Identifying and Probing Atomic Defects in 2D Semiconductors by Scanning Probe Microscopy

L. Huberich[1], J. Allerbeck[1], L. Bobzien[1], E. Ammerman[1], N. Krane[1], O. Gröning[1], R. Hennig[2], D. Qiu[3], J. Robinson[4] and B. Schuler[1]

[1]*Empa, Swiss Federal Laboratories for Materials Science and Technology, Dübendorf, Switzerland*
[2]*Department of Materials Science and Engineering, University of Florida, USA*
[3]*Department of Mechanical Engineering and Materials Science, Yale University, USA*
[4]*Department of Materials Science and Engineering, The Pennsylvania State University, University Park, USA*

Two-dimensional (2D) semiconductors provide an exciting platform to engineer atomic quantum systems in a robust, yet tunable solid-state system. In this talk, I will present our efforts to unravel the interesting physics behind single vacancies and dopant atoms in transition metal dichalcogenide (TMD) mono- and multilayers by means of high-resolution scanning probe microscopy [1-6].

Our recent studies on transition metal doped TMDs such as (n-type) Re-doped MoS_2 and (p-type) V-doped WSe_2 reveal the significance of the charge state in the spectroscopic signature of these defects [7,8]. By substrate chemical gating, we can stabilize three charge states of Re_{Mo}, where two of the charge states exhibit symmetry broken electronic orbitals and a distorted atomic configuration that we assign to a pseudo Jahn-Teller effect [7].

In the second part, I will share our recent advancements in probing ultrafast dynamics of single atomic defects in TMDs [9-10]. In monolayer WSe_2 (1ML), we observe rapid electron transfer from the lowest unoccupied orbital of the top Se vacancy to the graphene substrate within 1.2 ps. In multilayers, we find a sub-exponential increase of the charge lifetime of the top vacancy from 54 ps in 2ML, to 1.1 ns in 3ML, and 3 ns for 4 ML WSe_2. I will provide an outlook on our ongoing developments of ultrafast lightwave-driven scanning tunneling microscopy using single-cycle THz pulses to measure the sub-picosecond time dynamics at atomic spatial resolution [9].

References

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