Electronic Supplementary Information

Direct growth of SnS_2 nanowall photoanode for high responsivity self-powered photodetectors

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Materials

Tin chloride ($SnCl_2$) (AR,99%) was purchased from Shanghai Aladdin Biochemical Technology Co., Ltd. Sodium thiosulfate pentahydrat ($Na_2S_2O_3 \cdot 5H_2O$) (AR, 99.0+%) was purchased from Guangdong Guanghua Sci-Tech Co., Ltd. Sulfur powder (AR)was purchased from Damao Chemical Reagent Factory. Citric acid ($C_6H_8O_7 \cdot H_2O$) (99.5%) was purchased from Xi'an Chemical Reagent Factory. Sodium hydroxide (NaOH) (AR, 96.0+%) was purchased from Sinopharm Chemical Reagent Co., Ltd. Carbon disulfide (CS_2) (99.0%) was purchased from Tianjin Fuchen Chemical Reagent Factory. All chemicals were used as received without further purification.

Pre-treatment of FTO conductive glasses

Firstly, FTO conductive glasses were purchased from Luoyang Glass Co., Ltd with rectangular pieces (2.5 cm × 2.5 cm). Then they were cleaned ultrasonically with acetone, methanol, isopropanol, ethanol, and ultra-pure water in sequence for 30 minutes, respectively. Finally, the plates were dried with a stream of nitrogen.

Preparation of citric acid-sodium citrate buffer solution

0.02188 mol citric acid and 0.0042 mol NaOH were dissolved into 200 mL ultra-pure water by stirring magnetically to obtain a homogeneous citric acid-sodium citrate buffer solution (pH=3).

Measurement of the optical power density

After the light source is turned on and the shape of the light spot is stable, then the optical power density was measured by Anritsu ACCESS Master MT9085A-063 all-in-one spectroradiometer. The optical power density is the average value of the different position for the substrates to ensure its accuracy.

Materials characterizations

The morphology and microstructures of the obtained materials at different stages were observed using field-emission scanning electron microscopy (FE-SEM, SU2080) and transmission electron microscope (TEM, JEM-2100). The phase structures were studied by X-ray diffraction (XRD, Rigaku D/Max-3c X-ray diffractometer) with Cu Kα radiation (γ=1.5406 Å) and Raman spectroscopy (Renishawin Via) with an excitation wavelength of 532 nm. The composition and chemical state were determined by XPS (PHI Quantera II) and the binding energy calibration was referenced to C 1s at 284.6 eV.

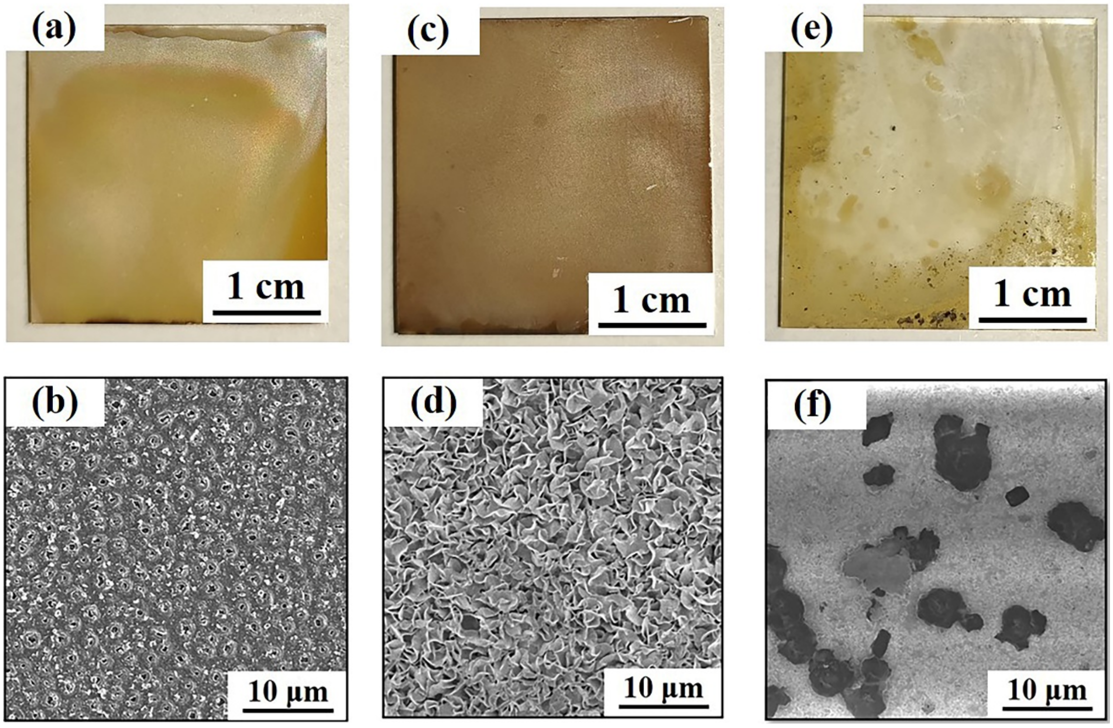

Fig. S1 Optical and SEM images of SnS_2 with different amounts of $SnCl_2$: (a)-(b) 0.25 mmol, (c)-(d) 0.5 mmol and (e)-(f) 1 mmol.

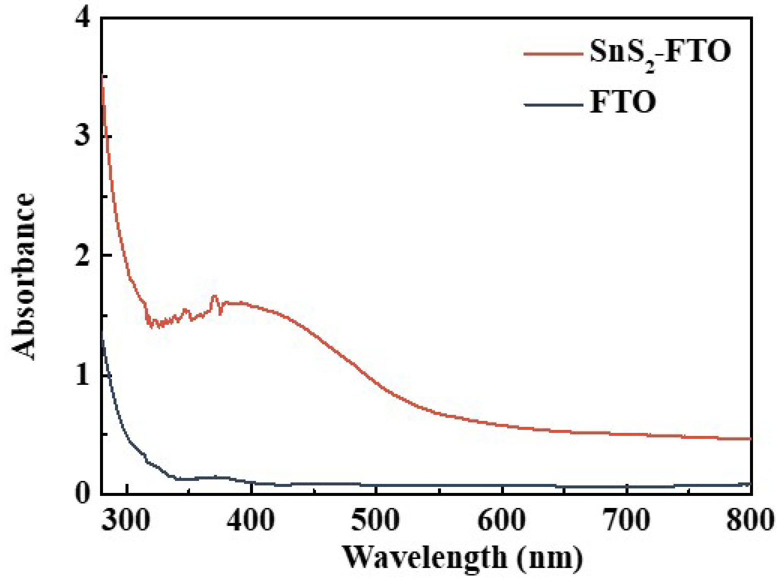

Fig. S2 UV-vis absorption spectra of SnS_2 and bare FTO glass.

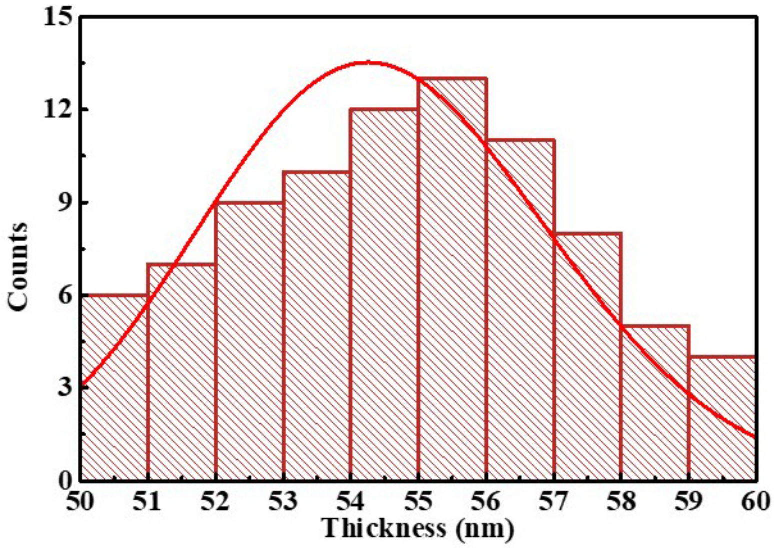

Figure S3. The statistical average thickness of SnS_2 nanosheets in the nanowalls.

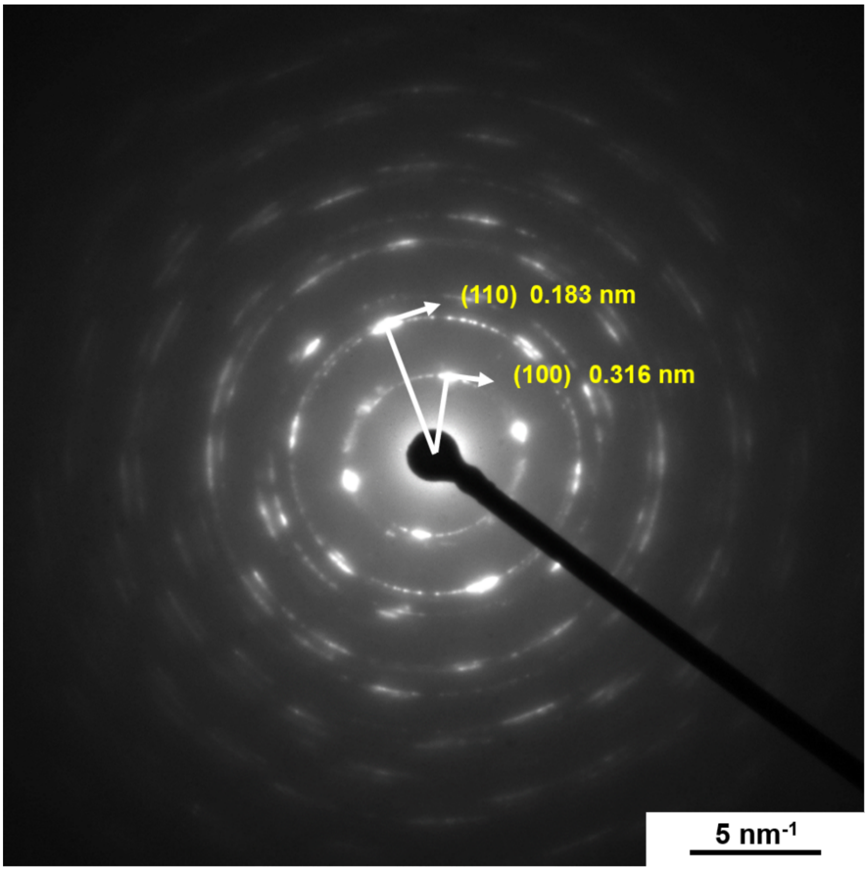

Figure S4. The SEAD pattern of SnS_2 nanowalls

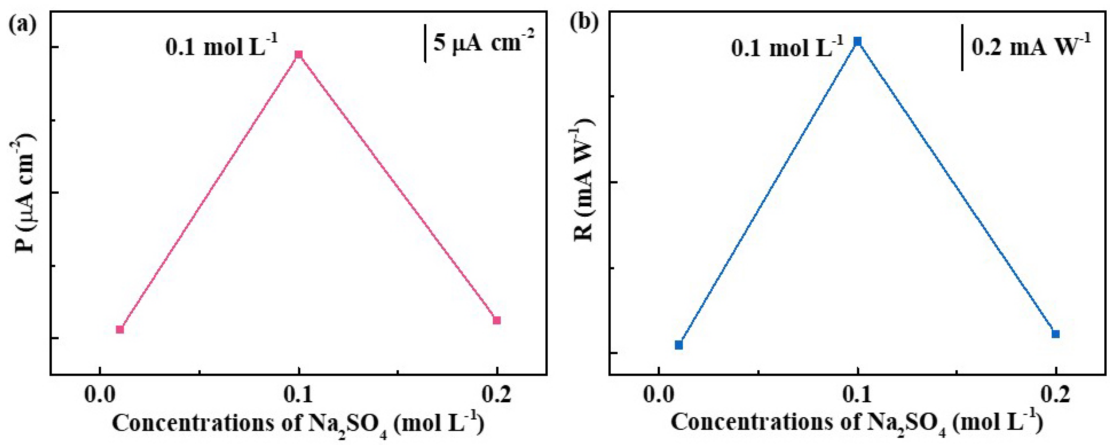

Fig. S5 (a) The calculated P and (b) R as a function of Na_2SO_4 concentrations.

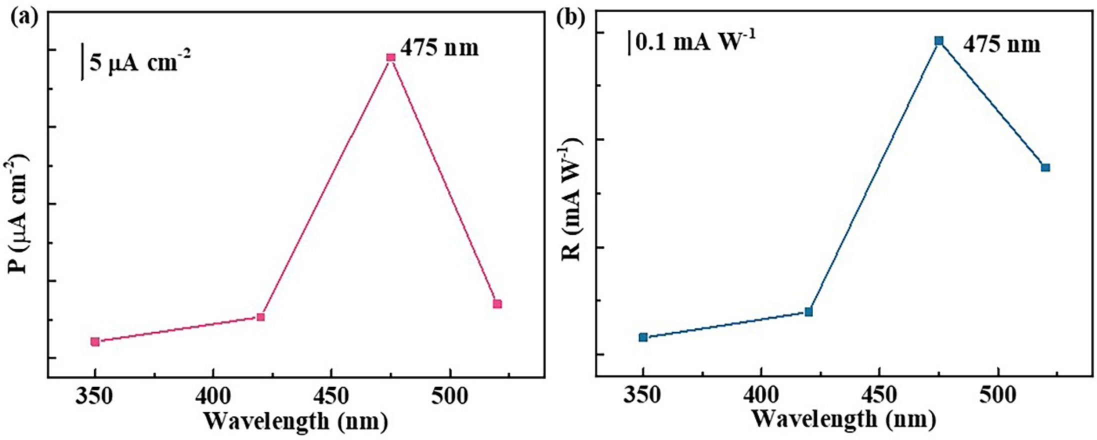

Fig. S6 (a) The calculated P and (b) R as a function of wavelengths.

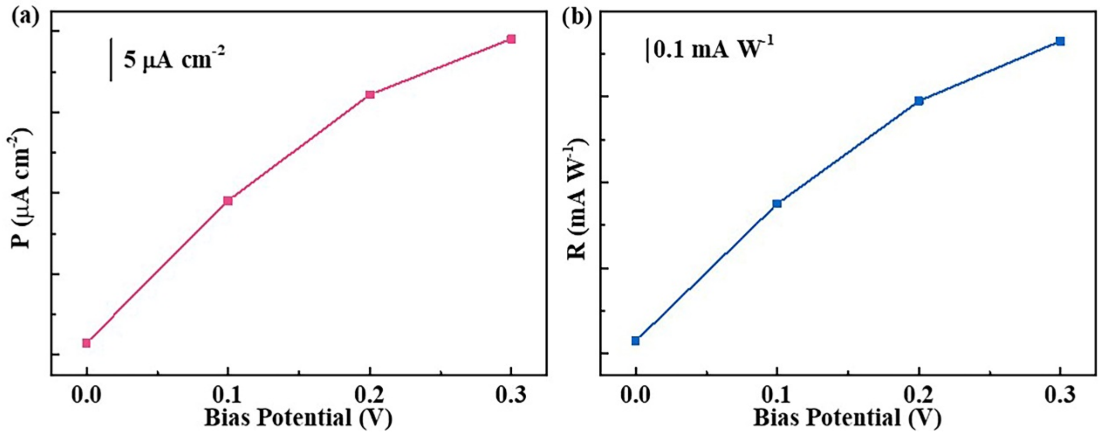

Fig. S7 (a) The calculated P and (b) R as a function of bias potentials.

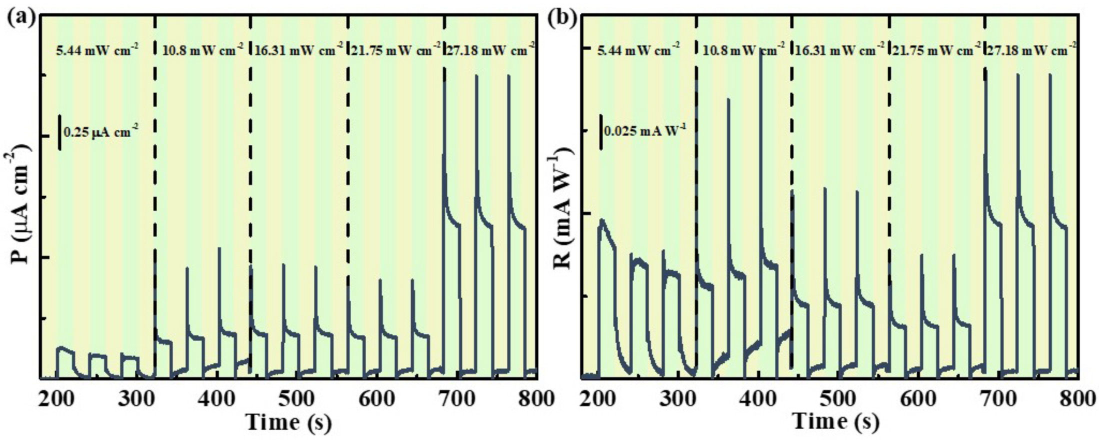

Fig. S8 Self-powered behaviors of SnS_2 nanowalls-based photodetectors under the wavelength of 475 nm illumination and in 0.1 M Na_2SO_4 electrolyte at 0 V bias potentials: (a) Photocurrent densities and (b) Responsivities.

Table S1. The calculated photocurrent density (P) of SnS_2 nanowalls-based photodetectors under various electrolyte concentrations and power densities at 475 nm illumination and 0.3 V bias potential in Na_2SO_4 electrolyte.

P (μA cm^{-2})	5.44 mW cm^{-2}	10.8 mW cm^{-2}	16.31 mW cm^{-2}	21.75 mW cm^{-2}	27.18 mW cm^{-2}
0.01 M	0.84	1.75	4.61	2.62	1.17
0.1 M	1.45	4.62	4.61	5.77	39.06
0.2 M	0.5	2.68	2.85	1.8	2.51

Table S2. The calculated responsivity (R) of SnS_2 nanowalls-based photodetectors under various electrolyte concentrations and power densities at 475 nm illumination and 0.3 V bias potential in Na_2SO_4 electrolyte.

R (mA W^{-1})	5.44 mW cm^{-2}	10.8 mW cm^{-2}	16.31 mW cm^{-2}	21.75 mW cm^{-2}	27.18 mW cm^{-2}
0.01 M	0.15	0.16	0.28	0.12	0.04
0.1 M	0.26	0.42	0.27	0.27	1.46
0.2 M	0.09	0.25	0.17	0.08	0.09

Table S3. The calculated photocurrent density (P) of SnS_2 nanowalls-based photodetectors under various wavelengths and power densities at 0.3 V bias potential in 0.1 M Na_2SO_4 electrolyte.

P (μA cm^{-2})	5.44 mW cm^{-2}	10.8 mW cm^{-2}	16.31 mW cm^{-2}	21.75 mW cm^{-2}	27.18 mW cm^{-2}
350 nm	0.98	1.32	1.27	2	2.14
420 nm	0.46	2.79	4.61	5.3	5.34
475 nm	1.45	4.62	4.61	5.77	39.06
520 nm	4.65	4.77	5.65	6.36	7.01

Table S4. The calculated photoresponsivity (R) of SnS_2 nanowalls-based photodetectors under various wavelengths and power densities at 0.3 V bias potential in 0.1 M Na_2SO_4 electrolyte.

R ($mA\ W^{-1}$)	5.44 $mW\ cm^{-2}$	10.8 $mW\ cm^{-2}$	16.31 $mW\ cm^{-2}$	21.75 $mW\ cm^{-2}$	27.18 $mW\ cm^{-2}$
350 nm	0.18	0.12	0.08	0.09	0.08
420 nm	0.08	0.26	0.28	0.24	0.19
475 nm	0.26	0.42	0.27	0.27	1.46
520 nm	0.85	0.44	0.35	0.29	0.26

Table S5. The calculated photocurrent density (P) of SnS_2 nanowalls-based photodetectors under various bias potentials and power densities at 475 nm illumination in 0.1 M Na_2SO_4 electrolyte.

P (μA cm^{-2})	5.44 mW cm^{-2}	10.8 mW cm^{-2}	16.31 mW cm^{-2}	21.75 mW cm^{-2}	27.18 mW cm^{-2}
0 V	0.22	0.44	0.33	0.58	1.5
0.1 V	0.29	2.15	0.76	0.94	19.09
0.2 V	0.66	2.16	2.33	2.34	32.17
0.3 V	1.45	4.62	4.61	5.77	39.06

Table S6. The calculated photoresponsivity (R) of SnS_2 nanowalls-based photodetectors under various bias potentials and power densities at 475 nm illumination in 0.1 M Na_2SO_4 electrolyte.

R (mA W^{-1})	5.44 mW cm^{-2}	10.8 mW cm^{-2}	16.31 mW cm^{-2}	21.75 mW cm^{-2}	27.18 mW cm^{-2}
0 V	0.04	0.04	0.02	0.03	0.06
0.1 V	0.05	0.2	0.05	0.04	0.7
0.2 V	0.12	0.2	0.14	0.11	1.18
0.3 V	0.26	0.42	0.27	0.27	1.46