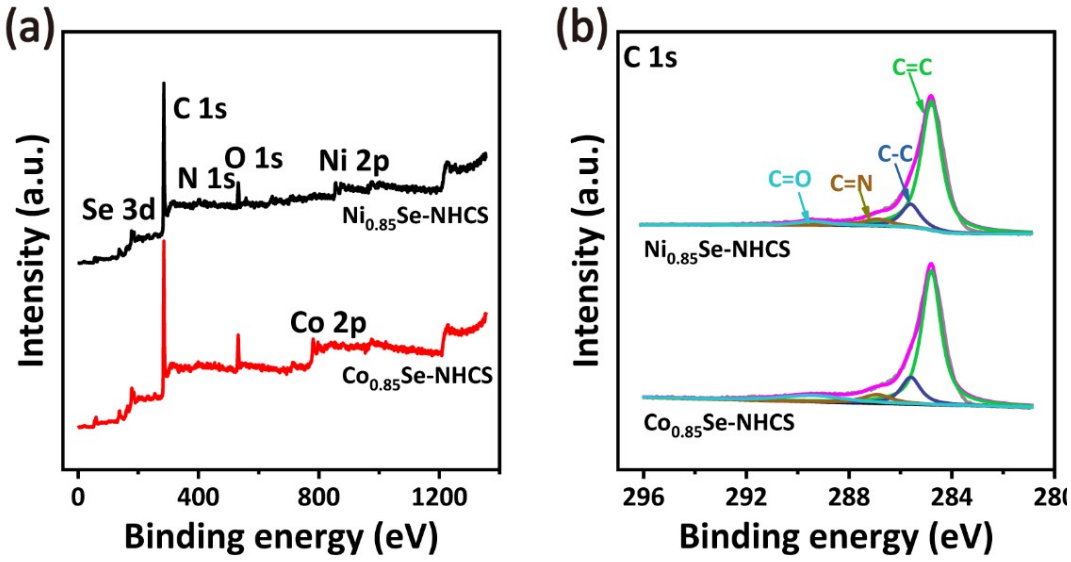


Fig. S6 X-ray photoelectron spectroscopy and corresponding C1s spectra

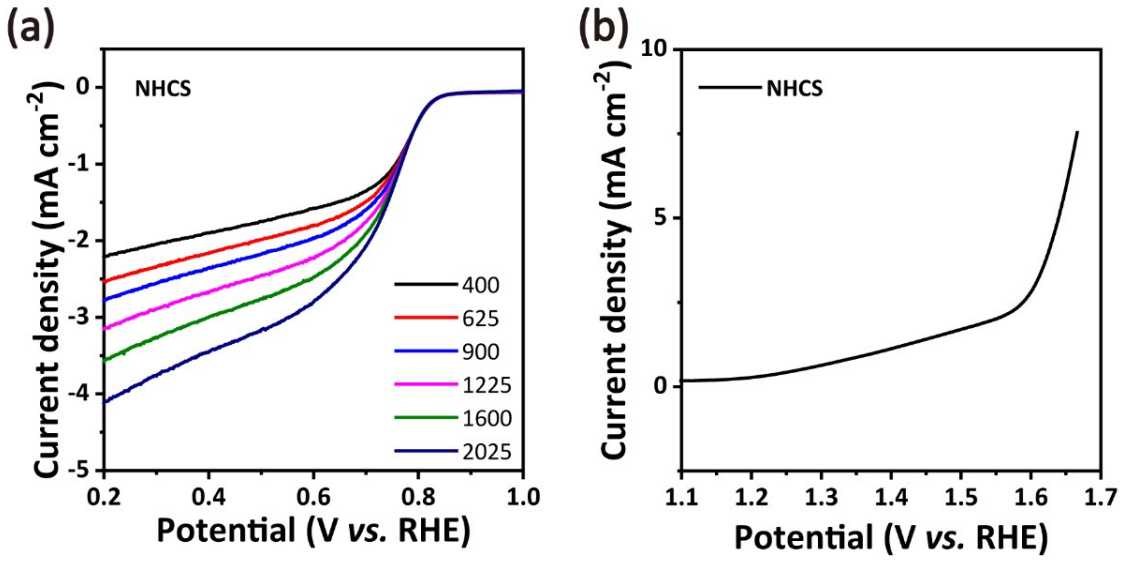


Fig. S7 LSV curves for ORR varying the 400 rpm to 2025 rpm and LSV curves for OER of NHCS.

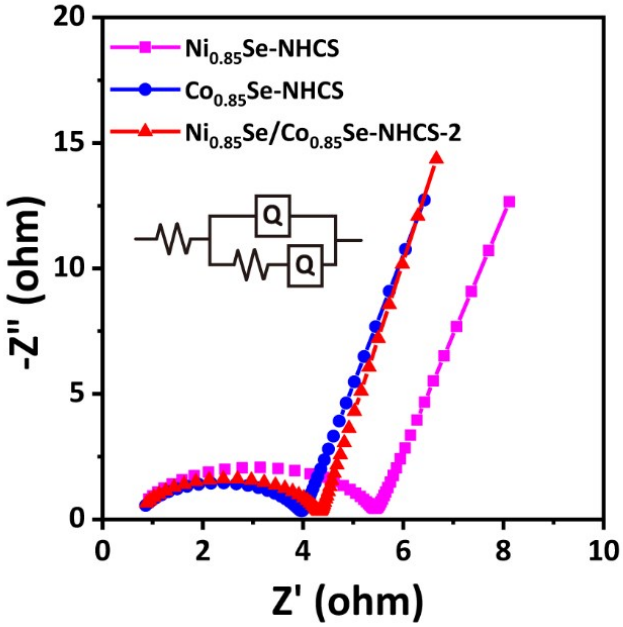


Fig. S8 EIS spectra of $Ni_{0.85}Se$-NHCS, $Co_{0.85}Se$-NHCS, and $Ni_{0.85}Se/Co_{0.85}Se$-NHCS-2.

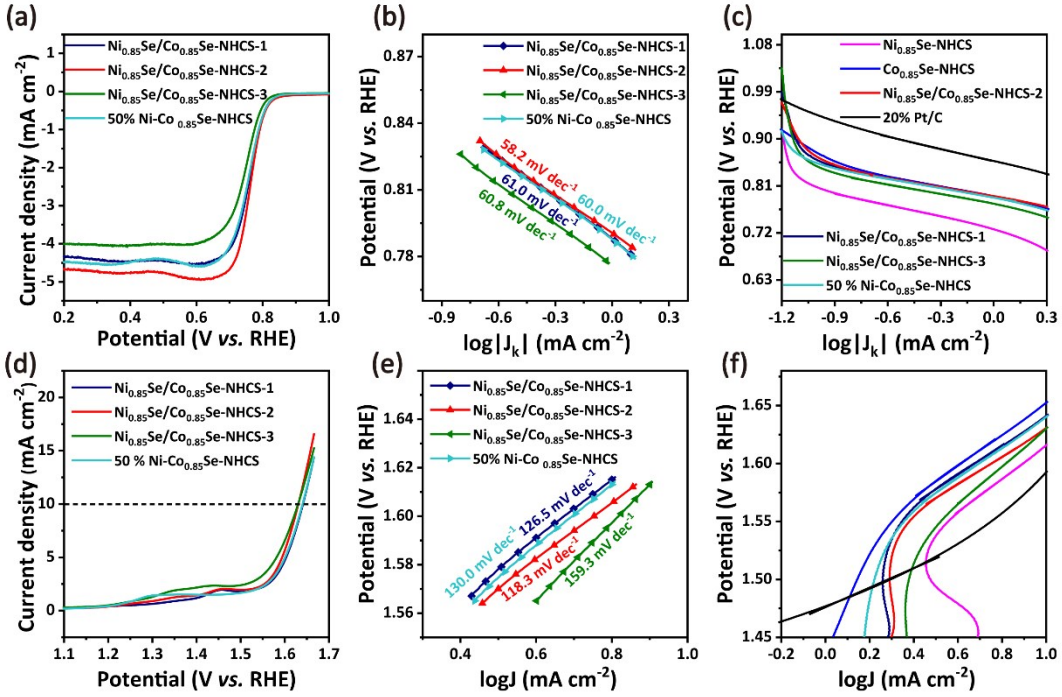


Fig. S9 LSV curves for (a) ORR, corresponding (b, c) Tafel curves, LSV curves for (d) OER and corresponding (e, f) Tafel curves of the as-synthesized catalysts.

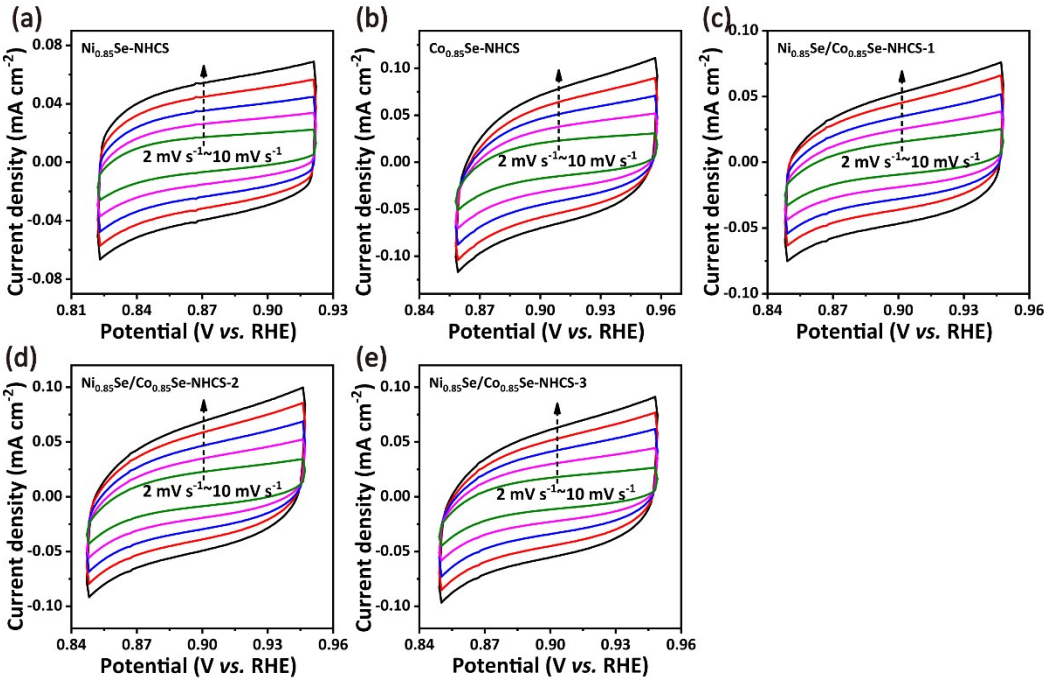


Fig. S10 CV curves of (a) $Ni_{0.85}Se$-NHCS, (b) $Co_{0.85}Se$-NHCS, (c) $Ni_{0.85}Se/Co_{0.85}Se$-NHCS-1, (d) $Ni_{0.85}Se/Co_{0.85}Se$-NHCS-2 and (e) $Ni_{0.85}Se/Co_{0.85}Se$-NHCS-3 at different scan rates**.**

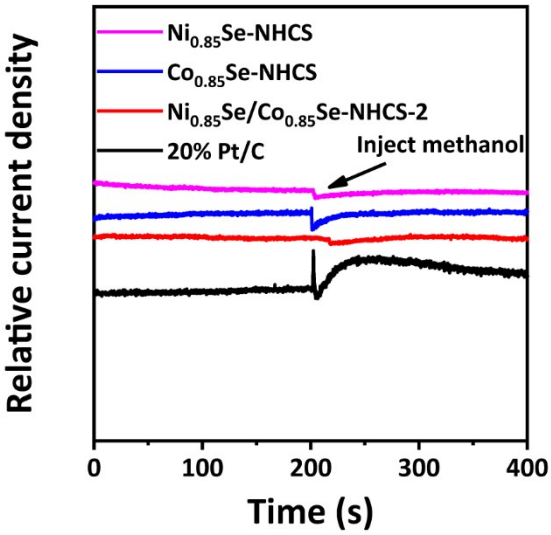


Fig. S11 The methanol tolerance of $Ni_{0.85}Se/Co_{0.85}Se$-NHCS-2 and 20 % Pt/C by the chronoamperometric test at 0.3 V *vs*. RHE in O_2-saturated 0.1 M KOH solution

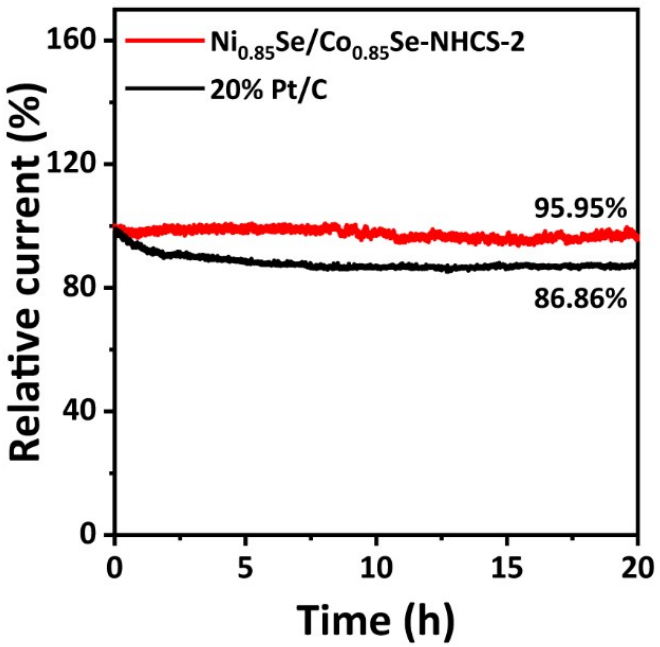


Fig. S12 The chronoamperometric test of $Ni_{0.85}Se/Co_{0.85}Se$-NHCS-2 and 20 % Pt/C at 0.3 V *vs*. RHE in O_2-saturated 0.1 M KOH solution

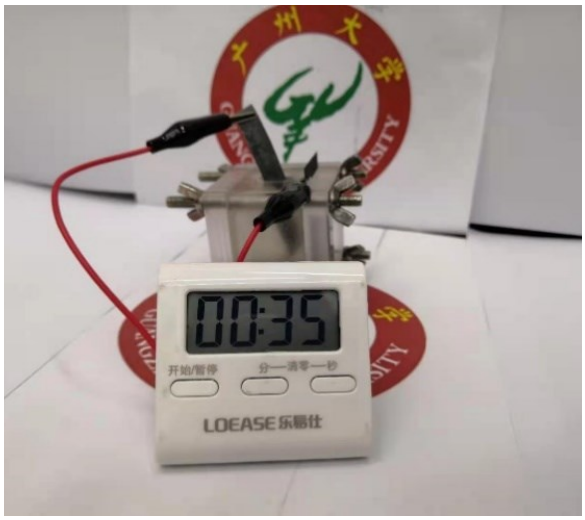


Fig. S13 The photo of the zinc-air battery assembled with $Ni_{0.85}Se/Co_{0.85}Se$-NHCS-2 driving a timer.

Table S1. The bifunctional activity of as-synthesized catalysts for ORR and OER

	E_{onset} (V)	$E_{1/2}$ (V)	$J_{limiting}$ (mA cm^{-2})	$E_{j=10}$ (V)	ΔE (V)
$Ni_{0.85}Se$-NHCS	0.79	0.69	3.71	1.62	0.93
$Co_{0.85}Se$-NHCS	0.89	0.76	4.67	1.65	0.89
$Ni_{0.85}Se/Co_{0.85}Se$-NHCS-1	0.84	0.76	4.34	1.64	0.88
$Ni_{0.85}Se/Co_{0.85}Se$-NHCS-2	0.90	0.77	4.66	1.63	0.86
$Ni_{0.85}Se/Co_{0.85}Se$-NHCS-3	0.86	0.75	4.02	1.63	0.88
20 % Pt/C & RuO_2	0.94	0.82	5.05	1.59	0.77

Table S2. Comparison with the bifunctional activity of different catalysts for ORR and OER

catalyst	Mass loading (mg cm^{-2})	Electrolyte (mol L^{-1})	ORR half-wave potential (V)	ORR Tafel slope (mV dec^{-1})	OER potential at 10 mA cm^{-2} (V)	OER Tafel slope (mV dec^{-1})	Reference
$Ni_{0.85}Se$-NHCS	0.12	0.1 M KOH	0.69	71.7	1.62	141.6	This work
$Co_{0.85}Se$-NHCS	0.12	0.1 M KOH	0.76	62.7	1.65	136	This work
$Ni_{0.85}Se/Co_{0.85}Se$-NHCS-2	0.12	0.1 M KOH	0.78	58.2	1.63	118.3	This work
$Ni_xCo_{0.85-x}Se$	0.60	0.1 M KOH	0.78	/	1.54	62	[1]
$Co_{0.85}Se$@NC	0.40	1 M KOH	/	/	1.55	75	[2]
$Co_{0.85}Se$@CNFs	0.23	0.1 M KOH	0.82	69	1.58	61	[3]
coral-like CoSe	0.28	0.1 M KOH	/	/	1.53	40	[4]
$Co_{0.7}Fe_{0.3}Se_2$	0.51	0.5 M H_2SO_4	0.584	110	/	/	[5]
$CoSe_2$	1	0.1 M KOH	/	/	1.74	67	[6]
$NiSe_2$	1	0.1 M KOH	/	/	1,64	50	[6]
(Ni, Co)Se_2	0.17	0.1 M KOH	0.7	/	1.59	86	[7]
$NiCo_2Se_4$	0.39	1 M KOH	0.77	/	1.56	56	[8]

Table S3. Comparison with the performance of zinc-air batteries of nonprecious catalysts.

Catalyst	Open circuit potential (V)	Maximum power density (mW cm^{-2})	Reference
$Ni_{0.85}Se/Co_{0.85}Se$-NHCS-2	1.40	118.34	This work
20% Pt/C	1.46	154.13	This work
(Ni, Co)Se_2	1.38	110	[7]
IOSHs-NSC-Co_9S_8	1.49	113	[9]
N-CoS_2 YSSs	1.41	81	[10]
Co/Co_3O_4@PGS	1.45	118.27	[11]
Co/Co_xM_y (M=P, N)	1.43	125.2	[12]
$Ni_{0.6}Co_{0.4}Se_2$-O	1.41	110	[13]
O-$Co_{1-x}Mo_xSe_2$	1.53	120.28	[14]
FeCo–N–C-700	1.39	150	[15]
Co-MOF-800	1.38	144	[16]

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