# Supplementary Information

## Device level modulation of carrier transport in 2D $WSe_2$ field effect transistor *via* plasma treatment

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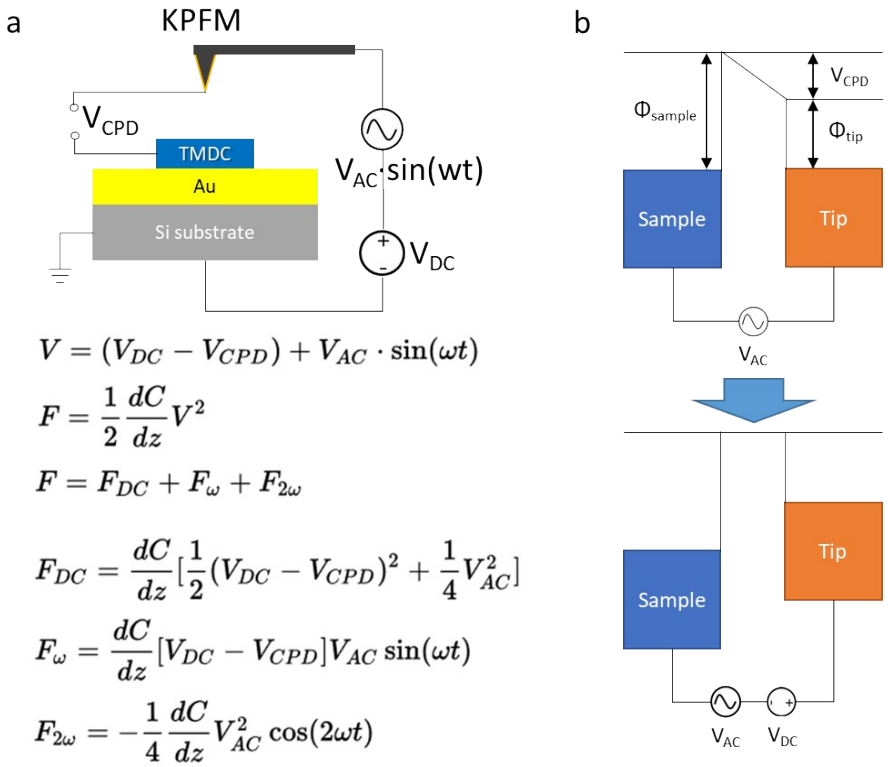


$$V = (V_{DC} - V_{CPD}) + V_{AC} \cdot \sin(\omega t)$$

$$F = \frac{1}{2}\frac{dC}{dz}V^2$$

$$F = F_{DC} + F_{\omega} + F_{2\omega}$$

$$F_{DC} = \frac{dC}{dz}[\frac{1}{2}(V_{DC} - V_{CPD})^2 + \frac{1}{4}V_{AC}^2]$$

$$F_{\omega} = \frac{dC}{dz}[V_{DC} - V_{CPD}]V_{AC}\sin(\omega t)$$

$$F_{2\omega} = -\frac{1}{4}\frac{dC}{dz}V_{AC}^2\cos(2\omega t)$$

Figure S1. Principle of KPFM. (a) Schematic diagram and relevant formulas (b) Energy band diagram involving measurement. In (a), V can be split up in two terms of $V = V_{ext} - V_{CPD}$ where the first term is the external voltage that is applied to the tip relative to the sample and the second term is contact potential difference as the difference between the work-function of tip and sample. Typically, one applies a DC voltage as well as an AC component with frequency ω. This potential is hence written as $V_{ext} = V_{DC} + V_{AC}\sin(\omega t)$ as shown in the bottom side of Figure S1b. Substituting $V = (V_{DC} - V_{CPD}) + V_{AC}\sin(\omega t)$ in the force expression above allows us to calculate the electrostatic force acting on the tip.
Among other terms, one component $F_{\omega}$ is proportional to $\sin(\omega t)$, and it vanishes when $V_{DC}$ equals $V_{CPD}$ (Figure S1b). So, modifying the DC voltage until the force is zero allows to measure the contact potential difference. To achieve this, $F_{\omega}$ simply needs to be recorded using a lock-in amplifier. Its output can then be used for a feedback that tries to modify $V_{DC}$, so that the vibration amplitude is zero.

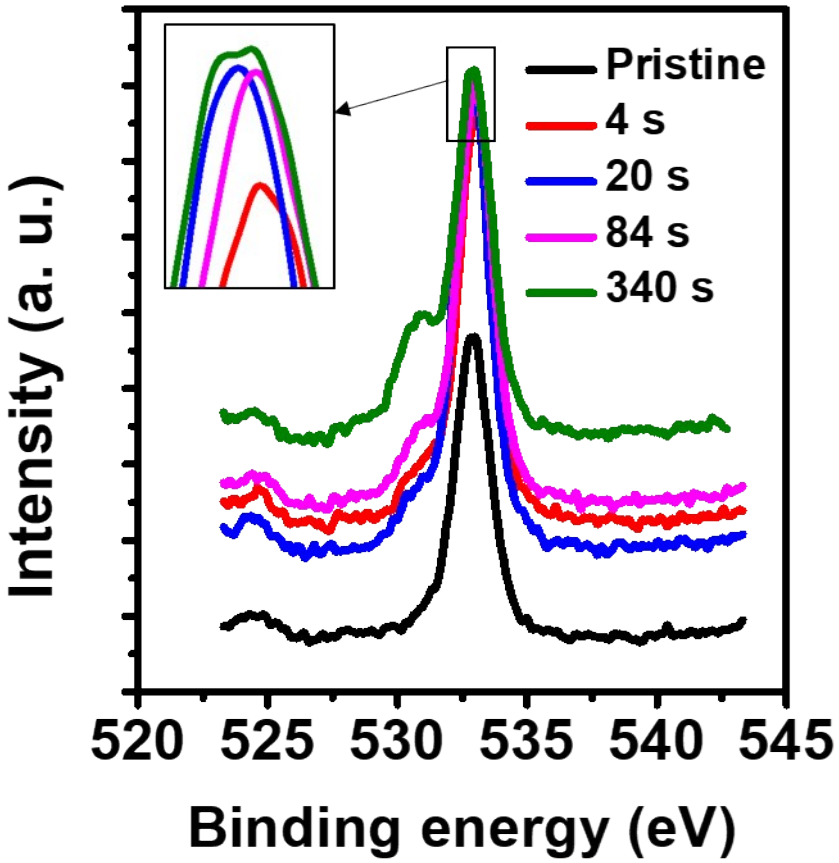


Figure S2. O1s XPS peaks as a function of oxygen plasma treatment time.

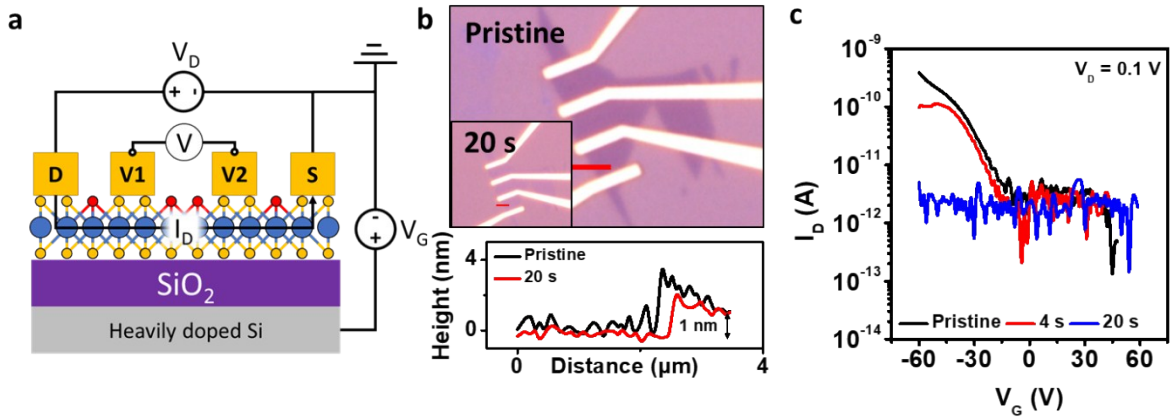


Figure S3. Monolayer $WSe_2$ FET oxidation test. After 20 seconds oxidation, the current flow blocked due to the channel changed to $WO_x$, which is an insulator.

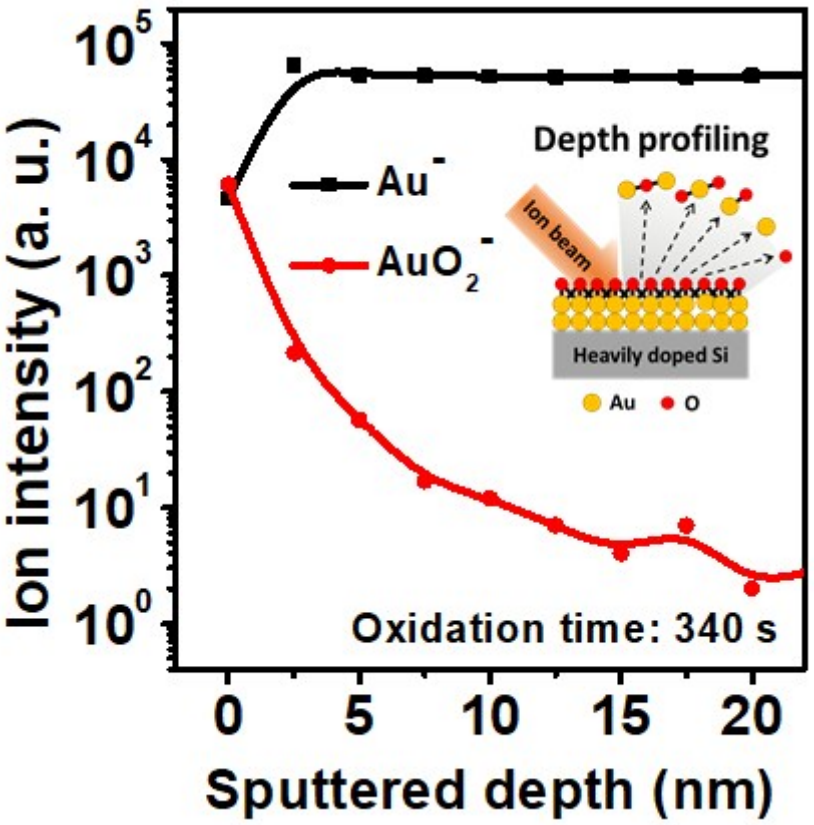


Figure S4. SIMS depth profile of oxidized gold.

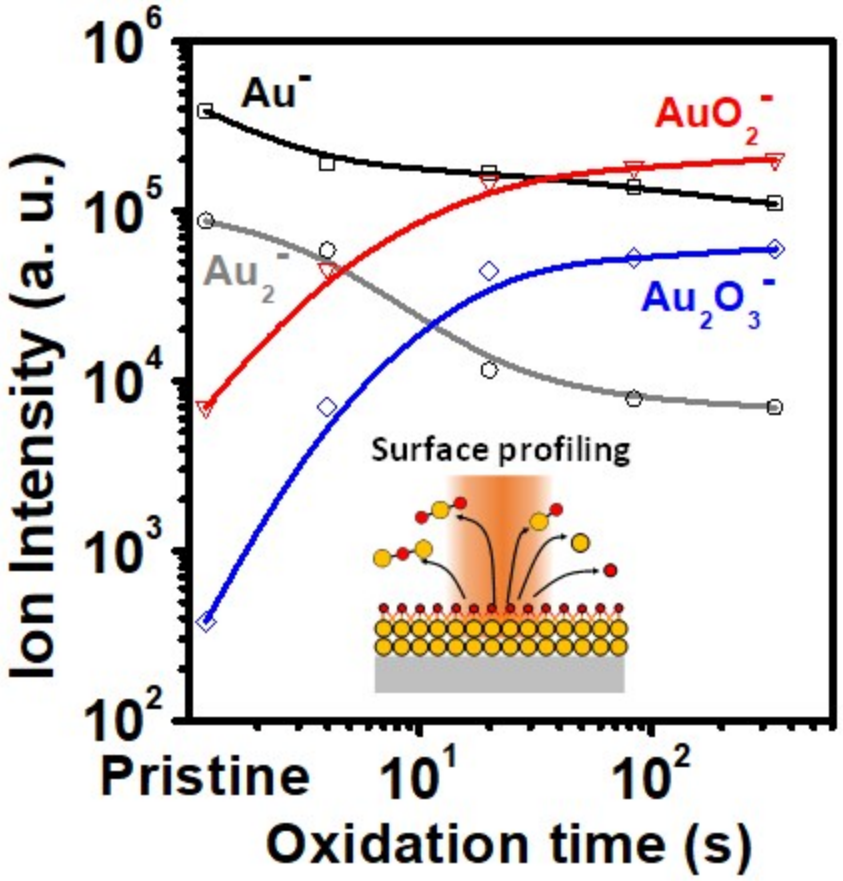


Figure S5. SIMS surface profiling as a function of plasma oxidation time. Measurements were performed on the same sample.

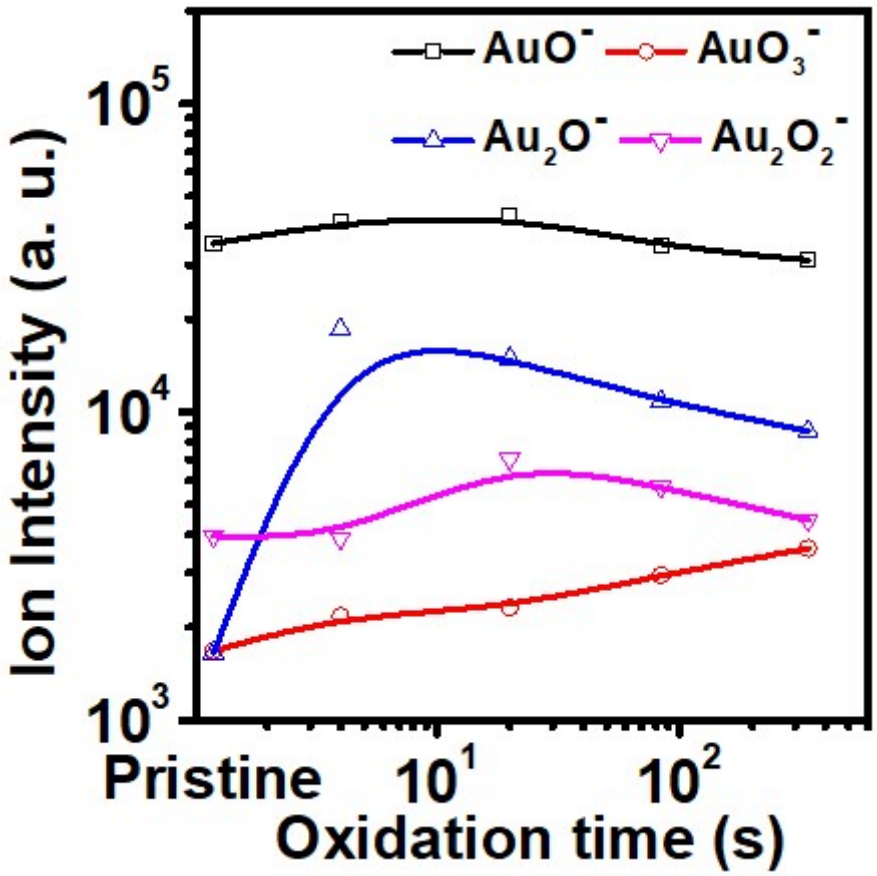


Figure S6. Additional gold oxide species measured with SIMS surface profiling with respect to oxidation time.

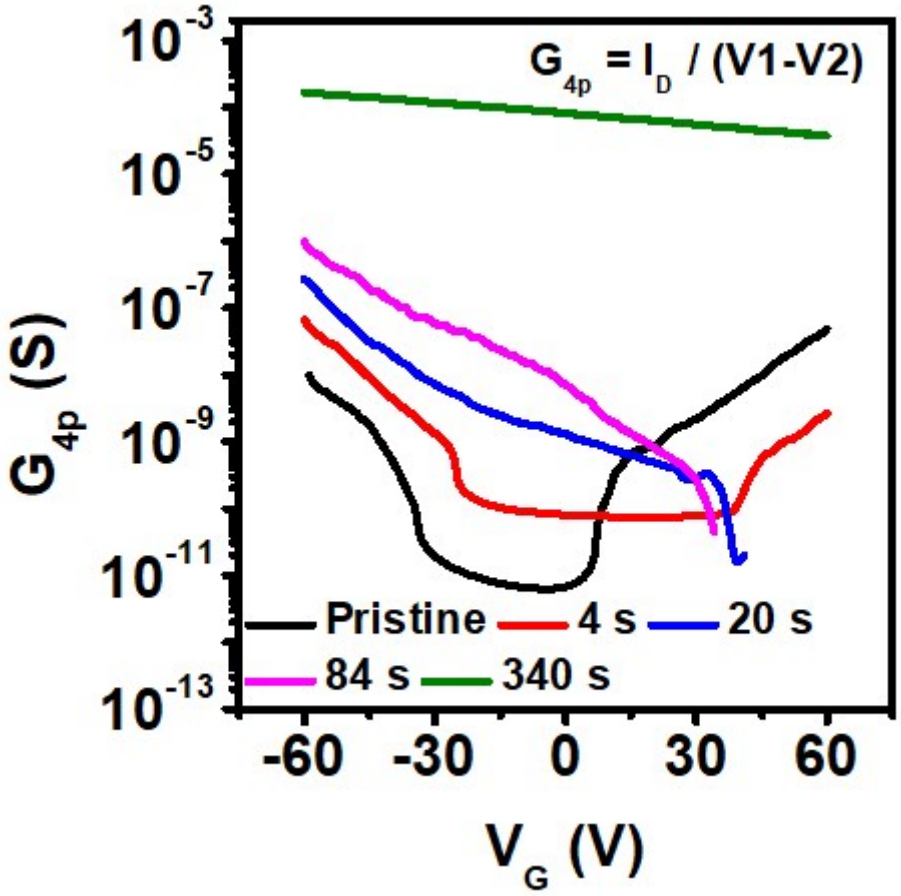


Figure S7. Four point conductance vs. gate bias and oxidation time.

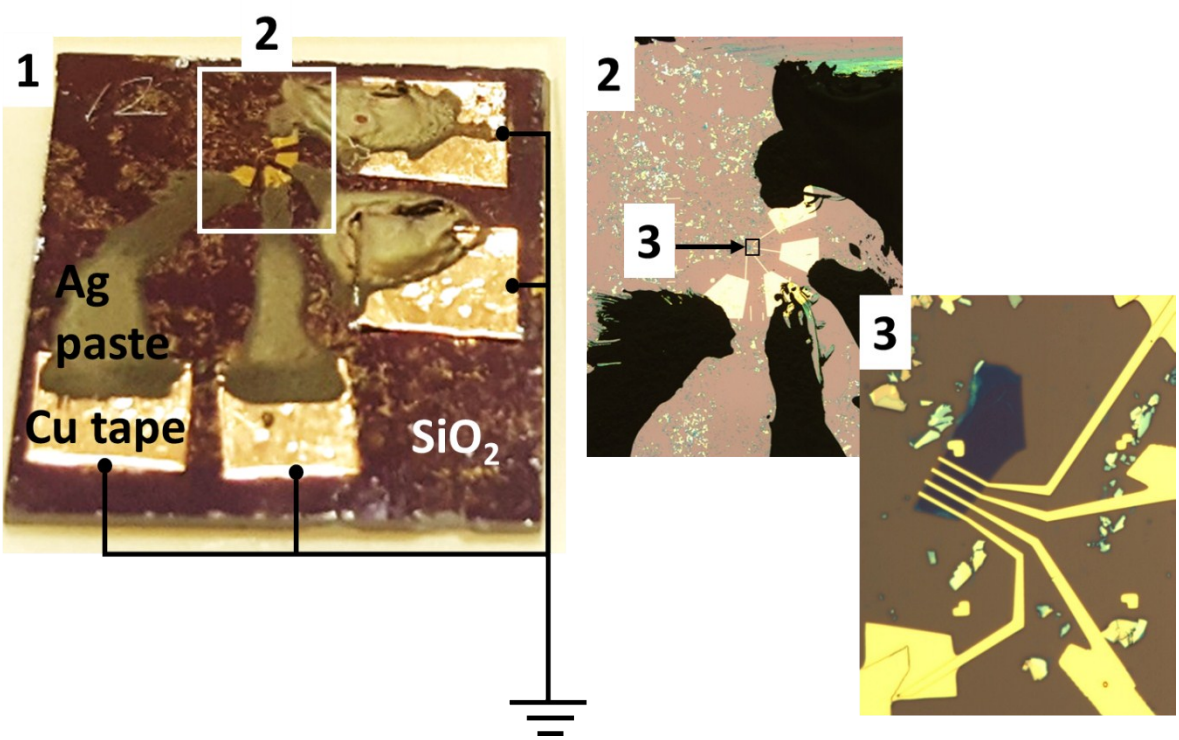


Figure S8. Grounding method for KPFM measurement $WSe_2$ FET device.

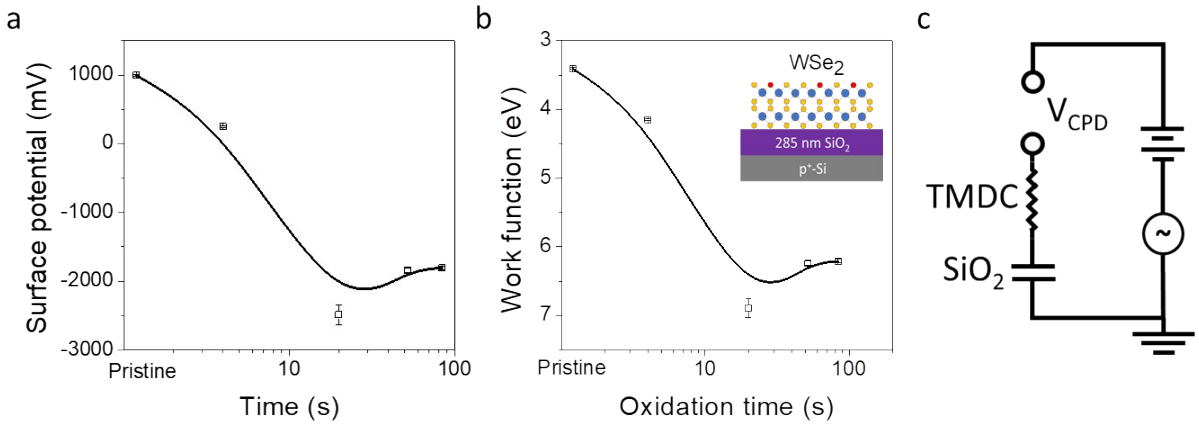


Figure S9. Substrate effect for KPFM measurement. The exaggerated surface potential values are detected due to the additional capacitance of $SiO_2$ substrate.

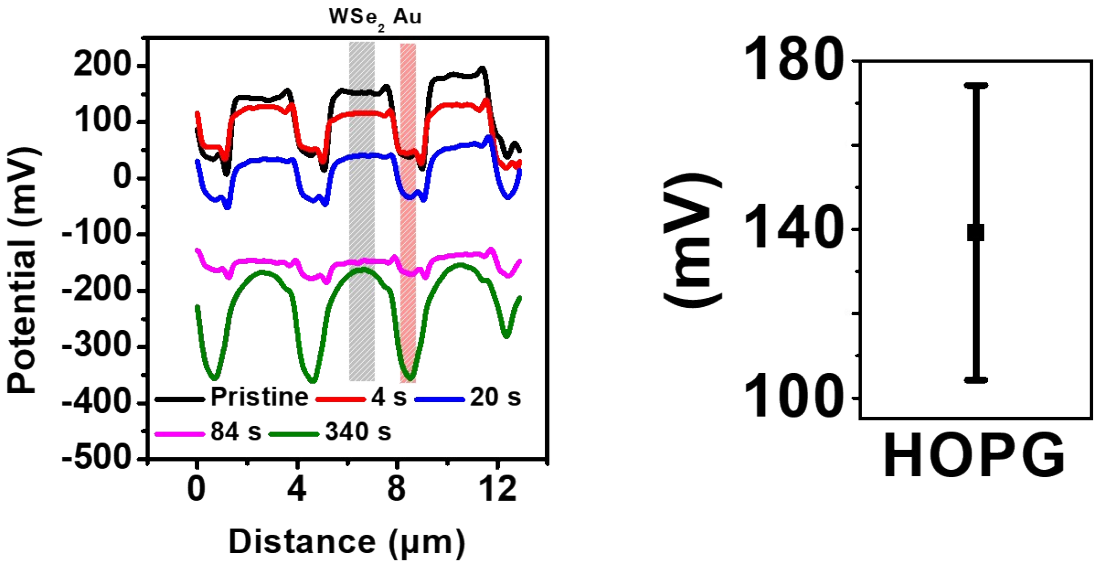


Figure S10. Line-extracted potential with respect to oxygen plasma treatment time. The potential of HOPG is in right side.

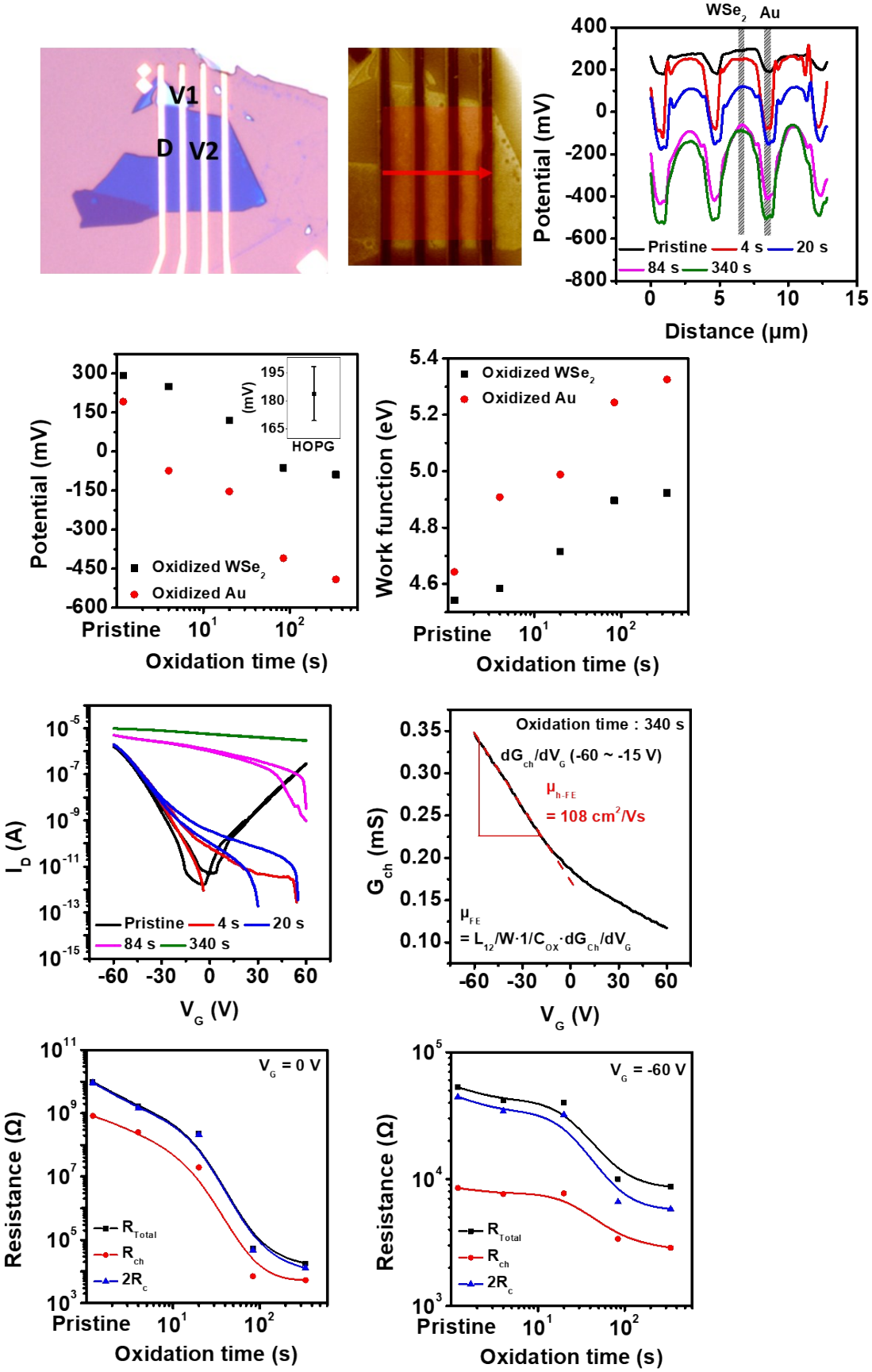


Figure S11. KPFM and I-V measurement results of Sample B

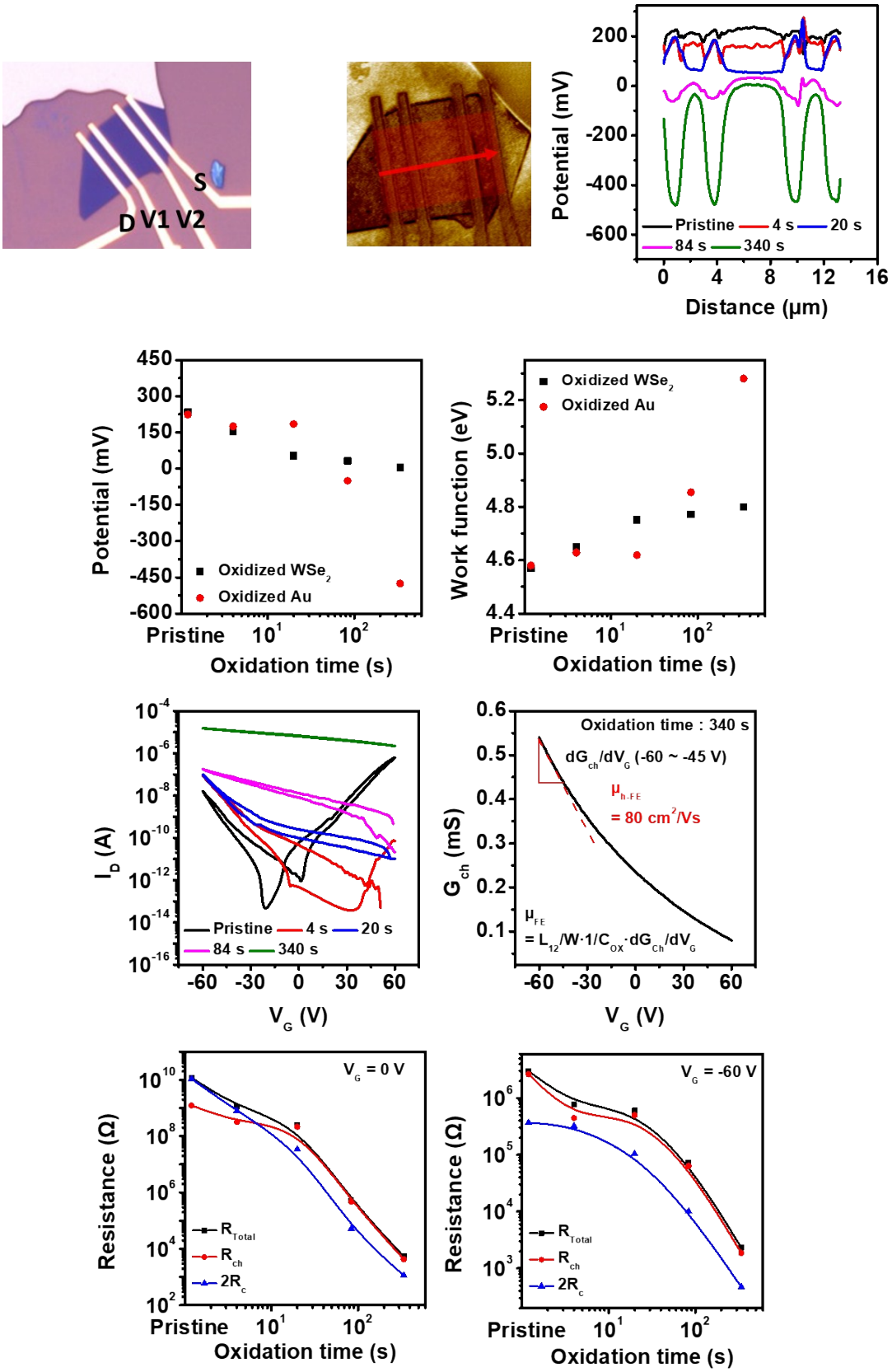


Figure S12. KPFM and I-V measurement results of Sample C

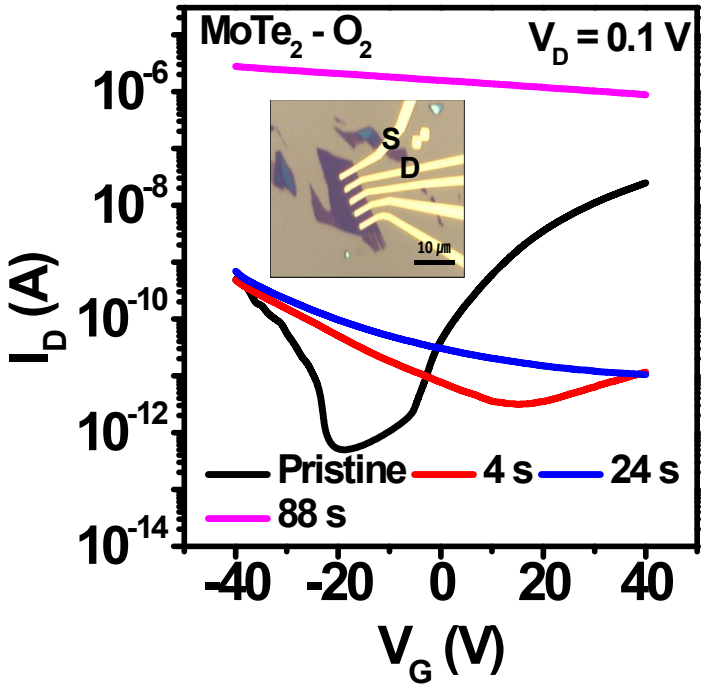


Figure S13. $MoTe_2$ FET transfer curves with respect to $O_2$ plasma treatment time.