Electronic Supplementary Material (ESI) for Nanoscale.

Enhancing the photocatalytic activity of $ZnSn(OH)_6$ achieved by a gradual sulfur doping tactics

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Supporting information

The precursor was kept under sulfuration temperature at 160 ^{o}C, 180 ^{o}C and 200 ^{o}C. It is clearly shown that under 160 ^{o}C, 180 ^{o}C the precursor ZSH underwent an incomplete sulfuration compared to 200 ^{o}C, indicating that complete sulfuration of ZSH requires a suitable temperature and duration due to the thermodynamics and dynamics of the reaction.

RhB degradation experiments also carried out over sulfuration products and the mechanical mixing samples (Fig.S3c and S3d). The mechanical mixing samples showed no clear degradation activity compared to S-ZSH. The k_{app} follows the order：S-ZSH> ZSH+0.1ZnS> ZSH+0.1ZnS+0.1SnS_2> ZSH+0.1SnS_2.

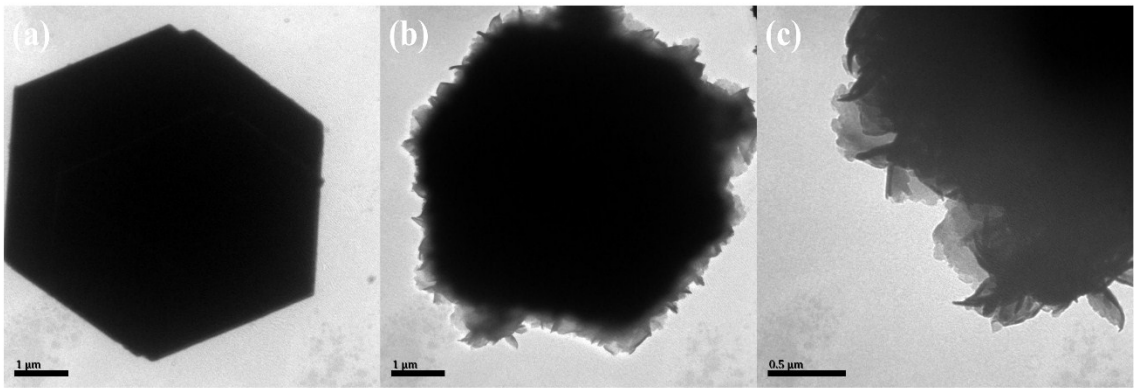

Fig. S1 Transmission electron microscopy (TEM) images of (a) ZSH and (b) (c) S-ZSH

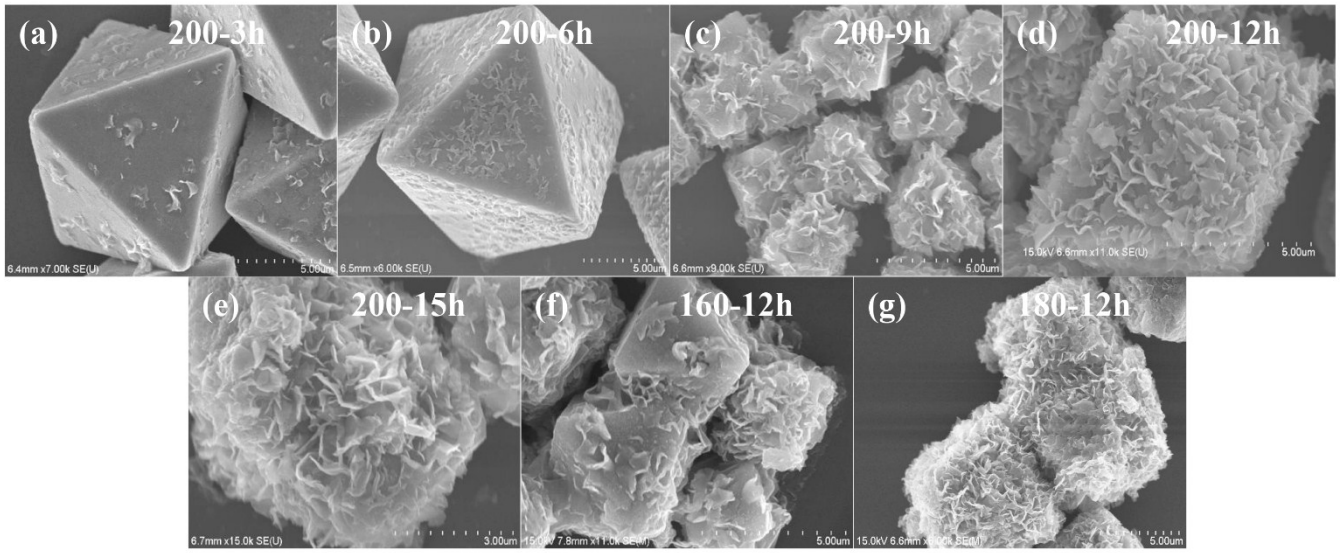

Fig. S2 Scanning electron microscopy (SEM) images of S-ZSH at 200 ^{o}C with different sulfuration time (a) 3 h, (b) 6 h, (c) 9 h, (d) 12 h, (e) 15 h and S-ZSH (f) at 160 ^{o}C and (g) 180 ^{o}C with 12 h.

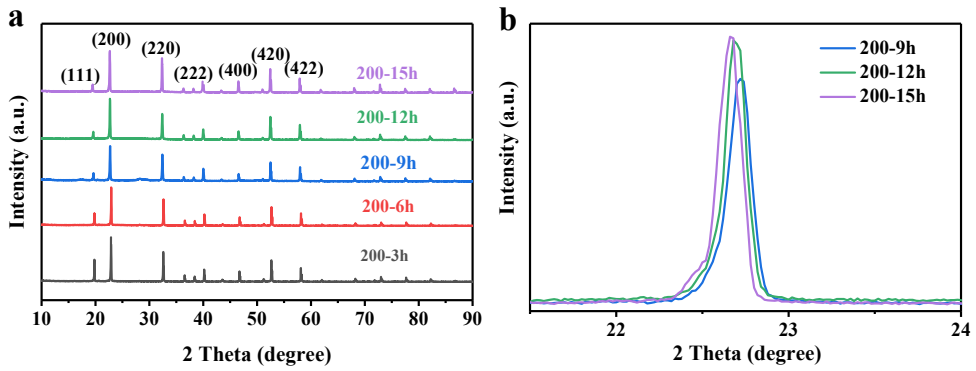

Fig. S3 (a) XRD patterns and (b) magnified XRD patterns of S-ZSH with different sulfuration time.

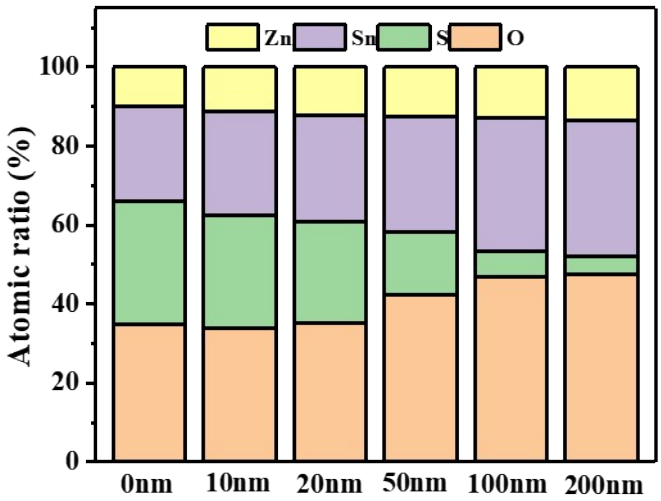

Fig. S4 The atomic ratio of S-ZSH based on XPS results.

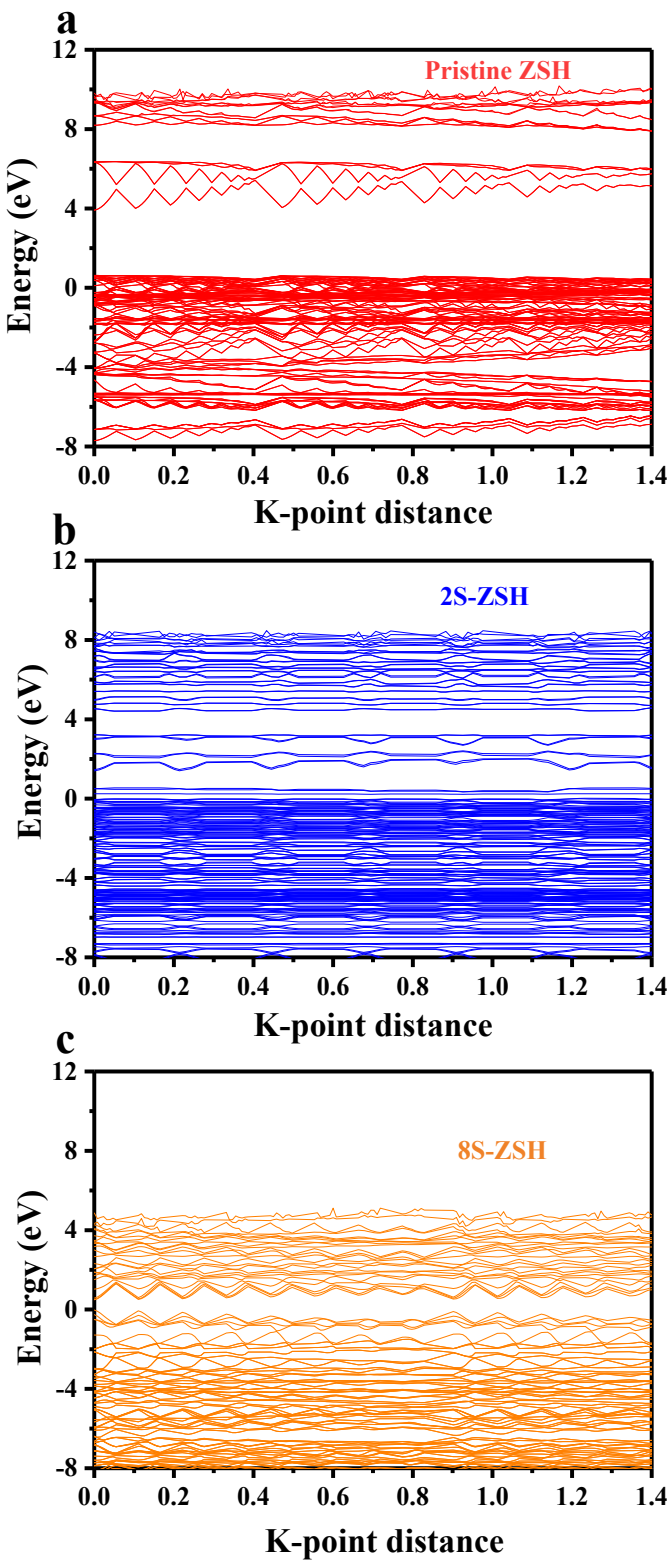

Fig. S5 The band structure of (a) pristine ZSH, (b) 2S-ZSH, (c) 8S-ZSH.

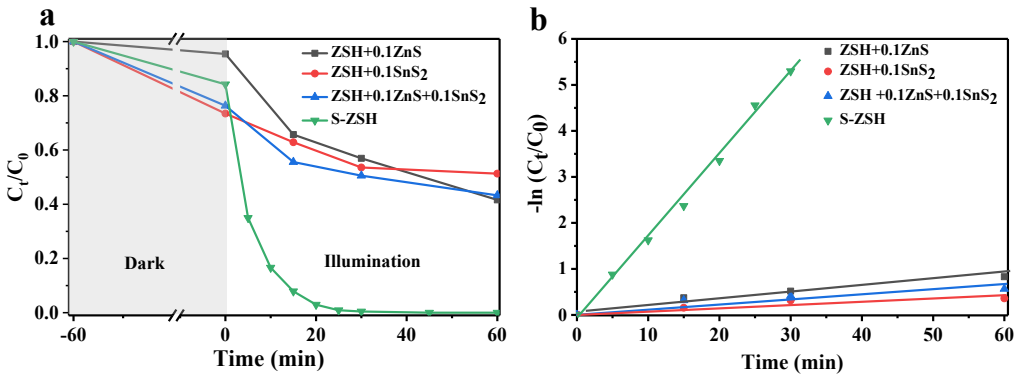

Fig. S6 (a) RhB degradation and degradation rate constants based on pseudo-first order kinetic over ZSH, mechanical mixing ZSH+0.1ZnS, ZSH+0.1ZnS+0.1SnS_2 and ZSH+0.1ZnS.

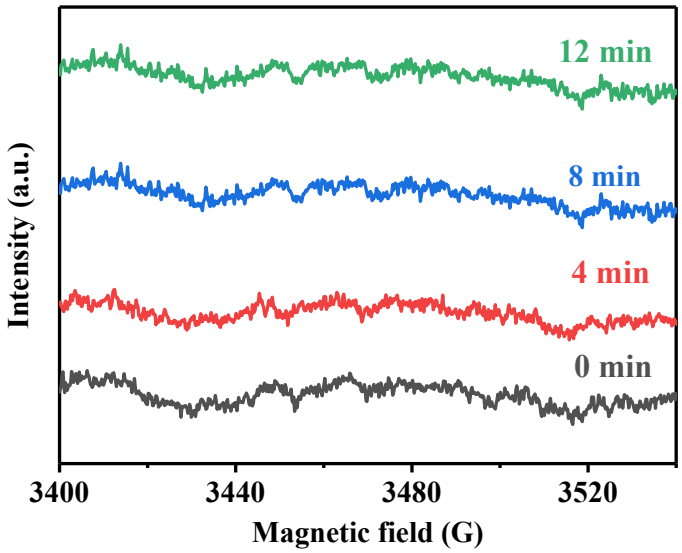

Fig. S7 ESR spectra of DMPO-•OH adducts in water solution with S-ZSH.

Table S1 The degradation efficiencies and detailed information of the catalysts mentioned above.

Catalysts	Prepared method	Reasons for promoting efficiency	Degradation efficiency
Ag@AgCl/ZSH heterojunction	Ultrasonic assisted precipitation-photoreduction method	Surface plasmon resonance (SPR) effect	The degradation efficiency of RhB reach to 99.86% in 60 min[1] (ref. S1)
AgI/ZSH	Deposition–precipitation method	Faster separation of electron-hole pairs with ZSH as an electron trap.	The removal efficiency of RhB reached 100% in 40 min[2] (ref.S2)
$Ag@Ag_3PO_4$/ZSH	In situ deposition and photoreduction reaction method	Surface plasmon resonance (SPR) effect	The removal efficiency of RhB was 93.04% [3](ref. S3) within 40 min
Ag_3PO_4/ZSH	In situ deposition		The degradation efficiency of RhB was 88.7% in 40 min[3] (ref. S3)
Pure ZSH nanocubes	Simple chemical bath approach		The degradation efficiency of RhB was 2.83% in 40 min[3] (ref.S3)
Plasmonic Bi nanoparticles and BiOCl sheets codecorated ZSH	One-pot precipitation, hydrolysis and UV-photoreduction process	Surface plasmon resonance effect	The octahedral ZSH-3-Bi gave the greatest degradation of 91.4 % after 120 min[4] (ref.S4)
BiOI/ZSH	Deposition method	Intimate contacts between $ZnSn(OH)_6$ and BiOI resulted in easier charge transfer and more efficient separation of electron–hole pairs	The best degradation efficiency of RhB was 95.8% in 40 min on 19.7% BiOI/ZSH[5] (ref. S5)
N-TiO_2	Sol-gel method		The degradation efficiency of RhB was 30% in 40 min[3] (ref. S3)

Reference:

[1] F. Chen, Q. Yang, C. Niu, X. Li, C. Zhang, G. Zeng, RSC Advances 5 (2015) 63152-63164.

[2] F. Chen, Q. Yang, C. Niu, X. Li, C. Zhang, J. Zhao, Q. Xu, Y. Zhong, Y. Deng, G. Zeng, Catalysis Communications 73 (2016) 1-6.

[3] F. Chen, Q. Yang, X. Li, D. Wang, Y. Zhong, J. Zhao, Y. Deng, C. Niu, G. Zeng, Catalysis Communications 84 (2016) 137-141.

[4] H. Wang, X. Yuan, Y. Wu, G. Zeng, W. Tu, C. Sheng, Y. Deng, F. Chen, J.W. Chew, Applied Catalysis B: Environmental 209 (2017) 543-553.

[5] H. Li, Y. Cui, W. Hong, B. Xu, Chemical Engineering Journal 228 (2013) 1110-1120.