Supporting Information

## Sulfurization Engineering of Single Zone CVD vertical and horizontal MoS<sub>2</sub> on p-GaN heterostructure for selfpowered UV PD

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**Figure S1.** (a) Raman spectroscopy of MoS<sub>2</sub> sulfurized for 30- and 60 minutes at different growth temperatures. (b) Raman spectroscopy of MoS<sub>2</sub> grown at 650 °C and 750 °C with different sulfurization duration.

	15 min				30 min		60 min			
	650 °C	750 °C	850 °C	650 °C	750 °C	850 °C	650 °C	750 °C	850 °C	
E <sup>1</sup> <sub>2g</sub> peak FWHM (cm <sup>-1</sup> )	9.64	8.17	6.10	8.75	6.92	5.90	8.60	7.12	7.75	
A <sub>1g</sub> peak FWHM (cm <sup>-1</sup> )	8.29	7.88	5.84	7.43	6.29	5.70	7.31	6.43	6.84	
E <sup>1</sup> 2g peak position (cm <sup>-1</sup> )	383.3	383.3	383.5	383.3	383.4	383.2	383.3	383.4	383.5	
A <sub>1g</sub> peak position (cm <sup>-1</sup> )	407.9	407.9	408.1	407.9	407.9	408.1	407.9	407.9	408.1	
Δk (cm <sup>-1</sup> )	24.6	24.6	24.6	24.6	24.5	24.9	24.6	24.5	24.6	
E <sup>1</sup> <sub>2g</sub> peak intensity (a.u)	3,056.88	3.787.28	10,980.60	4,043.23	5,592.29	7,682.77	3,470.98	5,126.09	5,646.40	
A <sub>1g</sub> peak intensity (a.u)	6,469.40	8,793.11	27,140.60	9,623.74	14,567.20	18,761.80	7,987.07	12,383.30	13,264.40	
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	0.47	0.44	0.40	0.42	0.38	0.41	0.43	0.41	0.43	

**Table S1.** Values of Raman  $E_{2g}^1$  and  $A_{1g}^1$  peaks position, FWHM, and  $E_2^1 / A_{1g}^1$  relative intensity ratio for grown MoS<sub>2</sub> at different sulfurization temperatures and duration



**Figure S2.** (a) XRD diffractogram of MoS<sub>2</sub> sulfurized for 30- and 60 minutes at different growth temperatures. b) XRD diffractogram of MoS<sub>2</sub> grown at 650 °C and 750 °C with different sulfurization duration.

Table S2.	Data extracted	l from XRD	measurements
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	15 min			30 min			60 min		
	650 °C	750 °C	850 °C	650 °C	750 °C	850 °C	650 °C	750 °C	850 °C
(002) peak FWHM (°)	1.49	1.21	1.03	1.29	1.09	0.87	1.26	1.07	1.15
Crystallite size (nm) (± 0.1)	5.29	6.52	7.65	6.11	7.23	9.06	6.26	7.37	6.86

**Table S3.** The results of room-temperature Hall effect measurements of  $MoS_2$  film sulfurized at 850°C for 15-, 30-, and 60 minutes.

MoS <sub>2</sub> Sample	Туре	Carrier density (/cm <sup>3</sup> )	Mobility (cm <sup>2</sup> /V·s)
15 minutes	n	9.58 × 10 <sup>13</sup>	7.9
30 minutes	n	$1.70 \times 10^{14}$	16.5
60 minutes	n	$5.29 \times 10^{13}$	3.5



**Figure S3.** Overall EDX area analysis and elemental quantification of FE-SEM images of  $MoS_2$  grown at conditions (a)  $850^{\circ}C - 15$  minutes (b)  $850^{\circ}C - 30$  minutes (c)  $850^{\circ}C - 60$  minutes

Quantifying Mo and S elements is difficult since the emission energies of Mo La (2.292 keV) and S Ka (2.309 keV) are very close to each other. But the sum of Mo and S is reliable to quantify the amount of  $MoS_2$ . The EDX spectrum corresponding to the FE-SEM image reveals the presence of elements Mo and S in which the atomic content ratio Mo/S is ~1:1.82, 1:1.91, 1:1.43 for the film sulfurized at 850°C for 15-, 30-, and 60- minutes. Upon longer sulfurization to 30 minutes, the stoichiometry improves nearly to the stoichiometry ideal value. A prolonged sulfurization however results in dropped Mo/S ratio. This means about ~30% of sulfur sites are vacancies.



**Figure S4**. a) UV–vis spectrum showing the characteristic excitonic peaks of 2H-MoS<sub>2</sub> nanosheets b) Determination of absorption band gaps through absorbance spectra.

Tauc plot of  $(\alpha h\nu)^{1/2}$  versus energy  $h\nu$  is shown in Figure S4 (b). By extrapolating the linear part of the curves to the energy axis (at  $\alpha h\nu = 0$ ), we obtained the band gap energy of ~1.42 eV.



Figure S5. Response spectra of the 355 nm UV LED.