Avila 2006

Why is nanostructuring essential for catalysis

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Abstract

Heterogeneous catalysts modify the rate of a chemical reaction by changing the activation barrier for at least one critical elementary step. This kinetic operation requires catalysts to be reactive themselves. The main difference to other reactive materials is their cyclic operation returning them after having performed a turnover of reactions in their initial state of geometric and electronic structure. This property is referred to as “dynamical”.

Solid surfaces can behave dynamical most easily when they are not in a highly ordered state in order to minimize collective activations of the geometric structure. Collective excitation of the electronic structure would lead easily to over-reaction and hence preclude selective reactions (concept of site isolation). These requirements call for a hierarchical structure of a working catalyst in which a stable matrix contains adaptive sites as clusters which change their properties according to the chemical potential of the gas phase to accommodate for adsorption of reactants and desorption of products. The relevance of nanostructuring is by no means a better utilization of an active component as often read in the literature but is the core functionality of all catalytic materials.

It is obvious that the design of such a structure is extremely demanding and has not been achieved in a way that is significant for application. It is merely the art of manufacture of technical catalysts that incorporates suitable dimensions of nanostructure even when the material is a bulk solid. Some insight into the still very rudimentary methods of structuring complex materials will be given.