Electronic supplementary information

High-performance photodetector based on two-dimensional Tin (II) sulfide (SnS) nanoflakes

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Contents list

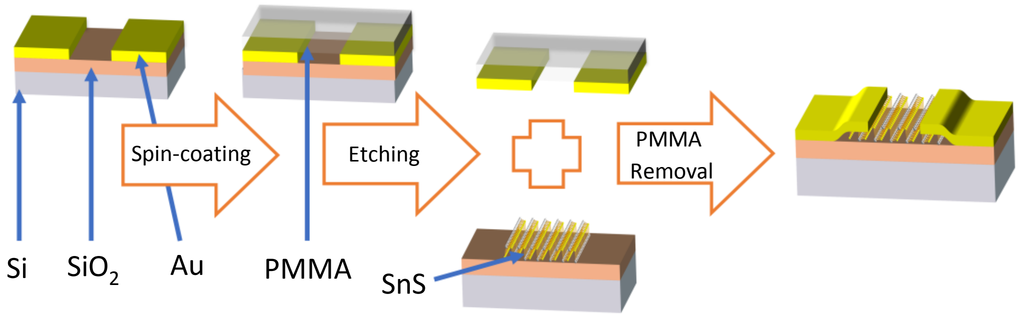

Figure S1 Flowchart of the Photolithographic-Pattern-Transfer (PPT) method to prepare the devices.

First, 20 wt% polymethyl methacrylate (PMMA) solution is spin-coated at Si/SiO_2 wafers with a speed of 2000 rmp/min, then, dry it at 80 °C in 5 minutes. Afterwards, immerse the wafers in 2 mol/L NaOH solution to peel off the Au electrodes and transfer them to as-grown SnS samples. After dry it at 80 °C in 5 minutes, the samples are soaked in hot acetone for 1 min to remove PMMA.

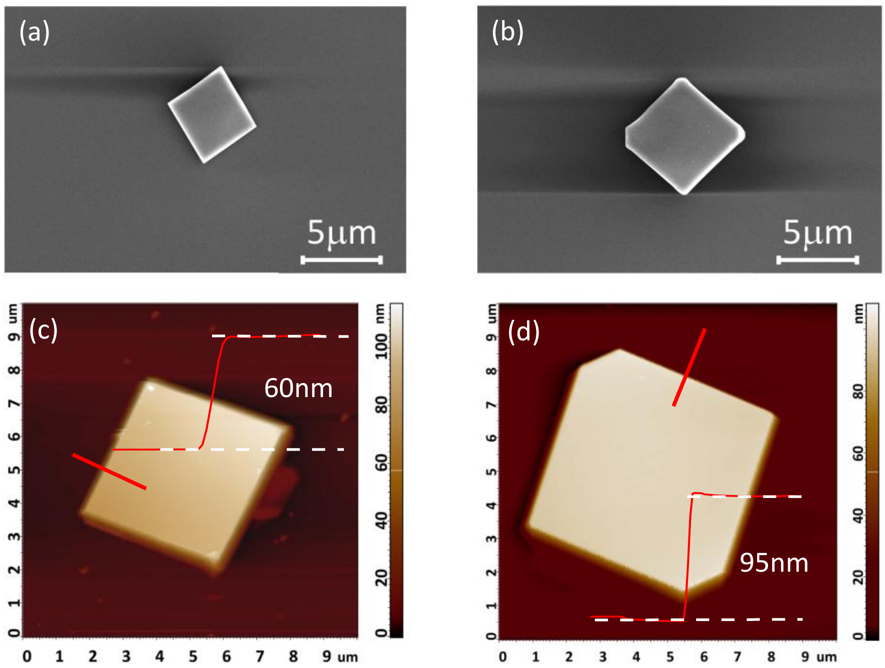

Figure S2 SEM and AFM image of as-grown SnS. (a) – (b) SEM image of as-grown sns nanoflakes with 5.5 (a),7.5 (b) minutes synthesis time. (d) AFM image of as-grown sns nanoflakes with 5.5 minutes synthesis time. (e) AFM image of as-grown sns nanoflakes with 7.5 minutes synthesis time.

Fig. S2a-c are AFM images of as-grown SnS nanoflakes. All nanoflakes show square shaped, and the feature size is increased from 4 μm (Fig. S2a) to 6 μm (Fig. S2c). The AFM images show that the thickness of as-grown SnS nano flakes increase form 60 nm (Fig. S2d) to 95 nm (Fig. S2e), with time changing from 5.5 min to 7.5 min.

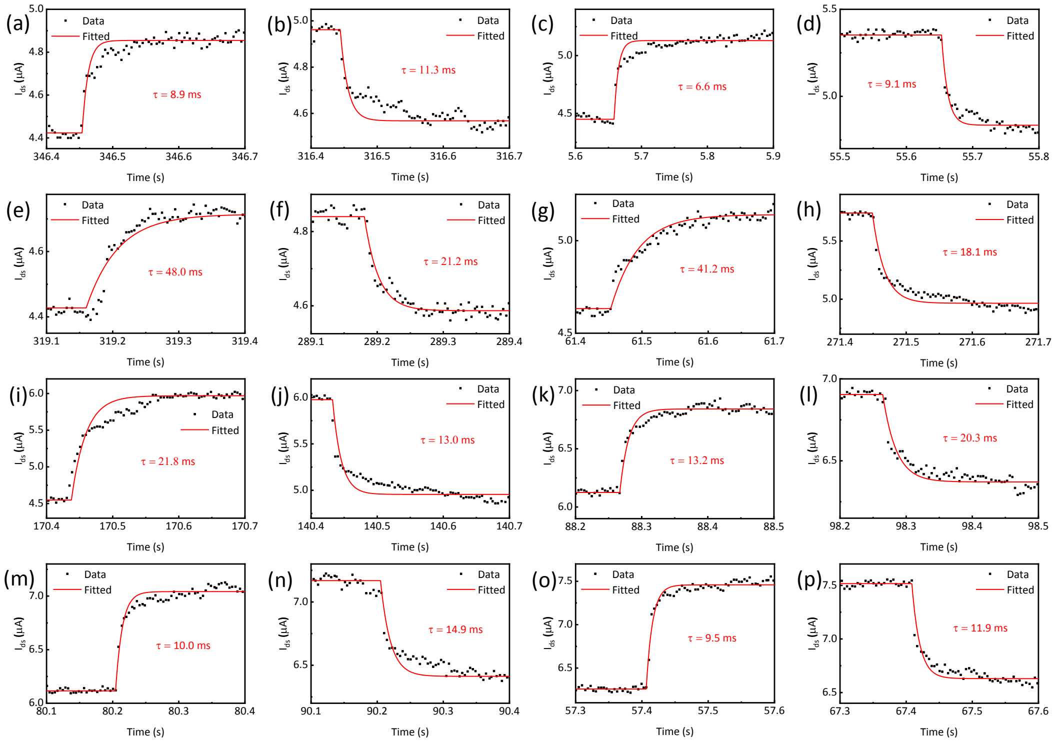

Figure S3 Switching characteristic of fabricated photodetectors. (a) - (d) The rise time and fall time at light power intensity of 0.41 (a, b) and 1.50 (c, d) mW/mm^2 respectively, under blue violet laser. The rise time and fall time at light power intensity of 2.77 (e, f), 4.49 (g, h) and 7.44 (i, j) mW/mm^2 respectively, under green laser. The rise time and fall time at light power intensity of 0.10 (k, l), 0.46 (m, n), and 1.66 (o, p) mW/mm^2 respectively, under red laser.

Switching characteristic of fabricated photodetectors is characterized by I_{ds} -T curve fitted with the equations:

$$I_{ds} = I + I_0 \times \exp[\,-(t-t_0)/\tau_f]$$

Those I_{ds} -T data in Fig. S3 are measured at V_{ds} = 1 V under the illumination of blue violet, green and red laser with different light power intensity. For blue violet laser, light power intensity is 0.41 (a, b) and 1.50 (c, d) mW/mm^2. For green laser, light power intensity is 2.77 (e, f), 4.49 (g, h) and 7.44 (i, j) mW/mm^2. For red laser, the light power intensity is 0.10 (k, l), 0.46 (m, n) and 1.66 (o, p) mW/mm^2. The gained rise time (τ_r) and fall time (τ_f) are shown in the following table S1.

Table S1 The response time of fabricated photodetectors

	P_{light} (mWmm^{-2})	τ_r (ms)	τ_f (ms)
Blue violet	0.42	8.9	11.3
	1.50	6.6	9.1
	3.24	5.1	8.8
Green	3.2	48.0	21.2
	3.3	41.2	18.1
	3.6	21.8	13.0
Red	0.10	13.2	20.3
	0.45	10.0	14.9
	1.66	9.5	11.9

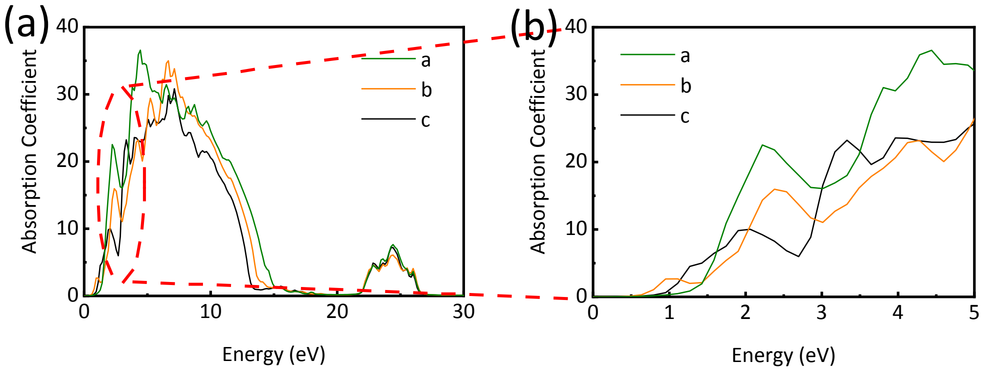

Figure S4 (a) Calculated absorption coefficient of bulk SnS in a, b and c directions, and its enlarged drawing (b) of the photon energy in the range of 0-5 eV.

The calculated absorption coefficient in a, b and c directions were calculated. Within the photon energy range of 0 -5 eV, light absorption first appears in the b direction at about 0.7 eV. The starting point of light absorption in a and c directions is at about 1 eV. The absorption coefficients in all directions rise firstly, then drop and rise again. The absorption coefficients in directions a and b have maximal values at about 2.5 and 4.3 eV, respectively, and have minima at 3 eV. Moreover, the result indicates that SnS has weak optical anisotropy.

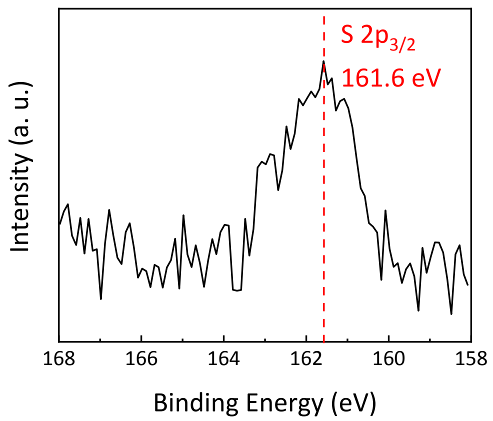

Figure S5 XPS spectra of as-grown SnS nanoflakes.

As shown in Fig. S5, the small area XPS spectra shows that the peak at 161.6 eV is coincident with S $2p_{3/2}$ (161.7 eV, {Y. B. Yang et al., *J. Phys. Chem. C*, 2016, **120**, 13199−13214}), and the atomic ratio of Sn and S is 1 : 1.05.