Supplementary Material: A New Effect of Oxygen Plasma on Two-Dimensional Field-Effect Transistors: Plasma Induced Ion Gating and Synaptic Behavior*

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Fabrication of $SnSe_2$ Devices: $SnSe_2$ flakes are exfoliated on heavily doped silicon wafer covered with 300 nm thick SiO_2 as the back-gate dielectric. Two-terminal and multiple-terminal metal contacts are patterned by standard electron-beam lithography (JEOL JSM-7800F and Raith) and the Ti (20 nm)/Au (30 nm) are deposited in a thermal evaporation system (Angstrom Engineering), followed by a lift-off process.

Oxygen Plasma Treatment Process: The $SnSe_2$ flakes and field-effect transistor (FET) devices are treated by the oxygen plasma (PLASMA-PREEN II 862, Plasmatic Systems). The plasma chamber operates at 2.45 GHz with a power of 750 W. O_2 gas (50 sccm) flows through the vacuum chamber (16 Pa) for 10 min before the O_2 plasma treatment. The exposure time of the $SnSe_2$ flakes and FET devices in the O_2 plasma system is 15 sec.

Atomic Force Microscopy (AFM), Raman, X-ray Photoelectron Spectroscopy (XPS) and Contact Angle Characterizations: The thickness of $SnSe_2$ is characterized using an AFM (MFP-3D-BIO, OXFORD INSTRUMENTS) with AC mode under ambient conditions. Raman spectra of pristine and plasma-treated $SnSe_2$ flakes and FET devices are performed using a Raman microscope (SR-500I-D2-1F1, ANDOR) with the laser spot size of 1 μm at an excitation wavelength of 532 nm. The XPS (ESCALAB 250Xi, Thermo Fisher Scientific) characterization uses an Al Kα X-ray source at a base pressure of ~10^{-10} mbar. The contact angle measurements are done using a commercial instrument (SL200KS, USA KINO Industry) with deionized water.

Electrical Characterization: The $SnSe_2$ FET devices are characterized in dark with a Janis ST-500-1 vacuum probe station using Keithley 2612B sourcemeters and Keithley 4200. We vent the probe station vacuum chamber with different types of gases through its venting port. 99.99% pure O_2 and N_2 are supplied with gas cylinders; dry air is produced with ambient air flowing through a 20 cm pipe filled with silica gel desiccant before entering the vacuum chamber. The Hall measurements are carried out using a physical property measurement system (PPMS DynaCool, Quantum Design). The usual operation mode of PPMS is under vacuum. However, to get the data in Figure 2b, we intentionally keep the ambient air in the PPMS measurement chamber for the Hall measurements. Then we pump down the system to do the conventional vacuum Hall measurement.

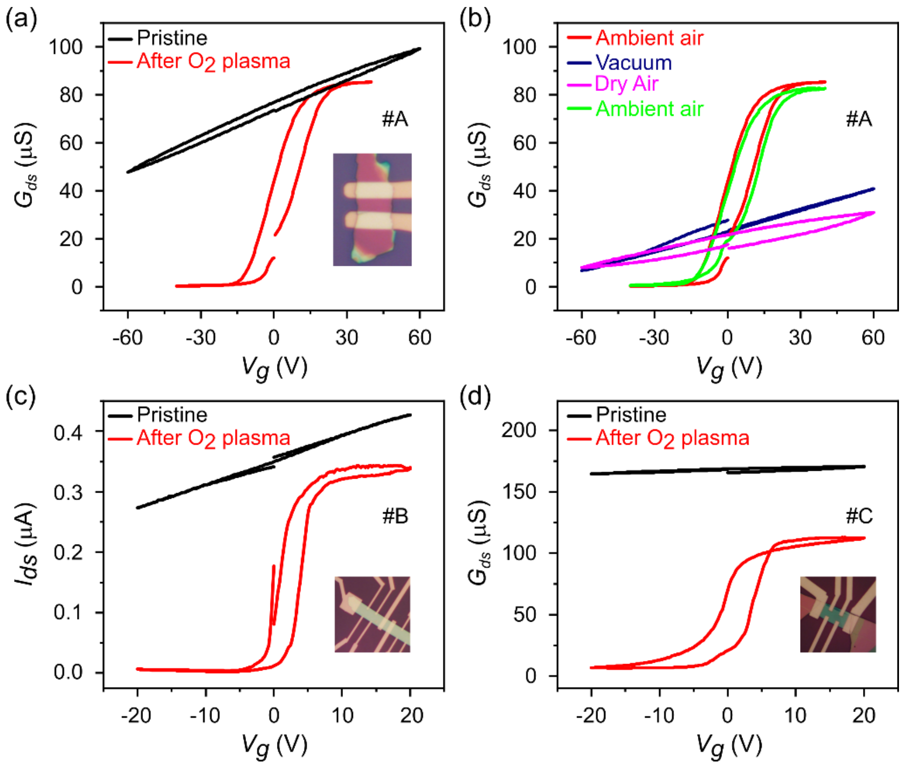

Figure S1. Conductance versus back-gate voltage for different $SnSe_2$ devices (a) sample #A, (c) sample #B and (d) sample #C before and after O_2 plasma treatment. After exposed to the O_2 plasma, the conductance modulation of the $SnSe_2$ devices sample #A, sample #B and sample #C increase from order one to 10^3, 10^2 and 10, respectively. Insets: the optical microscope images of the corresponding devices. (b) Transfer curves of the sample #A under different measurement conditions. The ambient air has a relative humidity of 60%.

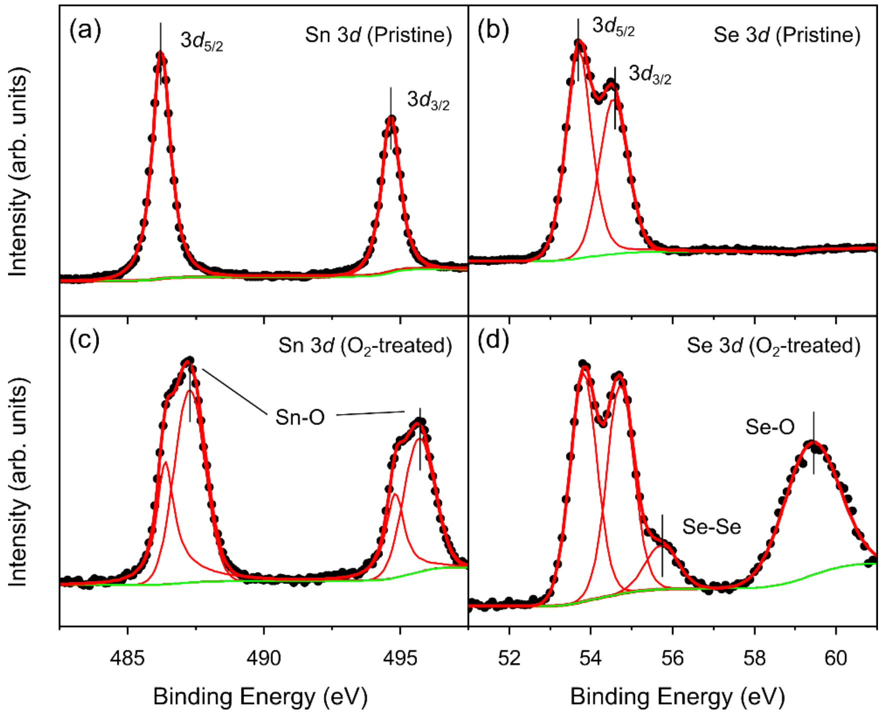

Figure S2. XPS characterizations of bulk $SnSe_2$ before and after the O_2 plasma treatment. XPS spectra of (a) Sn 3*d* and (b) Se 3*d* states for the pristine $SnSe_2$ sample. XPS spectra of (c) Sn 3*d* and (d) Se 3*d* states for the O_2 plasma-treated $SnSe_2$ sample. The O_2 plasma treatment leads to the partial oxidation of Sn and Se and the forming of amorphous Se on the $SnSe_2$ top layers.

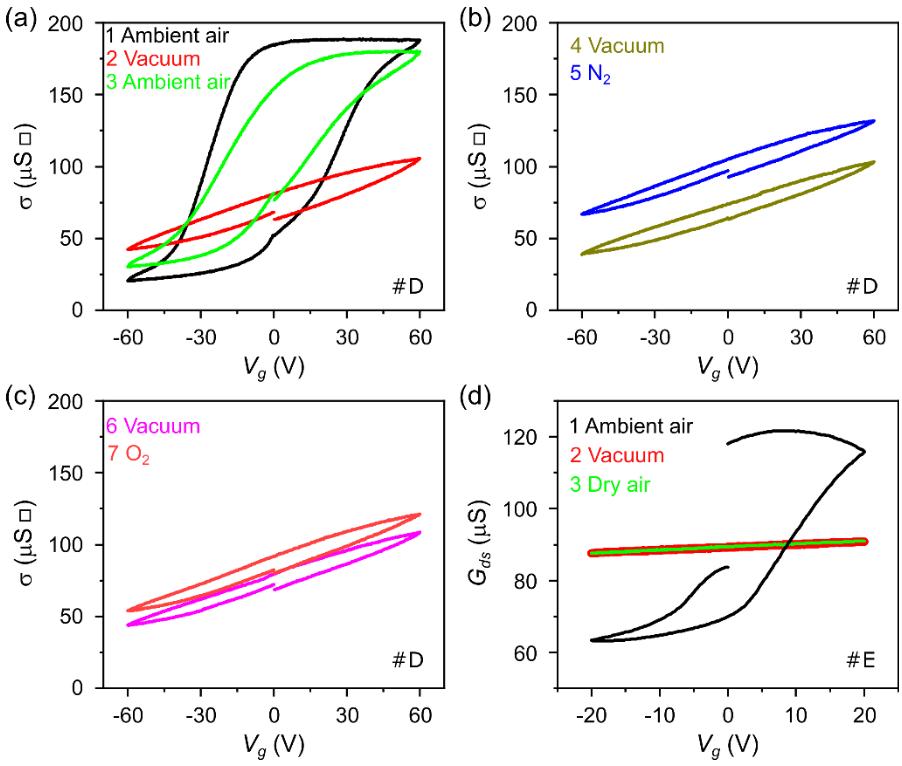

Figure S3. Transfer curves of the plasma-treated $SnSe_2$ FETs labeled as sample #D and #E with the vacuum chamber vented with different gases of (a) unprocessed ambient air with the relative humidity 60%, (b) pure N_2, (c) pure O_2 and (d) desiccated ambient air. Only venting the vacuum chamber with unprocessed ambient air recovers the large slope and hysteresis of the transfer curve.