Improving electron mobility in MoS_2 field-effect transistors by optimizing the interface contact and enhancing the channel conductance through local structural phase transition

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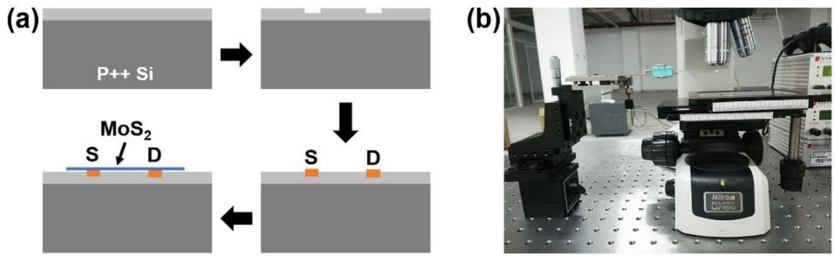

Fig. S1. (a) The fabrication process of MoS_2 vdW FETs. 285 nm silicon oxide (SiO_2) substrate cleaned with acetone and isopropyl alcohol (IPA), the bottom is p-type heavily doped Si (p+ Si), which can be used as a back gate; two sites were etched on SiO_2 and 80 nm thick Au electrodes were deposited as source and drain electrodes, here there was a small gap of about 5 nm between the sample and the electrode, which facilitated the subsequent entry of oxygen plasma; About 2-3 layers of MoS_2 channel are transferred onto the electrodes, where an optical microscope is used to align the MoS_2 sample and electrodes for anchored transfer (b).

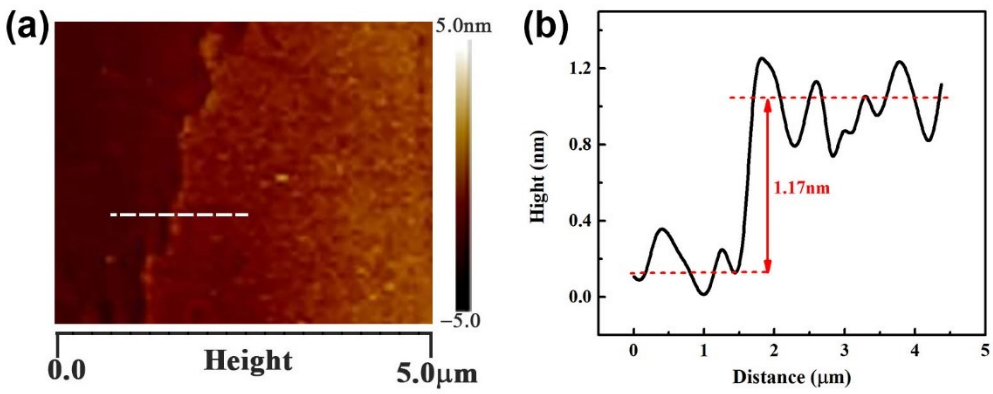

Fig. S2. (a) AFM spectra of MoS_2 channel in MoS_2 vdW device. (b) A height profile is extracted along the white line shown in panel (a). The MoS_2 domain thickness is 1.17 nm, equal to 2 monolayer thickness.

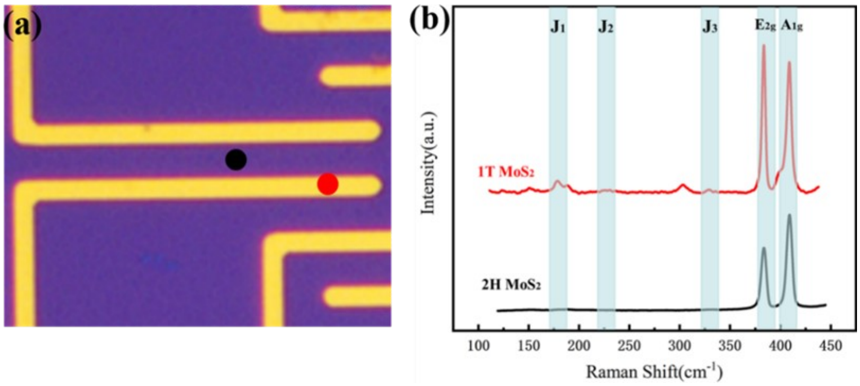

Fig. S3. Raman spectra (b) acquired from different regions highlighted in optical image of MoS_2 vdW devices (a) after O_2 plasma treatment for 1 s. The 1T phase transition of MoS_2 occurs in the region in contact with the Au electrodes firstly, which may be attributable to the catalytic effect of Au. Here Au provides free electrons in the plasma process, which can accelerate the kinetic process of the oxidation reaction, thus reducing the reaction energy barrier of oxygen doping.

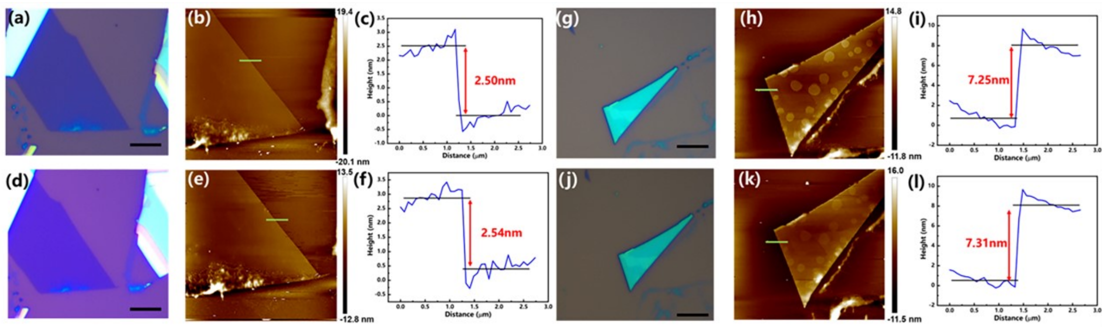

Fig. S4. The impact of O_2 plasma on the surface morphology of MoS_2. The optical images of few-layer MoS_2 nanosheets before (a, g) and after (d, j) being treated by oxygen plasma for 3 s. Scale bar: 10 μm. There is minimal change in color of the MoS_2, suggesting that the sample's surface did not experience significant thinning due to the plasma etching. The AFM characterizations of MoS_2 nanosheets before (b, h) and after (e, k) being treated by oxygen plasm for 3 s. The samples exhibit flat surfaces and similar thicknesses before (c, i) and after (f, l) oxygen plasma treatment, indicating that our soft oxygen plasma mainly plays a role of doping on MoS_2 samples, with almost no etching effect.

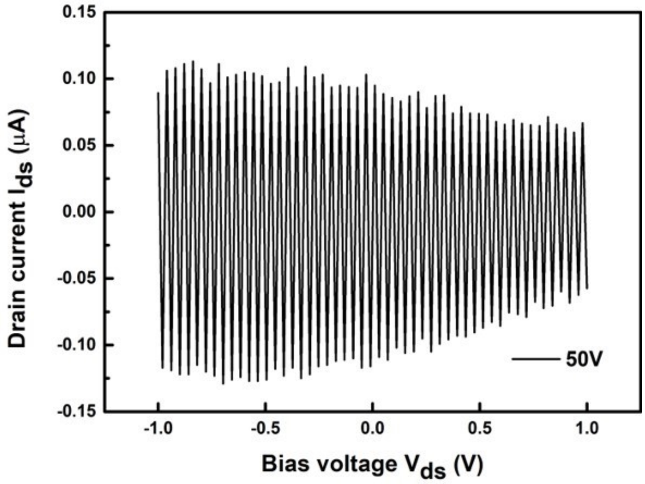

Fig. S5. Measurement of the leakage currents through the S or D electrodes and back gate.

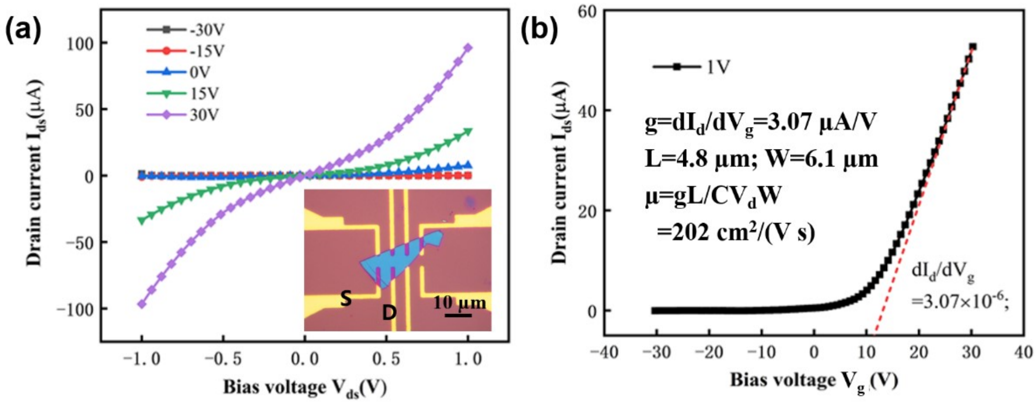

Fig. S6. Electronic characteristic curves of MoS_2 FET device2 after oxygen plasma exposure with 10 s. (a) I_{ds}–V_{ds} characteristics up to V_{ds}=1 V and V_g ranging from −30 V to 30 V. Inset: Optical image of the MoS_2 device with corresponding working principle. (b) Corresponding I_{ds}–V_g characteristics, exhibiting high electron mobility.

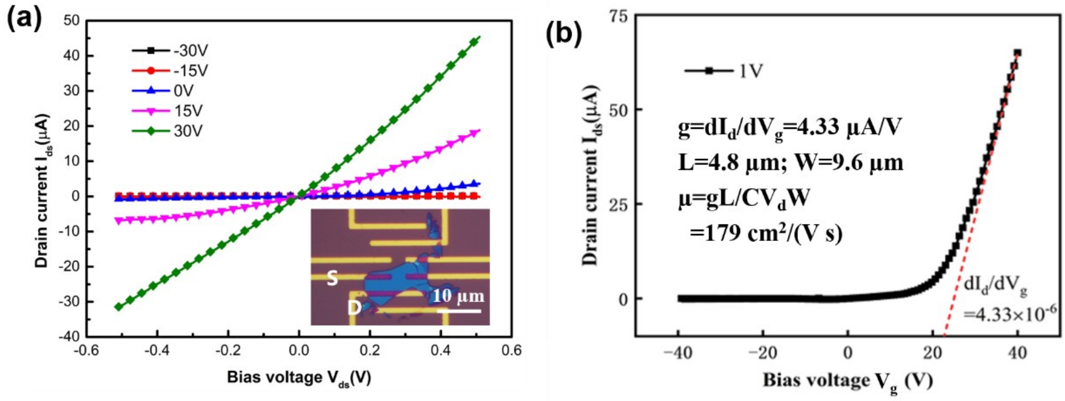

Fig. S7. Electrical characteristic curves of MoS_2 FET device3 after 5 s oxygen plasma exposure. (a) I_{ds}–V_{ds} characteristics up to V_{ds}=0.5 V and V_g ranging from −30 V to 30 V. Inset: Optical image of the MoS_2 device3 with corresponding working principle. (b) Corresponding I_{ds}–V_g characteristic curves.

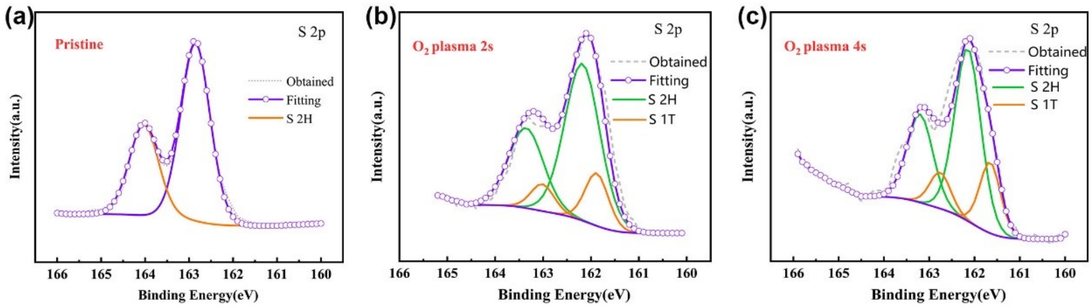

Fig. S8. XPS spectra showing S 2p core level peak regions for the pristine (a) and plasma-treated MoS_2 (b-d). The fitting green and orange curves represent the contributions of 2H and 1T phases to the S 2p peaks. For the pristine MoS_2, the convoluted spectra of S 2p show two prominent peaks at 162.7 and 164.0 eV, respectively. After oxygen plasma exposure of MoS_2 from 2 s to 4 s, the peak intensity of 1T-S 2p peaks gradually enhance, which indicates the increase of 1T domain concentration in MoS_2.

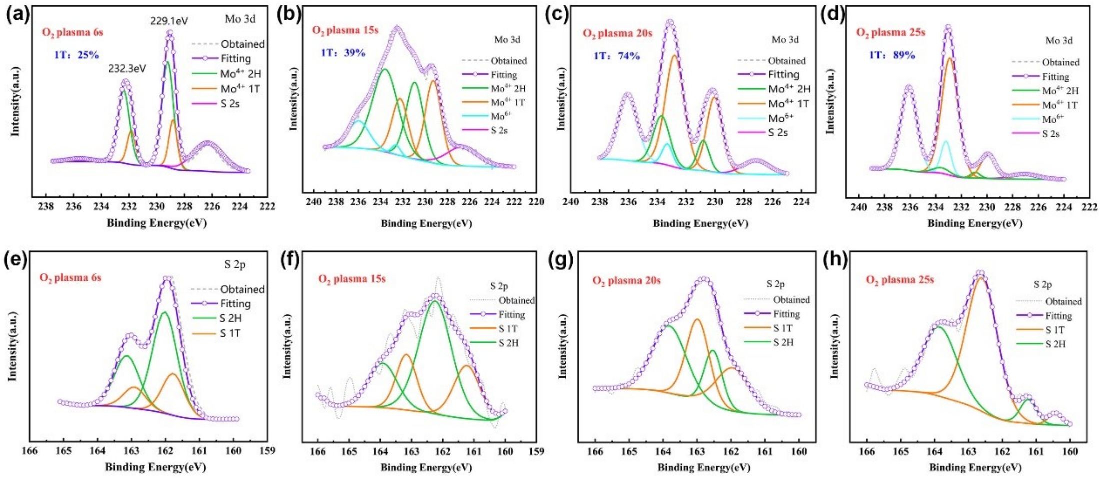

Fig. S9. XPS characterizations of Mo 3d (a-d) and S 2p (e-h) core level peak regions for the MoS_2 after O_2 plasma treatment with time varying from 6-25 s. We observed that the 1T phase concentrations continue to increase from 25% to 89% as the plasma treatment time increased.

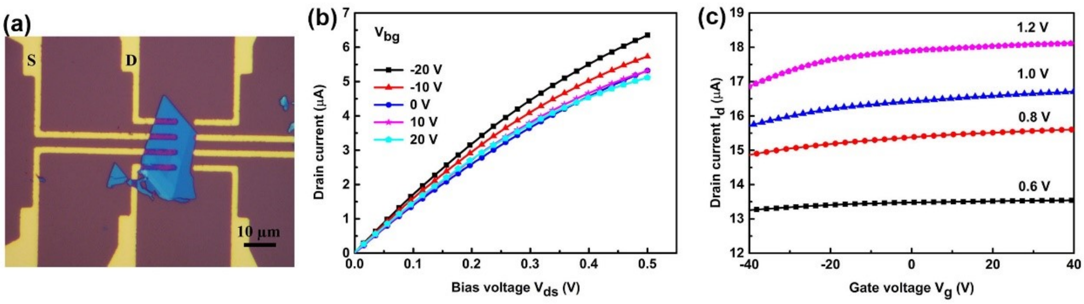

Fig. S10. I-V characteristic curve of MoS_2 device4 with plasma treatment time exceeding 6 s. (a) Optical image of MoS_2 device4. Here, the channel length (L) and width (W) are 2.8 μm and 6.5 μm, respectively. (b-c) Output (b) and transfer (c) characteristics of MoS_2 device4 with plasma treatment time exceeding 6 s.

Table S1 Literature survey of electrical performance of MoS_2 devices

Device	method	Contact Resistance (kΩ μm)	Conductivity ($S\ m^{-1}$)	Mobility ($cm^2V^{-1}s^{-1}$)	On/off ratio	Ref
MoS_2 FET	vdW contacts, Pt	430	4.2	44	10^7	[1]
MoS_2 FET	vdW contacts, Ag	2.3	~140	-	10^7	[2]
MoS_2 FET	vdW contacts, In	3±0.3(monolayer) 0.8±0.2(few layers)	20	167±20	-	[3]
MoS_2 FET	1T contacts	0.2-0.3	85	50	$>10^7$	[4]
MoS_2 FET	1T contacts	0.2	~20	56	-	[5]
MoS_2 FET	Bi contacts	123	100-373	20	$>10^7$	[6]
MoS_2 FET	vdW contacts, Graphene	115	~5	35	$>10^8$	[7]
MoS_2 FET	Au contacts	6.5	~140	20	-	[8]
MoS_2 FET	Re doping	26.65	0.7	-	-	[9]
MoS_2 FET	vdW contacts, Graphene	2-20	~1	40-120	-	[10]
MoS_2 FET	vdW contacts BN/Au	1.8	~30 (V_G=40V)	73	-	[11]
MoS_2 FET	Au /Al_2O_3 / TiO_2	5.4	~5	-	-	[12]
MoS_2FET	Thiol-Molecules	25.2	~10（V_G=40 V）	-	-	[13]
MoS_2 FET	Cl-doped	0.5	~160（V_G=45V）	60	$4*10^6$	[14]
MoS_2 FET	Mo/Au	2	~35（V_G=30 V）	27	-	[15]
MoS_2 FET	vdW 1T contacts	4	83.8	237	10^4	This work

Table S2 Comparison of MoS_2 FETs before and after plasma treatment

MoS_2 FETs	Property	Contact Resistances (kΩ)	Transconductance (μA/V)	Mobility (cm^2/V s)	On/off ratio
Device1 (L=3μm)	Before plasma treatment	477.2	0.1	7	~10^2
	O_2 plasma 3s	4.0	4.3	237	~10^4
Device2 (L=4.8μm)	O_2 plasma 10s	--	3.1	202	~10^3
Device3 (L=4.8μm)	O_2 plasma 5s	--	4.3	179	~10^3
Device4 (L=2.8μm)	Before plasma treatment	--	0.2	7	~10^2
	O_2 plasma 2s	--	0.9	55	~10^3
	O_2 plasma 4s	--	2.6	185	~10^4

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