Electronic Supplementary Material (ESI) for Materials Advances.

Gate-controlled Rectification and Broadband Photodetection in a P-N Diode based on TMDCs Heterostructure

Ehsan Elahi[1†*], Sobia Nisar[†2], Muhammad Rabeel[2,3], Malik Abdul Rehman[4], Mohamed Ouladsamne[5], Muhammad Irfan[6], Muhammad Abubakr[2,7], Jamal Aziz[8], Muhammad Asim[1], Ghulam Dastgeer[1*]

[1]*Department of Physics & Astronomy, Sejong University, 209 Neungdong-ro, Gwangjin-Gu, Seoul, 05006 South Korea*

[2]*Department of Electrical Engineering, Sejong University, 209 Neungdong-ro, Gwangjin-gu, Seoul, 05006, South Korea*

[3]*Department of Convergence Engineering for Intelligent Drone, Sejong University, Seoul, 05006, South Korea*

[4]*Department of Chemical Engineering, New Uzbekistan University, Tashkent, 100007, Uzbekistan*

[5]*Department of Chemistry, College of Science, King Saud University, Riyadh, 11451, Saudi Arabia*

[6]*Department of Electrical Engineering, University of Engineering and Technology, Faisalabad, Pakistan*

[7]*Graduate School of Optical Engineering, Sejong University, Seoul, 05006, South Korea.*

[8]*School of Electrical, Information and Media Engineering, Bergische Universität Wuppertal, Lise-Meitner-Straße 13, 42119 Wuppertal, Germany*

[*]*Corresponding author e-mail:* (Ehsan Elahi) Ehsanelahi@sju.ac.kr

(Ghulam Dastgeer) gdastgeer@sejong.ac.kr

†: Ehsan Elahi and Sobia Nisar shared the 1st authorship equally

AFM of WSe_2 and SnS_2

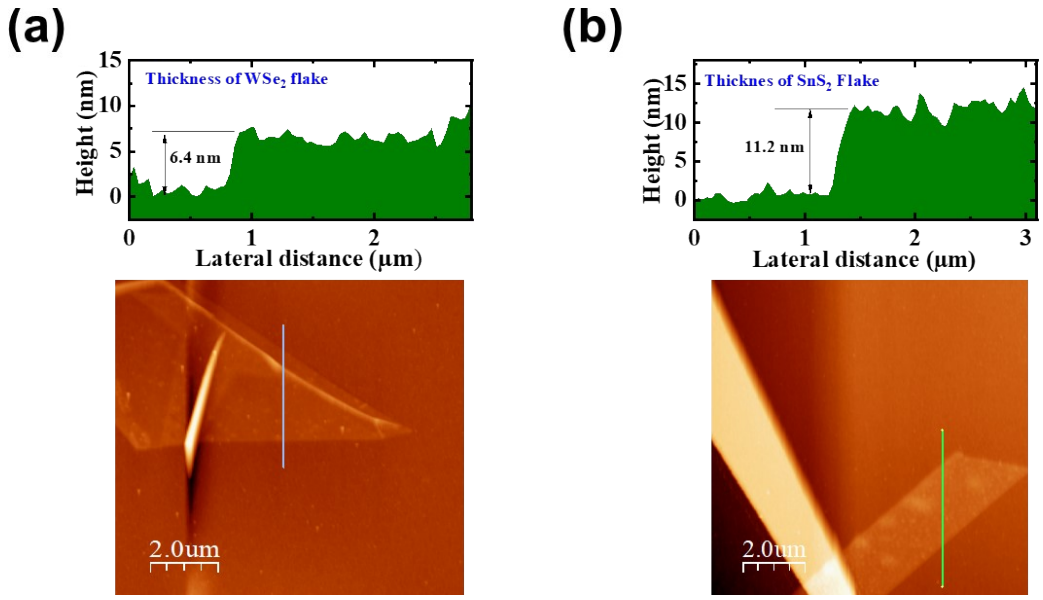

Figure S1: (a) AFM height profile and image of an individual flake of WSe_2. (b) AFM height profile and image of an individual flake of SnS_2.

Raman Spectra of WSe_2 and SnS_2

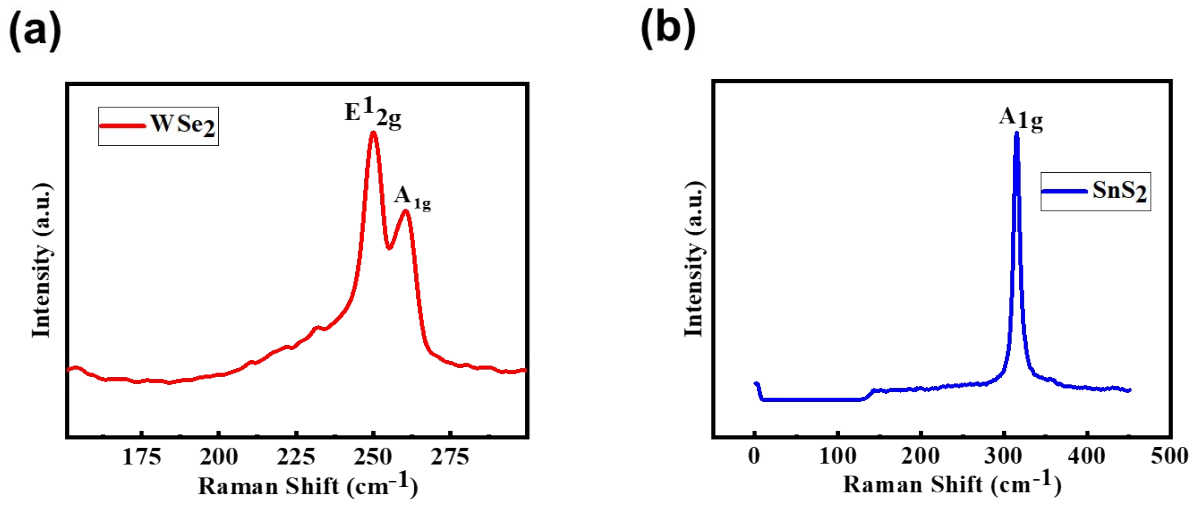

Figure S2: (a) Raman spectra of SnS_2 and (b) WSe_2.

Ideality factor calculation

The ideality factor was calculated for the forward-biased zone by fitting the logarithmic I-V characteristics to the Shockley diode equation.

$$I_D = I_S\left[exp\left(\frac{qV}{nk_B T}\right) - 1\right]$$

where I_D represents the diode current, I_S represents the reverse bias saturation current, V denotes the applied voltage, η symbolizes an ideality factor, T signifies temperature, q symbolizes electronic charge, and k_B indicates Boltzmann's constant. For applied voltages larger than k_BT (e.g., > 0.1 V), the term "-1" in the preceding equation can be ignored.

$$\ln\left(I_D\right) = \ln\left(I_S\right) + \left(\frac{q}{nK_B T}\right)V$$

$$\eta = \frac{1}{Slope}\left(\frac{q}{K_B T}\right)$$

$$\eta = \frac{1}{Slope}\left(\frac{1.6 \times 10^{-16} C}{1.38 \times 10^{-23} JK^{-1} \times 300K}\right)$$

Slope= 25.77

$$\eta = \frac{38.6}{27.30} = 1.41$$

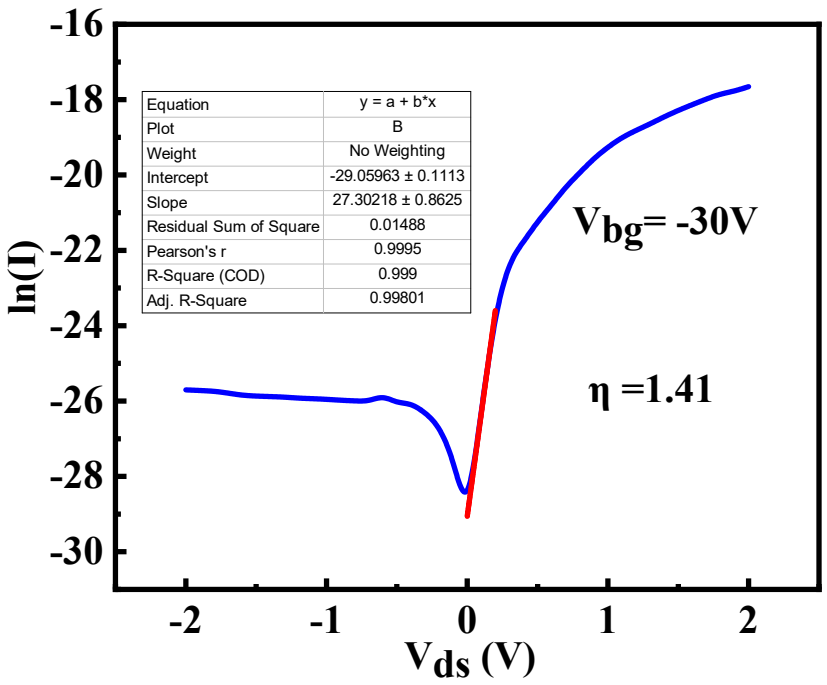

Figure S3: Logarithmic (I_{ds}-V_{ds}) curve to find the slope, the inset shows the slope.

Rise and Decay time

The rising and decay times were observed by fitting the data obtained through photocurrent. The fitting of rise and decay time is represented in **Figure S4**.

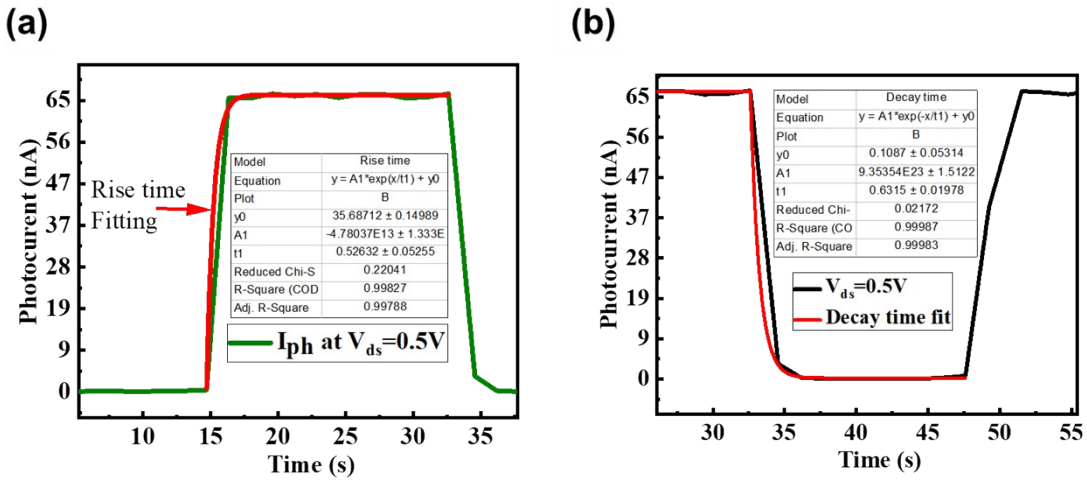

Figure S4: (a) The rise time for the photocurrent at V_{ds}=0.5V. (b) The fall time at V_{ds}=0.5V.

Logarithmic scale for Photocurrent

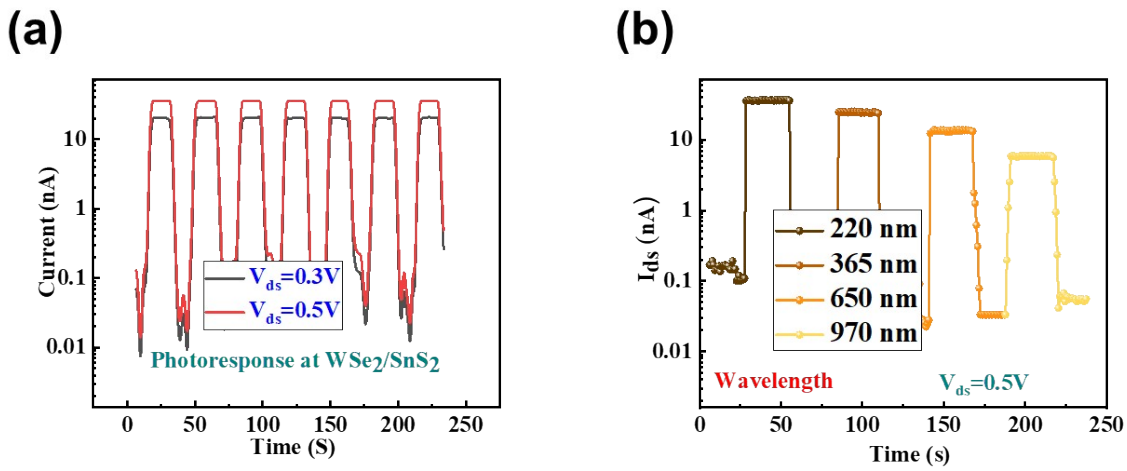

Figure S5: (a) The logarithmic scale of photocurrent at different V_{ds}. (b) The logarithmic scale of Photocurrent at different wavelengths.