DIELECTRIC SCREENING IN VAN DER WAALS MATERIALS PROBED THROUGH RAMAN SPECTROSCOPY

L. Moczko[1,*], A. Singh[2], X. Zhang[1], L.E. Parra López[1],
J. Wolff[1], E. Lorchat[1], M. Romeo[1], R. Singh[2], T. Taniguchi[3], K. Watanabe[3], S. Reichardt[4], L. Wirtz[4], and S. Berciaud[1,†]

[1]Université de Strasbourg, CNRS, Institut de Physique et Chimie des Matériaux de Strasbourg, France
[2]Indian Institute of Technology, New Delhi, India
[3]National Institute for Materials Science, Tsukuba, Ibaraki, Japan
[4]Physics and Materials Science Research Unit, University of Luxembourg, Luxembourg

Van der Waals heterostructures provide a unique platform to investigate and engineer near-field coupling and proximity effects in two-dimensions. These complex phenomena require sensitive and high throughput experimental probes. In this context, Raman spectroscopy stands out as a powerful characterization tool, that has been widely used to probe strain fields, doping or dielectric screening, in particular in graphene layers [1]. These characteristics can be finely engineered using van der Waals (vdW) heterostructures [2]. Here, using a large variety of graphene-based vdW heterostructures, we show that the well-known Raman 2D mode of graphene is uniquely sensitive to dielectric screening and undergoes a sizeable upshift in excess of 15 cm^{-1} when comparing a bare suspended graphene monolayer with a graphene/transition metal dichalcogenide (TMD) heterostructure (Fig. 2). This upshift stems from the smearing of the Kohn anomaly that affects transverse optical phonons at the K point of the Brillouin zone [3]. Our results show that a single TMD monolayer smears the Kohn anomaly more efficiently than bulk Boron Nitride (Fig. 2).

Interestingly, the Raman G mode of graphene is not affected by this effect (Fig. 2). Preliminary theoretical investigations suggests that this absence of blueshift for the G mode frequency points toward an effect originating from π-bands only, which are symmetry protected from the effects of dielectric screening.

As an outlook we will introduce our ongoing efforts to mechanically tune interlayer coupling in vdW heterostructures and more broadly light-matter interactions in nanomechanical resonators [4, 5] made from suspended graphene/TMD heterostructures.

References

[1] A.C. Ferrari & D.M. Basko, *Nature Nanotechnology*, 8 (2013) 235.
[2] G. Froehlicher, E. Lorchat & S. Berciaud, *Phys. Rev. X*, 8 (2018) 011007.
[3] F. Forster, A. Molina-Sanchez, S. Engels, A. Epping, K. Watanabe, T. Taniguchi, L. Wirtz & C. Stampfer, *Phys. Rev. B*, 88 (2013) 085419.
[4] P.G. Steeneken, R.J. Dolleman, D. Davidovikj, F. Alijani & H.S.J. van der Zant, *2D Mater.*, 8 (2021) 042001.
[5] X. Zhang, K. Makles, L. Colombier, D. Metten, H. Majjad, P. Verlot & S. Bericaud, *Nat. Commun.*, 11 (2020) 5526 .

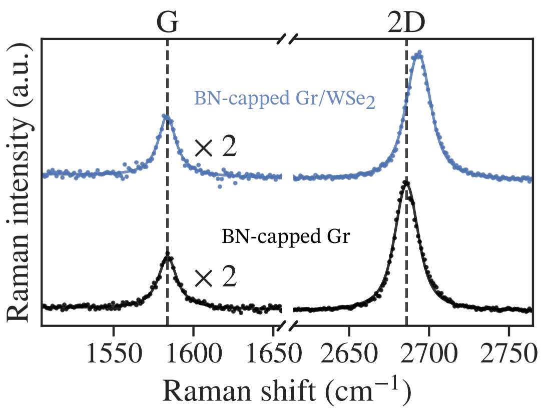

Figure 1: Typical Raman spectrum of graphene for a hexagonal Boron Nitride (BN) capped graphene/WSe_2 heterostructure showing a blueshift of the 2D mode relative to the case of a BN-capped graphene sample.

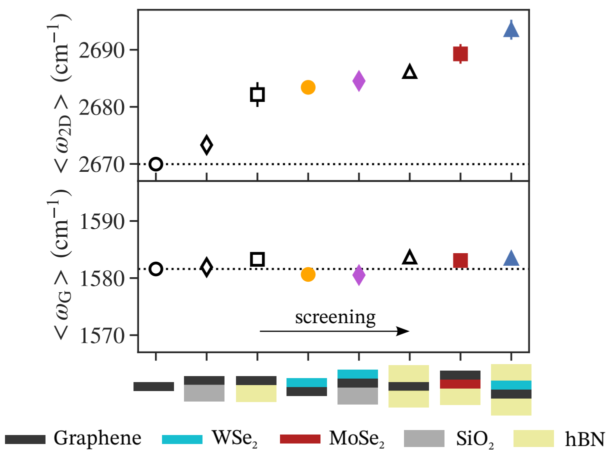

Figure 2: Top (bottom): spatially averaged 2D (G) mode frequency in graphene monolayers in various dielectric environments.

* loic.moczko@ipcms.unistra.fr
† stephane.berciaud@ipcms.unistra.fr