

Supplementary Information for

**Boosting Photocatalytic Hydrogen Production from Water by Photothermally
Induced Biphasic Systems**

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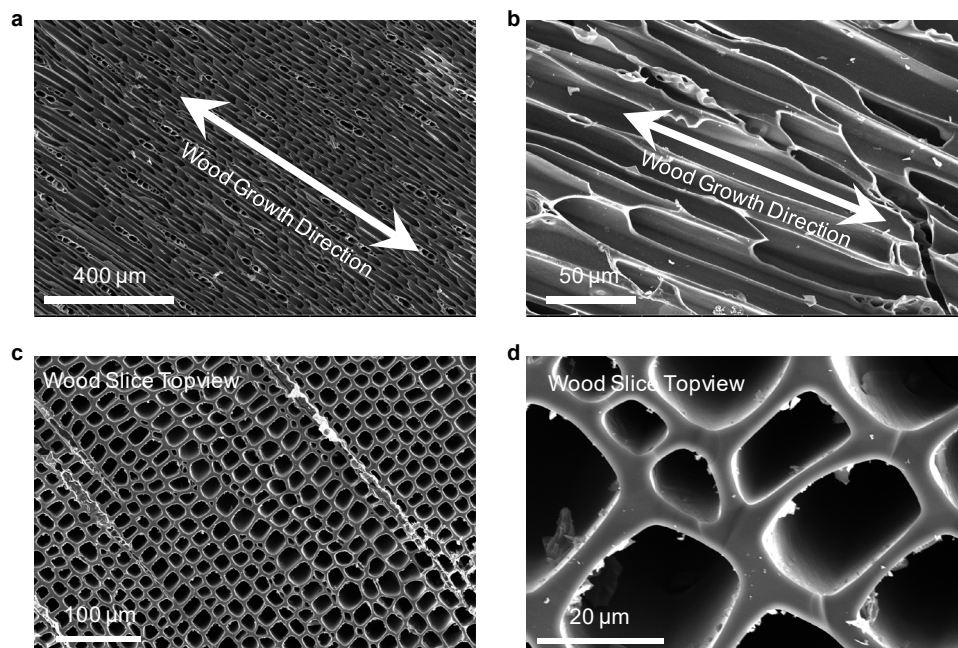
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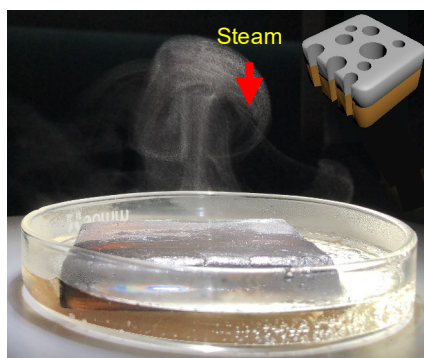
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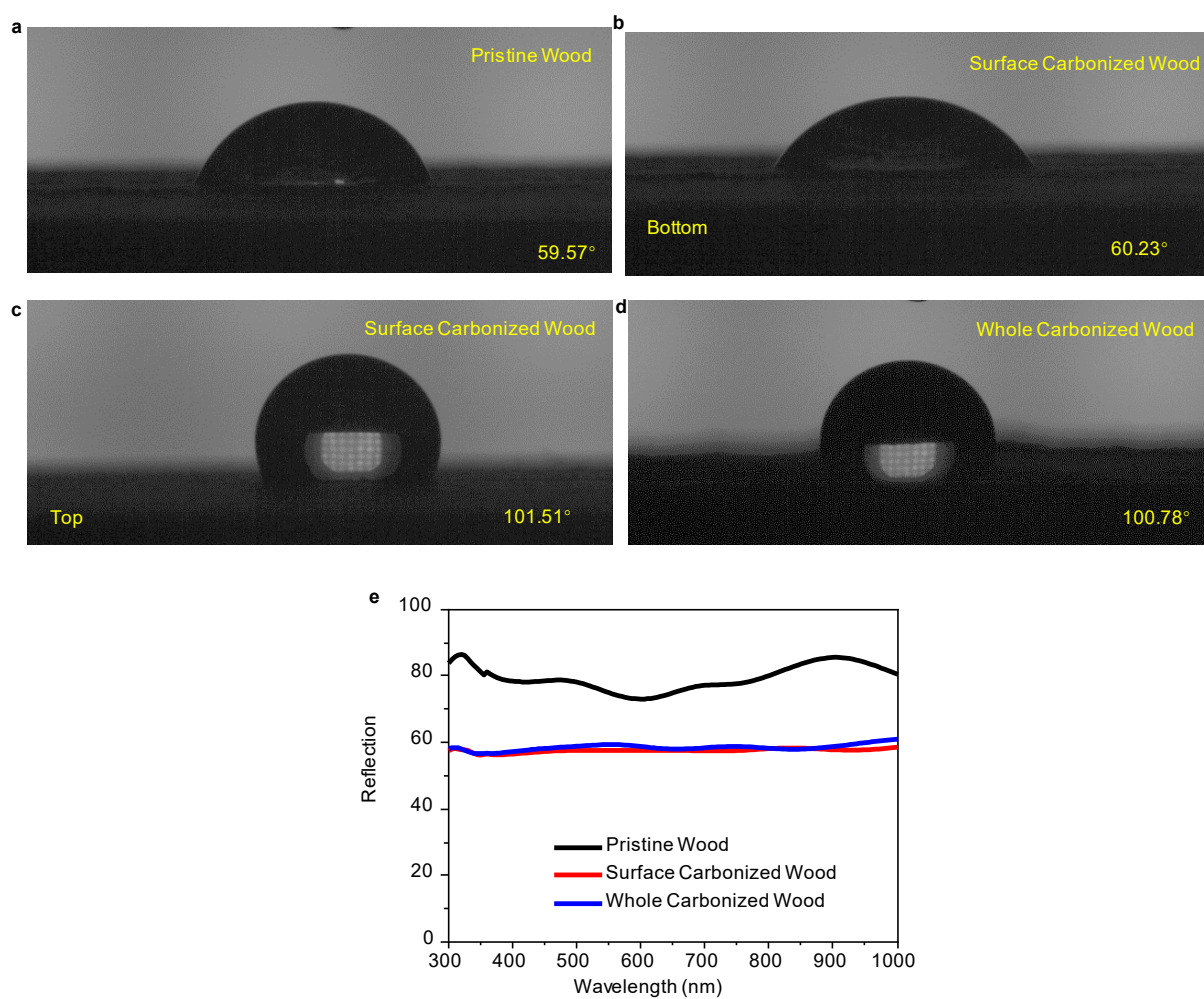
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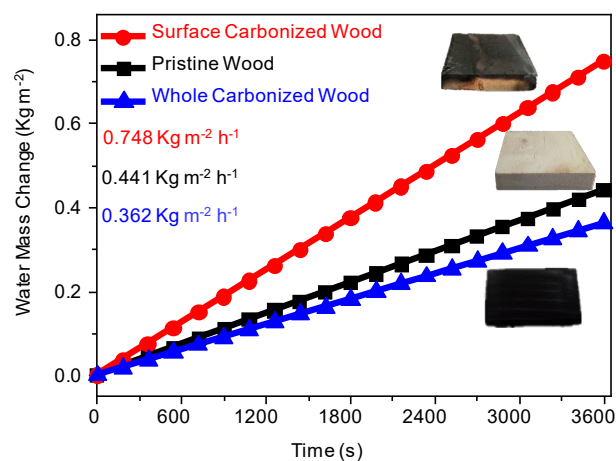
Supplementary Figure 1. SEM images of the wood slice. **a, b** Sideview SEM images of a pinewood. The pinewood growth direction has been observed. **c, d** Topview SEM images of the wood slice, which is cut from a tree perpendicular to its growth direction.



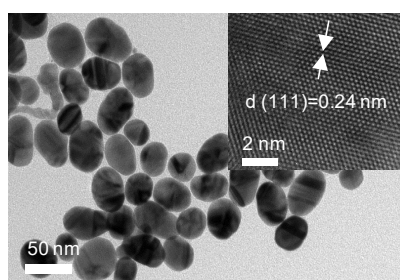
Supplementary Figure 2. Photograph of steam generation process from the surface carbonized wood under light illumination.



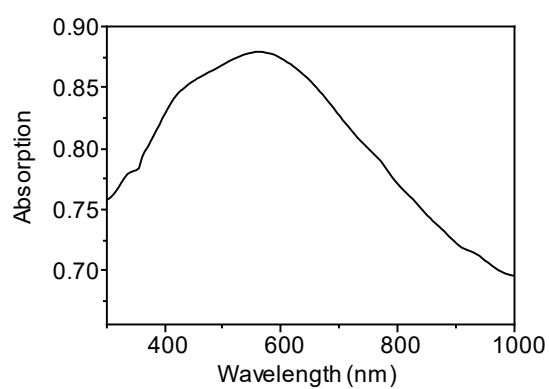
Supplementary Figure 3. **a-d** The contact angle measurement from the pristine wood, surface carbonized wood, and whole carbonized wood. **e** The reflection spectra of the pristine wood, surface carbonized wood, and whole carbonized wood.



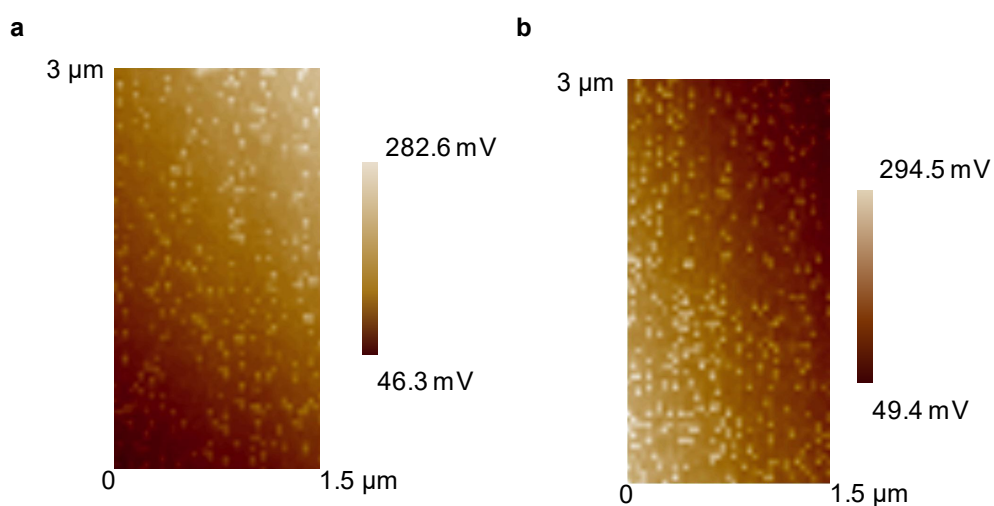
Supplementary Figure 4. Steam evaporation from wood induced mass changes in the water as a function of time. The inset image is the photograph of the pristine wood, surface carbonized wood, and whole carbonized wood. The surface carbonized wood shows the highest steam generation ability among three samples because of the good light absorptivity and the hydrophilic wood structure at the bottom.¹ The solar-to-steam conversion efficiencies of the pristine wood, surface carbonized wood, and whole carbonized wood are 27.65 %, 46.90 %, and 22.71 %, respectively.



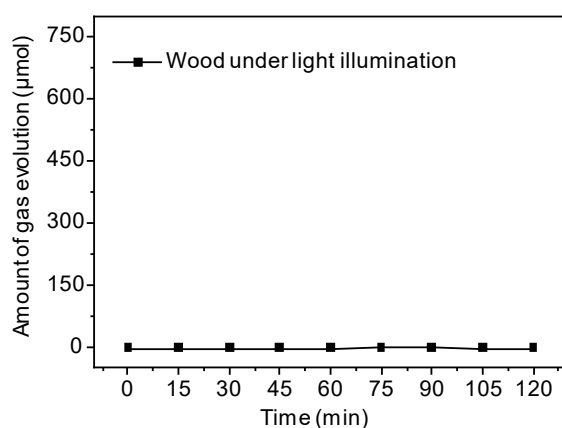
Supplementary Figure 5. TEM image of CoO NPs. Inset: HRTEM image of a CoO NP.



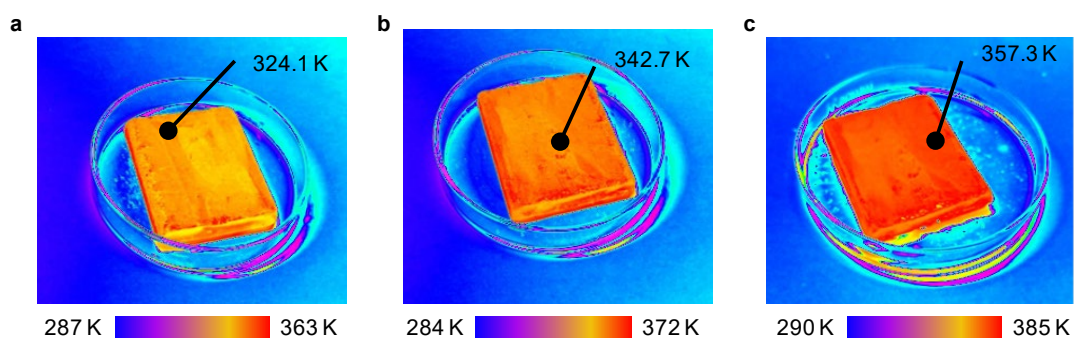
Supplementary Figure 6. The absorption spectra of CoO NPs.



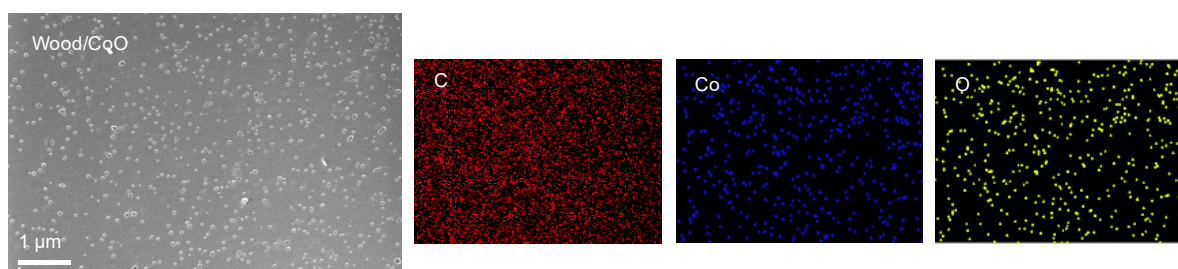
Supplementary Figure 7. **a** The potential of wood/CoO at 300 K, **b** the potential of wood/CoO at 308 K.



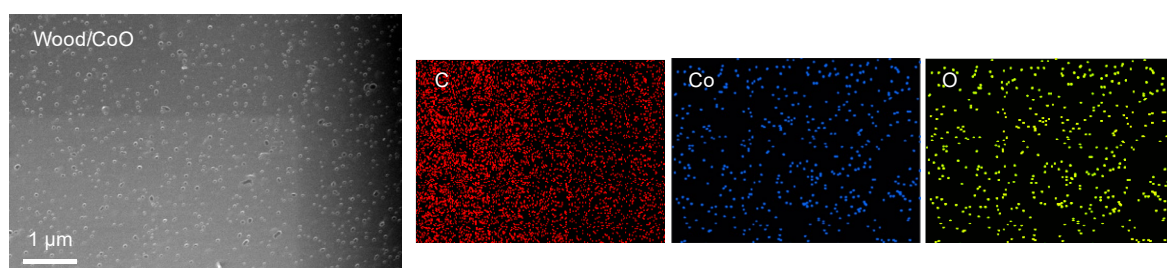
Supplementary Figure 8. Time-dependent photocatalytic gas production profile of the wood under light illumination.



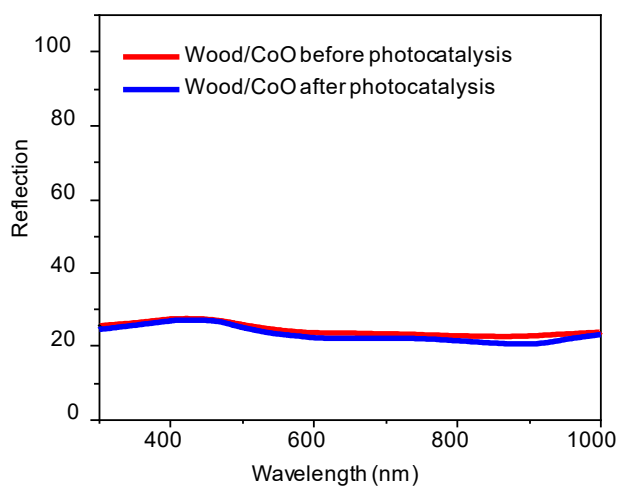
Supplementary Figure 9. Infrared radiation thermal images of the wood/CoO system under light illumination with different solar intensity. **a** 100 mW cm^{-2} , **b** 200 mW cm^{-2} , **c** 300 mW cm^{-2} .



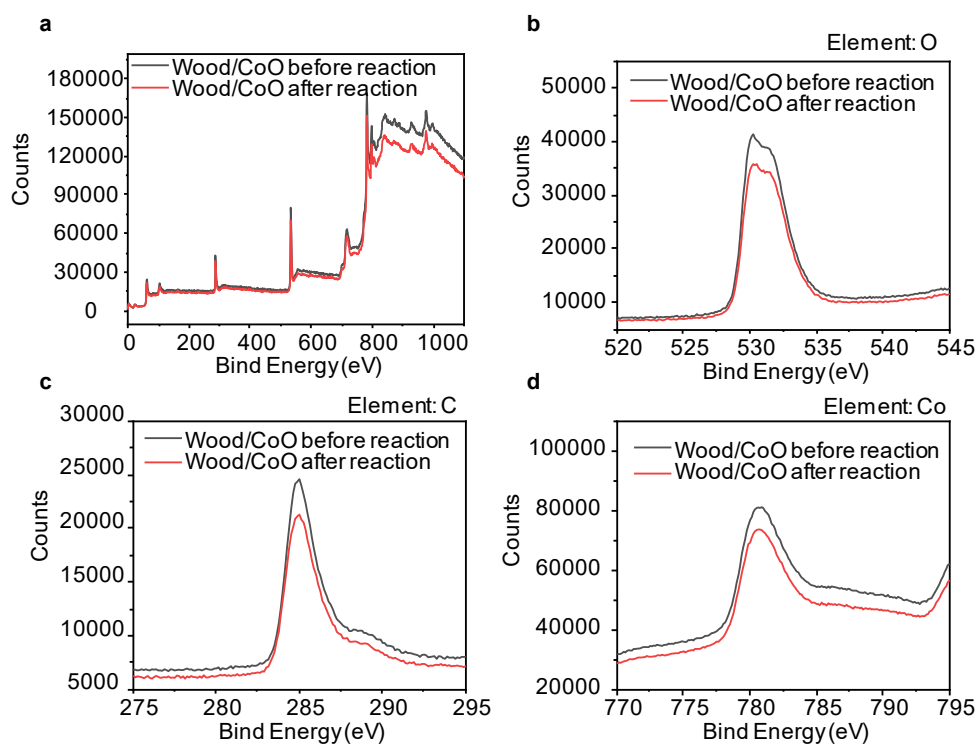
Supplementary Figure 10. SEM images and EDS element mapping of CoO NPs attached to the walls of the wood microchannels before photocatalytic reaction.



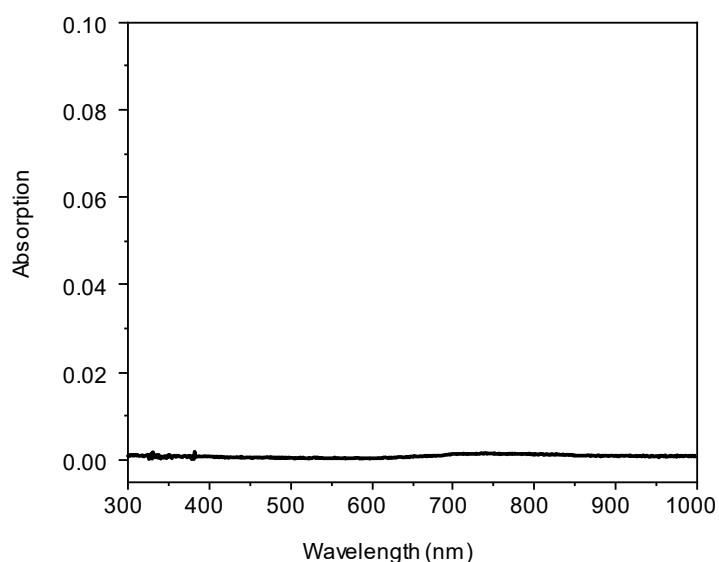
Supplementary Figure 11. SEM images and EDS element mapping of CoO attached to the walls of the wood microchannels after the photocatalytic reaction.



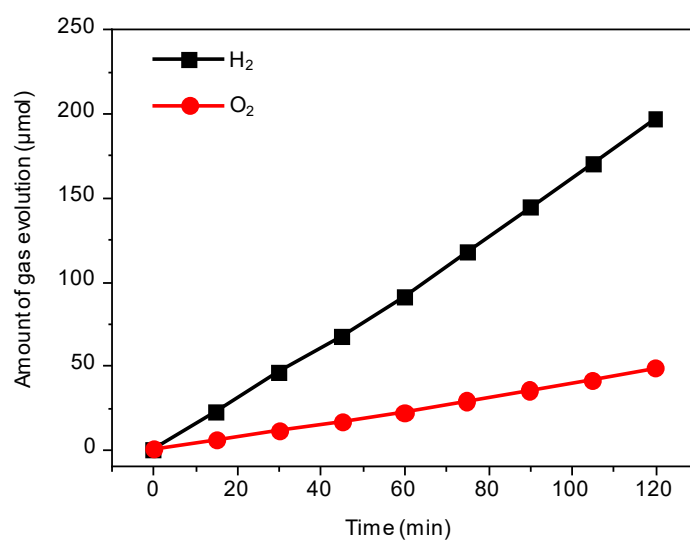
Supplementary Figure 12. The reflection spectra wood/CoO system before and after photocatalysis process.



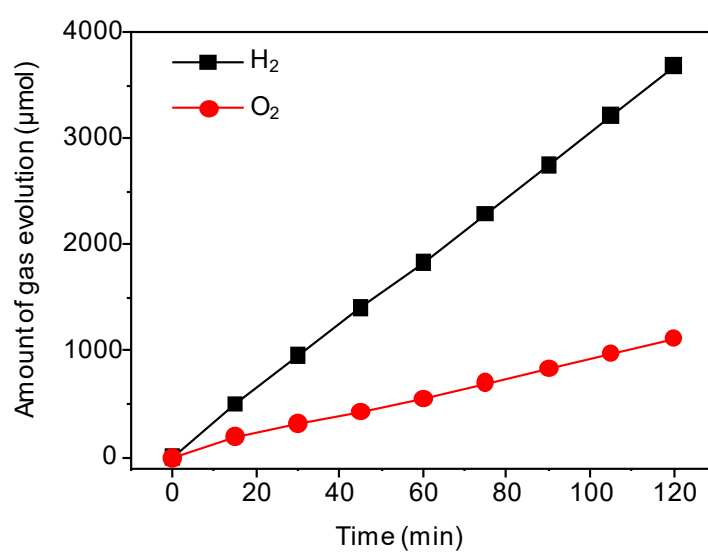
Supplementary Figure 13. The XPS spectra wood/CoO system before and after the photocatalysis process. **a** XPS full spectrum of the wood/CoO system before/after the reaction, **b** high-resolution XPS of element O, **c** high-resolution XPS of element C, and **d** high-resolution XPS of element Co for the wood/CoO system.



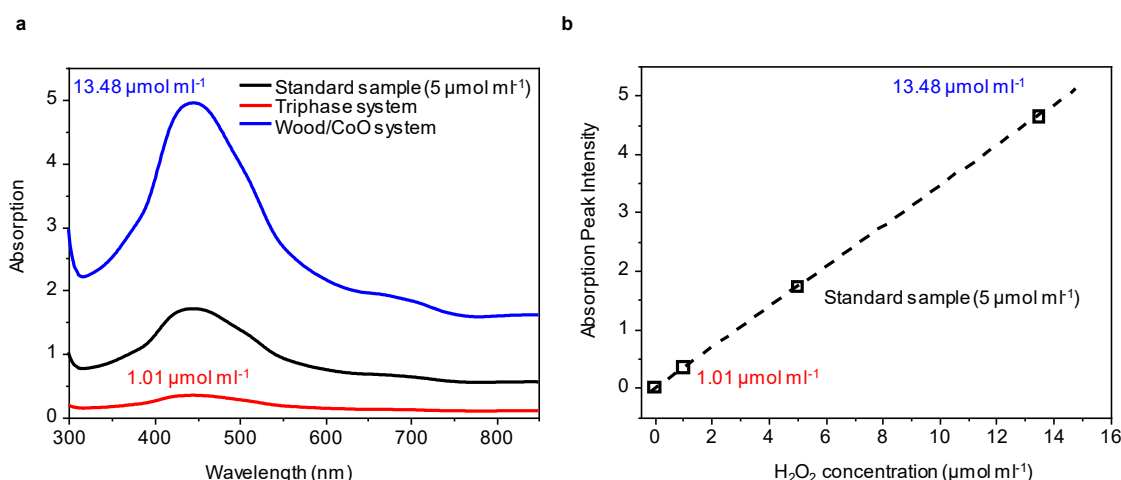
Supplementary Figure 14. The absorption spectrum from bulk water in the wood/CoO system after photocatalytic reaction.



Supplementary Figure 15. Time-dependent photocatalytic gas production profiles from the liquid water. The photocatalyst is CoO NPs, and the sacrificial agent is not added.



Supplementary Figure 16. Time-dependent photocatalytic gas production profiles from the wood/CoO.



Supplementary Figure 17. The H_2O_2 concentration determination from absorption spectra. **a** the absorption spectra from different H_2O_2 concentration, and **b** the linear fitting between absorption peak and H_2O_2 concentration.

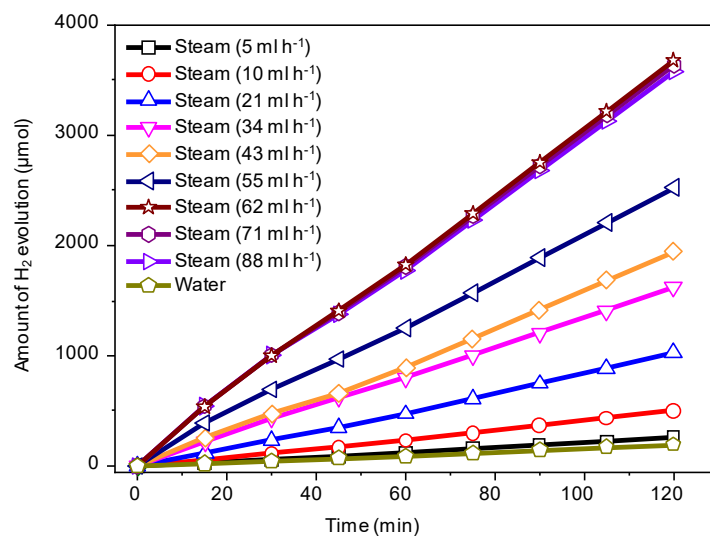
The $5 \mu\text{mol ml}^{-1}$ H_2O_2 was used as the standard sample to react with copper (II) sulfate solution and 2,9-dimethyl-1,10-phenanthroline (DMP) solution, and the obtained absorption spectrum was used as the baseline. Due to the linear relationship between absorption peak and H_2O_2 concentration², the H_2O_2 concentration in the solution after the photocatalytic reaction could be calculated based on the above absorption spectra. After the photocatalytic reaction, the concentration of H_2O_2 measured is about 1.01 and $13.48 \mu\text{mol ml}^{-1}$ for the triphase reaction system and wood/CoO systems, respectively.

In the triphase reaction system, after 120 min test, the amount of H_2 evolution is about 196.98 μmol , and the amount of O_2 evolution is about 48.04 μmol . After the reaction, the H_2O_2 concentration is $1.01 \mu\text{mol ml}^{-1}$ in 100 ml reaction solvent. Thus the amount of H_2O_2 is 101 μmol . The H_2O_2 converts to the O_2 following the reaction equation below:

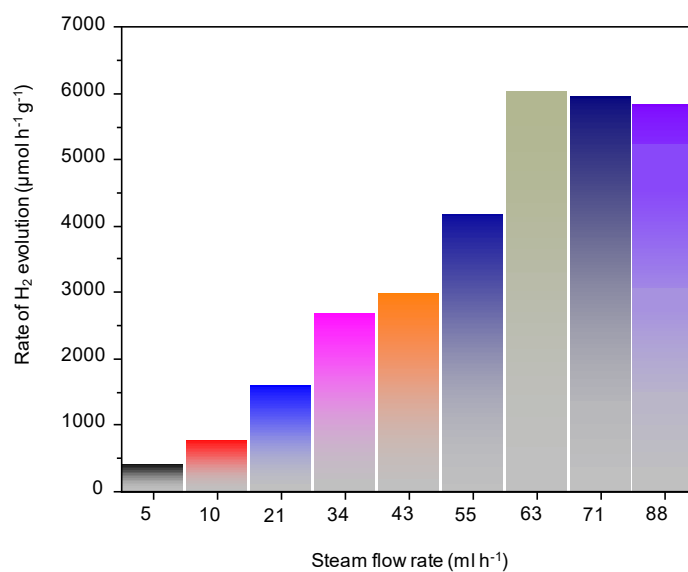


Combing the amount of directly produced O_2 (48.04 μmol) and the amount of indirectly converted O_2 from H_2O_2 (50.50 μmol), the total amount of O_2 is 98.54 μmol . Thus, the production ratio of H_2 and O_2 is 196.68:98.54 (i.e., 1.99:1).

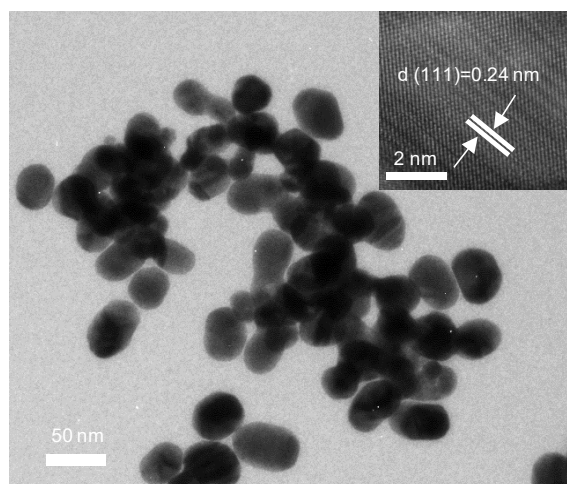
Regarding the wood/CoO system, the amount of H_2 evolution is about 3677.55 μmol , and the amount of O_2 evolution is about 1121.21 μmol after 120 min test. The H_2O_2 concentration is $13.48 \mu\text{mol ml}^{-1}$ in 100 ml reaction solvent after the catalytic reaction. Thus, the amount of H_2O_2 is 1348 μmol . Combing the amount of directly produced O_2 (1121.21 μmol) and the amount of indirectly converted O_2 from H_2O_2 (674 μmol), the total amount of O_2 is 1795.21 μmol . Thus, the converted amount of O_2 is 1795.21 μmol . Considering the above calculation, the production ratio of H_2 and O_2 is 3677.55:1795.21 (i.e., 2.04:1).



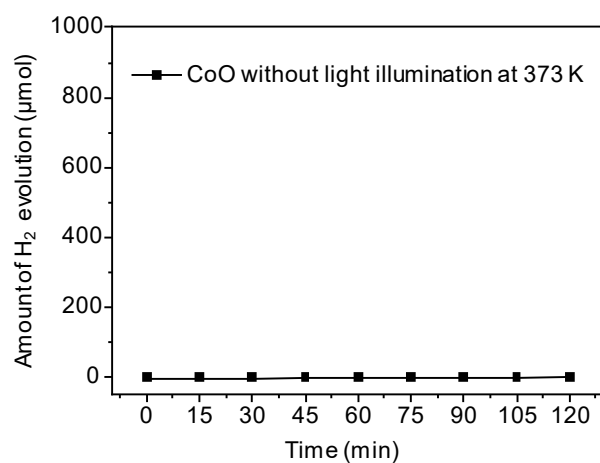
Supplementary Figure 18. Time-dependent photocatalytic hydrogen gas production profiles from the liquid water and water steam with different flow rates. The photocatalyst is CoO NPs.



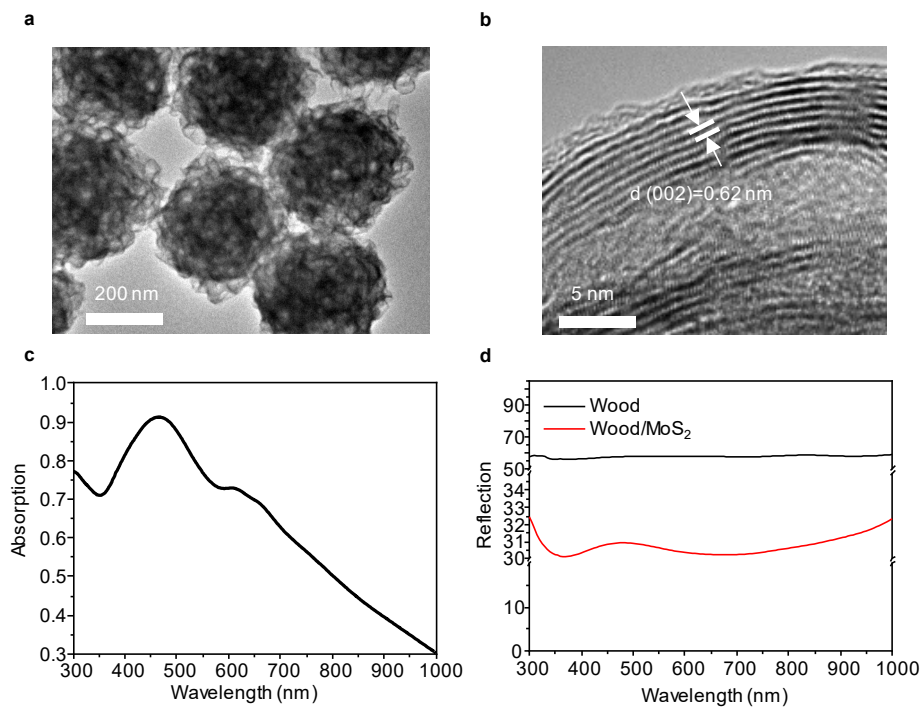
Supplementary Figure 19. The hydrogen production rate as a function of flow rate of the water steam. The photocatalyst is CoO NPs.



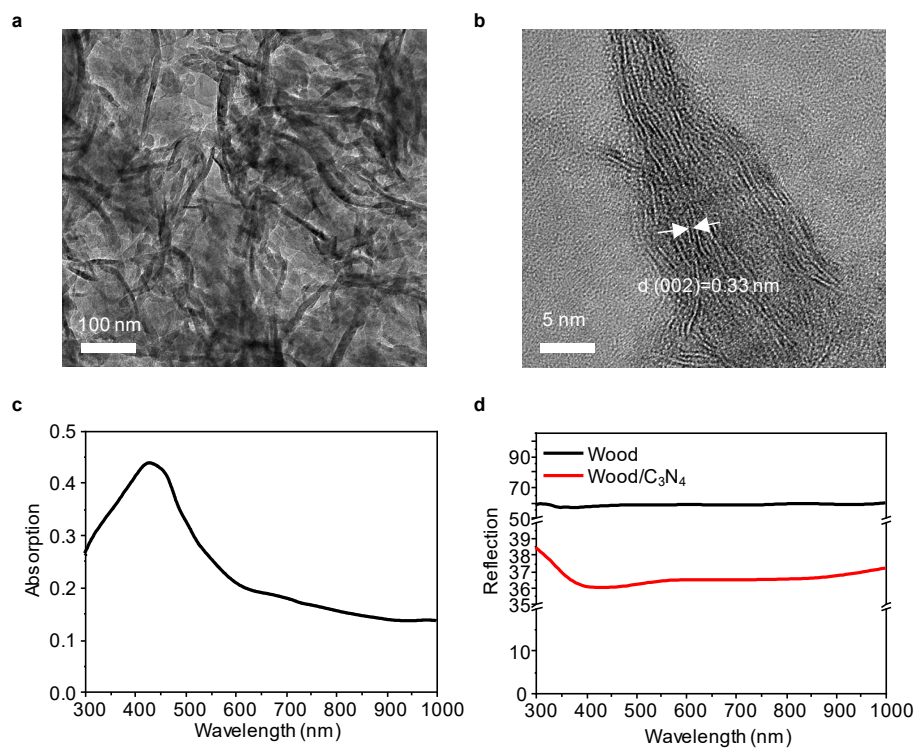
Supplementary Figure 20. TEM image of CoO NPs after the photocatalytic reaction. Inset: HRTEM image of a CoO NP.



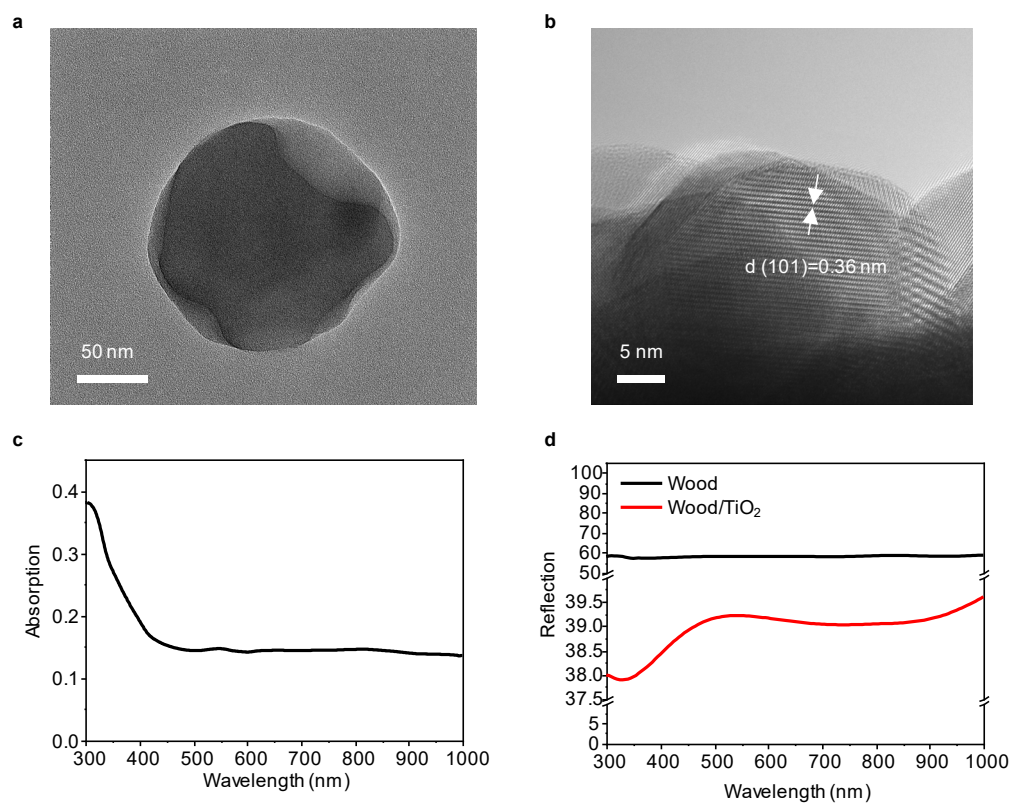
Supplementary Figure 21. Time-dependent photocatalytic hydrogen gas production profile from liquid water at the reaction temperature of 373 K without light illumination.



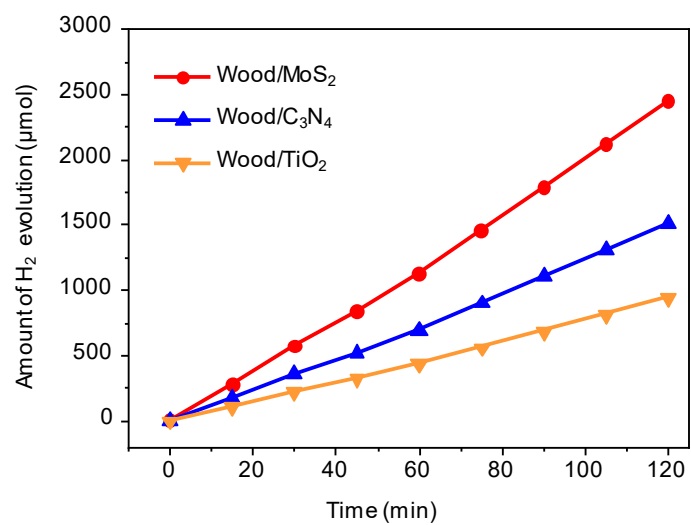
Supplementary Figure 22. **a** TEM image of MoS₂. **b** HRTEM image of MoS₂. **c** The absorption spectrum of MoS₂. **d** Reflection spectra of the wood and wood/MoS₂ system.



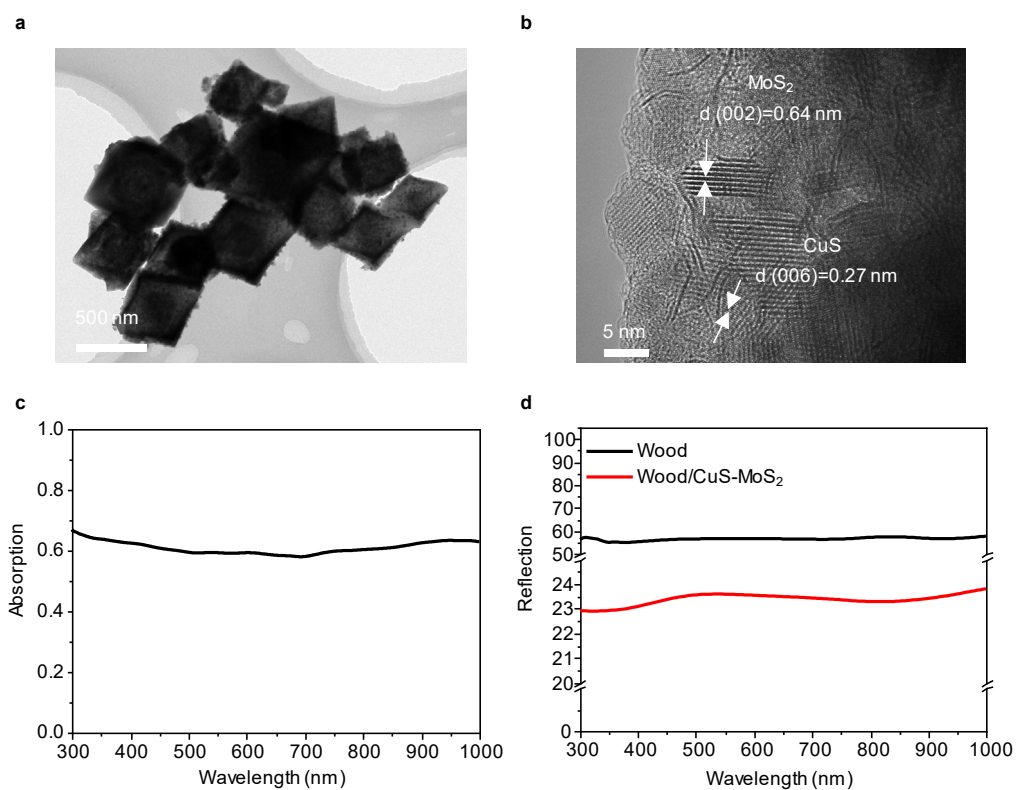
Supplementary Figure 23. **a** TEM image of C_3N_4 . **b** HRTEM image of C_3N_4 . **c** The absorption spectrum of C_3N_4 . **d** Reflection spectra of the wood and wood/ C_3N_4 system.



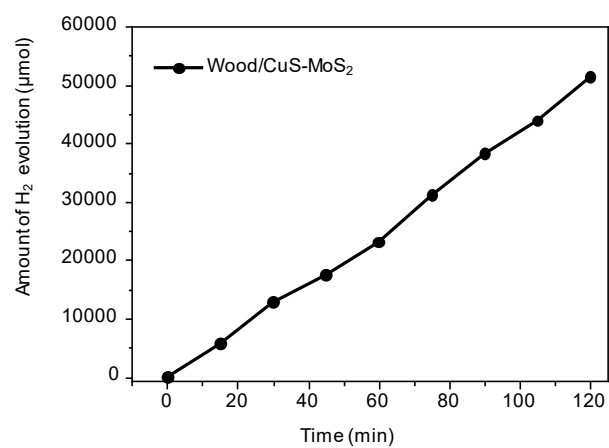
Supplementary Figure 24. **a** TEM image of TiO₂. **b** HRTEM image of TiO₂. **c** The absorption spectrum of TiO₂. **d** Reflection spectra of the wood and wood/TiO₂ system.



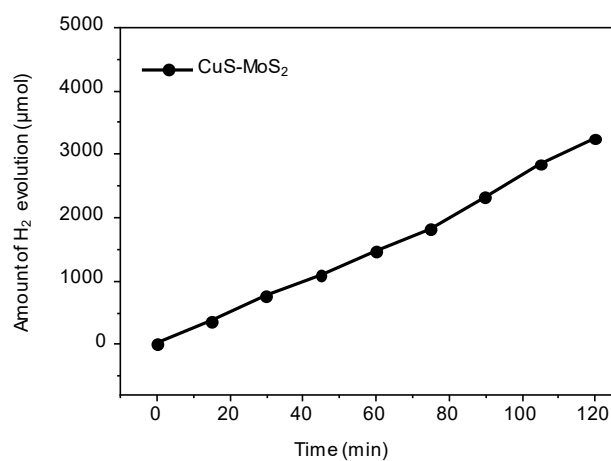
Supplementary Figure 25. Amount of hydrogen production for the wood/ MoS_2 , wood/ C_3N_4 , and wood/ TiO_2 system.



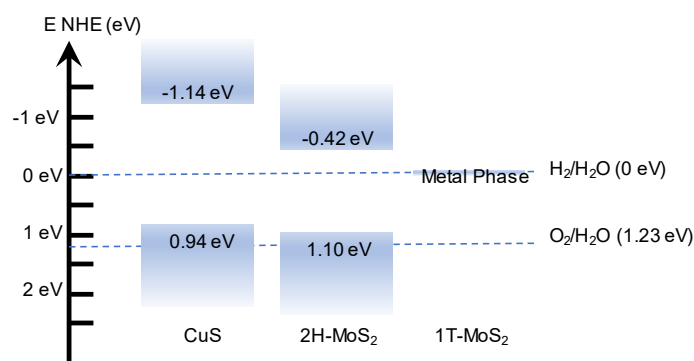
Supplementary Figure 26. **a** TEM image of CuS-MoS₂. **b** HRTEM image of CuS-MoS₂. **c** The light absorption spectra of CuS-MoS₂. **d** Reflection spectra of the wood and wood/CuS-MoS₂ system.



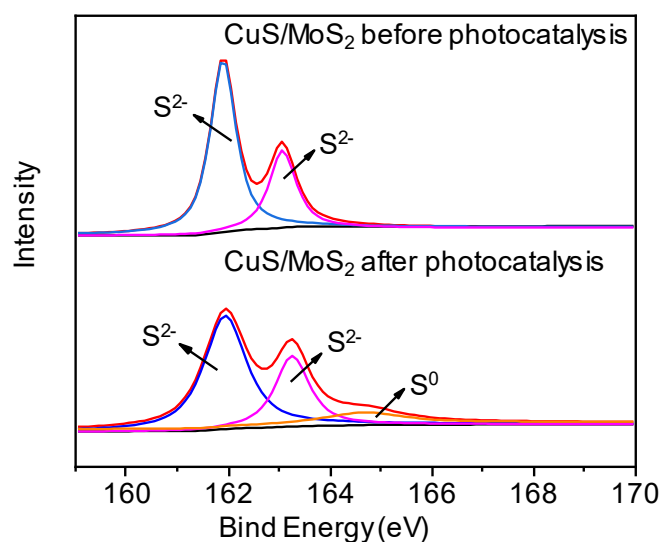
Supplementary Figure 27. Amount of hydrogen production for the biphasic wood/CuS-MoS₂ system without a sacrificial agent.



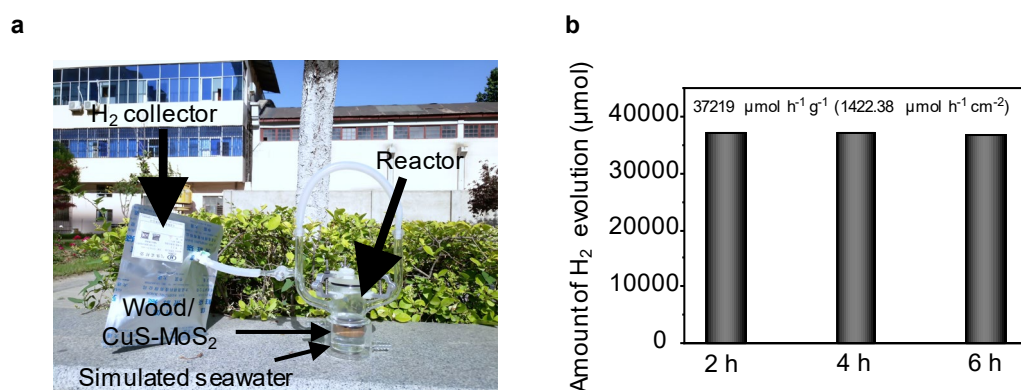
Supplementary Figure 28. Amount of hydrogen production for the triphasic CuS-MoS₂ system without a sacrificial agent.



Supplementary Figure 29. Scheme of energy band positions of CuS-MoS₂ photocatalyst.³



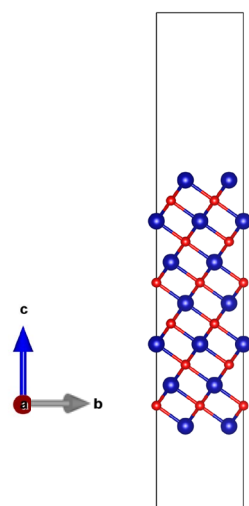
Supplementary Figure 30. The high-resolution XPS of element S for CuS/MoS₂ before and after photocatalytic reaction.



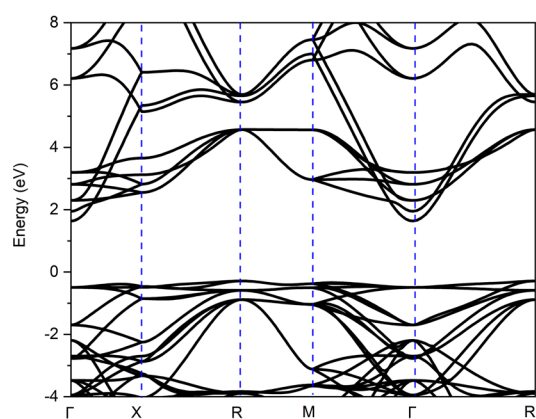
Supplementary Figure 31. Hydrogen evolution for the biphasic wood/CuS-MoS₂ system in simulated seawater. **a** Photograph of hydrogen evolution for the biphasic wood/CuS-MoS₂ architecture in simulated seawater under the illumination of sunshine. **b** Rate of H₂ evolution from the biphasic wood/CuS-MoS₂ system in simulated seawater. The H₂ collector was replaced by a new one every two hours to extract the gas, which was then introduced to the GC device for evaluating the H₂ production.



Supplementary Figure 32. The photograph of the light intensity measurement.



Supplementary Figure 33. The model structure schemes of CoO



Supplementary Figure 34. The band structures of CoO

Supplementary Table 1. The element Co concentration in the bulk water from the wood/CoO system after the photocatalytic reaction based on ICP measurement. Three samples are tested.

	Sample Test 1	Sample Test 2	Sample Test 3
Element Co Concentration ($\mu\text{g ml}^{-1}$)	0.0102	0.0123	0.0088

Supplementary Table 2. The measurement information for AQY calculation, including catalysts, wavelength, light intensity, and H₂ yield.

Catalysts	Wavelength (nm)/ Light intensity (mW cm^{-2})	H ₂ yield (μmol)/ AQY (%)
Wood/CoO	380/13.82	255.01/41.1
Wood/CoO	420/16.32	405.85/50.1
Wood/CoO	500/12.32	325.77/44.8
Wood/MoS ₂	380/13.77	195.87/31.7
Wood/MoS ₂	420/16.59	295.25/35.9
Wood/MoS ₂	500/11.97	223.16/31.5
Wood/C ₃ N ₄	380/13.63	122.67/20.0
Wood/C ₃ N ₄	420/16.12	273.49/34.2
Wood/C ₃ N ₄	500/12.43	175.35/23.9
Wood/TiO ₂	360/13.54	193.74/33.6
Wood/TiO ₂	380/16.87	90.24/11.9

References

- 1 Xue, G. et al. Robust and low-cost flame-treated wood for high-performance solar steam generation. *ACS Appl. Mater. Inter.* **9**, 15052-15057 (2017).
- 2 Baga, A. N., Johnson, G. R. A., Nazhat, N. B. & Saadalla-nazhat, R. A. A simple spectrophotometric determination of hydrogen peroxide at low concentrations in aqueous solution. *Anal. Chim. Acta* **204**, 349-353 (1988).
- 3 Xin, X. et al. In-situ growth of high-content 1T phase MoS₂ confined in the CuS nanoframe for efficient photocatalytic hydrogen evolution. *Appl. Catal. B-Environ.* **269**, 118773 (2020).