Electronic Supplementary Material

1 Experimental section

1.1 Materials

Indium trichloride ($InCl_3$, Tianjin Fengyue Chemical Co., Ltd., high purity reagent, ≥ 99.99%), sodium hydroxide (NaOH, Lianlong Bohua Pharmaceutical Chemical Co., Ltd., analytically pure, ≥ 96%), cetyltrimethylammonium bromide (CTAB, $C_{19}H_{42}BrN$, Shanghai Shanpu Chemical Co., Ltd., analytical purity, ≥ 99%), *n*-hexanol ($C_6H_{14}O$, Tianjin Kemeiou Chemical Reagent Co., Ltd., analytically pure, ≥ 98%), *n*-octane (C_8H_{18}, Tianjin Kemeiou Chemical Reagent Co., Ltd., analytically pure, ≥ 95%), red phosphorus (P, Beijing Red Star Chemical Factory, analytically pure, ≥ 99%), iodine elemental (I_2, Chengdu Kelong Chemical Co., Ltd., analytically pure, ≥ 99.8%), xylene (C_8H_{10}, Hongyan Reagent Factory, Hedong District, Tianjin, analytically pure, ≥ 99%), anhydrous ethanol (CH_3CH_2OH, Lianlong Bohua (Tianjin) Pharmaceutical Chemical Co., Ltd., analytically pure, ≥ 99.7%), hydrochloric acid (HCl, Sichuan Xilong Chemical Co., Ltd., analytically pure, 36%–38%), stannous chloride ($SnCl_2·2H_2O$, Sichuan Xilong Chemical Co., Ltd., analytically pure, ≥ 98%), potassium hydroxide (KOH, Lianlong Bohua (Tianjin) Pharmaceutical Chemical Co., Ltd., analytically pure, ≥ 85%), chloroplatinic acid ($H_2PtCl_6·6H_2O$, Tianjin Kemiou Chemical Reagent Co., Ltd., analytically pure, ≥ 99%), All reagents were used without further purification. Deionized water was prepared by ion exchange and filtration, and the specific resistance was 18.2 MΩ·cm (RFD, 250NB, Toyo Seisakusho Kaisha Ltd, Japan).

1.2 Preparation of SnO nanosheets

$SnO_2·2H_2O$ and KOH are used as raw materials to prepare SnO nanosheets by utilizing the hydrothermal method. The specific preparation process is as follows: Dissolve 4.96 g of $SnCl_2·2H_2O$ in 60 mL of deionized water to form a suspension, and then add 80 mL of KOH (0.7 M), ultrasonic dispersion for 20 min, magnetic stirring for 30 min, and pour 50 mL. The reaction vessel is reacted at 80°C for 15 h, and finally washed with deionized water and absolute ethanol, and dried at 60°C to obtain the final product.

1.3 Preparation and electrochemical testing of working electrodes

All electrochemical tests are performed at the electrochemical workstation (CH1660E). The test uses a three-electrode system with a platinum electrode as the counter electrode and a saturated calomel electrode (SCE) as the reference electrode. A certain amount of catalyst powder is ultrasonically dissolved in water. Then, it is applied on the indium tin oxide (ITO) conductive glass ultrasonically cleaned by ethanol, and dried naturally as a working electrode. The surface area of the working electrode exposed to the electrolyte is 1 cm^2 (that is, 1 cm × 1 cm). The electrolyte is 0.1 M Na_2SO_4 solution. The visible light source still uses a 300 W xenon lamp equipped with a 420 nm cutoff filter. The measured electrochemical impedance-potential spectrum analysis chart gives the Mott-Schottky curve through data fitting.

1.4 Characterization

The crystal structure of the photocatalyst material is analyzed by X-ray powder diffractometer (XRD). Transmission electron microscope (TEM) and high-resolution transmission electron microscope (HRTEM) are characterized on the Tecnai-G2-TF20 field emission transmission electron microscope, where the acceleration voltage is 300 kV. ESCALAB 250Xi-XPS photoelectron spectrometer is used to analyze the chemical composition and chemical state of the catalyst; ultraviolet-visible diffuse reflection spectroscopy (UV-vis DRS) with UV-2550 (Shimadzu) test, using $BaSO_4$ powder as an internal standard. The photoluminescence (PL) spectrum and time-resolved photoluminescence (TRPL) spectrum of all samples are studied with Edinburgh FL/FS 900 with an excitation wavelength of 532 nm. The electron transport properties of the samples are measured on the Keithley 4200 SCS by using the double-probe method. At

room temperature, Hall effect measurement is performed with a magnetic induction intensity of 0.55 T in a Van der Pauw four-point probe configuration (Quantum Technology Corp., Blaine WA, USA).

1.5 Isotope tracer experiment

Ten mg of Pt/SnO/$In(OH)_3$/InP catalyst was disperse in a sealed reaction flask containing 10 mL of D_2O or 2 mL of $H_2{}^{18}O$. After ultrasonic dispersion for 30 min, the suspension was bubbled by Ar for 40 min to replace the gas in the reaction flask. The photocatalytic water splitting test irradiation time lasts for 4 h or 6 h under visible light. Then 0.5 mL of gas was drawn from the reaction flask. In GC-MS, the m/z signal is analyzed according to the mass spectrum database.

1.6 $(PO_4)^{3-}$ concentration test

A certain amount of catalysts was weighed into the reaction flask. After adding water to ultrasonically disperse, the reaction in a water bath was stirred at 50 °C for 7 h. During this period, a certain amount of suspension was drawn each hour and centrifugated. Then, a certain amount of ascorbic acid solution and molybdate solution was added to the mix thoroughly. Finally, standing at room temperature for 20 min, the absorbance was measured with water as a reference at a wavelength of 700 nm. Based on Lambert Beer's law: $A = \lg(1/T) = Kbc$, the concentration of $(PO_4)^{3-}$ in the measured catalyst was calculated. Here A is the absorbance, T is the transmittance, K is the molar absorption coefficient, c is the concentration of the light-absorbing substance in mol/L, and b is the distance the light travels in the sample, usually the thickness of the cuvette, in cm.

2 Results and discussion

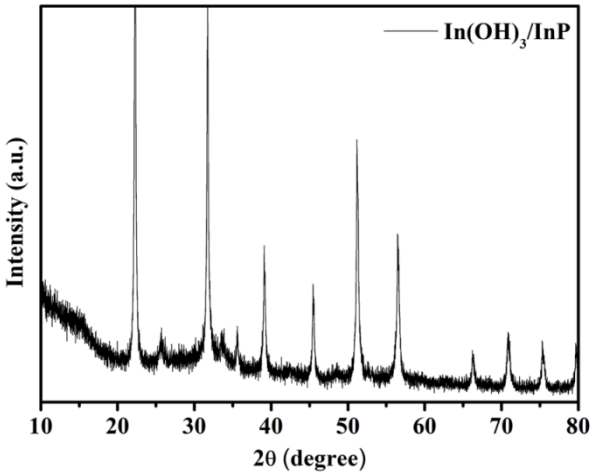

Fig. S1 XRD patterns of InP.

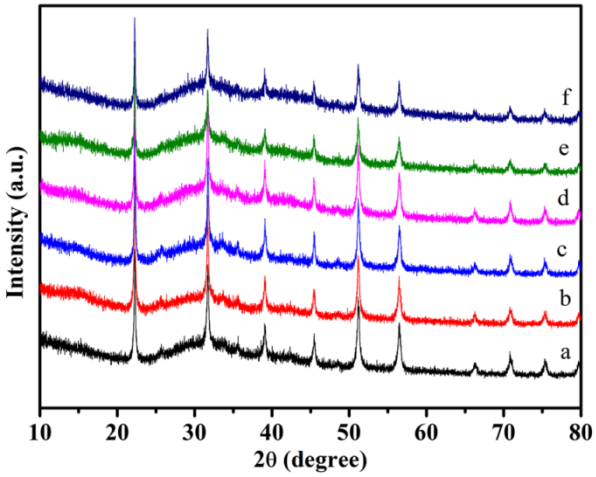

Fig. S2 XRD patterns of different catalysts.

(a) 5%; (b) 7%; (c)10% SnO/$In(OH)_3$/InP; (d) Pt/5%; (e) 7%; (f) 10% SnO/$In(OH)_3$/InP with at different SnO mass ratios.

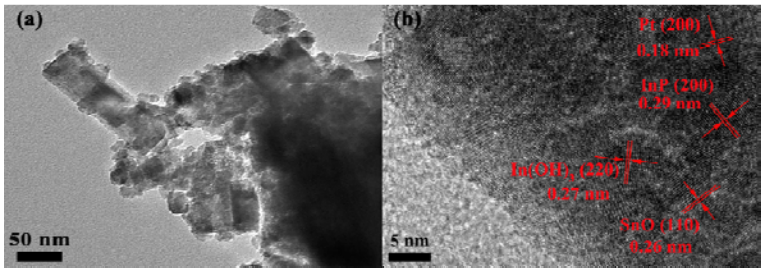

Fig. S3 Microstructure and morphology of catalysts.

(a) TEM images; (b) HRTEM images of Pt/SnO/$In(OH)_3$/InP.

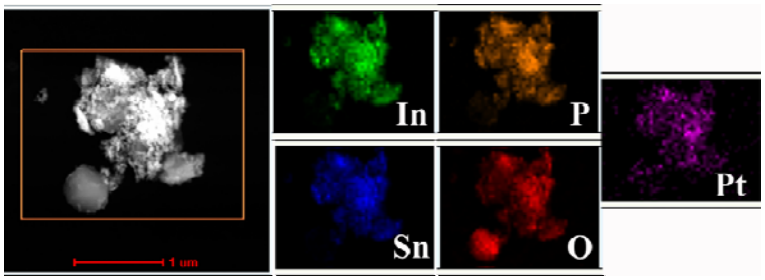

Fig. S4 Element distribution mapping of Pt/SnO/$In(OH)_3$/InP.

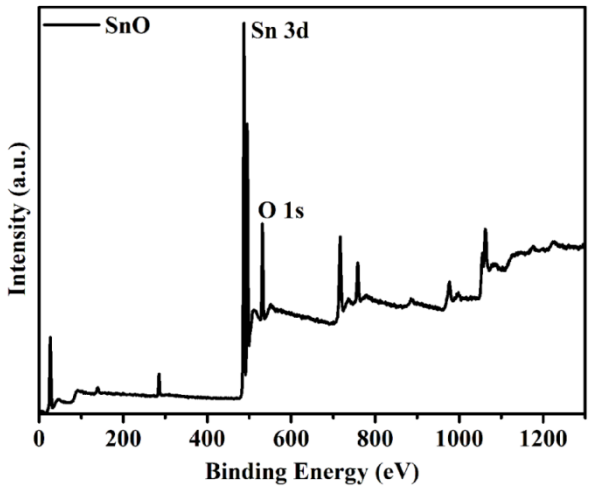

Fig. S5 XPS full spectrum of SnO.

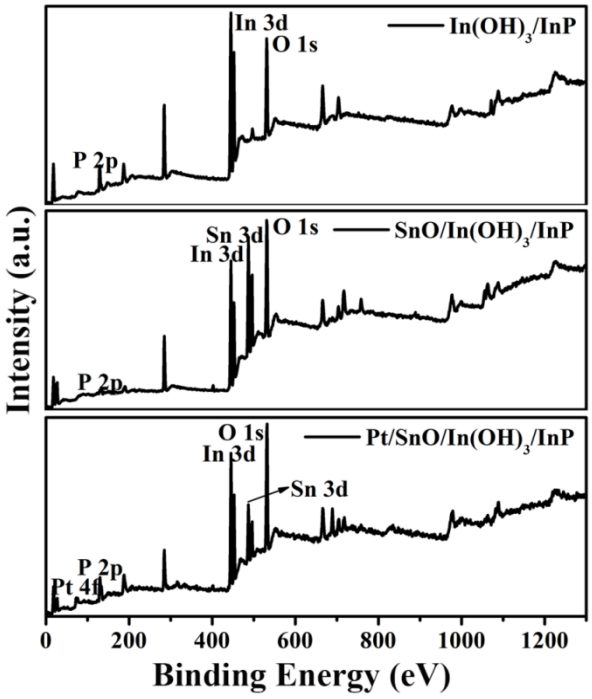

Fig. S6 XPS full spectrum of $In(OH)_3$/InP, 7%SnO/$In(OH)_3$/InP and 1%Pt/7%SnO/$In(OH)_3$/InP.

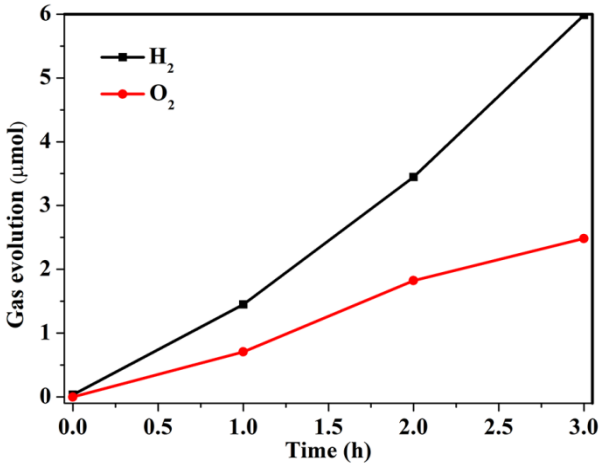

Fig. S7 Test of hydrogen and oxygen production over 1%Pt/7%SnO/$In(OH)_3$/InP catalyst under visible light irradiation in a pure water system.

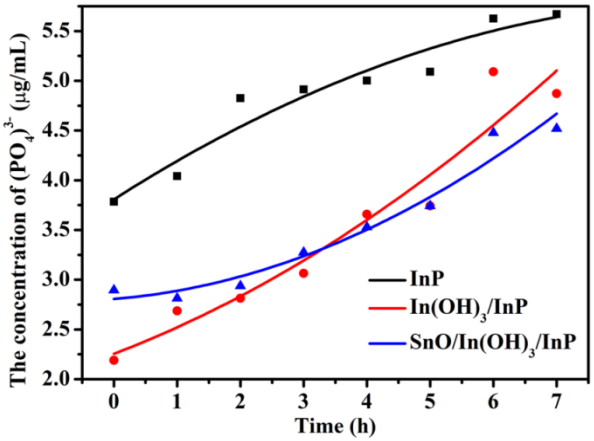

Fig. S8 Concentration curve of $(PO4)^{3-}$ in InP, $In(OH)_3$/InP and SnO/$In(OH)_3$/InP catalyst solution with time under the water bath condition of 50℃.

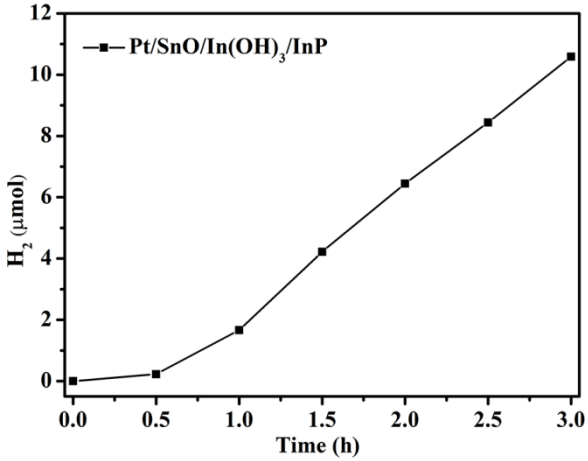

Fig. S9 Pt/SnO/$In(OH)_3$/InP full spectrum driven photocatalytic water splitting hydrogen production test.

Table S1 Decay parameter of $In(OH)_3$/InP in different catalytic systems

Samples	Lifetime/ns	Pre-exponential factors *B*/%	Average lifetime (τ)/ns
$In(OH)_3$/InP	τ_1=0.00614 τ_2=0.05050	B_1=8.40 B_2=91.6	0.050
Pt/$In(OH)_3$/InP	τ_1=0.00625 τ_2=0.06222	B_1=6.39 B_2=93.61	0.061
Pt/SnO/$In(OH)_3$/InP	τ_1=0.00609 τ_2=0.07124	B_1=34.17 B_2=65.83	0.068

Table S2 Electrical parameters extracted from Hall measurement of SnO

Samples	Type[a]	n[b]/cm^{-3}	μ[c] /($cm^2 \cdot Vs^{-1}$)	ρ[d]/($\Omega \cdot cm^{-1}$)	δ[e] /($\Omega^{-1} \cdot cm$)	RH[f] /($cm^3 \cdot C^{-1}$)
SnO	p	9.243×10^{14}	1.066×10^{1}	6.338×10^{2}	1.578×10^{-3}	6.753×10^{3}

Notes: *a* is type of semiconductor, *b* is the carrier concentration, *c* is the mobility, *d* is the resistivity, *e* is the conductivity, and *f* is the average Hall coefficient.