A highly active Z-scheme SnS/Zn_2SnO_4 photocatalyst fabricated for methylene blue degradation

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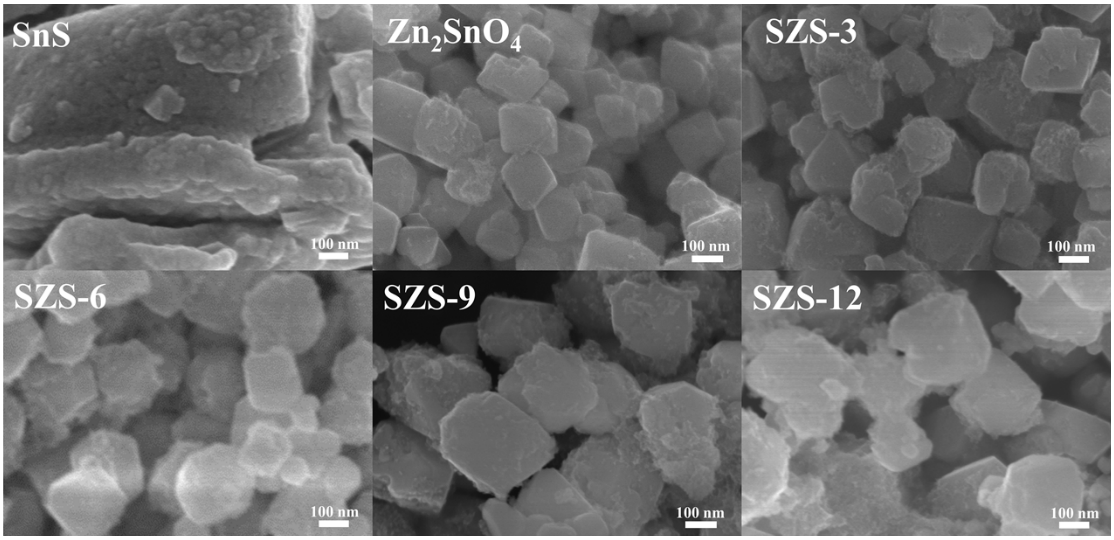

Fig.S1 SEM images of SnS, Zn_2SnO_4, SZS-*x*.

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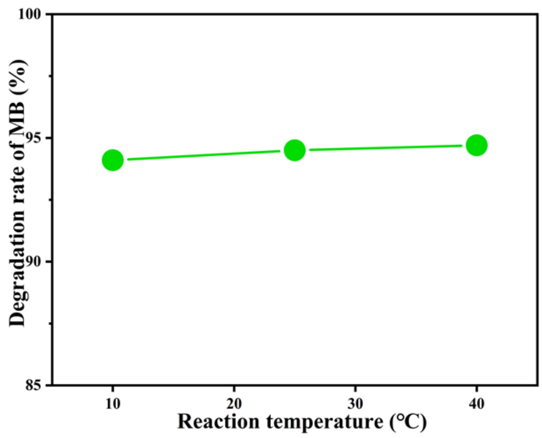

Fig.S2 Photocatalytic degradation rate of MB (10 mg/L) by 0.05 g SZS-6 at different temperatures.

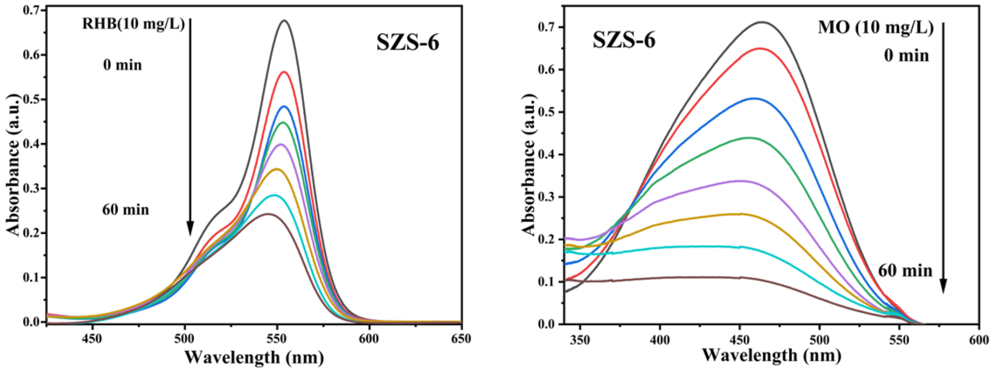

Fig.S3 The UV-vis absorption curves of RHB and MO by SZS-6 catalysis under visible light irradiation.

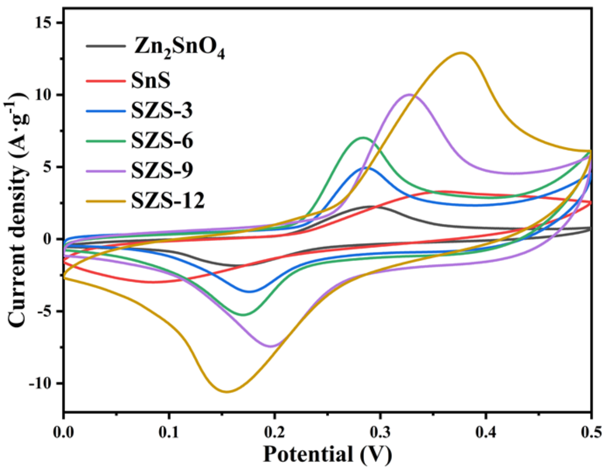

Fig. S4 Curves of cyclic voltammetry for Zn_2SnO_4, SnS and SZS-x.

Table S1

BET surface area, average pore size and pore volume of Zn_2SnO_4 and SZS-*x*.

Sample	Pore volume ($cm^3·g^{-1}$)	Pore diameter (nm)	BET surface area ($m^2·g^{-1}$)
Zn_2SnO_4	0.207139	15.4622	44.4447
SZS-3	0.026454	19.0930	5.0328
SZS-6	0.023729	21.8222	4.4387
SZS-9	0.039919	20.1118	6.6840
SZS-12	0.017606	15.0750	4.2618

The evaluation of energy efficiency factors [S1, S2]

In order to assess the energy efficiency factor in the photocatalytic process under study, the electrical energy per order (EE/O) and the average apparent quantum yield ($\varphi_{app,av}$) should be calculated.

EE/O is calculated by the following equation:

$$EE/O = \frac{P\frac{t}{60}3785}{V\log(C_{in}/C)} \quad (1)$$

where EE/O is defined as the kilowatt-hours of electricity required to reduce the concentration of a compound in 1000 gallons of water by one order of magnitude, P represents the lamp-emitted power in kW, *t* is the irradiation time in min, V is the total reactor volume, C_{in} the initial model pollutant concentration and *C* is the model pollutant concentration at time *t*.

The average apparent quantum efficiency ($\varphi_{app,av}$) is calculated by the following equation:

$$\varphi_{app,av} = \frac{\left(\frac{N_{90\%}}{t_{90\%}}\right)}{\int_{\lambda_1}^{\lambda_2} \frac{R.A_{irr}\lambda d\lambda}{hc}} \quad (2)$$

where $\varphi_{app,av}$ is the ratio of the number of electrons involved in the reaction to the total number of absorbed photons in the system, $N_{90\%}$ being the number of pollutant molecules degraded at the 90% conversion level, $t_{90\%}$ the time required to achieve 90% conversion in seconds, R is the radiation intensity in W $(m^2 \cdot nm)^{-1}$, A_{irr} the irradiated catalyst area in m^2, h is the Plank's constant ($6.62.10^{-34}$ J.s), c is the speed of light in vacuum ($2.997.10^8$ m/s).

The gibbs free energy of activation $\triangle G^{\theta}_{\neq}$ is calculated by the following equation:

$$\nabla G^{\theta}_{\neq} = \mathrm{RT} \ln\left[\frac{\mathrm{RT}}{\mathrm{N_A h}k}\right]$$

where $\triangle G^{\theta}_{\neq}$ is the change in the standard Gibbs energy of the reactants during the formation of the activated complex, R is the molar gas constant, T is reaction temperature, N_A is Avogadro constant, h is the Plank's constant ($6.62.10^{-34}$ J.s), *k* is the reaction rate constant.

With smaller values of the EE/O, less energy is required for decreasing the concentration of model pollutants in the photocatalytic system. The higher the average apparent quantum yield indicates that the more electrons are involved in the photocatalytic system, the more advantageous it is for photocatalytic reactions.

Reference

S1. A. n. O. z. Benito Serrano, Jesu´ s Moreira, and Hugo I. de Lasa, *Ind. Eng. Chem. Res.*, 2010, **49**, 6824-6833.

S2. B. S. M. S. Hugo de Lasa, *Photocatalytic Reaction Engineering*, 2005, 119-131.

Table S2

The electrical energy per order (EE/O) and the average apparent quantum yield (ϕapp,av) of samples.

Sample	EE/O ($\times10^4$ kW·h/L)	$\varphi_{app,av}$ %
Zn_2SnO_4	9.7	20.9
SnS	8.8	21.2
SZS-3	3.5	37.4
SZS-6	1.4	57.3
SZS-9	4.0	35.9
SZS-12	6.4	27.5

Table S3

Adsorption rate of samples

Sample	Adsorption rate %
Zn_2SnO_4	8.7
SnS	6.6
SZS-3	16.8
SZS-6	15.6
SZS-9	14.6
SZS-12	15.5