2D materials by design: Xenes and anisotropic TMDs

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The debut of graphene paved the way to the exploration of an "expanding universe" of 2D materials that may serve as building blocks for a multifunctional nanotechnology or as a playground for an undiscovered physics. A new challenge for emerging (or yet to come) 2D materials is how to manipulate them by design. In this framework, making artificially adjustable 2D materials is an emerging route to reach a superior control of new functional properties. With this aim in mind, here I will give consideration to two distinct cases. On one hand are the epitaxial Xenes, as an emerging class of 2D monoelemental lattice beyond graphene; on the other hand is the artificial modification of MoS_2 nanosheets in strongly anisotropic structures.
By close analogy with graphene, epitaxial Xenes are comprised of single-element atoms arranged in a honeycomb lattice; unlike graphene, Xenes are epitaxially grown on substrates and exhibit a varying degree of buckling and/or puckering in the lattice structure [1], see Fig. 1. Examples in this respect are silicene, stanene, epitaxial phosphorene, and recently synthesized antimonene. Taking silicene as a case in point [2], I will show the route and challenges for Xenes to be integrated in nanoelectronic devices (e.g. the silicone field effect transistor) by briefly describing a universal approach to Xene processing, and give tips for exploiting specific Xenes such as silicene, as promising materials for nanophotonics and plasmonics [3].
On the other hand, I will show how to make use of chemical vapour deposition to pattern MoS_2 and other TMDs in strongly anisotropic nano- and meso-structures (see Fig. 2). The so-induced morphological anisotropy is reflected in the anisotropy of the physical characteristics, such as the phonon spectrum, intrinsic charge fluctuations, and the exciton dynamics. Implications on the band-gap and exciton engineering will be discussed, and the potential for applications envisioned [3].

References

[1] A. Molle, J. Goldberger, M. Houssa, Y. Xu, S.-C. Zhang, and D. Akinwande, Nature Mater. 16, 163 (2017).
[2] A. Molle et al, Chem. Soc. Rev. 47, 6370 (2018).
[3] C. Grazianetti, et al., Nano Lett. 18, 7124 (2018)
[4] C. Martella et al., Adv. Mater. 30, 1705615 (2018)

Figures

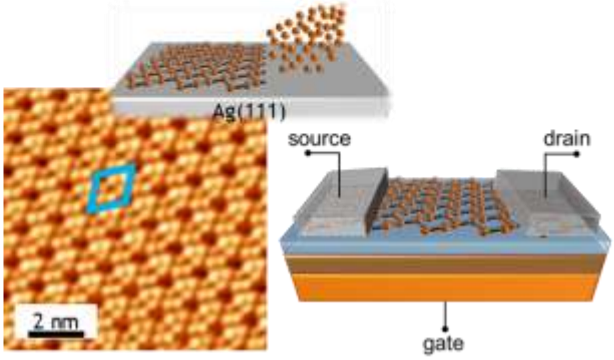

Figure 1: Atomic topography of silicene on Ag substrates and sketches of the growth and integration into a field effect transistor structure

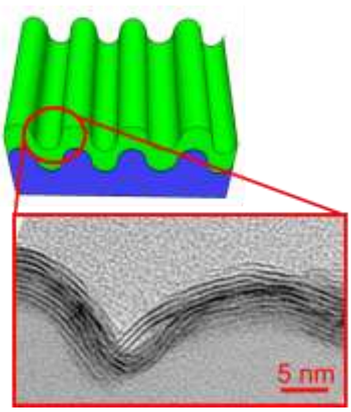

Figure 2: Sktech of nanopatterned MoS_2 nnaosheet and its atomic cross-section microscopy image.