Van der Waals crystals and monolayers under hydrostatic pressure – conclusions for piezo-reflectance spectroscopy

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The study of van der Waals (vdW) crystals under hydrostatic pressures helps to identify the nature of optical transitions [1, 2] and reveals interesting phenomena such as the semiconductor to superconductor transition or others. In the case of monolayers (or thin vdW flakes), we deal with a situation where such a layer is electrostatically attached to the substrate. This macro-scale electrostatic connection (vdW bindings in nanoscale) cannot be ignored in the study of these flakes under the high hydrostatic pressure. We have recently shown that exciton transitions in monolayer WS_2 deposited on different substrates shift with very different pressure coefficients under the influence of hydrostatic pressure [3]. These results clearly show that vdW layers remain fully adhered to the substrate even for incommensurate systems (vdW/glass or vdW/diamond) upon compression conditions. Therefore, it is important to consider the substrate effect for any high pressure experiment on two-dimensional vdW materials, including exfoliated vdW flakes directly on the diamond anvil. On the other hand, the "stiff" connection between the vdW flake and the substrate can be used for the periodic strain generation in the vdW layers, including piezo-reflectance measurements when the vdW crystals are exfoliated directly onto the piezoceramic substrate. An example of room temperature piezo-reflectance (PzR) spectrum of MoS_2 flake exfoliated on piezoceramic is shown in Fig. 1 together with photoreflectance (PR) and reflectance contracts (RC) spectrum for the same flake [4]. In this paper, I will present and discuss both the aspect of studying vdW flakes under hydrostatic pressure and piezo-reflectance measurements of vdW crystals. Both issues will be discussed in the context of electrostatic interactions (vdW interactions) between the vdW flake and the substrate.

[1] R. Oliva, M. Laurien, F. Dybala, J. Kopaczek, Y. Qin, S. Tongay, O. Rubel, R. Kudrawiec, Pressure dependence of direct optical transitions in ReS_2 and $ReSe_2$, npj 2D Materials and Applications 3, 20 (2019).
[2] R. Oliva, T. Woźniak, F. Dybala, J. Kopaczek, P. Scharoch, R. Kudrawiec, Hidden spin-polarized bands in semiconducting 2H-$MoTe_2$, Materials Research Letters 8 (2), 75-81 (2020).
[3] R. Oliva, T. Wozniak, P. E. Faria Jr, F. Dybala, J. Kopaczek, J. Fabian, P. Scharoch, R. Kudrawiec, Strong Substrate Strain Effects in Multilayered WS_2 Revealed by High-Pressure Optical Measurements, ACS Applied Materials & Interfaces 14 (17), 19857-19868 (2022).
[4] J. Kopaczek, K. Ciesiołkiewicz, R. Kudrawiec, to be submitted (2022).

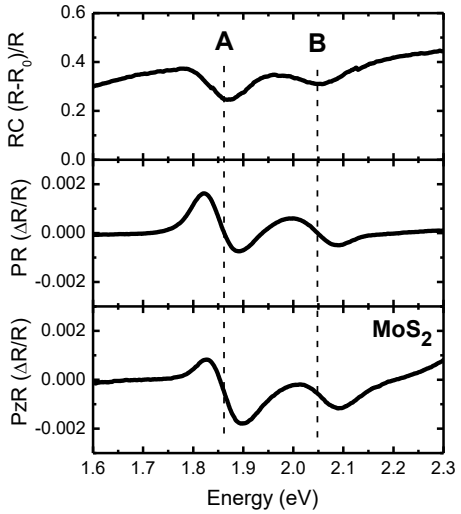

Figure. 1. Room temperature RC, PR and PzR spectrum of MoS_2 exfoliated on piezoceramic substrate.