Supporting information

Ultrathin Lateral 2D Photodetectors using Transition Metal Dichalcogenides $PtSe_2$-WS_2-$PtSe_2$ by Direct Laser Patterning

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S1 AFM study of $PtSe_2$ film

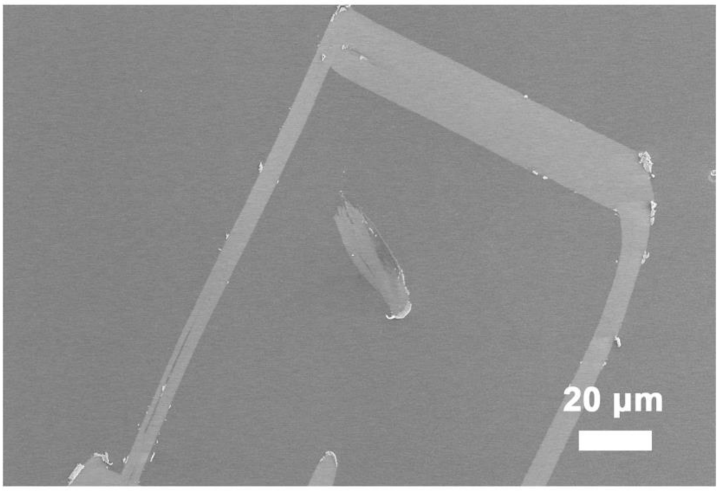

Figure S1. Sample preparation for AFM. SEM image of $PtSe_2$ film with the sharp edge scratched by a tungsten probe tip.

S2 Comparison study of single-layer recipe and bilayer recipe for photolithography

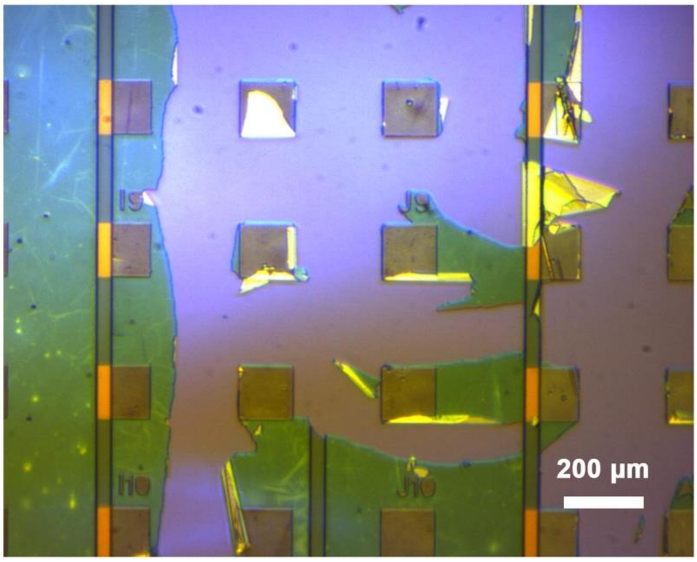

Figure S2. $PtSe_2$ film after develop in MF-319 developer for 30 s by using single-layer recipe (S1813). MF-319 can strongly react with $PtSe_2$, results in $PtSe_2$ film lift-off in some place.

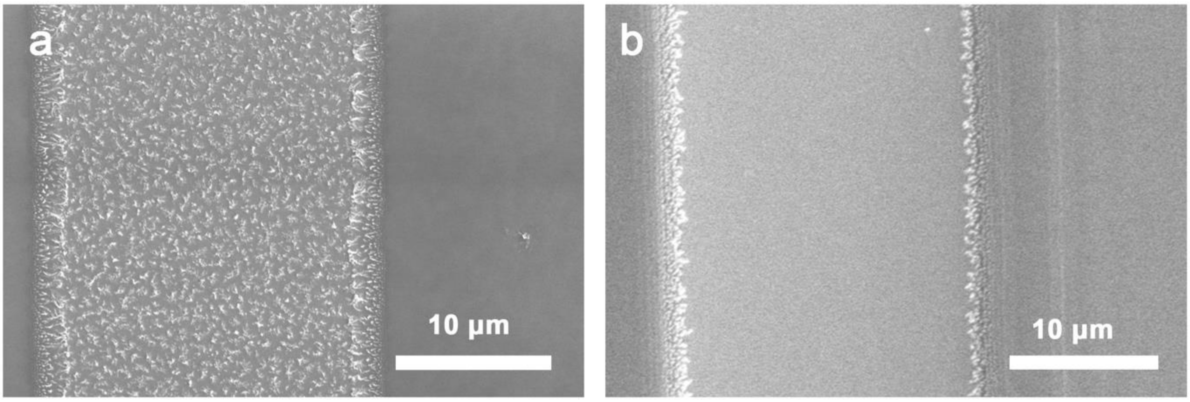

Figure S3. The surface of $PtSe_2$ ribbons after development, oxygen plasma and acton lift-off by using a) single-layer recipe (S1813) and b) bilayer recipe (PMMA/S1813). Comparing with S1813, it is much easier to remove the PMMA residues from $PtSe_2$ surface by using simply hot acetone bath.

S3 Channel width measurements

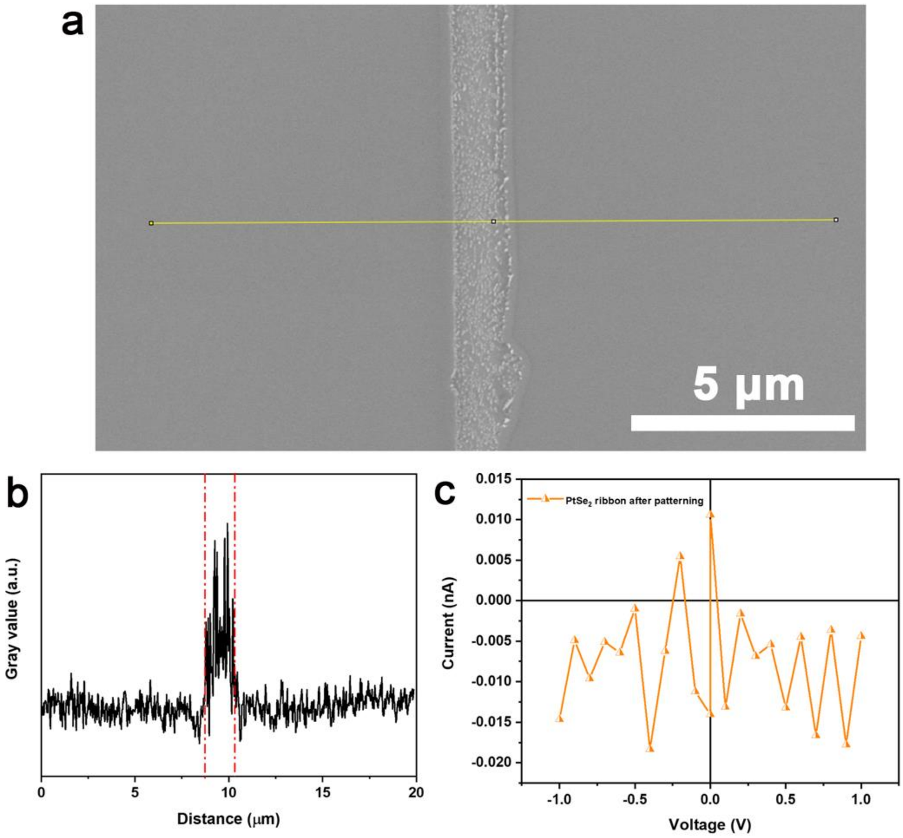

Figure S4. Width measurements for channel with a scanning step of 300 nm: a) SEM image, b) corresponding gray value profile of the yellow line drawn in a). c) Full scale I-V curve of $PtSe_2$ ribbon after patterning.

S4 Measurements of I-V curve for photodetector under dark condition

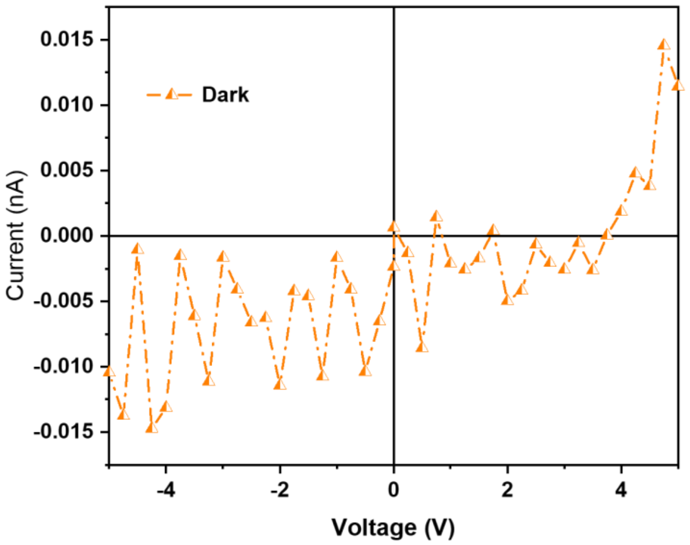

Figure S5. Non-linear I-V curve for photodetecor with a channel width of 1 μm under dark condition

S5 Time-resolved photoresponse of the device

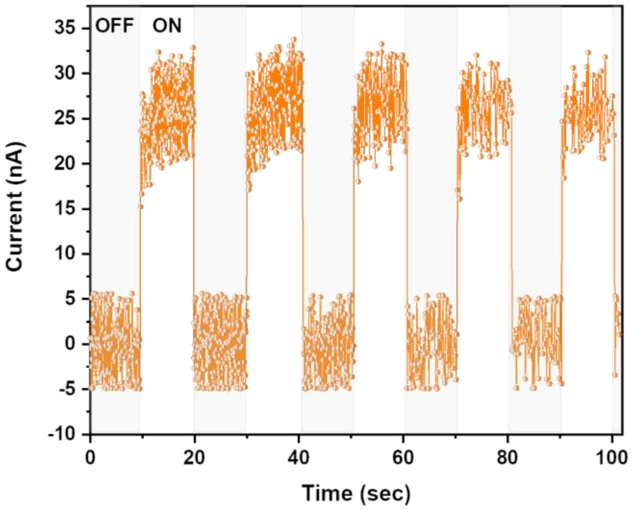

Figure S6. Cycles of ON/OFF tests for the photodetector with a channel width of 1 μm under the bias of +3 V and laser power of 82 μW

S6 Curve fittings by using back-to-back diodes model

Here, we use number 1, 2, 3 to consecutively label these three electric components shown in Figure 6 a) the left to right. For the system under bias, the major current transport process for a Schottky diode is emission of electrons from semiconductor to metal, accompanied with other minor transport processes like tunneling, diffusion and minority carrier injection.[1] Here, we use the modified thermionic theory to describe the current flowing through each diode by taking the image force into consideration:[2,3]

$$I = I_0 \exp\, [-(1-\frac{1}{n})\frac{qV_F}{kT}] \left[\exp\left(\frac{qV_F}{kT}\right)-1\right]$$

$$I = {}^{V_s}\!/_{R_s}$$

$$I = -I_0 \exp\, [(1-\frac{1}{n})\frac{qV_R}{kT}] \left[\exp\left(-\frac{qV_R}{kT}\right)-1\right]$$

$$V = V_F + V_S + V_R$$

$$I_0 = \ wA^* T^{\alpha} \exp\, [-\frac{q\phi^*}{kT}]$$

where I is the output current, V is output voltage, V_F, V_S, V_R are voltage drop across component 1, 2 and 3, k is Boltzmann constant, T is the temperature, q is elemental charge, n is the ideality factor to describe barrier lowering by image force, w is the contact width of metal and semiconductor ($w\ =\ 20\ um$ in our experiment), A^* is the effective Richardson constant (for 2D Schottky diode, $A^*_{2D} = 0.026\, {}^{A}\!/_{mK^{2/3}}$), α is an exponent (for 2D Schottky diode, $\alpha = 3/2$)and ϕ^* is the effective Schottky barrier height.

By solving the first four equations above, we can get another equation as following:

$$I = wA^* T^{\alpha} \exp\left[-\frac{q\phi^*}{kT}\right] \left[\frac{\cosh\, (\frac{1}{2}(1-\frac{1}{n})\frac{q}{kT}(V-IR_s))}{\cosh\, (\frac{1}{2n}\cdot\frac{q}{kT}(V-IR_s))}\right]^{-(1-\frac{1}{n})} \cdot \frac{\sinh\, (\frac{1}{2}\frac{q}{kT}(V-IR_s)}{\cosh\, (\frac{1}{2}\frac{q}{kT}(V-IR_s)}$$

with the known quantities: output voltage (V), output current (I), and the unknowns: Schottky barrier height ϕ^*, resistance of semiconductor R_s, ideality factor n.

S7. Summarized photoresponsivity of different WS_2-based M-S-M photodetectors

Electrode	WS_2	Channel width (nm)	P (mW/cm^2)/λ (nm)/ V_{ds} (V)	R (mA/W)	ref
Few-layered $PtSe_2$	CVD 1L	1000	5(μW)/532/5	1.6	this work
Au/Ti	CVD few-layered	50000	2.0(mW)/458/30	2.2×10^{-2}	4
Au/Cr	CVD 1L	200	1.0×10^6/532/4	2×10^4	5
Graphene	CVD 1L	200	2.5×10^7/532/5	2.5×10^3	6
Graphene	CVD 2L	200	2.5×10^7/532/5	3.5×10^3	6
Au (asymmetrical)	Exfoliation multi-layered	10000	185.61/405/-2	777	7

Reference:

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