Priority Programme

“Material Synthesis near Room Temperature”

Project Description – Project Proposal

Reducible oxide materials: knowledge-driven design of novel low-temperature synthesis routes

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Summary of proposal

The low-temperature synthesis of reducible oxide nanomaterials in ionic liquids (ILs) holds the potential to make novel materials with tailor-made structure and composition available. However, the knowledge-based design of new synthesis routes requires an in-depth understanding of the interfacial chemistry that controls particle nucleation and growth. The project aims at providing this knowledge and at applying it for synthesis in an integrated approach that combines fundamental interface science, in-situ spectroscopy and the preparation of real materials. Our strategy is based on the complementary expertise of the Wasserscheid Group with its know-how in synthetic bench chemistry with IL-related materials and of the Libuda Group bringing in its capabilities in surface science and in-situ spectroscopy. In addition, the project will benefit from intense cooperation within the SPP 1708.
Based on the methodic developments of the first funding period, the project for the second funding period aims in particular at the synthesis of cobalt oxide nanoparticles, materials that offer great potential to replace noble metals in catalysis and energy technology. We will

target the formation of nanomaterials with well-defined composition, shape and structure at near-room-temperature conditions. Nanomaterials will be formed from molecular precursors in imidazolium- and pyrrolidinium-based ILs using unconventional oxidizing agents such as ozone. We will combine fundamental studies of the IL/oxide interfacial chemistry with in-situ spectroscopy during synthesis of real materials. Thereby, we will explore the interactions between the ILs, molecular Co precursors and the oxidizing agent ozone, identify reaction mechanisms and intermediates, extract kinetic data using time-resolved in-situ spectroscopies and investigate practical aspects of synthesis such as optimized solubility properties. Investigating the structure dependence of IL adsorption, interaction and reaction at well-defined cobalt oxide interfaces, we will explore the origin of structure-directing effects. Based on these results, we aim to tune oxide-IL interactions by employing the structural diversity of ILs, e.g. by varying anions, cations, substitution and functionalization. Finally, we will correlate the mechanistic, spectroscopic and kinetic data to the properties of the nanomaterials obtained. This will also include strategies to remove contaminations and introduce dopants during synthesis, for instance by oxidative transformation of ILs into volatile products. Following this strategy, we expect to obtain fundamental insights into the factors that determine key properties such as particle shape, structure, size, and composition, which, eventually, will help to unleash the full potential of low-temperature synthesis of oxide nanoparticle in ILs.