Life and Fate of Energy Conversion Catalysts

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Climate change concerns have spurred a growing interest in developing environmentally friendly technologies for green energy generation and storage in the form of chemical bonds. The latter includes green H_2 production from water splitting and the re-utilization of CO_2 via its hydrogenation to methanol or electrocatalytic reduction into value-added chemicals and fuels. It is therefore of particular interest to develop low cost, efficient, selective and durable (electro)-catalysts that can operate under mild reaction conditions. Nonetheless, in order to tailor the chemical reactivity of catalysts, fundamental understanding of their structure and surface composition under reaction conditions must be obtained. It should also be kept in mind that even morphologically and chemically well-defined pre-catalysts will be susceptible to drastic modifications under operation, especially when the reaction conditions themselves change dynamically.

This talk will offer new insights into the thermal and electrocatalytic reduction of CO_2 as well as the oxygen evolution reaction in water splitting using model pre-catalysts ranging from single atoms, nanoparticles, thin films to single crystals. I will illustrate the need of a multi-technique *operando* microscopy and spectroscopy approach to gain understanding into the active state formation of complex catalytic materials. Moreover, examples will be given on the correlation between the dynamically evolving structure and composition of the catalysts under operando reaction conditions and their activity and selectivity.

These results are expected to open up new routes for the reutilization of CO_2 through its direct conversion into industrially valuable chemicals and fuels such as ethylene, methanol and ethanol and the generation of green H_2.