Synthesis of Intermetallic Nanoparticles by the Vapour-Solid Approach and their Application in Hydrogen Generation

Daniel Garstenauer, University of Vienna

Hydrogen plays a vital role in future energy scenarios. Yet, the production and storage of hydrogen remains challenging. In the year 2021 less then 0.7% of the global hydrogen production were carried out in sustainable processes. Potential green alternative production pathways include water electrolysis from excess electricity or sustainable electricity from wind and solar power plants as well as steam reforming of renewables. As practical storage and transport option, hydrogen can be stored chemically in small molecules like methanol.
Storing Hydrogen as methanol brings several benefits. Methanol is liquid and therefore more easy to handle compared to gasseous hydrogen. The absence of a carbon-carbon bond allows reformation at rather mild conditions. Methanol is biodegradeable and can be produced from a wide range of conventional and renewable feedstocks. Hence, methanol is one of the most abundant and easy to handle hydrogen carrier fuels.

The release and production of hydrogen is dependent on catalytic processes. Therefore, finding, optimizing and developing new catalyst materials is of mayor interest in latest research.

Intermetallic nanoparticles possess unique chemical and physical properties, which make them particularly interesting for catalytic applications. The adjustability of intermetallic materials promises high potential in a variety of heterogeneous catalysed reactions.
State of the art synthesis approaches often lack flexibility and precise composition control while significantly expand particle size distributions, hindering the broad application of intermetallic nanoparticles in catalysis.

A very promising alternative method of preparation is the direct vapour-solid synthesis of intermetallic nanoparticles by interaction of a metal with high vapour pressure in the gaseous phase with solid metal nanoparticles. In principle, the reaction is driven through the equilibration of a solid component with the vapour of a volatile element. The thermodynamic activity, vapour pressure and thus the product composition are controlled by the reaction temperatures in a temperature gradient.

In a present approach we performed the vapour-solid method to prepare a variety of catalyst materials in the systems Pd-Zn, Ni-Zn, Ni-Te. The catalysts where investigated by scanning transmission electron microscopy, powder X-Ray diffraction, gasadsorption and total X-Ray flourescence spectroscopy. Selected samples where further investigated regarding their catalytic performance in methanol steam reforming and electrocatalytic water-splitting. The results indicate beneficial behaviour of the intermetallic materials compared to their metallic benchmark catalysts.