Resolving nanometer-scale variations of doping and strain in single layer MoS_2

Antonios Michail[1,2], Dimitris Anestopoulos[1], Nick Delikoukos[1,2], **John Parthenios[1]**, Costas Galiotis[1,3] Konstantinos Papagelis[1,4]
[1]*FORTH / ICE-HT, Stadiou str. Platani GR-26504, Patras, Greece*
[2]Department of Physics, University of Patras, *GR-26504, Patras, Greece*
[3]Department of Chemical Engineering, University of Patras, *GR-26504, Patras, Greece*
[4]Department of Physics, University of Patras, *GR-26504, Patras, Greece*
jparthen@iceht.forth.gr

2D single-layer materials are characterized by an inherent extremely low bending rigidity and therefore are prone to nanoscale structural modifications due to substrate interactions. It is well established that such interactions can induce excess charge concentration, conformational ripples, and residual mechanical strain [1].

In this work, we employed spatially resolved Raman and photoluminescence (PL) images to investigate strain and doping inhomogeneities in a single layer MoS_2 crystal exfoliated onto a SiO_2 substrate. Due to the lack of relevant calibration data, we have determined the sensitivities and the corresponding Gruneisen parameters of the E' and A_1' Raman bands of monolayer MoS_2 upon biaxial strain application up to ~ 0.7% [2,3]. We found that correlations between the spectral parameters of the most prominent Raman bands A_1' and E' enable us to decouple and quantify strain and charge doping effects (fig. 1). The methodology is successfully applied to other MoS_2 crystals, either exfoliated or fabricated by chemical vapor deposition, onto different substrates (SiO_2 or PMMA) (Fig. 2). Moreover, in comparison with AFM topography, we show that the spatial distribution of the position of the A^- -trion PL peak is strain sensitive and its linewidth can capture features smaller than the laser spot size.

The proposed methodology may have implications in the development of high-quality devices based on 2D materials since structural and electronic modifications affect considerably their carrier mobility and conductivity.

References

[1] Neumann, C. et al. Nat. Commun., 6, (2015),8429.
[2] Androulidakis, C. et al. Sci. Rep. 5, (2015), 18219.
[3] Michail A., et al., Appl. Phys. Lett., 108(17), (2016), 173102

Figures

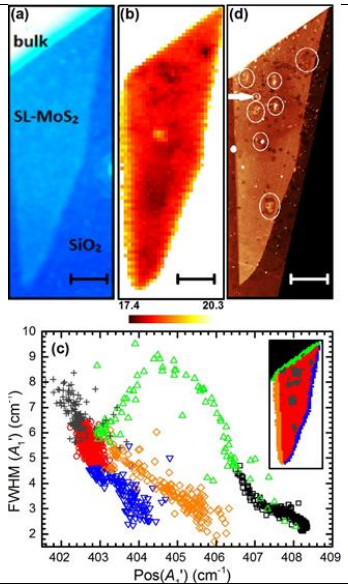

Figure 1: (a) Optical image of the exfoliated monolayer MoS_2 deposited onto a Si/SiO_2 wafer (scale bar, 2 μm), (b) Δω map of the monolayer area, (c) Correlation plot of FWHM(A_1') vs Pos(A_1') and (d) AFM topography of the single layer MoS_2 crystal.

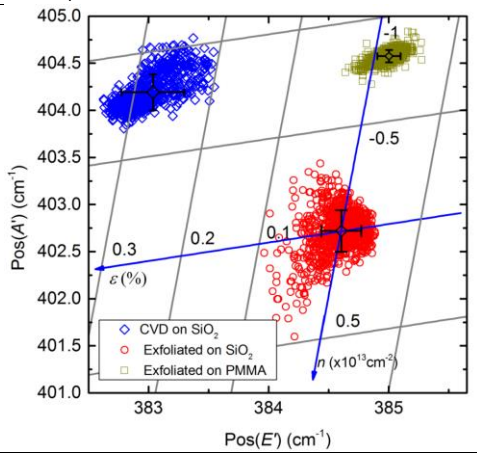

Figure 2: Pos(A_1´) vs Pos(E´) for single layer MoS2 exfoliated onto a polymeric substrate (green squares) and produced by CVD on SiO_2 substrate (blue diamonds). The red circles represent the data points of this work. The straight lines correspond to the ε-n system and represents iso-strain (n) and iso-doping (ε) conditions.