Molecular and Nanoscale Catalysts for Hydrogen-Storage (MaNCatal-H2)

Dr. Martin Prechtl

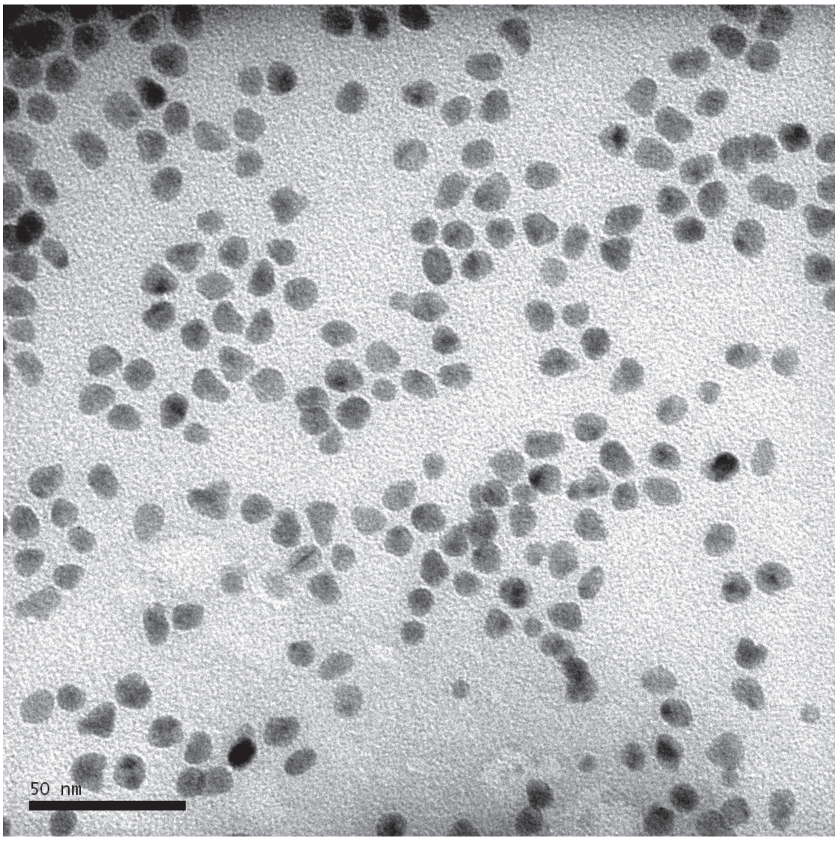

Fig. 1: TEM image of mono-dispersed Pd(0) nanoparticles in IL (scale 50 nm; 500k magnification at 120 kV)

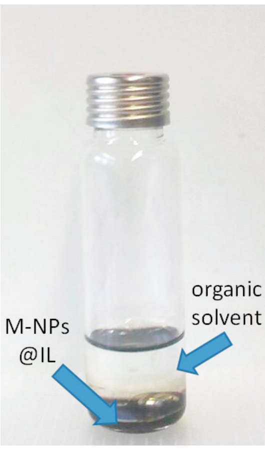

Fig. 2: Mono-dispersed nanoscale metal(0) catalyst (ca 7 nm) immobilized in ionic liquids (IL) in a biphasic system with an organic solvent.

In recent years, an increasing demand for catalytic transformation of renewable raw materials has been recognised. Such raw materials are available in large amounts as energy sources and substrates for the production of bulk and fine chemicals. The investigation of possible renewable energy sources /storage such as vegetable oils, biomass or CO_2 is a great challenge for the scientific community, especially for sustainable technologies. The technical approaches for organic synthesis and energy research involve molecular metal complexes for homogeneous catalysis and nanoscale materials in heterogeneous catalysis for the conversion of biomass. Large amounts of "bio"-alcohols are readily available from renewable sources, such as sugar cane (Brazil), corn (USA, Mexico), cellulose (Canada, Scandinavia, USA) or plant oils for the "bio"-diesel production derived soy bean oil (Brazil), or rape seed oil (Germany). "Bio"-alcohols are used as combustion fuels, producing simply water and CO_2, here "bio"-alcohols are described as CO_2-neutral. However, the agriculture uses fertilisers and agrotoxics, which both influence the neutrality of the CO_2-cycle.

Materials

As an innovative alternative for the current use of "bio"-alcohol as combustion fuels, the project MaNCatal-H2 focuses on biomass-based molecules for H_2-storage. Those taylor-made hydrogen storage materials are complement for "bio"-fuels. Attractive molecules for hydrogen storage are for example methanol, ethanol or formic acid. All these molecules have in common a light molecular weight, relatively high hydrogen storage capacity and low costs. Such materials and others can be derived from biomass. Moreover, these materials might be also suitable to reduce the world-wide CO_2 emission by simple use for emission-free H_2-storage and not combustion to CO_2. Furthermore, the efficiency factor of common combustion engines is not higher than 30%, and this can be optimized by H_2-based systems. The drawbacks of current H_2-storage systems are high costs, short life-time, high weight, low capacity, temperature and safety aspects (flammability, explosion hazard, cryogenic techniques).

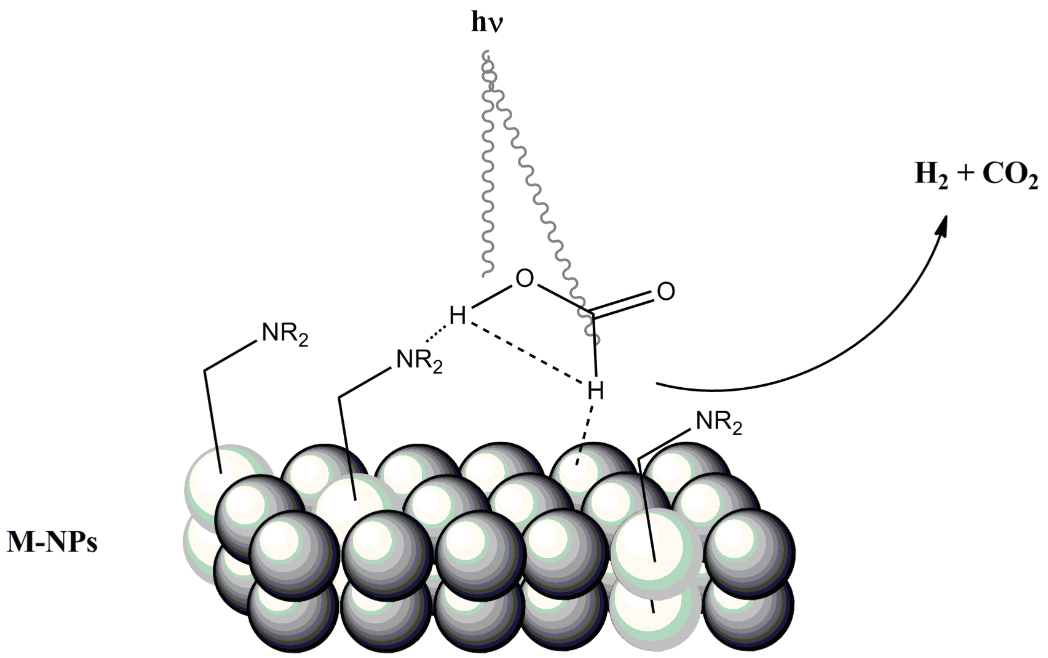

Fig. 3: Nanoscale hybride catalysts for H_2-generation under visible light.

Catalysis

For more effective H_2-storage we want to develop new nanoscale and molecular metal hydrides catalysts with pincer ligands which are highly active for dehydrogenation (H_2-generation) and hydrogenation (H_2-storage). Moreover, it is important to develop new catalytic systems to close the energy gap with innovative H_2-storage due to the limited fossil sources which is substantial for a more sustainable synthetic chemistry. The chemical and pharmaceutical industry strongly depends on molecular building blocks derived from fossil petroleum. And, this gap of natural resources must be compensated with synthetic building blocks derived from renewable resources through novel technologies.

Outlook

In summary, we develop molecular and nanoscale catalyst systems for sustainable and environmental benign chemistry with a focus on hydrogenation and dehydrogenation processes for H_2-storage and synthetic tools. Especially for the synthesis of novel H_2-storage materials and for further development in the field of activation of small molecules to make them feasible for 21st century H_2-storage materials. As tools for these applications we will develop new cooperative ligands and nanoscale hybride catalysts. Our studies include mechanistic aspects of catalytic processes for more in-depth understanding to develop taylor-made catalysts. All synthetic aspects focus on the development of sustainable methods with high atom economy and selectivity to avoid waste and by-products.

References

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Martin Prechtl studied chemistry (99-04) in Wuppertal and São Paulo (Brazil). After research at the Max-Planck-Institute for Coal Research, he obtained his Ph.D. from RWTH Aachen in 2007. As Humboldtian he performed research in Porto Alegre (BR) and in Berlin (07-10). He received the Scientist Returnee Award 2009 (MIWF-NRW; W2) and accepted a call to Cologne as independent group leader in 2010. His main interest is catalysis and hydrogen storage.