Recent Developments in Environmental High-Resolution Transmission Electron Microscopy

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Transmission electron microscopy has proven to be a powerful tool to measure composition, chemistry and internal structure at the nanoscale and below. The two transformative developments in electron microscopy in the last two decades are (1) the emergence of aberration-corrected lenses that allow for unprecedented spatial and spectral resolution and (2) the rapid advances in *in situ* capabilities for observations of dynamic phenomena.

Recent and rapid developments of in situ transmission electron microscopy (TEM) has demonstrated it to be a transformative tool to gain unique dynamic processing/structure/property relationships of nanomaterials. Of particular interest are the structural changes occurring under "real" environmental conditions observable by environmental TEM (ETEM). The ETEM allows for dynamic studies for fundamental, atomic-level understanding of surface chemical reactions, such as oxidation and heterogeneous catalysis. In this presentation, I will focus on two cases of using ETEM to give fundamental insights into surface reactions: oxidation and heterogeneous catalysis. Using a ultra-high vacuum ETEM, we have demonstrated that the transient oxidation stage of Cu and its alloys bear a striking resemblance to heteroepitaxy, where the initial stages of growth are dominated by oxygen surface diffusion. The second part of my talk will focus on heterogeneous catalysis, which depends sensitively on the nano-sized 3-dimensional structural habits of nanoparticles (NPs) and their physicochemical structural sensitivity to the environment. To exemplify synergistic combination of experimental tools (X-ray absorption spectroscopy, ETEM) coupled with theoretical simulations, we have shown that Pt NPs may be both ordered and disordered, depending on its size, support and adsorbates. A statistical description of nanoparticles is more appropriate in understanding structure/property of nanoparticles and their surface reactions. I will also highlight recent technical developments in this field, outline the current status as well as future needs and directions of high-resolution characterization methods, including combining spectroscopy and microscopy by using a versatile enclosed environmental cell that is compatible with both TEM and synchrotron sources.