Electronic Supplementary Material (ESI) for Catalysis Science & Technology.

Supporting Information

$PtNi_xCo_y$ Concave Nanocubes: Synthesis, Application in Photocatalytic Hydrogen Generation

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For the investigation of quantum efficient (QE), the cut-off filter (λ>420 nm) was replaced by a 420±5 nm band-pass filter, and the irradiance was measured by means of an ultraviolet radiation meter (UV-B, Beijing normal University). QE can be calculated as:

$$QE = \frac{The\ number\ of\ evolved\ hydrogen\ atoms (N_H)}{The\ number\ of\ incident\ photons (N_p)} \times 100\%$$

$$N_H = 2 \times n_{H_2} \times L$$

$$N_p = \frac{A \cdot I}{E} = \frac{A \cdot I}{({hc}/{\lambda})}$$

$QE =$ Where n_{H2} is the moles of evolved hydrogen molecular, mol; L the Avogadro constant, 6.02×10^{23} mol^{-1}; I the irradiance at 420 nm, W/m^2; A the illuminate area, m^2; E the photon energy, eV; h the Plank Constant, 6.63×10^{-34}, J·s; c the light rate, 3×10^8 m/s.

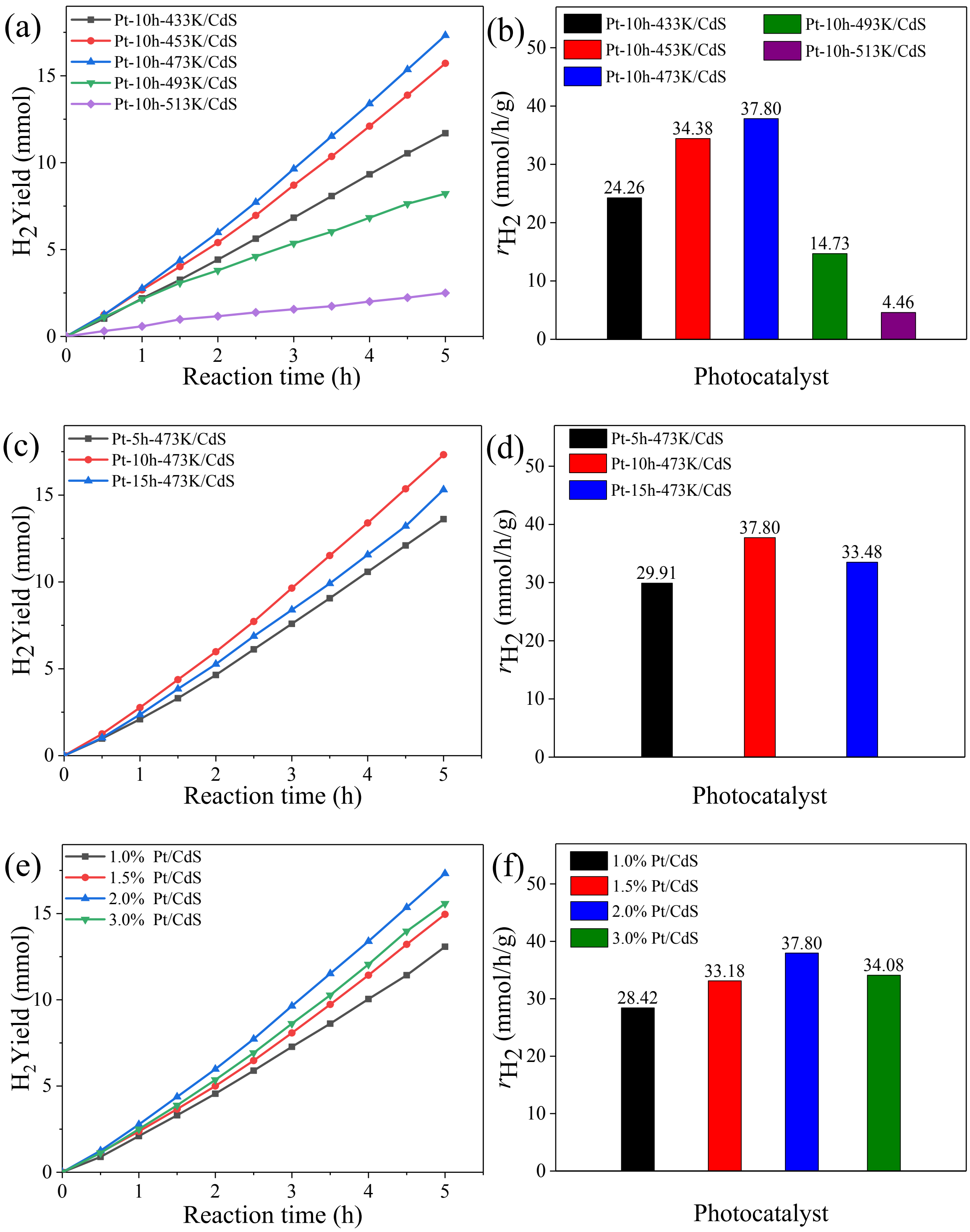

Fig. S1 (a) the effect of synthesis temperature of Pt CNCs on the hydrogen evolution rate of CdS, (c) the effect of synthesis time of Pt CNCs on the hydrogen evolution rate of CdS, (e) the effect of the amount of Pt CNCs on hydrogen evolution rate of CdS, (b), (d), (f) the hydrogen evolution rate of each photocatalyst when their activity is stable.

The reaction conditions: 0.1 g CdS photocatalyst (loading amount of Pt CNCs is 2.0 wt % in Fig. a and Fig. c), 50 mL of 1 M $(NH_4)_2SO_3$ solution, 300W Xenon lamp (λ≥420 nm).

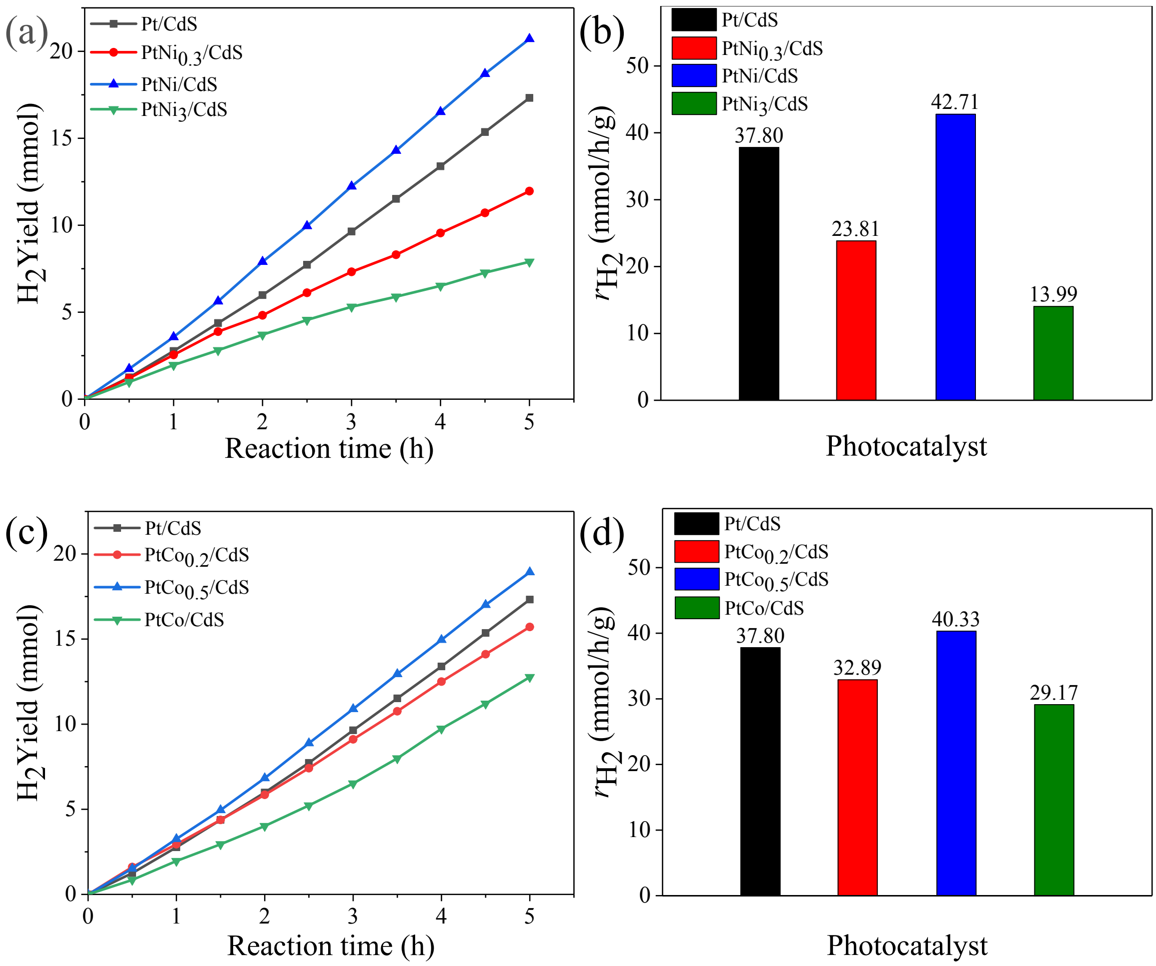

Fig. S2 Hydrogen generation rate of (a) $PtNi_x/CdS$ (x=0, 0.3, 1, 3) and (c) $PtCo_y/CdS$ (y=0, 0.2, 0.5, 1) photocatalysts. The hydrogen generation rate of (b) $PtNi_x/CdS$ (x=0, 0.3, 1, 3) and (d) $PtCo_y/CdS$ (y=0, 0.2, 0.5, 1) when its activity gets stable.

The reaction conditions: 0.1 g CdS (loading amount of $PtNi_x$ or $PtCo_y$ CNCs is 2.0 wt %), 50 mL 1 M $(NH_4)_2SO_3$ solution, 300W Xenon lamp (λ≥420 nm).

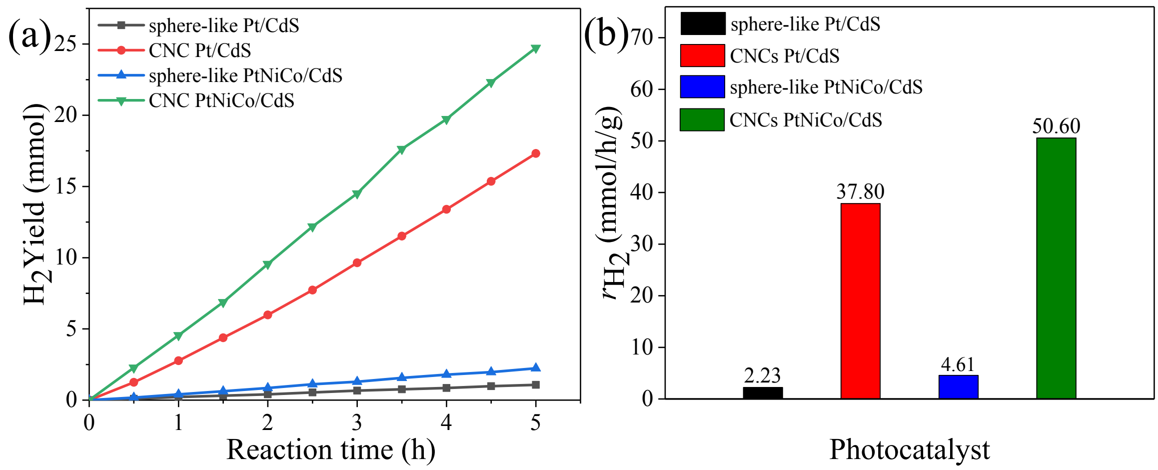

Fig. S3 Comparison of hydrogen production rate of sphere-like Pt/CdS and CNCs Pt/CdS and sphere-like PtNiCo/CdS and CNCs PtNiCo/CdS.

The reaction conditions: 0.1 g CdS photocatalyst (under the same loading (2 wt %)), 50 mL 1 M $(NH_4)_2SO_3$ solution, 300W Xenon lamp (λ≥420 nm).

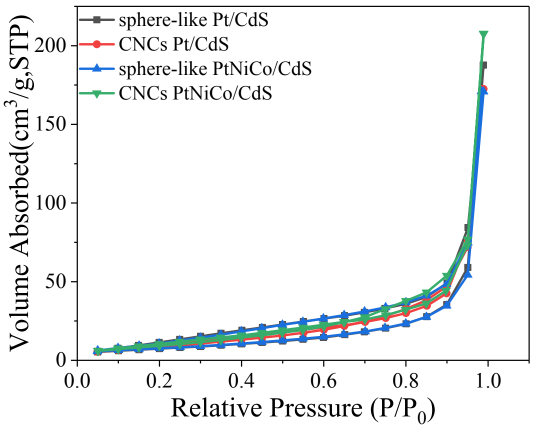

Fig.S4 Isotherms for nitrogen adsorption-desorption of sphere-like Pt, PtNiCo and CNCs Pt, PtNiCo loaded CdS.

Table S1 Surface areas of sphere-like Pt, PtNiCo and CNCs Pt, PtNiCo loaded CdS.

Sample	Surface area/(m^2/g)
sphere-like Pt/CdS	27.52
CNCs Pt/CdS	34.35
Sphere-like PtNiCo/CdS	28.07
CNCs PtNiCo/CdS	37.30

Table S2 The relationship between the photocatalytic performance and hydrogen evolution overpotential for $PtNi_xCo_y/CdS$.

Photocatalyst	Activity toward H_2 evolution (mmol/h/g)	Overpotential of H_2 evolution (V)
Pt/CdS	37.80	0.66
PtNi/CdS	42.71	0.65
PtNiCo/CdS	50.60	0.63

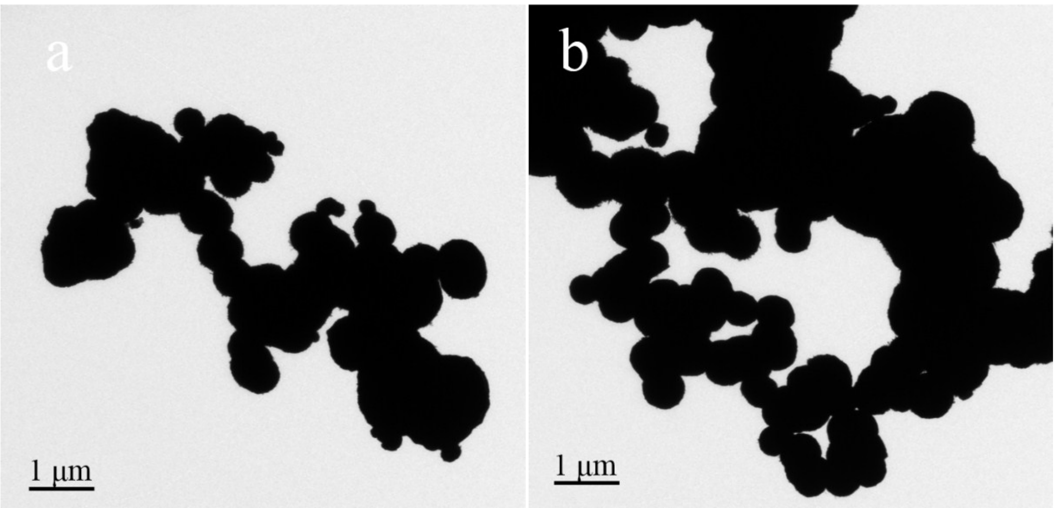

Fig. S5 TEM images of (a) sphere-like Pt and (b) sphere-like PtNiCo.

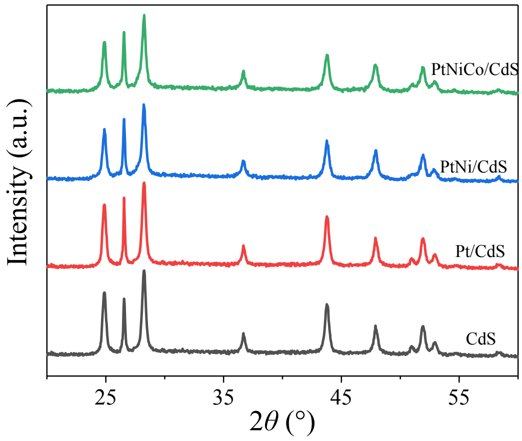

Fig. S6 XRD spectra of CdS, Pt/CdS, PtNi/CdS and PtNiCo/CdS photocatalysts before photocatalytic reaction.

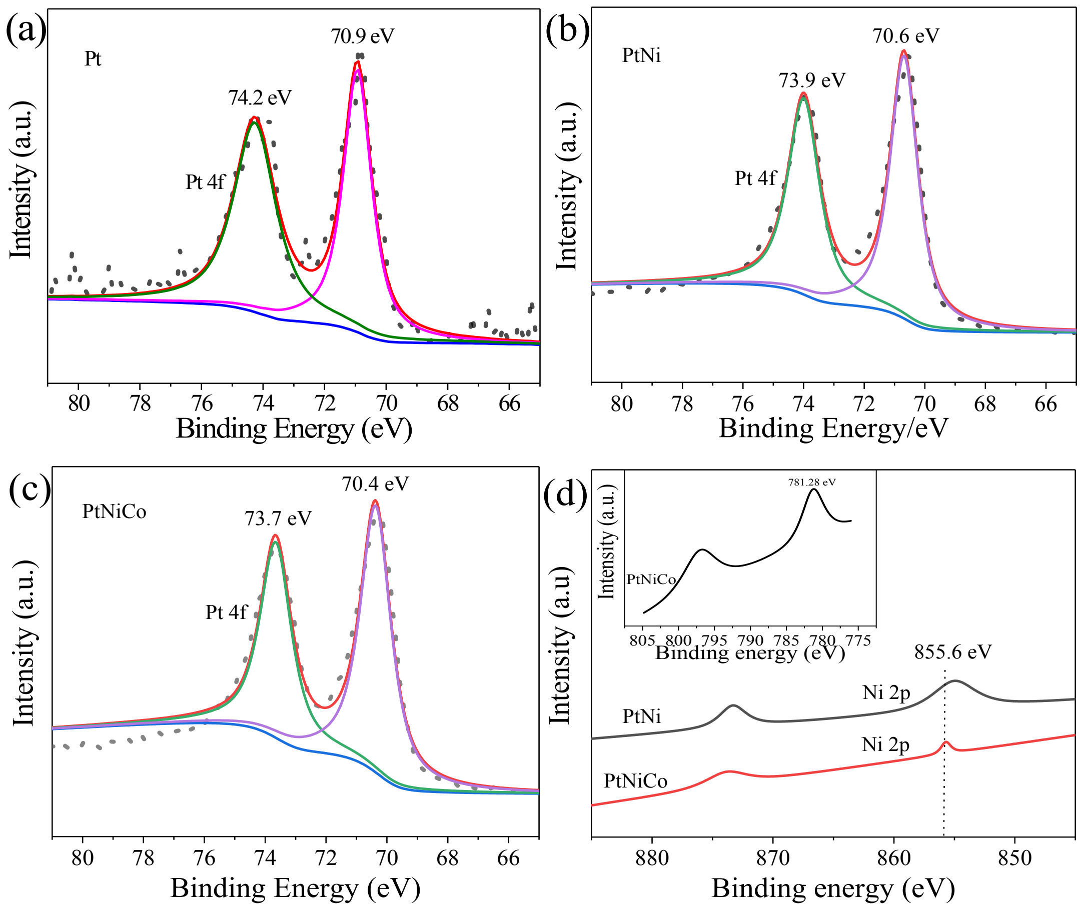

Fig. S7 XPS spectra of Pt CNCs, PtNi CNCs and PtNiCo CNCs prepared at 473 K for 10 h.

Table S3 XRD analysis of $PtNi_xCo_y/CdS$ photocatalysts.

2θ	Lattice Plane	I				$I_{Pt/CdS}/I_{CdS}$	$I_{PtNi/CdS}/I_{CdS}$	$I_{PtNiCo/CdS}/I_{CdS}$
		CdS	Pt/CdS	PtNi/CdS	PtNiCo/CdS			
24.84	（100）	1708	1345	1136	1240	0.787	0.665	0.725
26.53	（002）	1335	1598	1352	1409	1.197	1.013	1.055
28.22	（101）	2149	2039	1678	1871	0.949	0.781	0.871
36.66	（102）	631	682	676	745	1.081	1.071	1.181
43.74	（110）	1399	1094	1102	1109	0.782	0.788	0.792
47.89	（103）	831	886	847	852	1.066	1.019	1.025
50.95	（200）	416	378	414	403	0.909	0.995	0.969
51.89	（112）	843	843	787	783	1	0.936	0.929
52.89	（201）	513	466	501	502	0.908	0.977	0.979

Table S4 Lifetime of CdS, Pt/CdS, PtNi/CdS and PtNiCo/CdS photocatalysts after photocatalytic reaction.

Sample	τ_1 (ns)	α_1 (%)	τ_2 (ns)	α_2 (%)	τ_{ave} (ns)
CdS	771.90	79.65	7527.65	20.35	5592.79
Pt/CdS	784.18	70.11	8371.24	29.89	7004.48
PtNi/CdS	788.80	64.01	8445.00	35.99	7354.31
PtNiCo/CdS	777.70	57.67	8467.80	42.33	7612.59