SEMICONDUCTING THIN LAYERS OF TRANSITION METAL DICHALCOGENIDES UNDER PRESSURE

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Semiconducting monolayers of transition metal dichalcogenides (mTMDCs) are intensely studied in the community of 2D materials owing to their manifold and unique properties for optoelectronics and photonics: artificially stacked van der Waals structure, moirée superlattice, high exciton binding energy, spatially separated electron-hole pair in heterostructure, spin-valley physics and so on. One particular hot topic in the field is the tuning of intralayer and interlayer exciton properties in multilayers heterostructure via tailoring the number of layers [1, 2] applied gate voltage [3], magnetic field [4], strain [5], and pressure [6, 7], all in order to achieve high-performance spin-valleytronics and excitonic devices.

In this context we elected to study mTMDCs heterostructures under pressure. We developed an experimental setup to study materials in extreme environment of low temperature, high magnetic field, and high pressure using a diamond anvil cell (DAC) reaching up to 10GPa [8]. The experimental setup offers novel and exciting possibilities to explore how optical properties (photoluminescence, Raman scattering, reflectivity) vary with interlayer distance and lattice parameters change when hydrostatic pressure is applied. In particular, the large polarisability in plane compared to out-of-plane and the drastic change in the dielectric environment completely modify the screening of the coulomb interaction between electrons and holes.

Several fundamental questions are raised by the possibility of applying pressure to a monolayer of 2D material. The first one being how is pressure transferred to a monolayer or to a van der Waals heterostructure ? Using low temperature optical spectroscopy on high quality TMDC encapsulated in hBN and inserted in a DAC, we investigate the exciton properties including its excited states series [10], and its evolution when applying high pressure. We will discuss the potential structural changes affecting the TMDC via Raman scattering analysis together with the changes of the dielectric environment [9] when reducing the van der Waals gaps.

References

[1] Q. Tan, *Science Advances 2021*, 7, 30.
[2] N. Ubrig, *Nat. Mater. 2020*, 19, 299.
[3] O. Karni, *Phys. Rev. Lett. 2019*, 123, 247402.
[4] A. Delhomme *2D Mater. 2020*, 7, 041002.
[5] L. Ren *Appl. Phys. Lett. 2022*, 120, 053107.
[6] J. Xia *Nat. Phys. 2021*, 17, 92.
[7] W. Zhao *Nano Lett. 2021*, 21, 8910.
[8] I. Breslavetz *Review of Scientific Instruments 2021*, 92, 123909.
[9] A. Raja *Nature Communications 2017*, 8, 15251.
[10] A. Chernikov *Phys. Rev. Lett. 2014*, 113, 076802.

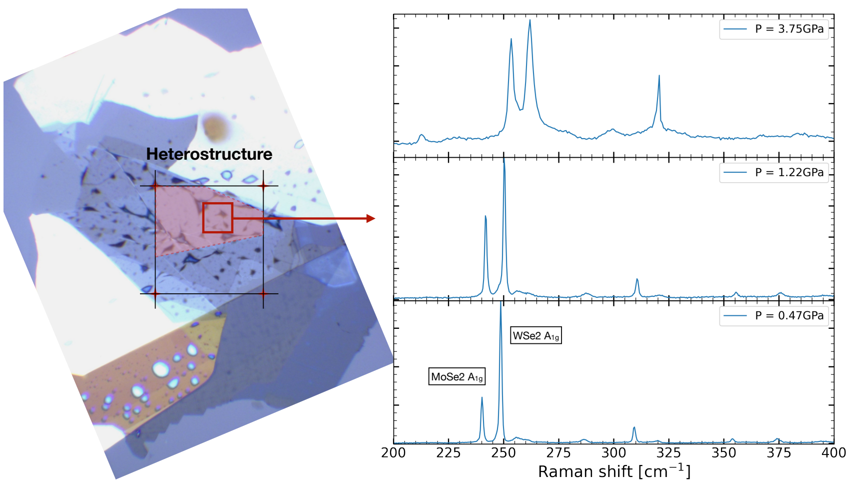

Figure 1: Raman spectra at different value of pressure inside the DAC. Each raman spectrum on the right panel is averaged over the area on the MoSe2/WSe2 heterostructure denoted by the red square on the picture.

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