High Efficiency and Stable Tungsten Phosphide Cocatalyst for Photocatalytic Hydrogen Production

Supporting Information

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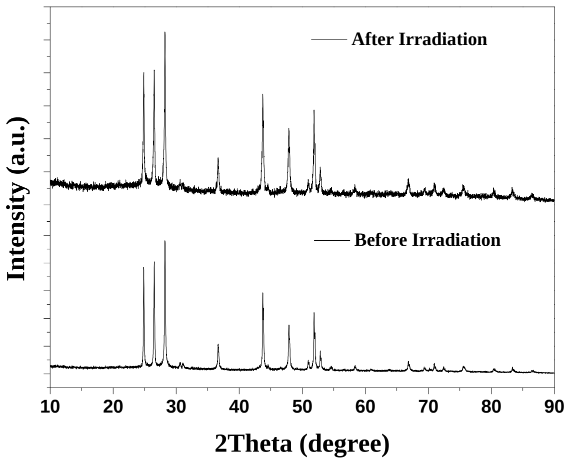

Figure S1. XRD patterns of 4.0 wt.% WP/CdS photocatalyst before and after photocatalytic hydrogen production under visible light irradiation (λ > 420 nm).

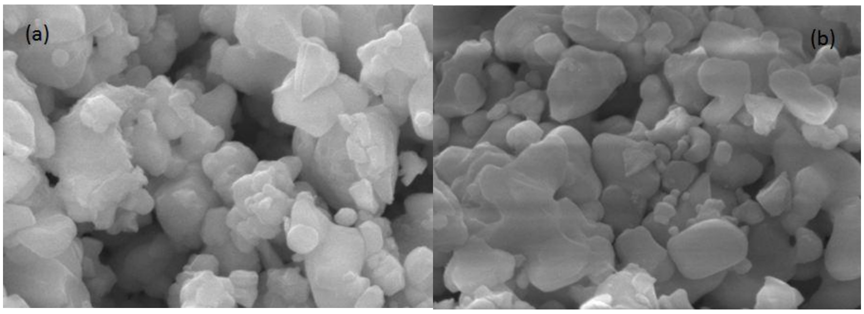

Figure S2. SEM images of WP/CdS before (a) and after (b) photocatalytic hydrogen production.

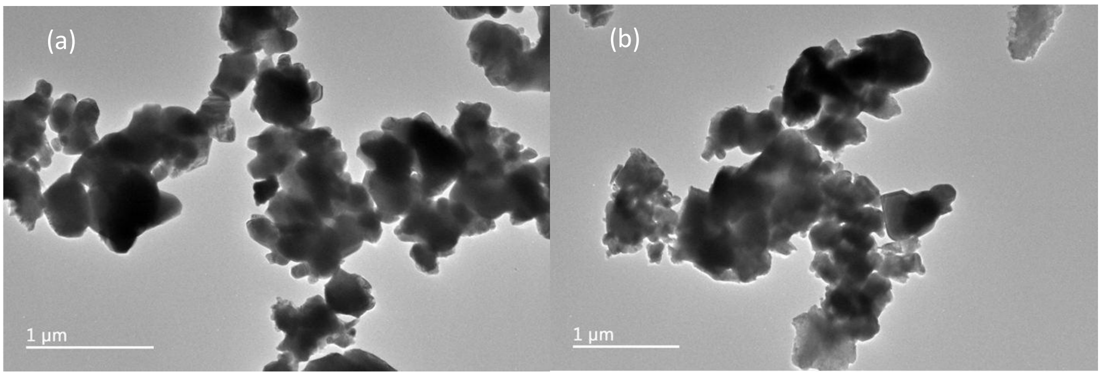

Figure S3. TEM images of WP/CdS before (a) and after (b) photocatalytic hydrogen production.

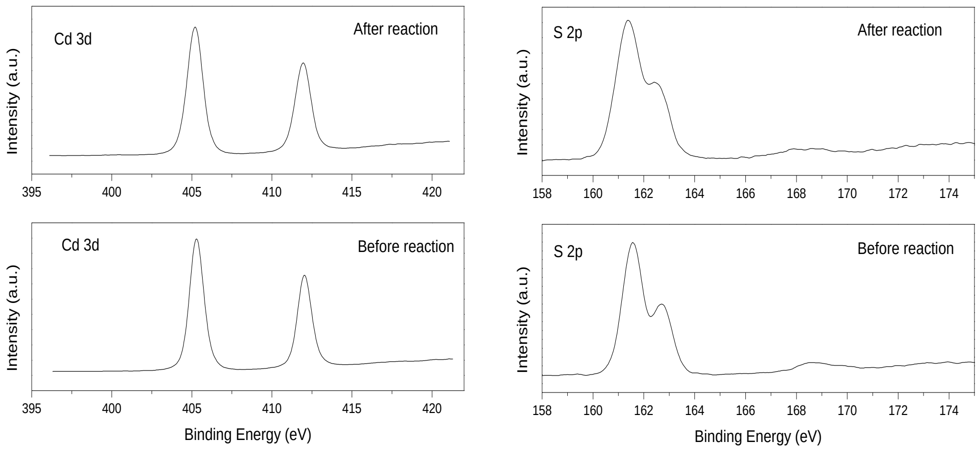

Figure S4. Cd 3d (left) and S 2p XPS (right) spectra of 4.0 wt.% WP/CdS photocatalyst before and after photocatalytic hydrogen production

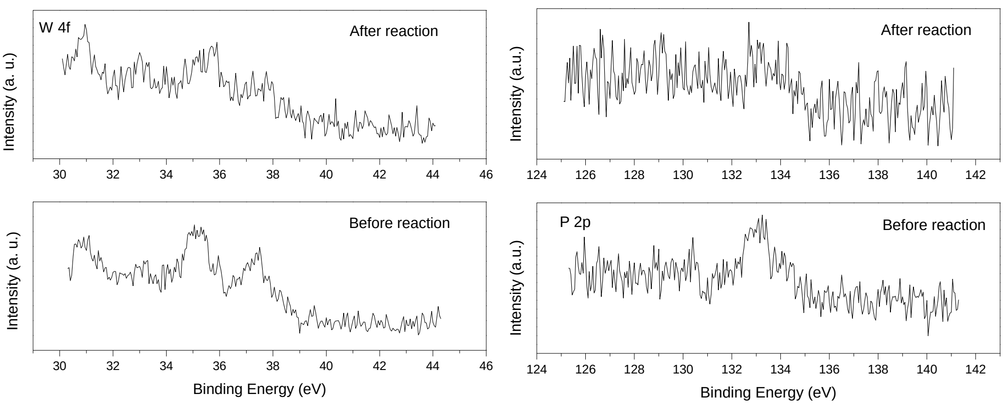

Figure S5. W 4f (left) and P 2p (right) XPS spectra of 4.0 wt.% WP/CdS photocatalyst before and after photocatalytic hydrogen production.

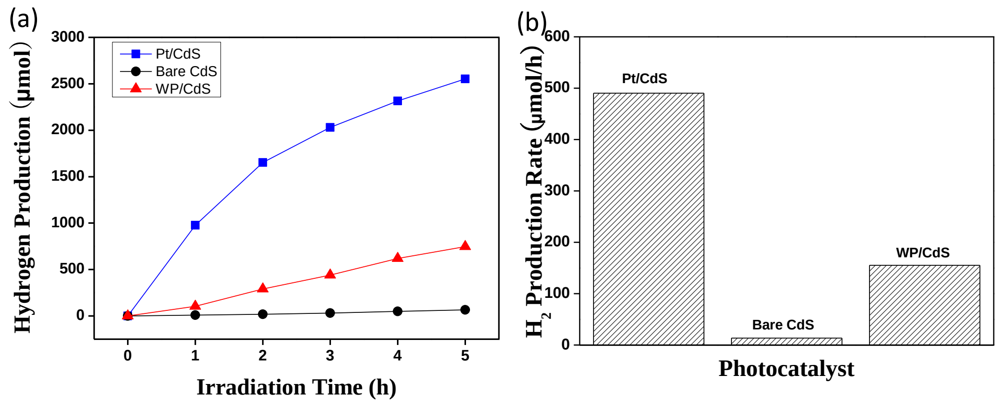

Figure S6. (a) Hydrogen production and (b) Rate of hydrogen production from WP/CdS, bare CdS and Pt/CdS photocatalysts under visible light. (Reaction temperature: room temperature; Light Source: visible light ($\lambda > 420$ nm); Catalyst weight: 50 mg; Photolyte: 100 mL of 1.0 M $(NH_4)_2SO_3$ solution).

Table S1. Summary hydrogen production rates and quantum efficiencies for non-noble metal based cocatalysts.

Non-noble metal Cocatalyst/Photocatalyst	Sacrificial Agent	H2 Production Rate	Quantum Efficiency	Ref.
2.0 wt.% $NiS_2/g\text{-}C_3N_4$	TEOA*	4.06 $\mu mol\cdot h^{-1}$	N/A	C. Xue et al. [1]
0.33 mg CdS + 0.75 mg Co_2P	DL-mandelic acid	19373 $\mu mol\cdot h^{-1}\cdot g^{-1}$	6.8%	Y Chen et al.[2]
16.7 wt.% MoP/CdS	Lactic acid	163.2 $\mu mol\cdot h^{-1}\cdot mg^{-1}$	5.6% at 450 nm	P. Du et al. [3]
5.0 wt.% FeP/CdS	Lactic acid	202000 $\mu mol\cdot h^{-1}\cdot g^{-1}$	Over 35% at 520 nm	Y Chen et al. [4]
0.5 wt.% Ni_2P/CdS	Na_2S+ Na_2SO_3	553 $\mu mol\cdot h^{-1}\cdot mg^{-1}$	41% at 450 nm	P. Du et al. [5]
1.25 wt.% NiS/C_3N_4	TEOA	48.2 $\mu mol\cdot h^{-1}$	1.9% at 440 nm	R. Xu et al. [6]
5.0 mol% CoS_x/TiO_2	CH_3CH_2OH	838.9$\mu molh^{-1}g^{-1}$	N/A	Y. Li et al.[7]
60.0 wt.% CdS + WS_2-40.0 wt.%	Lactic acid	373.41$\mu mol\cdot h^{-1}\cdot g^{-1}$	25.03% at 420 nm	Y Wu et al. [8]
MoS_2/TiO_2/EY**	TEOA	16.7 $mmol\cdot h^{-1}\cdot g^{-1}$	N/A	P. Du et al. [9]
4.0 wt.% WP/CdS	$(NH_4)_2SO_3$	155.17 $\mu mol\cdot h^{-1}$	10.2% at 420 nm	This work

*Triethanolamine; **Eosin Y.

Table S2. EDX and XPS element content analysis of WP/CdS

Element	Atom content (atom%)			
	XPS		EDX	
	Before	After	Before	After
Cd	58.2	56.2	48.3	47.7
S	40.0	41.7	44.8	44.0
W	0.3	0.3	4.7	5.4
P	1.5	1.7	2.3	2.9

Table S3. Summary hydrogen evolution reaction (HER) activities in acid media for WP based electrocatalysts.

Catalyst	**Tafel Slope ($mV\ dec^{-1}$)**	**Current density j (mA/cm^2)**	**Overpotential at the corresponding j (mV)**	**Ref.**
WP	127 (0.5 M H_2SO_4)	10	435	This work
Amorphous WP	54 (0.5 M H_2SO_4)	10	120	R E.Schaak[10]
WP NPs@NC*	58 (0.5 M H_2SO_4)	10	102	X Liu[11]
WP NAs/CC**	69 (0.5 M H_2SO_4)	10	130	X Sun[12]
	125 (1.0 M PBS***)	10	200	
	102 (1.0 M KOH)	10	150	

*Nitrogen-doped carbon; **Nanorod arrays on carbon cloth. ***Phosphate Buffered Saline.

Table S4. Specific BET surface areas of pure CdS, 4.0 wt.% WP/CdS and 0.5 wt.% Pt/CdS photocatalysts

Photocatalyst	S_{BET} [$m^2 \cdot g^{-1}$]
Pure CdS	3.6
4.0 wt.% WP/CdS	4.7
0.5 wt.% Pt/CdS	4.3

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