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Energy Transition

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Winner

Multifaceted Approach to Enable the Transformation of Energy Systems

Research Description

The transformation of energy systems from fossil-based towards a sustainable basis with large admixtures of renewable energy is a global trend. Unfortunately renewable electricity is no drop-in solution for fossil power and half of the energy system is not electrical. In order to give renewable electricity a more than marginal share in an energy system we need to convert electricity into solar fuels. This conversion is needed to compensate the volatility of renewable electricity by chemical energy conversion (CEC). Catalysis is the central enabling science and technology. The scale at which we will have to perform CEC exceeding the dimension of the global chemical industry by an order of magnitude and the fact that we need to activate very stable molecules such as water, nitrogen, oxygen and CO_2 require most effective chemical processes with large amounts of stable and abundant catalysts.
The traditional methods of catalyst development are empirical and combinatorial. These methods have not delivered solutions for CEC when it is executed beyond the current exploratory stages. We thus need to base catalysis technology upon a quantitative descriptive and predictive science. This long desire is an intricate endeavor due to the multi-scale nature of chemical transformations. The understanding reached of elementary step processes in theory and experiment is not in parallel to the materials science of catalysts from the nanoscale up to the macro scale. The integrated research approach of the laureate aims at a generic methodology to develop the material science of heterogeneous catalysts. The core approach is to recognize that both, synthesis and operation of catalysts are kinetic phenomena that depend on their environments. The reactivity of catalysts and of reactants is intertwined and in the limit of high performance cannot be separated from each other. Hence it is essential to control environments both during making and using of catalysts. For that we need to watch the working systems without disturbing the environment. Within the ecosystem of the Max-Planck Society the laureate and his team successfully developed and applied a suite of "in-situ" techniques allowing watching catalysts at work for a variety of CEC processes.
The immediate use of these results helps the technical design of catalyst for electrochemical water splitting and for the hydrogenation of CO_2 to methanol, a platform molecule in CEC. The laureate holds a number of patents in the area and has initiated several large interdisciplinary research projects documenting his efforts in transferring the results of fundamental science into technical practice. One actual application area of the combination of the two research fields is the synthesis of so called e-fuels replacing fossil Diesel with the double use of eliminating particulate emission and greatly reducing NOx emission at the car and bringing renewable energy as green hydrogen into the transportation sector without changing the infrastructure of mobility. This concept can be extended to electrical drives with on-board fuel processors (plug in hybrid).
In the long run the integrating function of CEC in sustainable energy systems will pose more demanding challenges that require optimized catalytic processes foremost in providing sufficient green hydrogen, in processing biomass, in activating small alkane

molecules and in closing material cycles as general task in sustainable systems. The generic nature of the multifaceted operando methodology developed by the laureate holds great promise as science innovation to development strategies for catalysts enabling through CEC the deep transformation of energy systems.