In situ growth and characterization of oxides and novel 2D materials on transition metal surfaces

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In the nearly six decades after its original invention and experimental realization in 1962, low-energy electron microscopy (LEEM) [1] has matured into a powerful and reliable experimental technique for structural characterization of crystalline surfaces. The inherent full-field imaging principle of LEEM provides unprecedented insights into the morphology of surfaces at nanometer resolution and video rates, enabling the monitoring of an ever-expanding variety of dynamical phenomena at surfaces, such as, e.g., thin-film growth and etching, structural phase transitions, and surface-chemical reactions. Owing to its intimate relation to (very)-low-energy electron diffraction ((V)LEED), both sample morphology and local atomic structure may be probed simultaneously, making it possible to assess surface structure across many different length scales [2]. This is also of considerable importance for the characterization of extended defect structures, whose occurrence may intimately be related to distinct parameters and conditions in the growth process.

In this presentation, I will focus on the growth and characterization of two different classes of materials systems, i.e., rare-earth oxides (REO) as well as two-dimensional (2D) materials deposited on transition metal surfaces. In both cases, the growth is performed within the microscope by reactive molecular beam epitaxy, and the evolution of the morphology and structure is followed in situ.

Among the REOs, ceria, praseodymia, and terbia may occur in two major oxidation states of the metal cation (+3 and +4), giving rise to a rich structural phase diagram and tunable materials properties. These characteristics make them very promising candidates for a wide range of technological applications including, e. g., energy harvesting, storage, and conversion, chemical sensing, and heterogeneous catalysis. In this context, epitaxially grown oxide thin films and nanostructures represent important model systems allowing for the investigation of their peculiar materials properties using surface science methodology [3]. Here, I will highlight the influence of the transition metal substrate on the resulting structure and morphology of the oxide film.

In the second part of the presentation, I will demonstrate the capabilities of LEEM in shedding light on the growth of 2D materials, focusing on single-layer graphene as well as single-layer transition metal dichalcogenides deposited on transition metal surfaces. These materials have recently attracted tremendous attention due to their fascinating physical and chemical properties, suggesting their use in, e.g., next-generation microelectronics and optoelectronics devices. Apart from their growth and structural characterization [4, 5], it will be also be shown that layer decoupling processes from the substrate, e.g., via intercalation, may also be followed in real-time, enabling a new level of understanding of the layer-substrate interaction.

References

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