Reversible Photo-induced Doping in WSe_2 Field Effect Transistors

Xuyi Luo[1], Kraig Andrews[2], Tianjiao Wang[1], Arthur Bowman[2], Zhixian Zhou[2], and Ya-Qiong Xu[*,1,3]

[1]Department of Electrical Engineering and Computer Science, Vanderbilt University, Nashville, TN 37235, USA

[2]Department of Physics and Astronomy, Wayne State University, Detroit, MI 48201, USA

[3]Department of Physics and Astronomy, Vanderbilt University, Nashville, TN 37235, USA

[*]Correspondence to: yaqiong.xu@vanderbilt.edu

S1. Retention properties of the photo-induced doping effect in WSe_2 FETS on h-BN substrates.

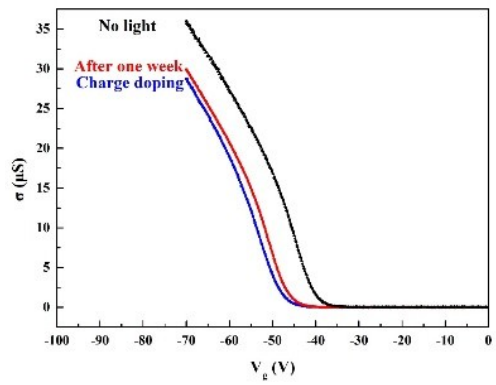

Figure S1. Retention properties of the photo-induced doping effect in WSe_2 FETs on h-BN substrates. The black and blue traces represent the WSe_2 FET before and after light illumination with $V_g^{light} = -30\ V$, respectively. The red trace shows the transport curve after the device was stored under high vacuum condition with a dark environment for a week.

S2. Temperature dependence of the photo-induced doping in WSe_2 FETs on h-BN substrates.

As shown in Figure S2, the device shows reversible photo-induced doping properties at both 297 K and 77 K, while the charge doping at 77 K is twice as efficient as that at 297 K. At low temperature, the mobility of electrons in h-BN increases due to the reduction of phonon scattering; therefore, the photo-excited electrons can move faster towards the WSe_2 channel and then leave the positively-charged defects behind, leading to an enhanced charge doping efficiency. In addition, this type of charge doping technique is expected to perform under high vacuum because the chemisorption of ambient molecules (e.g. water and oxygen) may induce addition scattering centers and thus compromise the charge carrier mobility of the devices.[1] Furthermore, oxygen may also reduce the photo-induced n-type doping efficiency since the electron can transfer from WSe_2 to O_2, leading to p-type doping in WSe_2.[2]

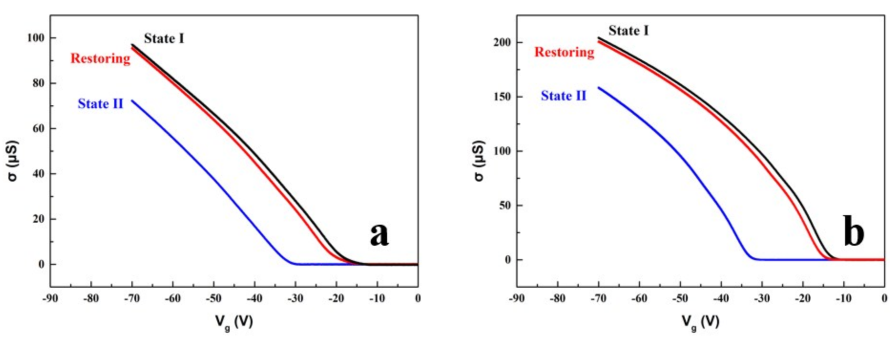

Figure S2. Temperature dependence of the photo-induced doping in WSe_2 FETs on h-BN substrates. State I (black trace) and State II (blue trace) represent the response of the device before and after 460 nm illumination with $V_g^{light} = -30V$, respectively. The red trace shows the transport curve after the device was restored. Reversible photo-induced doping properties at (a) 297 K and (b) 77 K, respectively.

S3. AFM analysis of WSe_2 FETs on h-BN substrates

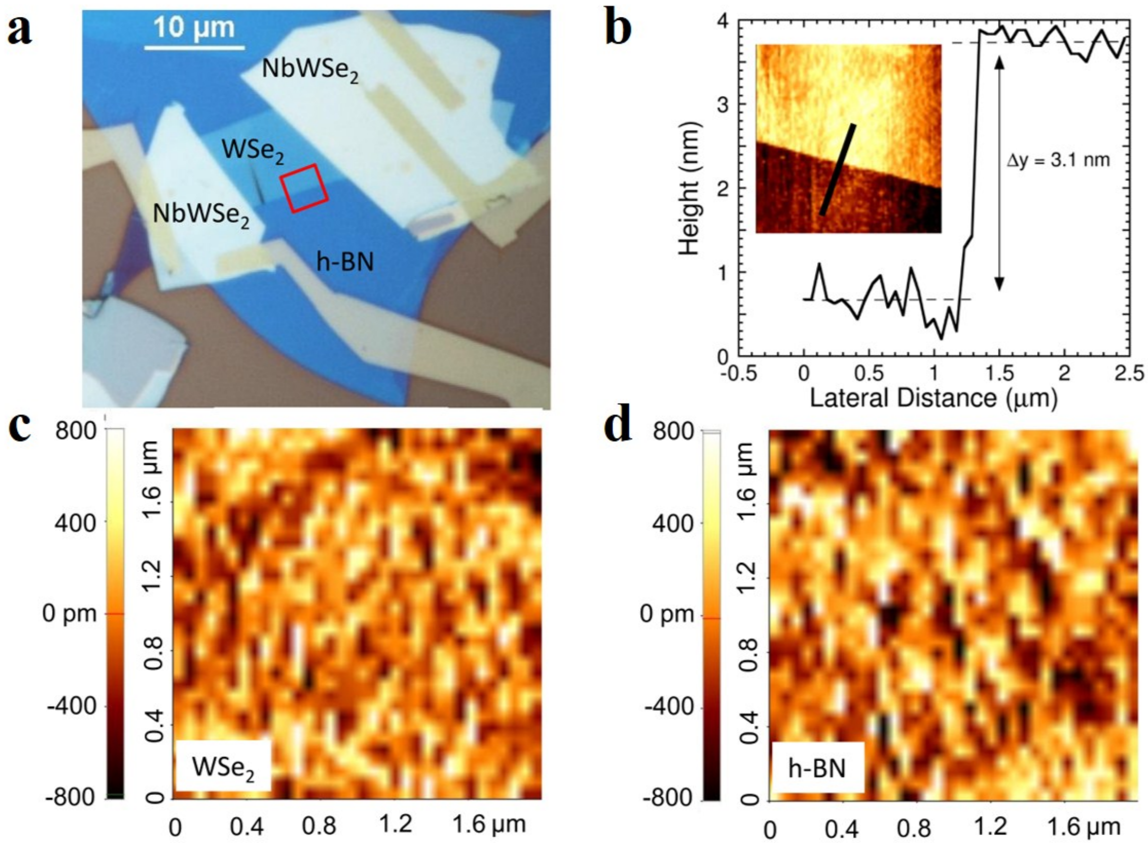

Figure S3. Optical and AFM images of a WSe_2 FET on the h-BN substrate. (a) Optical micrograph of a WSe_2 FET. (b) Line profile of a 3.1 nm WSe_2 channel on hBN taken along the solid line in the inset. The inset shows the AFM image of the area inside the red square in (a). AFM surface topography for the (c) WSe_2 and (d) h-BN surfaces, respectively. The RMS roughness for the WSe_2 surface was determined to be 294 pm and 344 pm for the h-BN surface.

References

1. Qiu, H.; Pan, L.; Yao, Z.; Li, J.; Shi, Y.; Wang, X. *Applied Physics Letters* **2012,** 100, (12), 123104.
2. Tongay, S.; Zhou, J.; Ataca, C.; Liu, J.; Kang, J. S.; Matthews, T. S.; You, L.; Li, J.; Grossman, J. C.; Wu, J. *Nano Letters* **2013,** 13, (6), 2831-2836.