Supporting Information

Broad-Spectrum Response of $NiCo_2O_4$-$ZnIn_2S_4$ p-n Junction Synergies Photothermal and Photocatalytic Effects for Efficient H_2 Evolution

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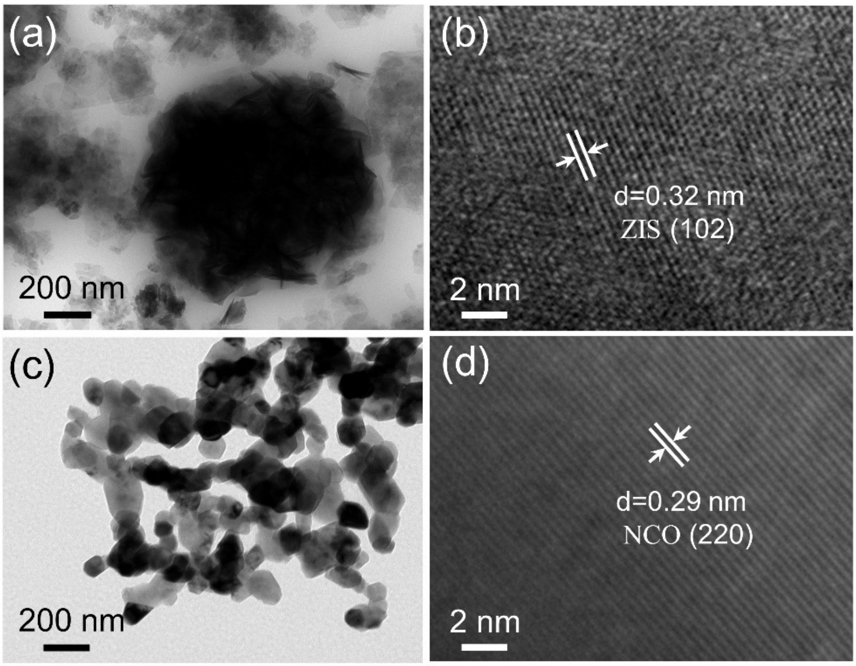

Fig. S1 (a) TEM, and (b) HRTEM images of ZIS. (c) TEM, and (d) HRTEM images of NCO.

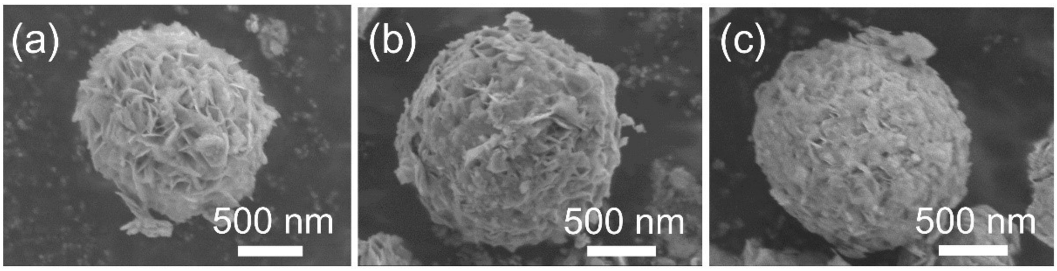

Fig. S2 SEM images of NCO-ZIS-X. (a) NCO-ZIS-1. (b) NCO-ZIS-10. (c) NCO-ZIS-20.

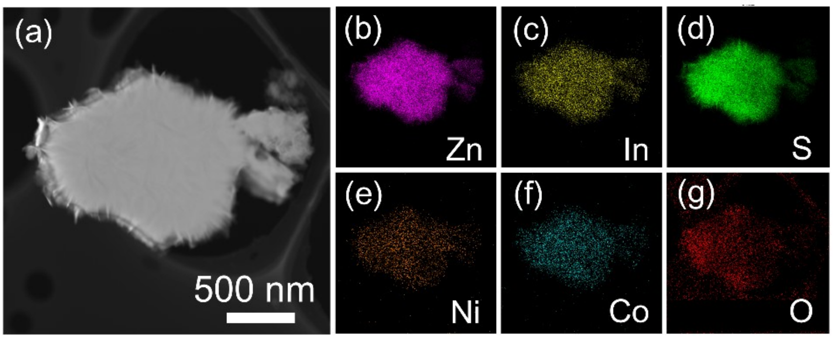

Fig. S3 EDS and corresponding element mapping images of Zn, In, S, Ni, Co, and O in NCO-ZIS-5.

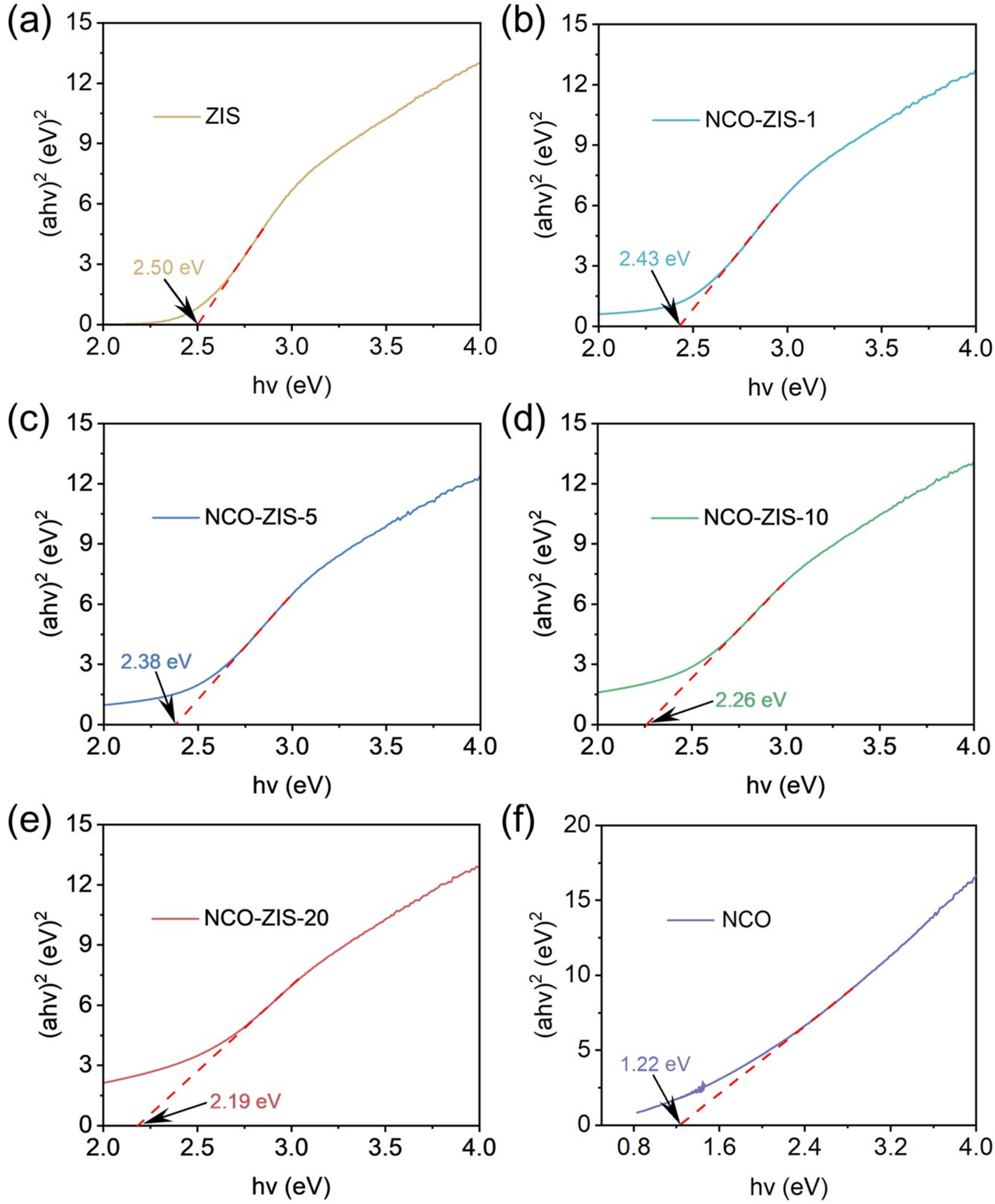

Fig. S4 Tauc plots deriving from the absorbance spectra to evaluate the band gaps of (a) ZIS, (b) NCO-ZIS-1, (c) NCO-ZIS-5, (d) NCO-ZIS-10, (e) NCO-ZIS-20, and (f) NCO.

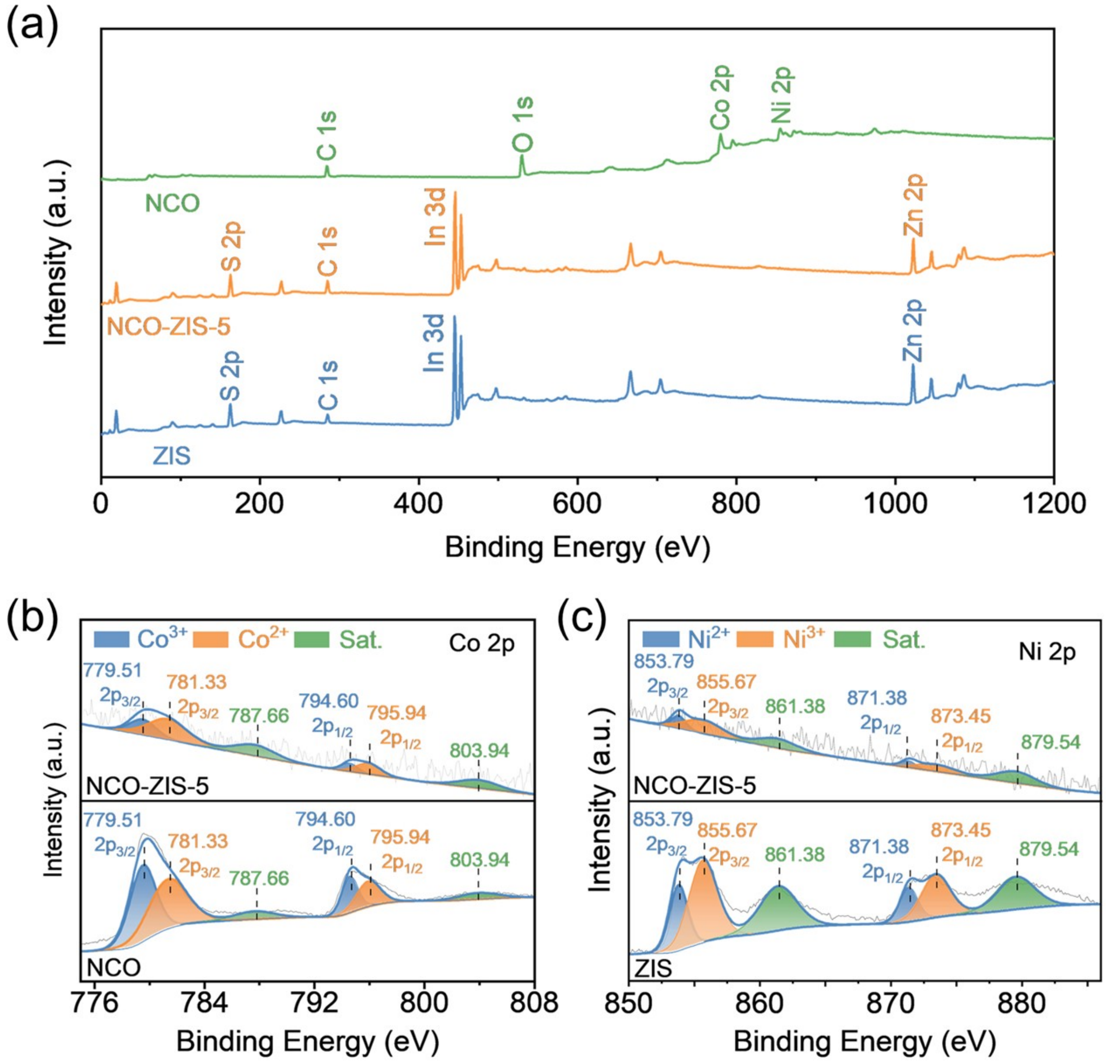

Fig. S5 (a) XPS survey spectra and high-resolution XPS spectra of (b) Co 2p and (c) Ni 2p of the as-prepared samples.

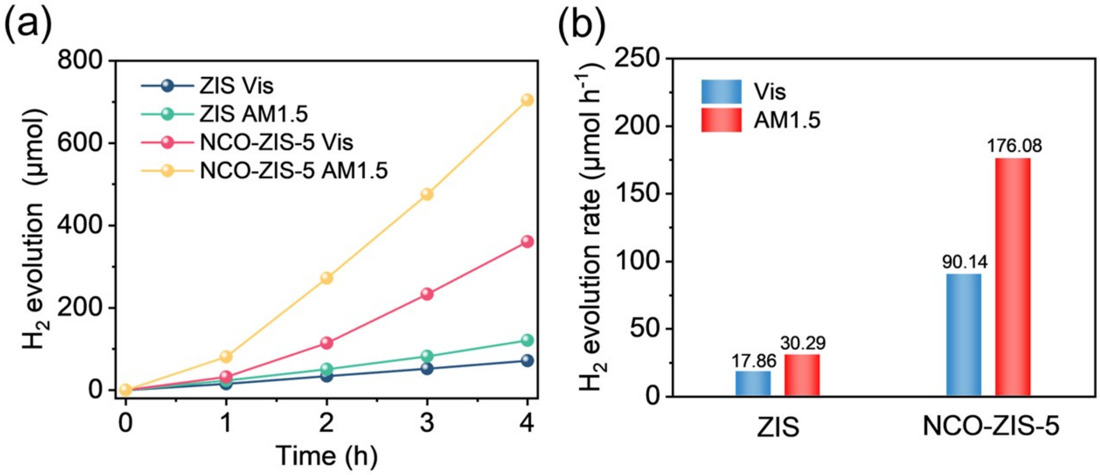

Fig. S6 (a) Time-course photocatalytic H_2 evolution over ZIS and NCO-ZIS-5 and (b) the corresponding H_2 evolution rates under visible light irradiation and full spectrum.

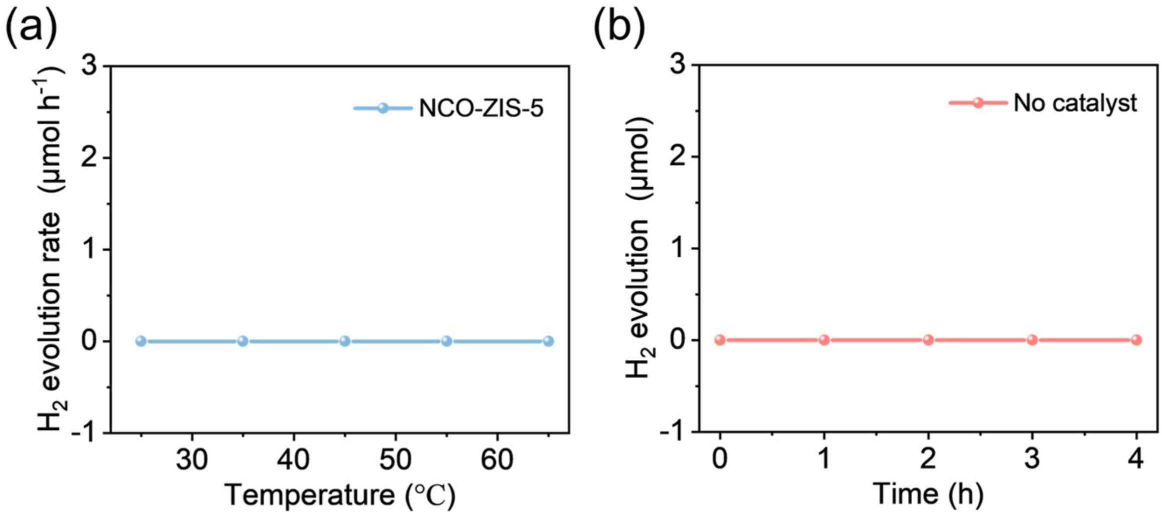

Fig. S7 The blank experiments of hydrogen evolution under (a) dark condition and (b) without catalyst.

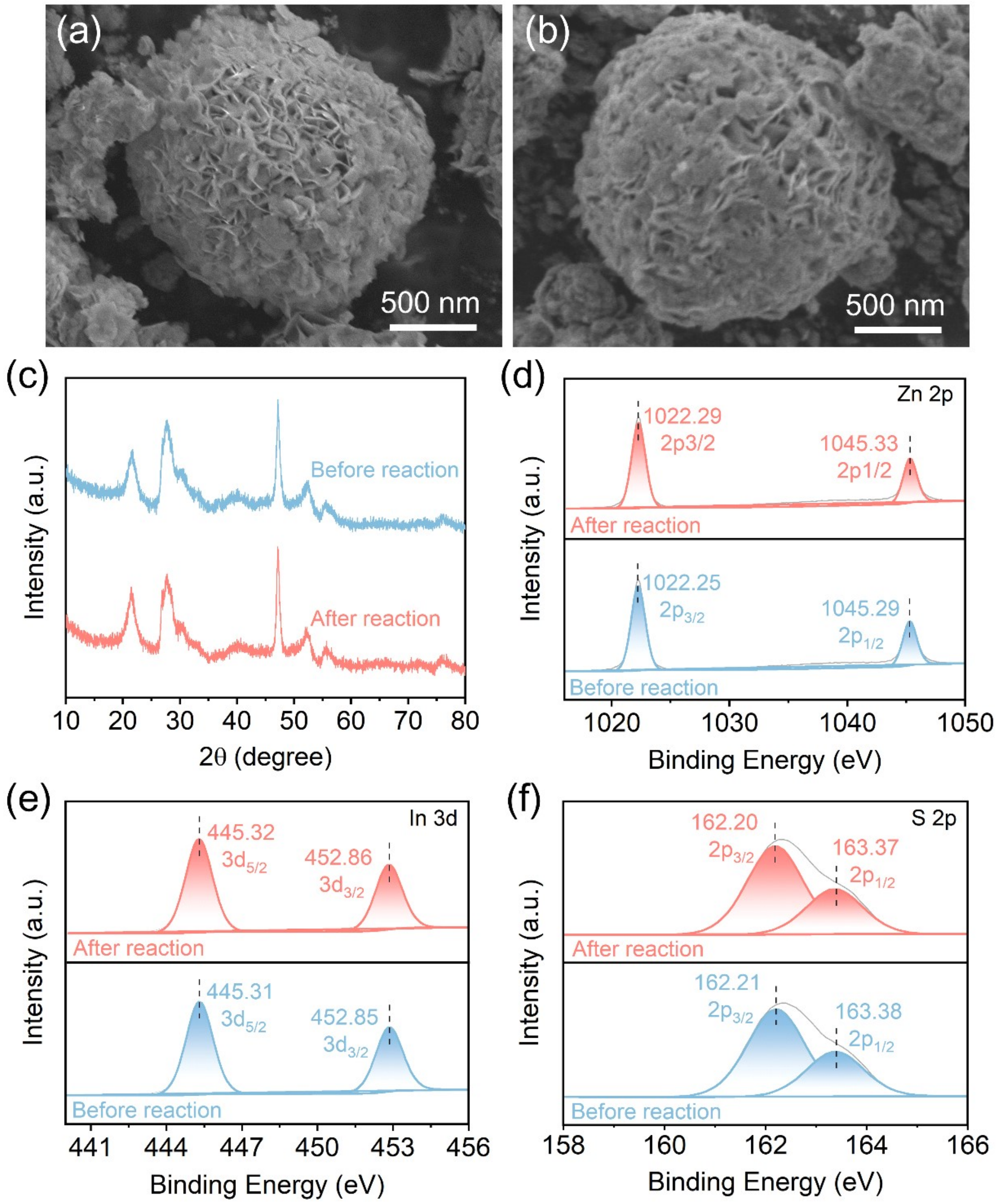

Fig. S8 SEM images of NCO-ZIS-2 (a) before and (b) after photocatalytic reaction. (c) XRD patterns and (d-f) XPS spectra of Zn 2p, In 3d, and S 2p before and after photocatalytic reaction.

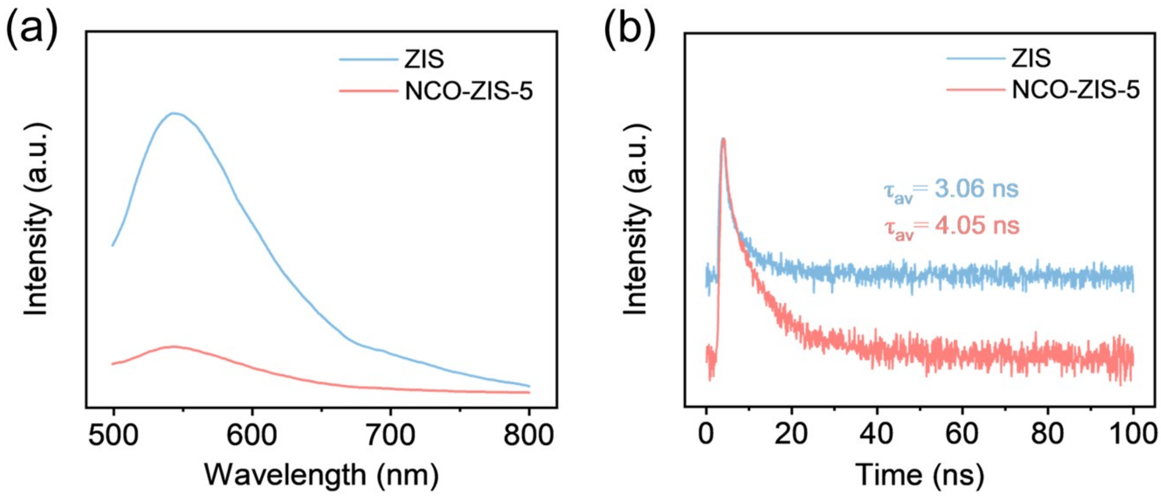

Fig. S9 (a) Steady-state PL spectra and (b) TRPL spectra of ZIS and NCO-ZIS.

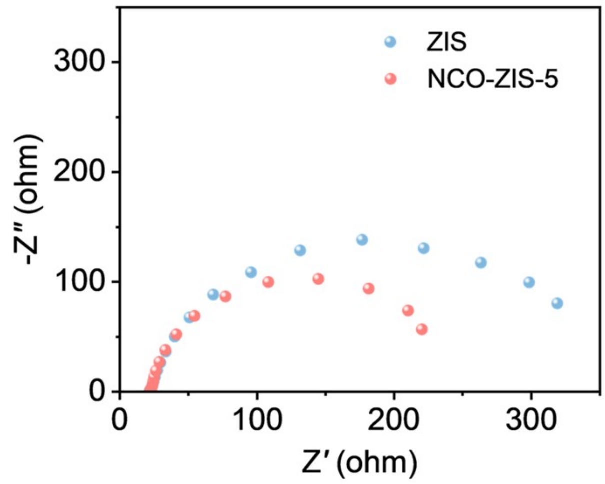

Fig. S10 EIS of ZIS and NCO-ZIS.

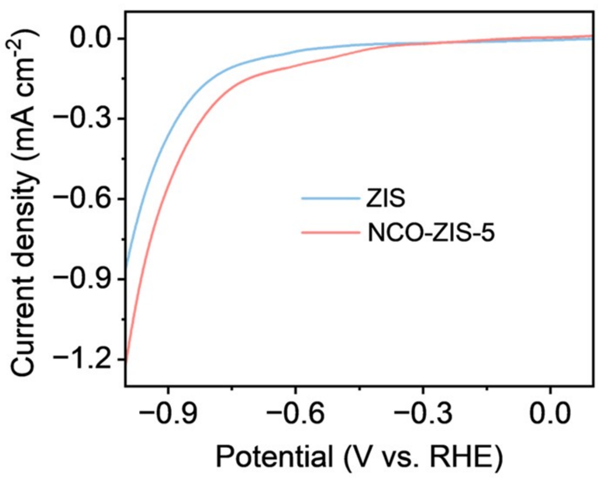

Fig. S11 LSV curves of ZIS and NCO-ZIS.

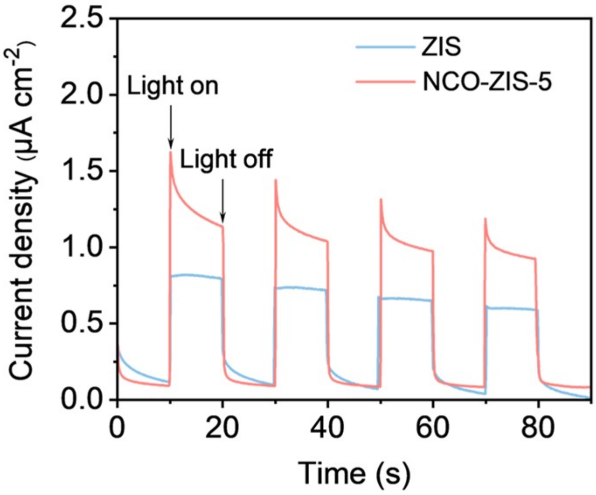

Fig. S12 Transient photocurrent spectra of ZIS and NCO-ZIS.

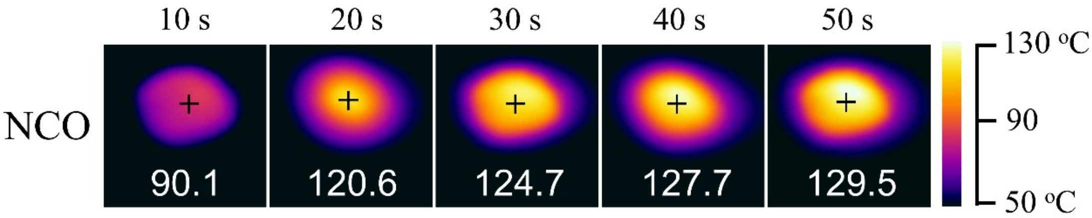

Fig. S13 The temperature fluctuation of NCO under visible light irradiation.

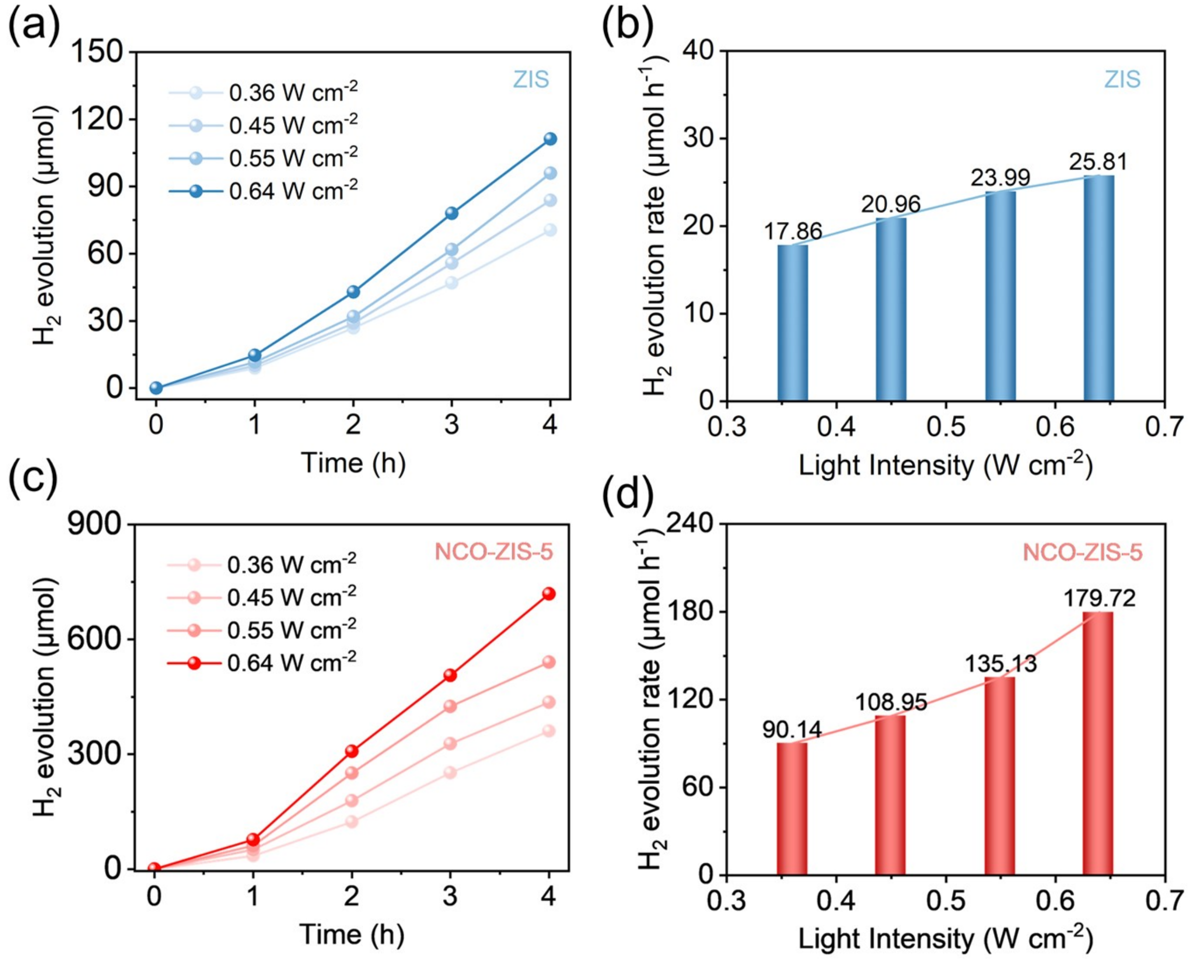

Fig. S14 The photocatalytic hydrogen production rate of (a-b) ZIS and (c-d) NCO-ZIS under different light intensities.

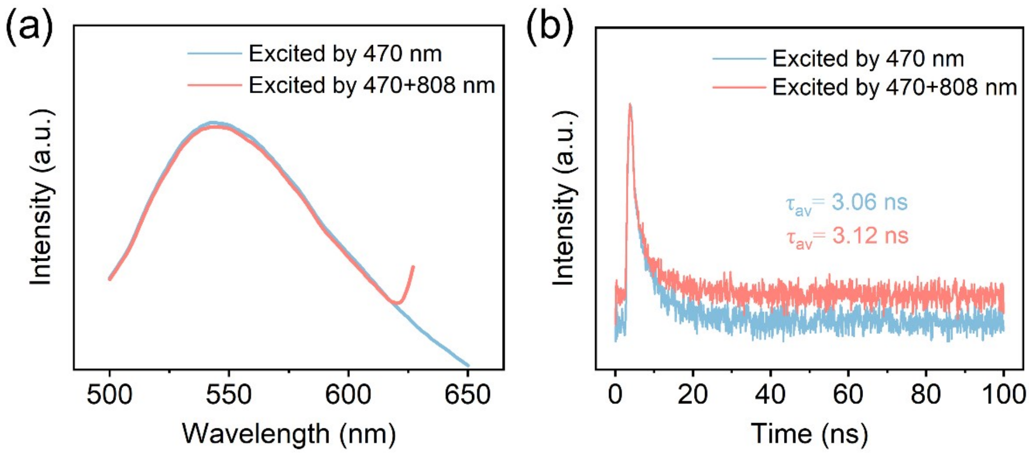

Fig. S15 (a) PL spectra and (b) TRPL decay spectra of ZIS under different excitation.

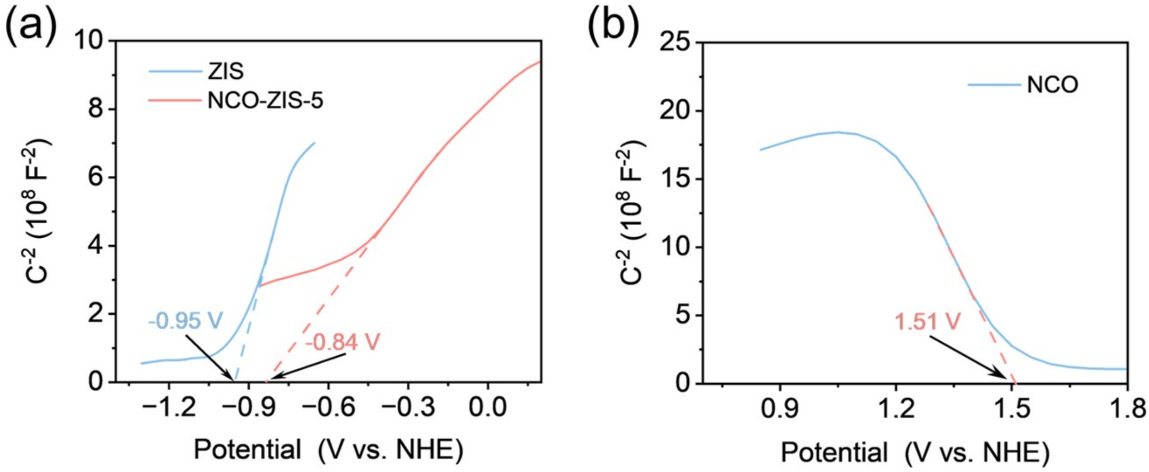

Fig. S16 M-S plots of (a) ZIS and NCO-ZIS, (b) NCO.

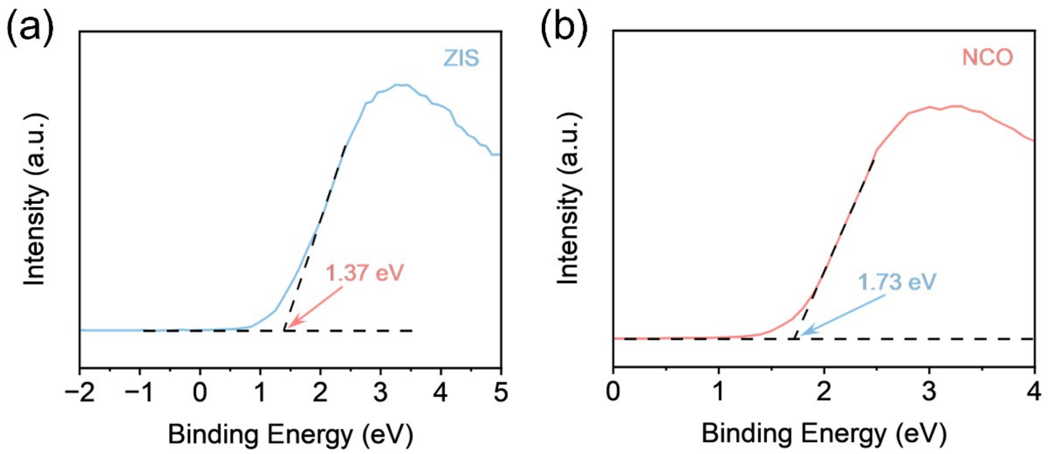

Fig. S17 The XPS valance band spectra of (a) ZIS and (b) NCO.

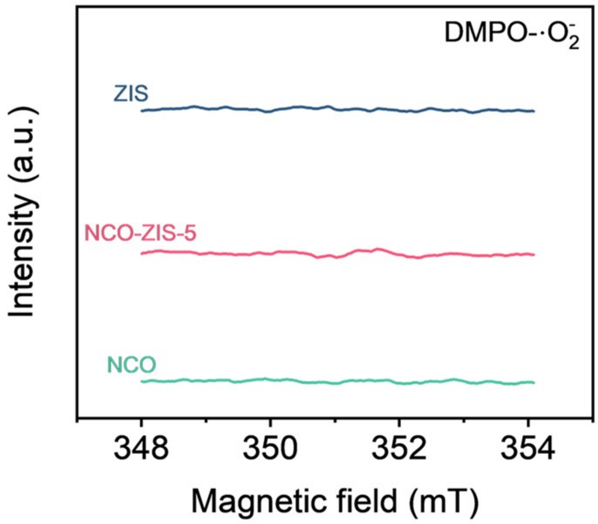

Fig. S18 DMPO spin-trapping EPR spectra of DMPO-·O_2^- under dark condition.

Table S1 Comparison of the photocatalytic H_2 generation over $ZnIn_2S_4$-based photocatalysts.

Photocatalysts	Light source	Sacrificial agent	co-catalyst	H_2 evolution rate (umol/h/g)	Ref.
$ZnIn_2S_4$@PCN-224	300 W Xe amp (λ>420 nm)	Triethanolamine	/	526	1
$Mo_2C/ZnIn_2S_4$	300 W Xe amp (λ>400 nm)	Triethanolamine	Mo_2C	4093	2
$Ti_3C_2T_x$/ $ZnIn_2S_4$	300 W Xe amp (λ>400 nm)	Triethanolamine	Ti_3C_2Tx	2035	3
BC/$ZnIn_2S_4$	150 W Xe amp	Triethanolamine	/	4466	4
$TiO_2/ZnIn_2S_4$	300 W Xe lamp	Triethanolamine	/	215	5
dZni-$ZnIn_2S_4$	300 W Xe lamp (λ>420 nm)	Triethanolamine	/	42.8	6
$CeO_2/ZnIn_2S_4$	300 W Xe lamp	Na_2S/Na_2SO_4	/	1497	7
Ni_xP/CuWO4/$ZnIn_2S_4$	300 W Xe lamp	Triethanolamine	Ni_xP	3015	8
CNF_S-$ZnIn_2S_4$	300W Xe lamp (λ >420nm)	Triethanolamine	/	3166	9
$Ti_3C_2T_X$/ $ZnIn_2S_4$	300W Xe lamp (λ >420nm)	Triethanolamine	/	3280	10
C_3N_4-$ZnIn_2S_4$	300W Xe lamp (λ >420nm)	Triethanolamine	/	2780	11
RGO/$ZnIn_2S_4$	350W Xe lamp (λ >420nm)	Na_2S/Na_2SO_4	Pt/RGO	1210	12
$NiCo_2O_4$/ $ZnIn_2S_4$	**300W Xe lamp (λ>420nm)**	**Triethanolamin e**	/	**4507**	**This work**

Table S2 Lifetime Parameters of ZIS and NCO/ZIS-2 from the TRPL results.

	τ_1(ns)	A_1(%)	τ_2(ns)	A_2 (%)	τ_3(ns)	A_3(%)	τ_{av} (ns)
ZIS (470 nm)	0.63	41.74	4.80	58.26	/	/	3.06
ZIS (470 nm+808 nm)	0.63	42.87	4.99	57.13	/	/	3.12
MC-ZIS-2 (470 nm)	0.47	22.22	2.69	52.41	10.00	25.37	4.05
MC-ZIS-2 (470 nm+808 nm)	0.65	47.04	4.33	52.96	/	/	2.60

Table S3 The hydrogen evolution rate growth multiple of NCO-ZIS relative to ZIS under different light intensities.

Light intensity (W cm^{-2})	Hydrogen production rate of ZIS (μmol h^{-1})	Hydrogen production rate of NCO-ZIS (μmol h^{-1})	Growth multiple
0.36	17.86	90.14	5.04
0.45	20.96	108.95	5.29
0.55	23.99	135.13	5.63
0.64	25.81	179.72	6.96

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