Studies of surface reaction mechanisms for renewable and sustainable energy applications

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Solid catalyst materials are a foundational component of energy-related technologies ranging from fossil fuel refining to production and utilization of renewable and sustainable energy alternatives. The advent of modern high-speed computing and advanced spectroscopic techniques has enabled recent advances in the detailed understanding of the surface reactions that occur on such catalysts, and this in turn has led to the increased ability to design new catalytic materials with improved properties. This series of lectures will introduce basic concepts in heterogeneous catalysis and the study of surface reactions. Important surface-catalyzed processes in traditional fuel refining will be discussed, as will more recent efforts to adapt catalysts for other applications. Common structures of industrially used heterogeneous catalysts will be presented, along with methods of characterizing those catalysts both as to their physical structure and catalytic behavior. We will highlight how model studies--often conducted under ultrahigh vacuum conditions over single-crystal surfaces—can be used to map out reaction pathways and structure-property relations in detail. The “pressure gap” and “materials gap” inherent in comparing such model studies to industrial catalysis, and efforts to bridge these gaps, will also be discussed.

The latter part of the lecture series will focus on modern research in catalysis for applications in renewable and sustainable energy. Catalysts play a vital role in numerous sustainable energy technologies, including biorefining of sugars, manufacture of fuel cells for power applications, and production of fuels using solar energy. The unique challenges associated with developing catalysts for biomass refining, and some possible strategies for developing improved catalysts, will be addressed. Recent advances in electrocatalysis for fuel cell applications will also be discussed, and the relationship of such catalysts to those proposed for use in solar fuel cells will be discussed. Finally, some recent investigations in photocatalysis and photoelectrocatalysis for solar-driven water splitting will be presented. A key focus of these lectures will be emphasizing the connections across these application areas, which are in many ways united by “universal” approaches for designing optimal catalysts.