

Exploring CO oxidation reaction on platinum by in-situ microscopy

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Carbon monoxide (CO) oxidation to carbon dioxide (CO₂) is a complex reaction with profound implications for both fundamental understanding and practical applications. The presence of CO and its related compounds poses a significant environmental challenge and has a direct impact on the development of alternative fuels. For example, excessive CO poisoning of platinum-based hydrogen fuel cells results in reduced catalyst efficiency and, ultimately, decay in their electro-generation performance [1]. Despite intensive investigations over the past decades, this principal reaction system is governed by unknown phenomena that have yet to be experimentally backed up.

Early efforts in spatially- and temporarily- resolved catalysis observations were focused on changes in the work function caused by absorbed species. Among the first pioneering techniques was scanning LEED (low energy electron diffraction) microscopy [2]. However, these early techniques were limited by their spatial resolution and the requirement of a flat surface, contrary to a real 3D catalyst. Fortunately, recent advancements in in-situ techniques [3] offer unprecedented opportunities to unravel the dynamic evolution of individual substances during catalytic operations and provide deeper insights into the underlying mechanisms. In this context, our research focuses on the application of advanced in-situ microspectroscopy techniques, including system dual-beam scanning electron microscopy (SEM), atomic force microscopy (AFM), and secondary ion mass spectrometry (SIMS).

We demonstrate that at relatively low pressures, the polycrystalline platinum surface comprises of alternating waves of platinum oxide and CO-covered platinum. This spatial- and temporal-dependent behavior results from adsorption and diffusion mechanisms of gas-phase and temperature-induced CO oxidation. The underlying factors influencing the catalytic activity include the crystallographic orientation of the surface and its possibility to reconstruct to different termination rearrangements, sticking coefficients, surface oxide formation, and other hypothesized aspects [4]. By integrating these complementary in-situ techniques, we aim to encompass both spatial aspects of the reaction, allowing us to track the evolution over time and observe the formation of intermediates and reaction products at the nanoscale. Our findings highlight the significant influence that external conditions (e.g., temperature, partial pressure) and surface modifications have on the catalytic reaction. By modifying the multifaceted platinum surface, we can confine the reaction to specific regions on a facet. Furthermore, using AFM within the SEM chamber allows us to correlate probe and electron imaging and study the influence of tip-sample interactions on the reaction. Additionally, we explore the impact of the selection of illuminating particles, specifically electrons or ions, on the dynamics and lifespan of the reaction. Apart from the detection of work function changes, we monitor chemical composition in reaction waves by time-of-flight mass spectrometry with high spatial resolution.

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