Supporting Information

Type-II WS_2/AsP Van der Waals Heterojunctions with High Rectification Ratio and High Detectivity

Runmeng Jia[1], Tingting Guo[1], Yifei Wang[1], Yuhai Lin[1], Cheng Zhu[1], Ahmad Farhan[1], Jing Xu[1], Banqin Ruan[1], Aidi Zhang[2], Xiang Chen[1], Zhi Li[1], Xiufeng Song[1*] and Haibo Zeng[1*]

[1]MIIT Key Laboratory of Advanced Display Materials and Devices, School of Materials Science and Engineering, Nanjing University of Science and Technology, Nanjing 210094, People's Republic of China

[2]Engineering Research Center of Functional Polymer Membrane Materials of Jiangsu Province, Nanjing Bready Advanced Materials Technology Co., Ltd, No. 8 Baoding Road, Nanjing 211103, People's Republic of China

* Authors to whom any correspondence should be addressed.

E-mail: xiufengsoong@njust.edu.cn and zeng.haibo@njust.edu.cn

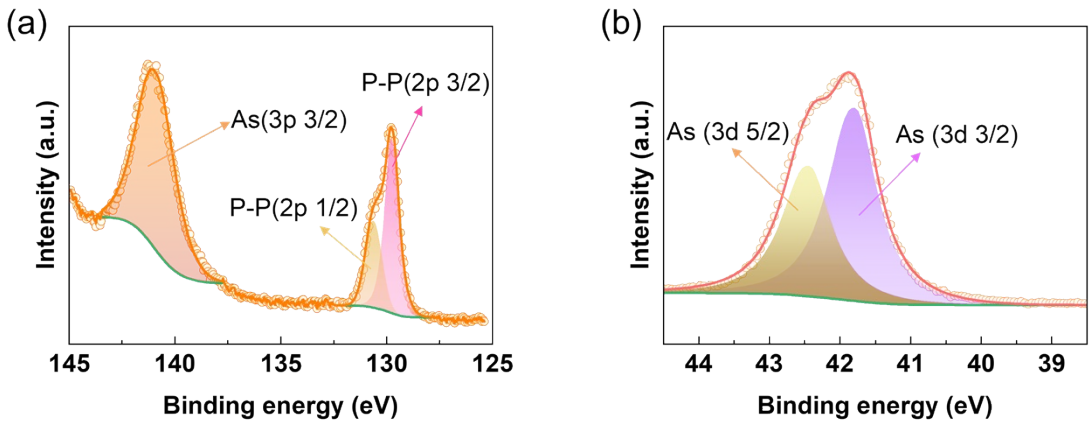

Figure S1. The XPS of AsP. (a) The high-resolution nuclear grade spectra of P 2p in the pure AsP sample. (b) The high-resolution nuclear grade spectra of As 3d in the AsP samples.

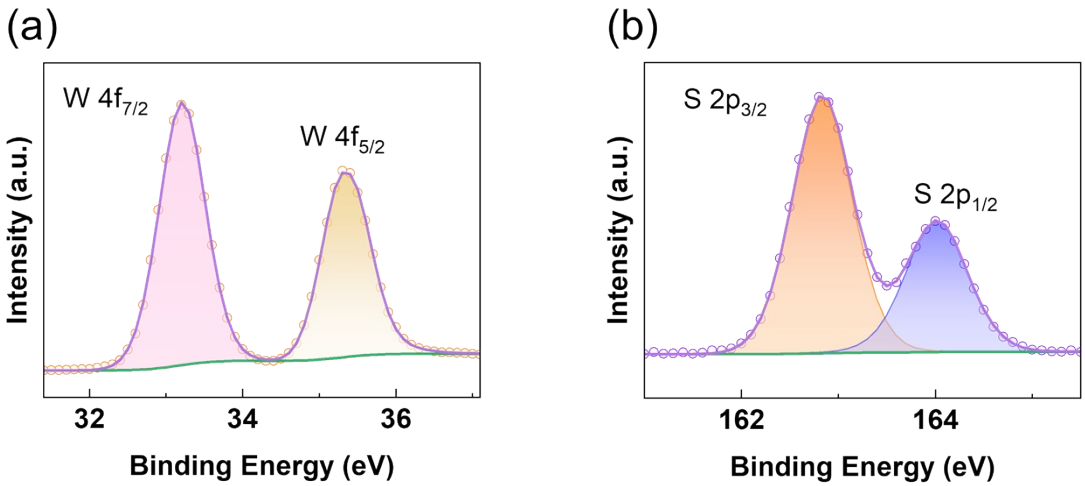

Figure S2. The XPS of WS_2. (a) The high-resolution nuclear grade spectra of W 4f in the pure WS_2 sample. (b) The high-resolution nuclear grade spectra of S 2p in the WS_2 samples.

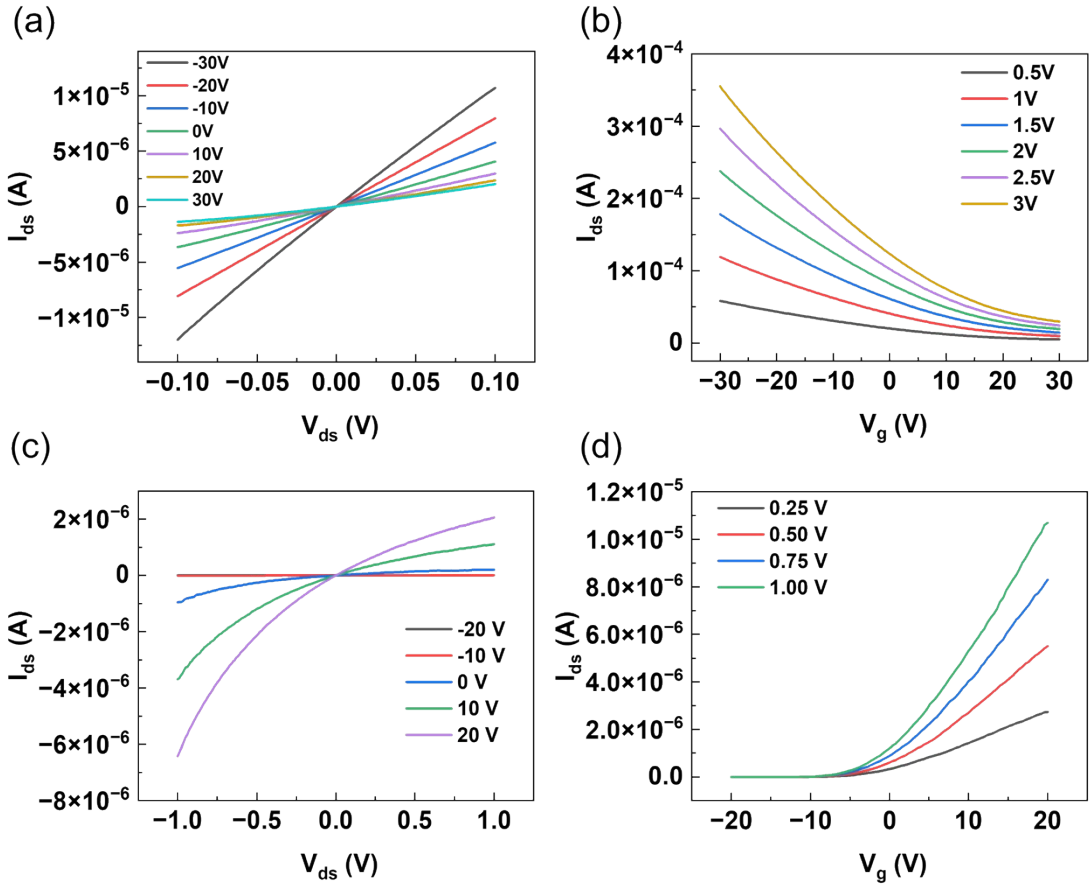

Figure S3. Electrical properties of the AsP and WS_2. (a) I_{ds}–V_{ds} curves and (b) I_{ds}–V_{bg} curves of AsP device. (c) I_{ds}–V_{ds} curves and (d) I_{ds}–V_{bg} curves of a WS_2 device.

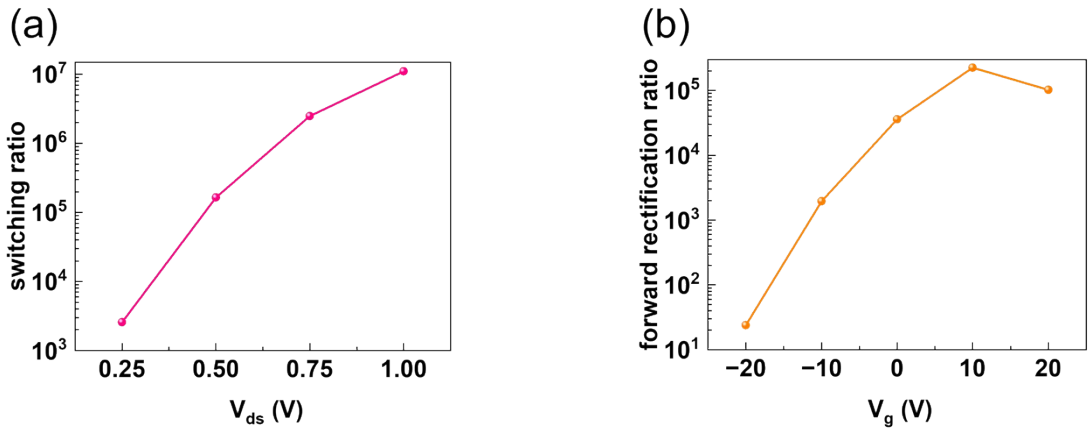

Figure S4. (a) The switching ratios of WS_2/AsP vdWHs device at different V_{ds}. (b) The forward rectification ratio of WS_2/AsP vdWHs device at different V_g.

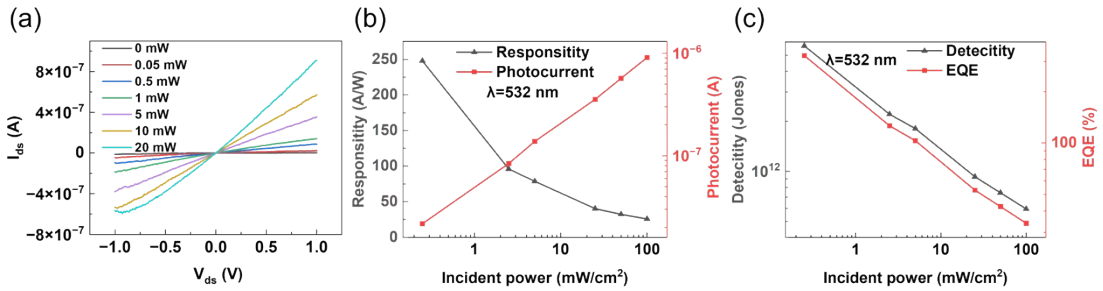

Figure S5. Photoresponse characteristics of the WS_2 device. (a) I_{ds}–V_{ds} curves of the device under 532 nm laser illumination with different power intensities. (b) Dependence of photocurrent and responsivity on light power density (V_{ds} = 1 V). (c) Detectivity and EQE under different light power densities.

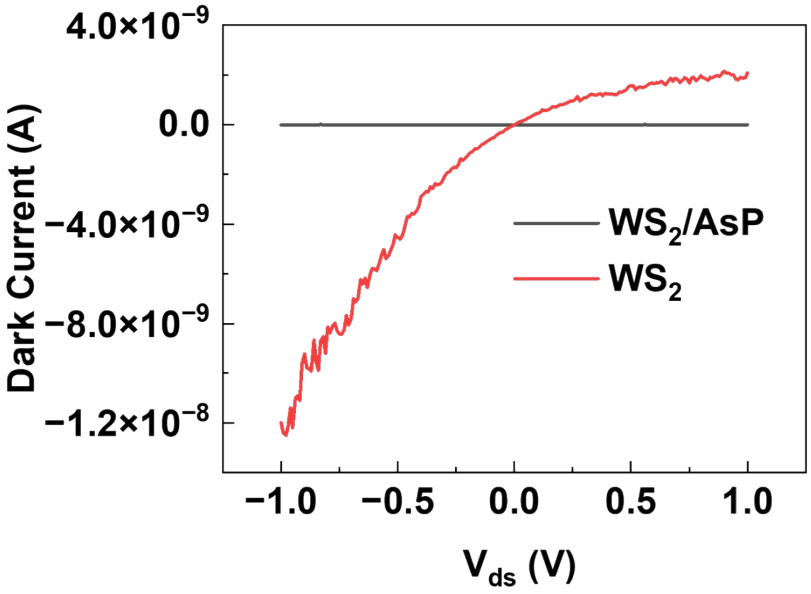

Figure S6. Dark current in WS_2 and WS_2/AsP vdWHs device.

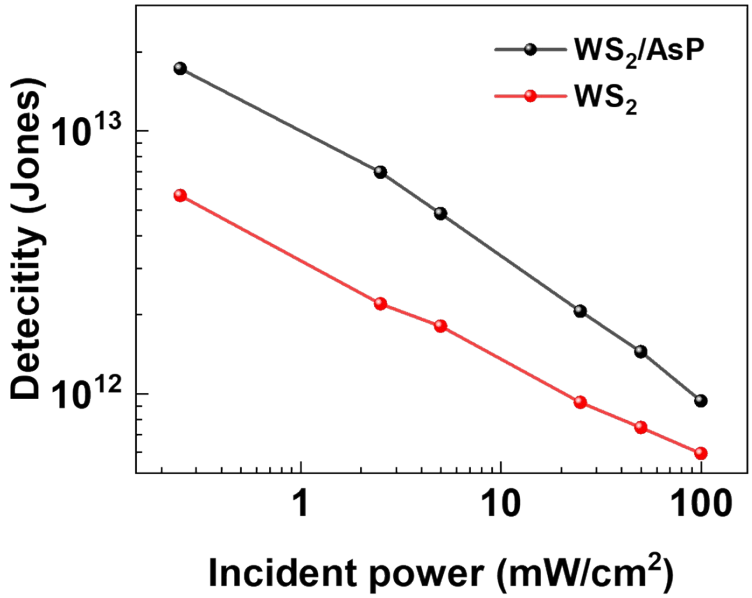

Figure S7. Detectivity of WS_2 device and WS_2/AsP vdWHs device under different light intensities.

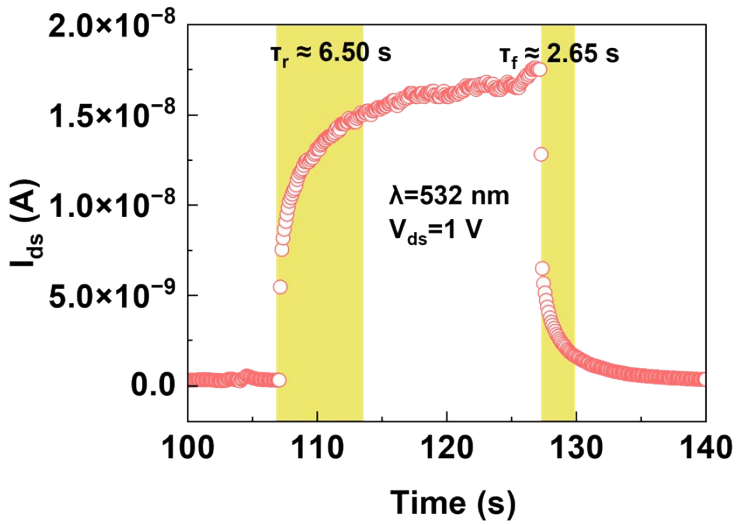

Figure S8. Response speed of the device under 532 nm laser illumination at V_{ds} = 1 V.

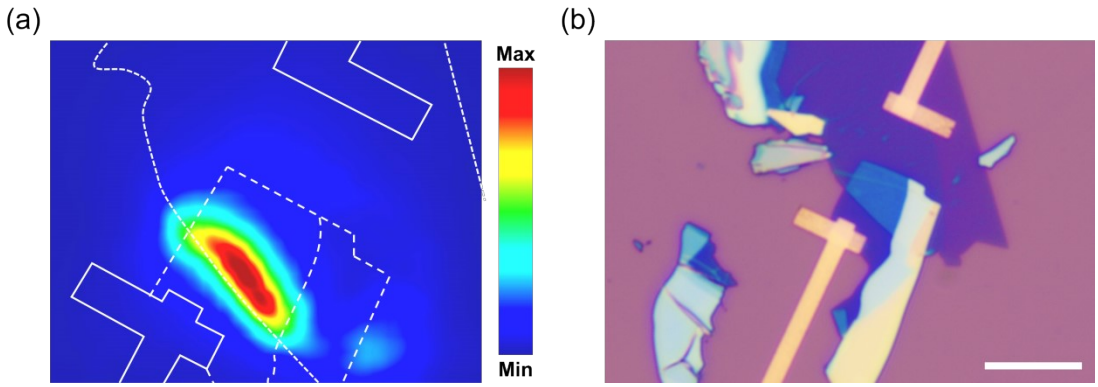

Figure S9. (a) Photocurrent mapping of the device under 532 nm laser irradiation with V_{ds} = 1 V. (b) Photomicrograph of the device corresponding to photocurrent mapping. (Scale bar: 10 μm)

Table S1. Performance parameters of WS_2/AsP and other heterojunction photodetectors

Devices	Wavelength (nm)	D^* (Jones)	R	T_{rise}	T_{fall}	Refs
WS_2/AsP	532	1.72×10^{13}	14.6 A/W	10 ms	10 ms	This work
WS_2/InSe	520	2.5×10^{11}	61 mA/W	63 μs	76 μs	1
AsP/InSe	520	10^{12}	1 A/W	217 μs	89 μs	2
SnS_2/MoS_2	532	4×10^{11}	28 A/W	0.64 s	~	3
$TaSe_2$/WS_2/$TaSe_2$	633	2.43×10^{11}	292 mA/W	43 μs	54 μs	4
n-MoS_2/p-GaSe	532	3.6×10^{11}	249 mA/W	10.5 μs	7.3 μs	5
ReS_2/MoS_2	532	10^{12}	0.197 A/W	13 μs	15 μs	6
b-AsP/WSe_2	275	2.27×10^{12}	244 A/W	5.1 ms	4 ms.	7
ReS_2/AsP	532	5×10^{10}	12.56 A/W	700 ms	800 ms	8
WS_2/Bi_2O_2Se	532	9.5×10^{8}	628 mA/W	33 ms	38 ms	9

[1]Chen J, Zhang Z, Ma Y, et al. High-performance self-powered ultraviolet to near-infrared photodetector based on WS_2/InSe van der Waals heterostructure. Nano Research, 2023, 16(5): 7851-7857.

[2]Wu F, Xia H, Sun H, et al. AsP/InSe van der Waals tunneling heterojunctions with ultrahigh reverse rectification ratio and high photosensitivity. Advanced Functional Materials, 2019, 29(12): 1900314.

[3]Quan S, Li L, Guo S, et al. SnS_2/MoS_2 van der Waals Heterostructure Photodetector with Ultrahigh Responsivity Realized by a Photogating Effect. ACS Applied Materials & Interfaces, 2023, 15(51): 59592-59599.

[4]Wang X, Tong L, Fan W, et al. Air-stable self-powered photodetector based on $TaSe_2/WS_2/TaSe_2$ asymmetric heterojunction with surface self-passivation. Journal of Colloid and Interface Science, 2024, 657: 529-537.

[5]Wu X, Guo W, Li M, et al. Influence of the Device Structure on the Electrical and Photodetector Properties of n-MoS_2/p-GaSe Heterojunction Optoelectronic Devices. ACS Applied Nano Materials, 2023, 6(13): 11327-11333.

[6]Wang Y, Wu Z, Zheng P, et al. High-performance and broadband 2D ReS_2/MoS_2 semivertical heterojunction photodiodes. Materials Science in Semiconductor Processing, 2023, 165: 107650.

[7]Zhao F, Wang D, Zhang F, et al. Gate-controlled photoresponse improvement in b-AsP/WSe_2 heterostructures with type-I band alignment. Applied Physics Letters, 2023, 122: 151105.

[8]Jian Y, Song X, Wang X, et al. ReS_2/black arsenic–phosphorus van der Waals heterojunction for a high-performance photodetector. ACS Applied Electronic Materials, 2022, 4(12): 6013-6019.

[9]Fang C, Han J, Yu M, et al. WS_2/Bi_2O_2Se van der Waals heterostructure with straddling band configuration for high performances and broadband photodetector. Advanced Materials Interfaces, 2022, 9(9): 2102091.