2D materials as host for single-atom impurities, metal nanostructures and van der Waals materials

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Graphene—the one-atom-thick sheet of carbon—is the most famous of 2D materials due to its unique electronic properties and mechanical strength. However, its chemical inertness makes graphene also an excellent nearly electron-transparent support for other materials and nanostructures. In this presentation, I will give an overview of our recent work enabled by a unique interconnected vacuum system [1] containing an aberration-corrected scanning transmission electron microscope Nion UltraSTEM 100 with a unique objective area that allows sample cleaning via laser, in situ chemical experiments, and direct vacuum transfer to an atomic force microscope, to-and-from an argon glove box, target chamber with a plasma ion source and evaporators, and long term vacuum sample storage.In brief, I will demonstrate that defect-engineering of graphene [2] (and hBN) enables its substitutional heteroatom doping [3] and growth of nanoclusters, as well as the direct correlation of its atomic structure and mechanical properties. I will also show that the chemical environment inside a microscope plays an important role in observed structural changes [4]. I will further show that graphene can be used as a support for the growth metal islands [5,6]. Finally, I will provide examples of otherwise unstable structures being stabilized in the van der Waals gap between two graphene sheets, including small 2D noble gas clusters [7].

[1] Mangler et al., *Microsc. Microanal.* **28S1**, 2940 (2022).
[2] Trentino et al., *Nano Lett.* **21**, 5179 (2021).
[3] Trentino et al., *2D Mater.* **9**, 025011 (2022).
[4] Leuthner et al., *2D Mater.* **8**, 035023 (2021).
[5] Zagler et al., *2D Mater.* **7**, 045017 (2020).
[6] Zagler et al., *2D Mater.* **10**, 045025 (2023).
[7] Längle et al., *Nat. Mater.* 10.1038/s41563-023-01780-1 (2024).