Growth and nanoscale surface properties of two-dimensional nanocrystals synthesized by pulsed laser deposition

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Scanning Tunneling Microscopy (STM) and Spectroscopy (STS) have been proved to be valuable surface science techniques for the experimental investigation of graphene and non-carbon 2D materials, capable to provide fundamental atomic- and nanoscale information on the local structure and electronic properties, thus allowing to access the fundamental physics of few-layer-thick structures and address their potential for applications [1][2]. Traditionally, model systems for surface science investigations are mostly produced under ultra-high vacuum (UHV) conditions using well-established techniques, such as Molecular Beam Epitaxy. On the other hand, Pulsed Laser Deposition (PLD)—a versatile technique mostly used in applied sciences for the growth of a wide variety of functional films and nanostructures—has recently shown great potential for the growth of 2D crystals of different materials, providing good control of stoichiometry, thickness and crystal quality, with the additional capability to scale-up the lateral size of 2D films over the centimeter scale [3].

In this work, aiming to exploit the PLD potentialities and the unique characterization capability of STM/STS, we combine UHV PLD and *in situ* STM/STS to synthesize and study 2D nanocrystals of different materials supported by a model substrate. In particular, we focused on the growth of 2D zinc oxide (ZnO) [4]—which is expected to adopt a graphitic-like structure—and single-layer (SL) molybdenum disulphide (MoS_2) on Au(111). After proper tuning of PLD and post-annealing parameters, we achieved the synthesis of well-ordered ZnO and MoS_2 nanocrystals of surface quality comparable to that obtainable with more conventional techniques. This allowed us to acquire high resolution STM images, which clearly show the atomic lattices and the moiré patterns of single- and bi-layer ZnO and SL MoS_2 structures on Au(111) (fig. 1, 2), as well as intriguing features, such as the formation of in-plane junctions at the lateral interface between Au and MoS_2. Room-temperature STS measurements and differential conductivity maps allowed us to observe the semiconducting electronic character of 2D ZnO and MoS_2 and spatial variation of the local density of states. By simply controlling the number of laser pulses in the PLD process, we were also able to grow a large area SL MoS_2 film on Au(111), which we further characterized by *ex situ* Raman spectroscopy, revealing the main MoS_2 vibrational features and highlighting possible effects of strain and doping due to the interaction with the substrate. We are currently working on using our PLD-STM approach to investigate 2D ZnO/MoS_2 heterostructures, focusing on the possibility to study nanoscale model systems as well as large-area 2D films with potential applications.

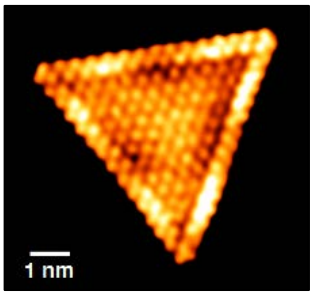

Figure 1: Atomic resolution STM image of a SL ZnO nanocrystal on Au(111) [4].

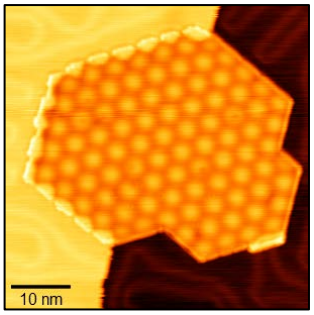

Figure 2: STM image of a SL MoS_2 nanocrystal on Au(111), showing the surface hexagonal moiré pattern and the formation of an in-plane heterojunction with Au.

References:
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