Carbon dots anchored on octahedral CoO as a stable visible-light-responsive composite photocatalyst for overall water splitting

Supporting Information

1. Apparent quantum efficiency (AQE) calculations.

In the photocatalytic water splitting, the catalyst solution was irradiated by a 300W Xe lamp (XD-300, China) with 420 ± 20 nm band-pass filter for 24 h. The light source possesses a focused intensity of about 2.80 mW/cm^2 (the irradiation intensity was determined by CEL-NP2000 spectroradiometer, Fig. S9) and the irradiation area is 4.27 cm^2. The number of incident photons (N) was calculated to be 2.18×10^{21} by Equation S1.[S1] The amount of H_2 produced in 24 h for 5% CDs/CoO as photocatalysts was 19.23 μmol. The apparent quantum efficiency (AQE) of 5% CDs/ CoO was 1.02% as calculated by Equation S2.

$$N = \frac{E\lambda}{hc} = \frac{2.80 \times 10^{-3} \times 4.27 \times 24 \times 3600 \times 420 \times 10^{-9}}{6.626 \times 10^{-34} \times 3 \times 10^{8}} = 2.18 \times 10^{21}$$

Equation S1

$$AQE = \frac{2 \times the\ number\ of\ evolved\ H_2\ molecules}{the\ number\ of\ incident\ photons} \times 100\%$$

Equation S2

$$= \frac{2 \times 19.23 \times 10^{-6} \times 6.02 \times 10^{23}}{2.18 \times 10^{21}} \times 100\% = 1.02\%$$

2. Turnover number (TON) calculations.

Here is our current condition: We have 10 mg catalyst in 20 mL water. Converting this to moles, 10 mg of 5% CDs/CoO (since 5 wt.% by weight is CDs we have 9.5 mg of CoO). Take this and convert to micromoles to further calculate the TON.

9.5 mg CoO × (1 g/1000 mg) × (1 mol CoO/75 g CoO) × (10^6 μmol/1mol) = 127 μmol CoO

Consequently, our TON would be >1 if the catalyst produced 63.5 μmol of O_2. From the cumulative production experiment (Fig.S6b), the total amount of gaseous O_2 collected reached 216 μmol after 10 days. It can be therefore estimated that TON is approximately 3.4.

3. Additional Figures.

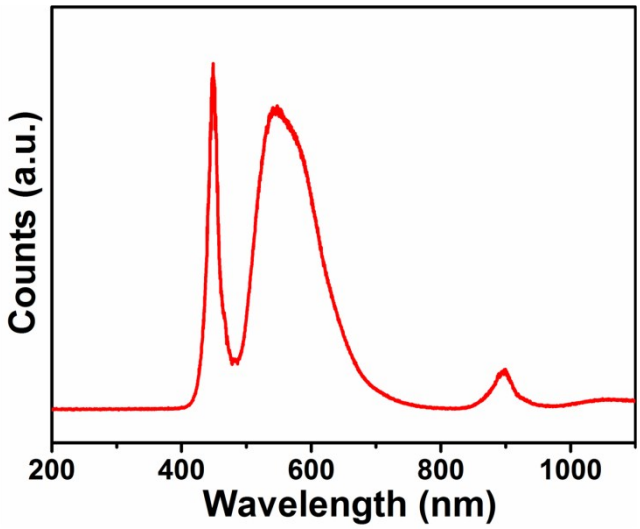

Fig.S1. The spectrum of the LED light source used for irradiation

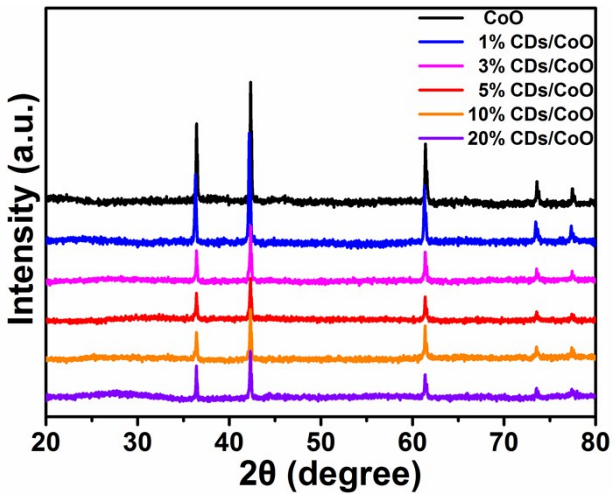

Fig.S2. XRD patterns of as-prepared samples.

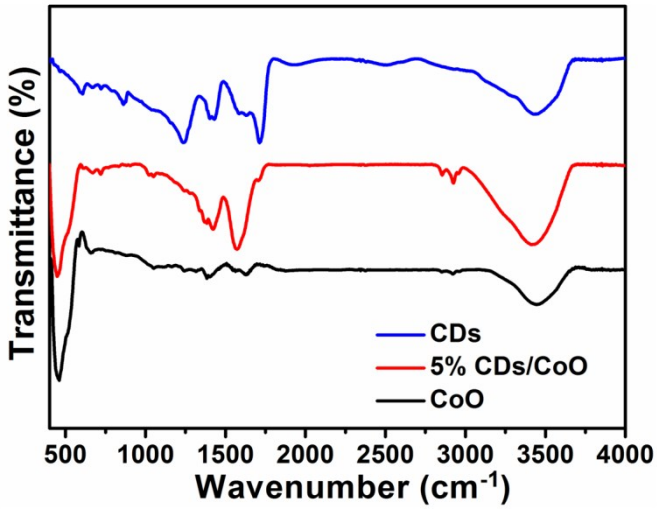

Fig.S3. FT-IR spectra of CDs, CoO and 5% CDs/CoO.

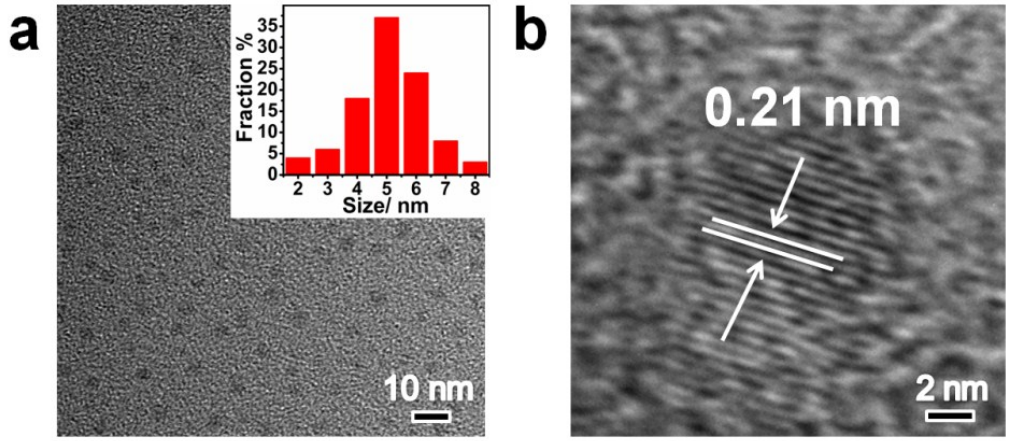

Fig.S4. (a) TEM (inset is size distribution of CDs) and (b) HRTEM images of CDs.

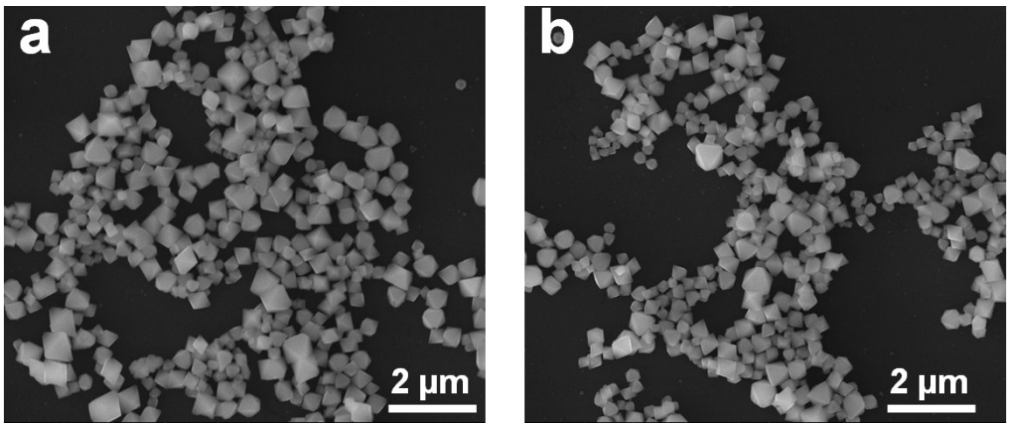

Fig.S5. SEM images of (a) octahedral CoO and 5% CDs/CoO composite.

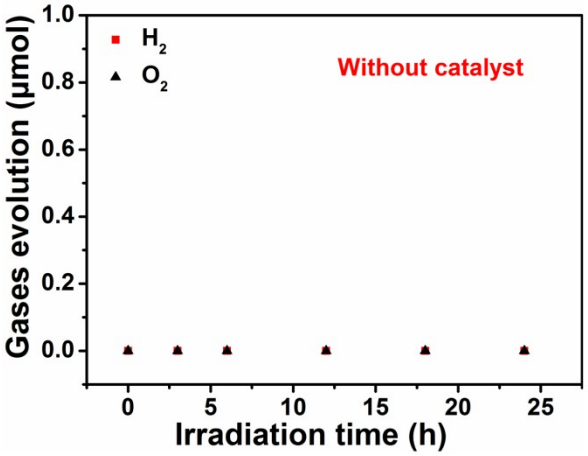

Fig.S6. The H_2/O_2 evolutions from pure water without any catalysts under visible light irradiation ($\lambda > 400$ nm).

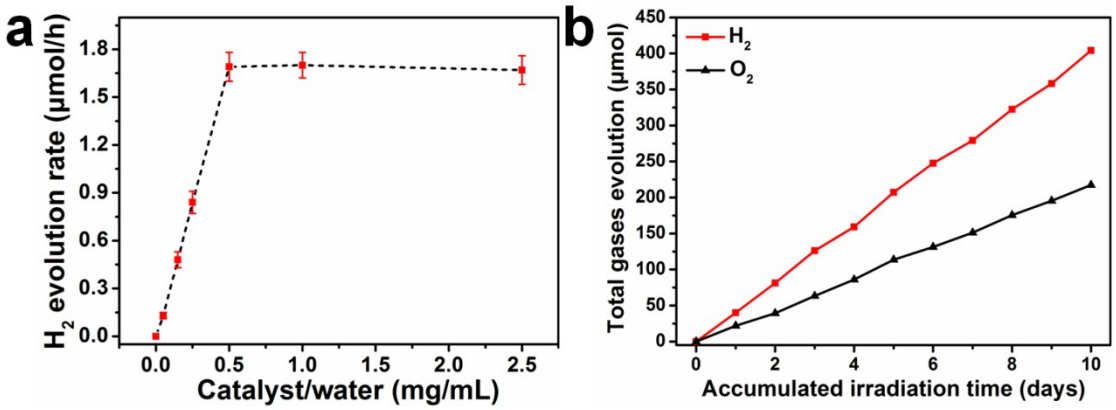

Fig.S7. (a) H_2 evolution rates for adding different amounts of catalyst in 20 mL of pure water. (b) The total H_2/O_2 production from pure water with 5% CDs/CoO composite (10 mg, 20 mL pure water) under different accumulated irradiation time.

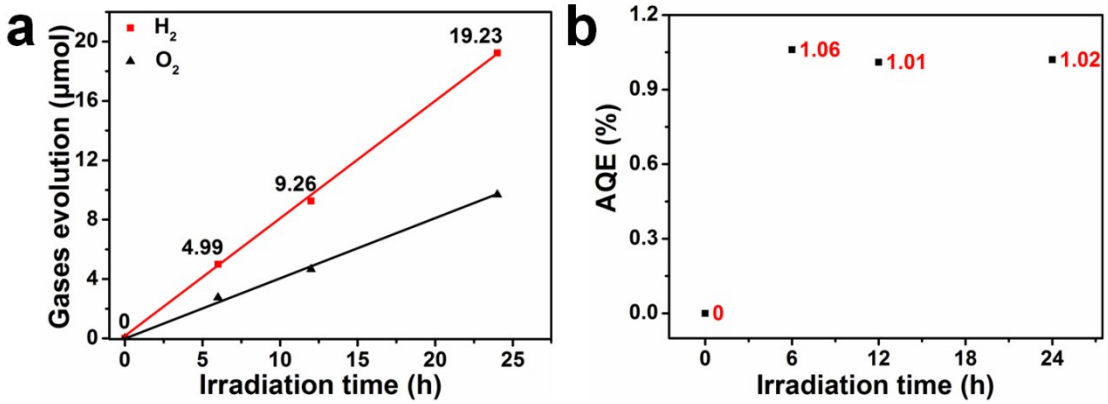

Fig.S8. (a) The H_2/O_2 evolutions from pure water over 5% CDs/CoO under visible light irradiation (420 ± 20 nm, 2.80 mW/cm^2). (b) The AQE of 5% CDs/CoO under different irradiation time.

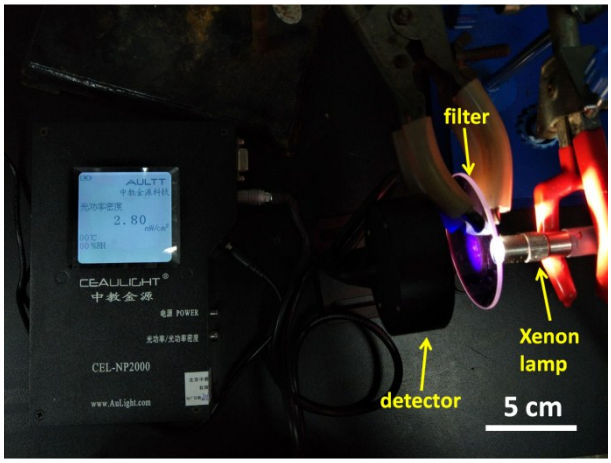

Fig.S9. The light power measurement of Xenon lamp (300 W) with a 420 nm band-pass filter. Irradiance intensity was determined as 2.80 mW cm^{-2}.

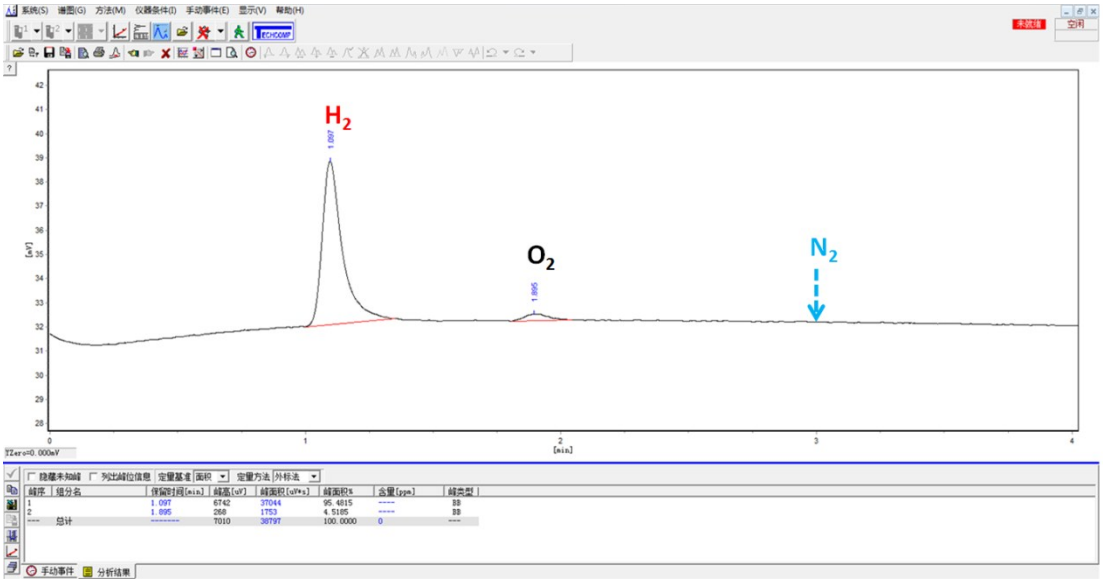

Fig.S10. A typical GC trace of evolved hydrogen and oxygen.

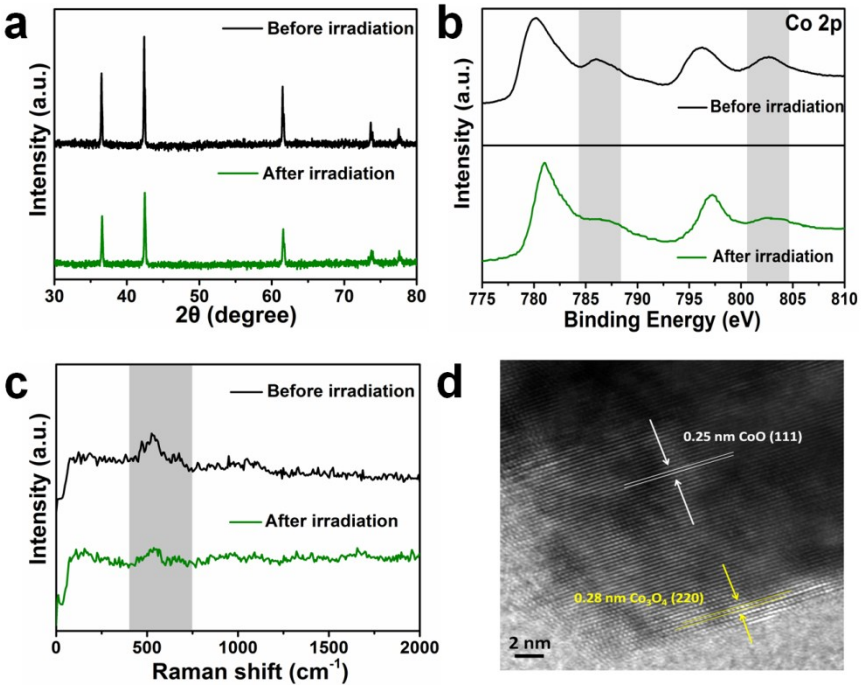

Fig. S11. (a) XRD patterns, (b) high-resolution Co 2p spectra and (c) Raman spectra of CoO before and after irradiation. (d) HRTEM image of CoO after irradiation.

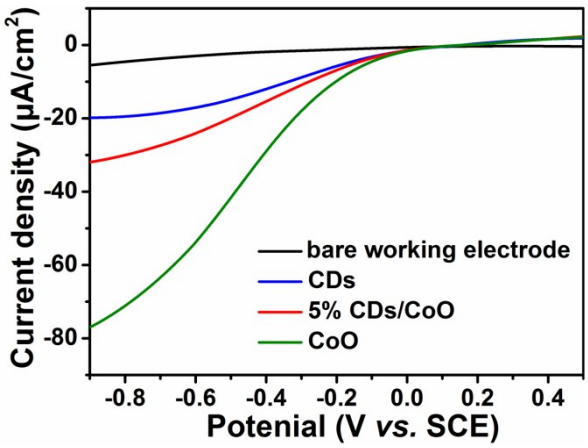

Fig.S12. LSV curves for CDs, 5% CDs/CoO, CoO, and the bare working electrode in 20 mM H_2O_2 solution.

Table S1. A summary of the photocatalytic-hydrogen-production apparent quantum efficiency (AQE) of representative CD-based photocatalysts.

Photocatalyst	**Co-catalyst**	**Sacrificial agents**	**AQE (%) at 420nm**	**Ref.**
CDs/CNNS	No	Methanol (20 vol%) solution	0.136%	Ref.S2
CDs/$ZnIn_2S_4$	Pt (0.3 wt.%)	TEOA (10 vol%) solution	0.2%	Ref.S3
CDs/$BiVO_4$QDs	No	No	0.63%	Ref.S4
CDs/CoO	No	No	1.02%	This work

References

S1. J. Liu, Y. Liu, N. Liu, Y. Han, X. Zhang, H. Huang, Y. Lifshitz, S. T. Lee, J. Zhong and Z. Kang, *Science*, 2015, **347**, 970-974.

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S3. Q. Li, C. Cui, H. Meng, and J. G. Yu, *Chem. Asian J.* 2014, **9**, 1766–1770.

S4. X. Q, Wu, J. Zhao, S. J. Guo, L. P. Wang, W. L. Shi, H. Huang, Y. Liu and Z. H. Kang, *Nanoscale* 2016, **8**, 17314-17321.