

# Control of electron density in WSe<sub>2</sub> monolayers via photochlorination

E. Katsipoulaki<sup>1,2,\*</sup>, I. Demeridou<sup>1,2</sup>, E. Stratakis<sup>1,2</sup>, and G. Kioseoglou<sup>1,3,\*</sup>

<sup>1</sup> FORTH/IESL, Heraklion, 71110, Crete, Greece

<sup>2</sup> Department of Physics, University of Crete, Heraklion, 71003, Crete, Greece

<sup>3</sup> Department of Materials Science and Technology, University of Crete, Heraklion, 71003

Transition Metal Dichalcogenides (TMDs) of the form MX<sub>2</sub> (where M=Mo or W and X=S, Se, Te), are a special class of 2D-layered materials [1]. Unlike their 3D-counterparts that are indirect gap semiconductors, single layers of MX<sub>2</sub> have a direct-gap, with tremendous consequences in the PL quantum yield [2]. In addition, TMDs are characterized by valley dependent optical selection rules that make them ideal candidates to store and process quantum information (valleytronics), due to broken inversion symmetry in combination with time reversal symmetry [3,4]. In this work, the effect of doping (i.e., the electron/hole density) on the optoelectronic properties of single layers of WSe<sub>2</sub> is investigated. Photochemical doping is realized by intense UV laser pulses in a gas environment that provides the dopant atoms or molecules. By controlling systematically, the irradiation parameters, it is possible to control the doping level and consequently the electronic band structure of the monolayer crystal [5]. In the case of WSe<sub>2</sub>, photochlorination induces n-type doping that is a partially reversible process achieved by a raster scanning procedure using a continuous wavelength laser. In addition, a significant increase in the spin valley polarization was achieved in accordance with an increase of the electron density after the photochemical doping [6,7].

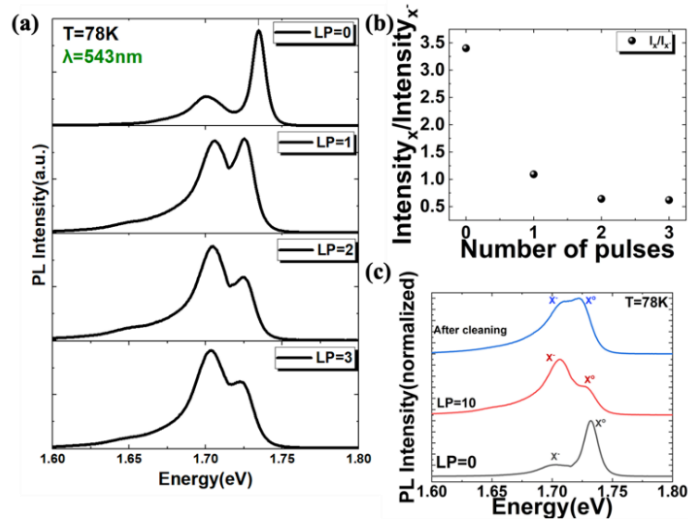


Figure 1: (a) Evolution of the PL spectra of 1L-WSe<sub>2</sub> at 78K, with the number of UV pulses. (b) The ratio of normalized intensities of the X and X\* peaks as a function of the number of UV pulses, at 78K. (c) PL spectra of a pristine 1L-WSe<sub>2</sub> (grey curve), photochlorinated for 10 UV pulses (red curve) and dechlorinated (blue curve), at 78K.

## Acknowledgements

E.K. acknowledge support by the European Regional Development Fund of the European Union and Greek national funds through the Operational Program Competitiveness, Entrepreneurship and Innovation, under the call RESEARCH – CREATE – INNOVATE (SMARTPACK). I.D. acknowledge support by the European Union’s Horizon 2020 research and innovation program through the project NEP, EU Infrastructure, GA 101007417 – INFRAIA-03-2020 and by the synergy grant SPIVAST funded by FORTH. G. Kio., acknowledge funding by the Hellenic Foundation for Research and Innovation (H.F.R.I.) under the ‘First Call for H.F.R.I. Research Projects to support Faculty members and Researchers and the procurement of high-cost research equipment grant’ project No: HFRI-FM17-3034.

## References

- [1] K. Novoselov, et al. *Proc. Natl. Acad. Sci* **102**, 10451 (2005); [2] K.F. Mak, et al. *PRL* **105**, 136805 (2010); [3] G. Kioseoglou, et al. *APL* **101**, 221907 (2012); [4] K.F. Mak, et al. *Nat. Nanotechnology* **7**, 494 (2012); [5] I. Demeridou, et al. *2D Materials* **6**, 015003 (2018); [6] I. Demeridou, et al. *APL* **118**, 123103 (2021); [7] S. Konabe, *APL* **109**, 07310 (2016).

\* ekatsip@physics.uoc.gr