Supporting Information

Substrate-enhanced MoS_2 Photodetector through Dual-photogating Effect

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1. PL and AFM characterizations of CVD-grown MoS_2.

Its PL spectrum consists of two peaks at 670nm (1.85eV) and 620nm (2.00eV), corresponding to the A and B direct gap optical transition. The thickness measured by AFM is ~0.7 nm, which approaches to the theoretical thickness of monolayer MoS_2.

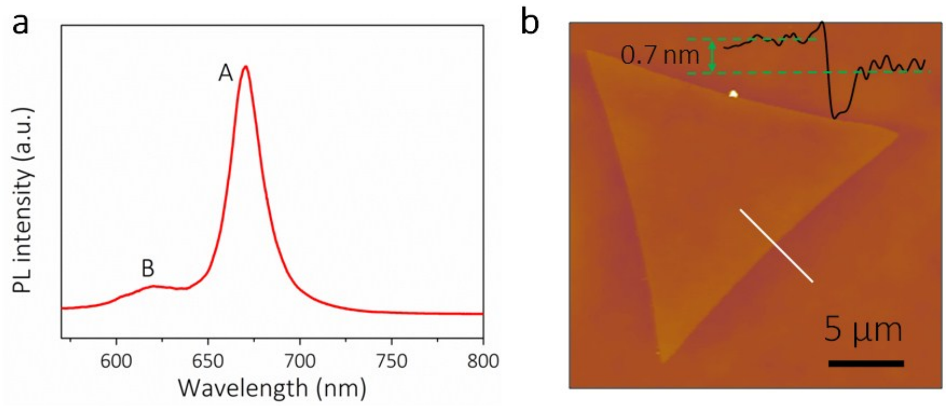

Figure S1. (a) Typical PL spectrum of monolayer MoS_2. (b) AFM morphology measurement of triangle MoS_2 flake. The thickness is ~0.7 nm.

2. Surface morphologies of four kinds of substrate and roughness measurements.

Rigid substrates, such as SiC and SiO_2/Si, has more flat surface because of maturing growth and polishing techniques. In contrast, flexible polymer substrates, such as Kapton and PET, are relatively coarse. The surface roughness of SiO_2/Si, SiC, Kapton and PET are 0.152 nm, 0.340 nm, 0.994 nm and 2.466 nm, respectively.

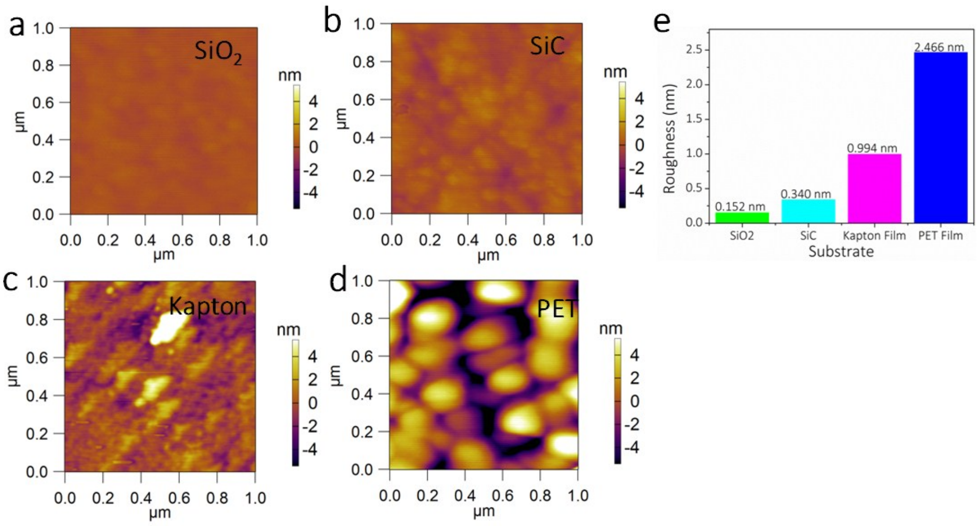

Figure S2. (a-d) Surface morphologies of SiO_2/Si, SiC, Kapton and PET, respectively. (e) Surface roughness of four substrates.

3. In-plane conductivity of undoped-SiC substrate.

Undoped-SiC substrate has ultra-weak in-plane current (Cr/Au electrodes and $L_{channel}$= 5 μm), even in illumination. Meanwhile, it presents asymmetric I-V curves both under UV and VIS illumination.

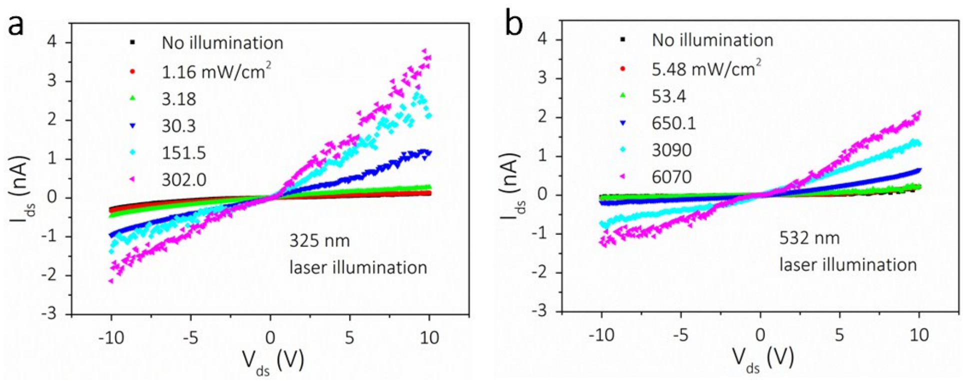

Figure S3. (a) In-plane current of undoped-SiC substrate itself under UV illumination. (b) In-plane current of undoped-SiC substrate itself under VIS illumination.

4. Photoresponse performances of MoS_2 PDs under referred substrate.

As reference, we also measured the photoresponse performance of MoS_2 PDs based on common SiO_2/Si substrate and Kapton substrate in order to reveal the effect of substrate. By contrast, substrates with light absorption (SiC and Kapton) have significant assistance for photoresponse enhancement of MoS_2 PD.

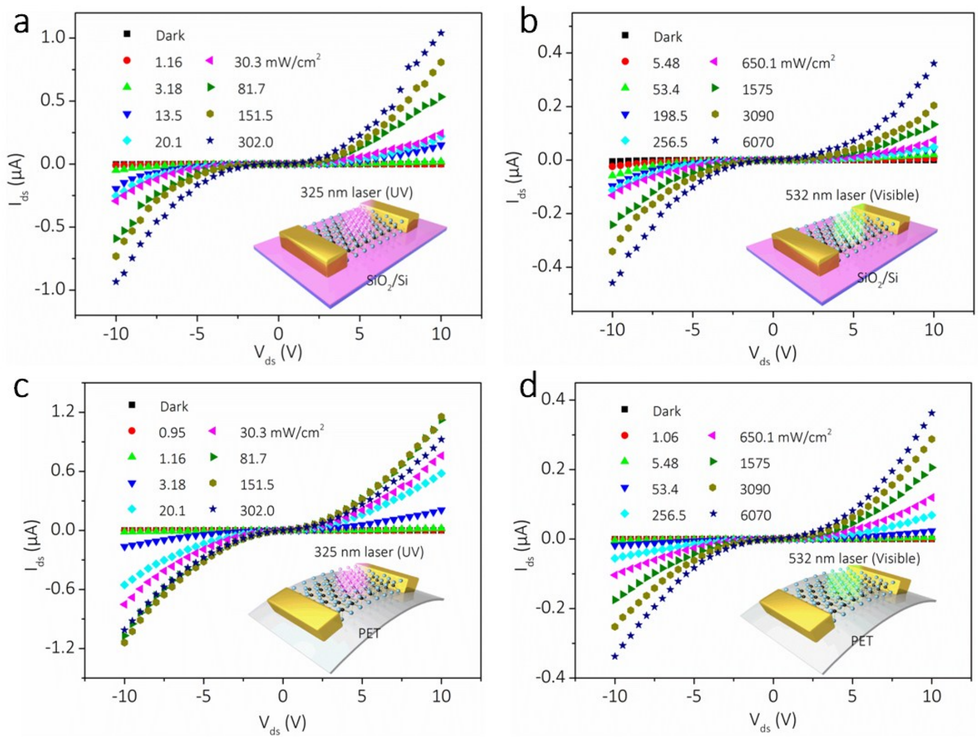

Figure S4. (a-b) I-V curves of $MoS_2/SiO_2/Si$ PD under UV and VIS illumination, respectively. (c-d) I-V curves of MoS_2/PET PD under UV and VIS illumination, respectively.

5. Photoresponse performance of MoS_2/Kapton PD under VIS illuminations.

The photoresponse of MoS_2/Kapton PD is not substantively enhanced under VIS illumination. The energy of VIS light is not enough to excite the photoelectret states and generate photoexcited carriers. Therefore, second photogating effect will be not happened at MoS_2/Kapton interface and not improve the photocurrent.

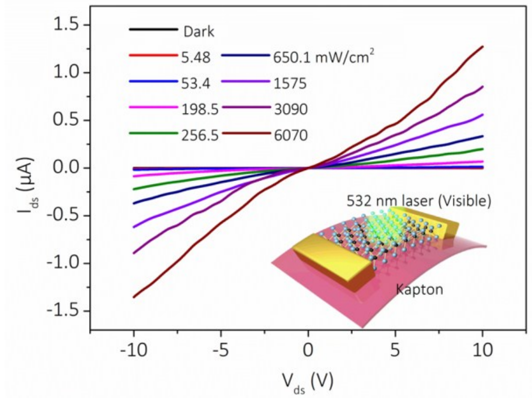

Figure S5. I-V curves of MoS_2/Kapton PD under VIS (532 nm laser) illumination.

6. Fabrication of MoS_2-FET with PI gate.

Monolayer MoS_2 FET firstly is constructed on SiO_2/p+-Si substrate in same method with PDs. Secondly, a layer of PMMA is spun-coated in the device and baked at 150 ℃ for 3 mins. Thirdly, the area of MoS_2 is exposured by EBL. Fourthly, a layer of PI precursor (Poly (pyromellitic dianhydride-co-4,4'-oxydianiline), amic acid solution) is spun-coated and the whole device is baked at 180 ℃ for 4 hours in Ar atmosphere. Finally, PMMA layer is dissolved by acetone solution. Figure S6b shows the optical image of the device. Monolayer MoS2 is outlined by red dashed line (triangle). PI gate is outlined by green red dashed line (rectangle).

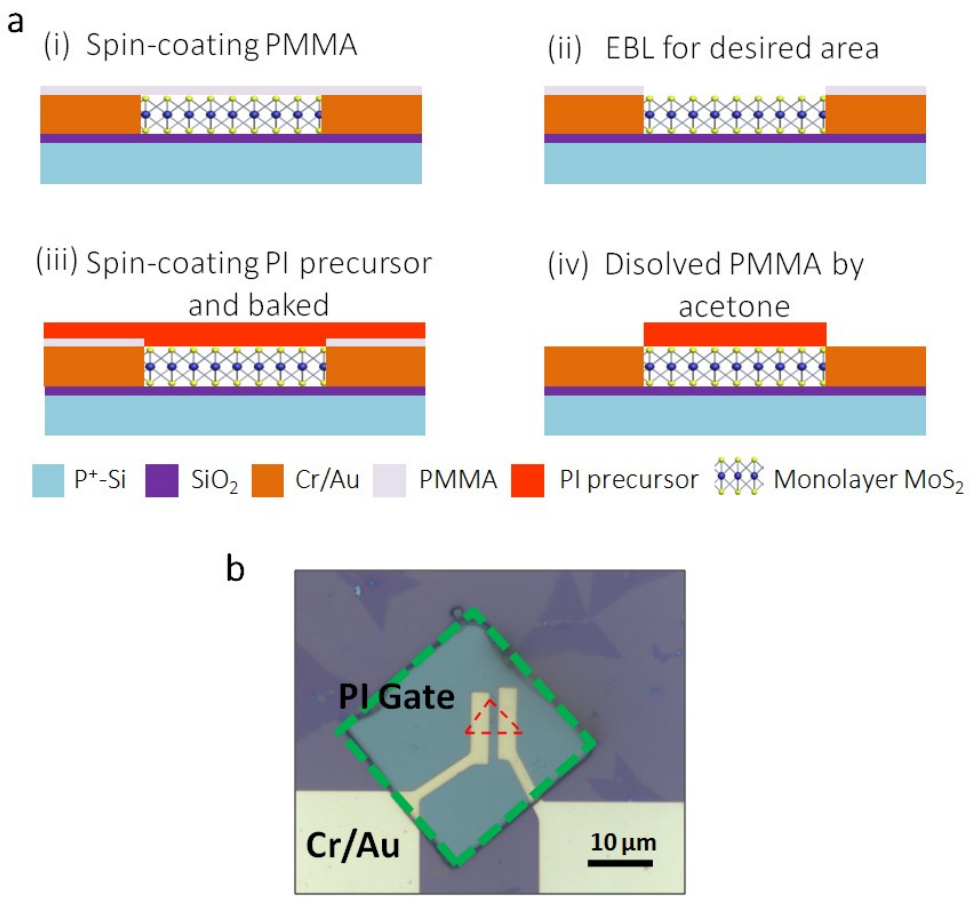

Figure S6. (a) The construction processes of MoS_2-FET with a layer of PI coating. (b) Optical microscope image of MoS_2-FET with PI gate.

7. Output curves measurement of MoS_2-FET under UV illuminations.

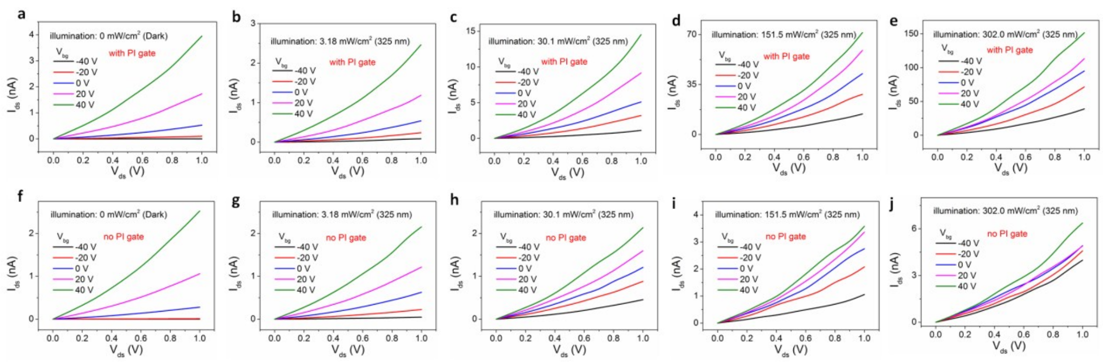

Figure S7. I_{ds}-V_{ds} output characteristics of monolayer MoS_2 FET (a-e) with PI gate and (f-j) without PI gate in dark and different UV optical power intensity.

8. Transient performances of MoS_2-based PDs.

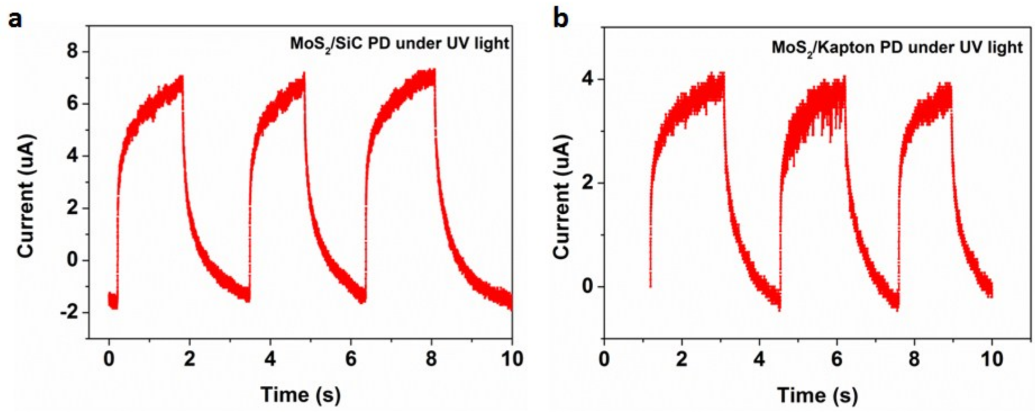

Figure S8. The transient response of (a) MoS_2/SiC PD and (b) MoS_2/Kapton PD.

9. Summary of photoresponse performances of MoS_2 PDs in this work.

Table S1. Summary and comparison in photoresponse performances of MoS_2 PDs under different substrates under UV and VIS illumination.

325 nm laser illumination						532 nm laser illumination				
Parameters / Devices	I_{dark} (nA)	I_{ph}/I_{dark}	R (A/W)	D (Jones)	G	I_{dark} (nA)	I_{ph}/I_{dark}	R (A/W)	D (Jones)	G
MoS_2/SiC	83.6	9813	10231	$6.4x10^{11}$	39132	83.6	1208	1602	$1.0x10^{11}$	3749
MoS_2/SiO_2/Si	3.27	284.5	44	$1.4x10^{10}$	168	3.27	139.3	30	$9.5x10^{9}$	70
MoS_2/Kapton	0.17	107879	319	$4.5x10^{11}$	1222	0.17	7692	5	$6.4x10^{9}$	11
MoS_2/PET	0.16	7382	136	$2.0x10^{11}$	518	0.16	2316	9	$9.7x10^{9}$	16

10. Summary of MoS_2 PDs in previous studies and this work.

We summarized the photoresponse performances of MoS_2 PDs in previous studies and this work. It is observed that MoS_2 PDs in this work can achieve high photoresponse behaviors without applying electric gate voltage or other assistant methods. The performance is enhanced through dual-photogating effect from MoS_2 and substrates.

Table S2. Summary and comparison of the photoresponse performances of MoS_2 PDs in previous studies and this work.

Devices	Substrate	Regulation	Excitation laser (nm)	R (A/W)	I_{ph}/I_{dark}	D (Jones)	Ref.
MoS_2/SiC	undoped-SiC	dual-photogating effect	325	10231	~10^4	6.4×10^{11}	this work
MoS_2/SiC	undoped-SiC	dual-photogating effect	532	1602	~10^3	1.0×10^{11}	this work
MoS_2/Kapton	Kapton	dual-photogating effect	352	319	~10^5	4.5×10^{11}	this work
MoS_2 phototransistor	p^+-SiO_2/Si	gate voltage (-70 V)	561	880	_	_	[10]
MoS_2-P(VDF-TrFE)	SiO_2/Si	ferroelectrics	635	2570	~10^3	2.2×10^{12}	[13]
MoS_2-CuO	PET	strain	532	0.01	~10^3	3.3×10^8	[21]
MoS_2-GaN nanowires	Kapton	strain & gate voltage (1V)	550	734.5	~10^5	_	[22]
MoS_2-PbS QDs	p^+-SiO_2/Si	QDs & gate voltage (-100 V)	633	~10^6	_	7×10^{14}	[18]
MoS_2-Au structure	quartz	plasmon induced	1070	5.2	_	_	[20]
MoS_2-WS_2	SiO_2/Si	heterojunction	633	1.42	_	_	[23]
Multilayer MoS_2 PD	glass	gate voltage (8 V)	532	342.6	~10^2	_	[14]