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Multimodal Operando Studies in Catalysis

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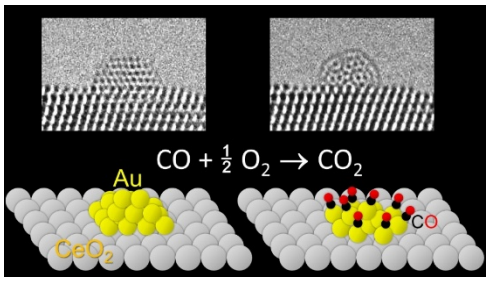
The development of more effective catalysts is a passionate topic at the forefront of modern science and engineering. Given that the surface of a solid catalyst is dynamic and highly dependent on the reaction environment, operando techniques are essential for identifying the nature of active sites. To establish a meaningful correlation between the architecture of active sites and their catalytic performance, it is critical to characterize both the surface and subsurface structures at the atomic level under working conditions.



The geometric and electronic properties of active sites dictate catalytic performance, and in many cases, these sites only form under specific reaction conditions, remaining unstable in air or vacuum. A wide range of operando techniques available at synchrotron facilities provides valuable insights into catalytic processes. Near-ambient pressure X-ray photoelectron spectroscopy (NAP-XPS), X-ray diffraction (XRD), and X-ray absorption spectroscopy (XAS) offer complementary perspectives on catalyst behavior. XRD is ideal for studying crystalline materials, XPS provides surface and subsurface sensitivity, and XAS enables the characterization of atomic environments in both crystalline and amorphous phases. Incorporating in situ transmission electron microscopy (TEM) into this powerful toolkit allows for a comprehensive understanding of catalytic phenomena. With these advanced characterization methods, it becomes possible to develop theoretical models that accurately describe the architecture and behavior of active catalytic sites. This knowledge paves the way for groundbreaking approaches in catalyst design and preparation, potentially revolutionizing the field.