Operando Spectroscopy of Catalysts to Make Fuels and Chemicals from Carbon Dioxide

Bert Weckhuysen
Utrecht University, Utrecht, Netherlands

As we enter the era of catalytic activation of small molecules, such as CO_2, N_2 and H_2O, to realize the so-called refinery of the future one of the main questions to answer for scientists involve the coupling of carbon fragments, originating from CO_2, either produced at point sources, or harvested from direct air capture units. The overall goal is to manufacture increasingly complex (and thus value-added) carbon-containing molecules from CO_2 instead of making them from crude oil fractions. This requires a profound knowledge of the chemical processes taking place at the catalytic surface of both thermo- and electrocatalytic activation processes of CO_2, was well as of the subsequent chemical conversion processes in which carbon monoxide (Fischer-Tropsch synthesis), methane (via C-H activation to make e.g. olefins and aromatics) and methanol (methanol-to-hydrocarbons process) are used. This is the topic of this lecture, in which I discuss the latest progress in understanding CO_2 activation over nickel (thermocatalytic conversion) and copper (electrocatalytic conversion), as well as the subsequent conversion processes to make fuels and chemicals, including long-chain hydrocarbons, methanol and aromatics. Special emphasis is on the use of operando spectroscopy and microscopy methods to elucidate reaction and deactivation mechanisms.