Supporting Information

High Photoresponsivity in Ultrathin 2D Lateral Graphene:WS$_2$:Graphene Photodetectors Using Direct CVD Growth

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Table S1. Comparison of photoresponsivity of TMD-based photodetector

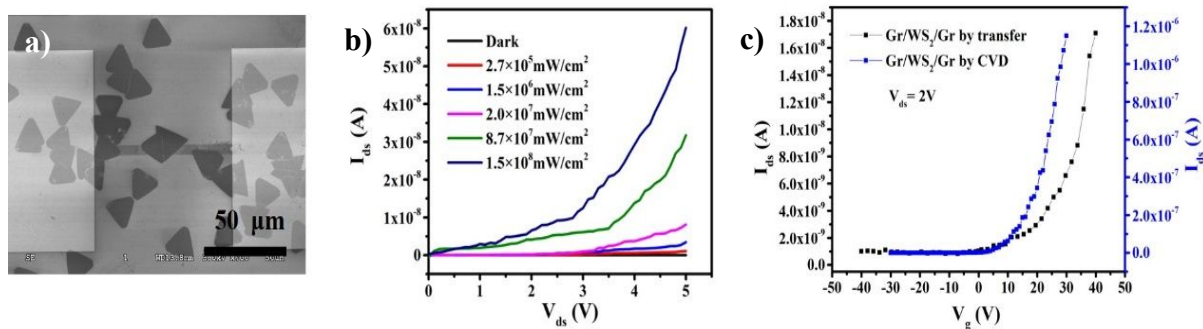| Device	λ	P	Vds	Vg	Photoresponsivity	Photogain	Reference
1L MoS2	400-800	100μW	1V	-1V	45.5A/W		1
1-2L MoS2	520	60μW	1V	-1V	3.5A/W		2
1L WS2	532nm	0.1μW	5V	80V	~4A/W	136	3
2L WS2	532nm	2.5×10^7 mW/cm^2	5V	0V	3.5A/W	9.3	4
1L WS2	532nm	2.5×10^7 mW/cm^2	5V	0V	2.5A/W	5.8	4
1-2L WS2	532nm	2.7×10^5 mW/cm^2	5V	30V	121A/W	4050	This work

Figure S1. Gr/WS$_2$/Gr photodetectors made by transfer method (a) SEM image of a Gr/WS$_2$/Gr photodetectors made by transfer WS$_2$ triangular domains on pre-patterned graphene gap; (b) I-V curves of Gr:WS$_2$:Gr FET under various illumination power with 0V gate voltage; (c) I-V$_g$ curve of device made by transfer and CVD method obtained under 2V bias.
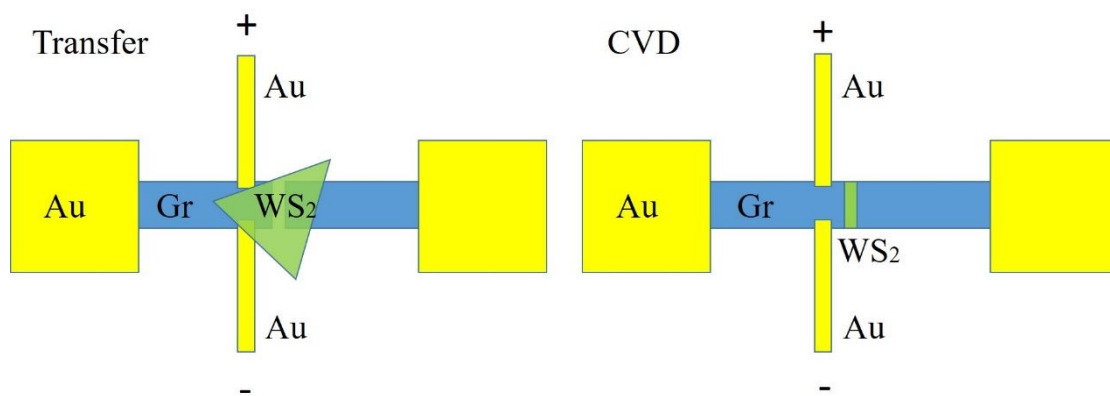
Figure S2. Schematic illustration of setup used to measure the Dirac point of graphene after transfer of WS$_2$ and CVD growth of WS$_2$

S1 Extraction of Schottky barrier using back-to-back diode model

We introduced a modified thermionic emission equation for Schottky barrier extraction from I-V curves. Given the semi-metal and semiconductor properties of graphene and WS_2, we simplified it into a back-to-back Schottky diode pair in series. The current of the device could be expressed as following set of equations:

$$I = I_0 \times \exp\left[-\left(1 - \frac{1}{n}\right)e\beta V_1\right] \times [\exp(e\beta V_1) - 1] \tag{1}$$

$$I = \frac{V_2}{R} \tag{2}$$

$$I = -I_0 \times \exp\left[-\left(1 - \frac{1}{n}\right)e\beta V_3\right] \times [\exp(e\beta V_3) - 1] \tag{3}$$

$$U = V_1 + V_2 + V_3 \tag{4}$$

By solving equation (1)-(4), we can obtain:

$$I = I_0\left[\frac{\cosh\left(\frac{1}{2}(1 - \frac{1}{n})e\beta(U - IR)\right)}{\cosh\left(\frac{1}{2n}e\beta(U - IR)\right)}\right]^{-(1 - \frac{1}{n})} \times \frac{\sinh\left(\frac{1}{2}e\beta(U - IR)\right)}{\cosh\left(\frac{1}{2n}e\beta(U - IR)\right)} \tag{5}$$

Where I is the source-drain current, U is the source-drain bias, n is the ideality factor, e is the elementary charge unit and $\beta = 1/k_B T$ is the Boltzmann factor, V_i (i = 1, 2, 3) are the voltage drop across the left diode, middle resistance, and right diode. I_0 is a constant related to the Schottky barrier height which could be expressed as

$$I_0 = wA_{2d}T^{\frac{3}{2}} \times \exp(-\beta e\Phi_{SB}) \tag{6}$$

Where w is the contact width of graphene and A_{2d} is the two-dimensional equivalent of Richardson constant, T is the temperature, and Φ_{SB} is the effective Schottky barrier height.

Reference:

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