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Catalysis Engineering for Sustainable Development

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Ensuring the long-term sustainability, reliability, and equality of the chemicals and energy sectors is a central global concern tightly connected to the environment and other societal factors, including quality of life, human health, and the economy. Spearheading the current revolution towards defossilized and circular chemicals manufacture, the vibrant discipline of catalysis is constantly refining its design principles, requiring an increasingly interdisciplinary and cross-scale mindset that covers from atom to planet. In this talk, I will discuss recent examples from my laboratory to illustrate how this intellectual growth in understanding catalyzed processes can kindle revolutionary technological advancements. Specifically, I will demonstrate the importance of precisely controlling the architecture and speciation of supported metals, revealing how even slight structural changes in low-nuclearity catalysts can switch on or off the desired performance. I will show how the precision enabled by the availability of increasingly powerful tools fosters catalyst discovery, presenting case studies in CO_2 valorization, polymer manufacture, and organic synthesis. These cases will also exemplify approaches for nanoscale engineering, with an emphasis on scalable and versatile methods. Throughout the talk, I will highlight current frontiers in the synthesis and characterization to improve catalyst design and the importance of quantitative metrics for guiding low-carbon strategies.