Contribution ID: **35** Type: **Oral presentation**

Advances in Hydrogen Production and Storage

Tuesday 4 November 2014 13:15 (30 minutes)

The storage of renewable energy is the greatest challange for the transition from the fossil aera to a sustainable future energy economy. Hydrogen produced from renewable energy leads to a closed cycle, because the water relesed from the combustion condenses in the atmosphere. The challange in the large scale application of H2 is the storage with a high gravimetric and volumetric density. based on todays knowledge a hydrogen storage is limited to about 20 mass% and 70 kg/m3. Moreover the afforable and sustainable production of hydrogen using renewable energy faces challenges in off-grid and small-scale (distributed) application. The work package "Hydrogen Production and Storage" of the SCCER "Heat & Electricity Storage" focuses on the following topics:
1) Hydrogen production by chemical discharge of a reversible flow battery (RFB) [1]
Conventional RFBs are charged and discharged electrochemically, with electricity stored as chemical energy in the electrolytes. In the RFB system reported here, the electrolytes are conventionally charged but are then chemically discharged over catalytic beds in separate external circuits. The catalytic reaction of particular interest generates H2. Indirect water electrolysis was performed generating hydrogen and oxygen in separated catalytic reactions. The electrolyte containing V(II) was chemically discharged through proton reduction to H2 on a molybdenum carbide catalyst, whereas the electrolyte comprising Ce(IV) was similarly discharged in the oxidation of H2O to O2 on a RuO2 catalyst. This approach is designed to complement electrochemical energy storage and may circumvent the low energy density of RFBs especially as hydrogen can be produced continuously whilst the RFB is charging.
2) Sustainable Electrocatalysts for Hydrogen production using renewable energy [2]
A challenge in the production of Hydrogen from renewable energy using water electolysis at low current density (ca. 10 mA cm−2 is the identification of inexpensive and scaleable catalysts materials to reduce the overpotential required to drive the water oxidation and reduction reactions. While Platinium is traditionally used for the water rediction half-reaction, it is not scalable to the terawatt range necessary. Abundant transition metal compunds (e.g. MoS2) have been identified as promising replacments for Pt in this appication. We have recently developed a novel way to solution process natural (bulk) MoS2 into thin film electrodes. [2] Subsequently we have demonstrated that these electodes have high activity for water reduction at low overpotential (0.2 V at 10 mA cm−2) even with only a few atomic layers of (solution-processed) MoS2.
3) Hydrogen storage in hydrides [3]
Bogdanovic [4] presented at MH1996 the Ti-catalyzed hydrogen sorption in NaAlH4. The mechanism of the catalysis remains unclear despite the large number of proposed models. We developed an atomistic model, where the catalyst acts as a bridge to transfer the Na+ and H- from AlH4- to AlH63- and finally to form NaH based on thermodynamic considerations. The proposed mechanism is symmetric and the catalyst is active on the intermediates NaH and AlH3 for the hydrogen de- and absorption.
4) Hydrogen storage in formic acid [5]
Hydrogen as an energy vector could be a solution for transport/mobile applications, based on its high energy content and the high efficiency with which its chemical energy can be transformed into electricity in state-of-the-art fuel cells. Classical hydrogen storage methods suffer from weight, cost and safety issues. Chemical hydrogen storage has found considerable attention and formic acid is among the most promising compounds to achieve it. Formic acid has a high volumetric hydrogen content, favorable physical properties and is simple to use, ideal for both mobile and stationary applications. Also, a hydrogen/energy storage-and-release cycle based on formic acid decomposition and carbon dioxide hydrogenation can be envisioned that could solve the inflexibility of decentralized power generation.

References

[1] V. Amstutz, K. E. Toghill, F. Powlesland, H. Vrubel, C. Comninellis, X. Hu and H. H. Girault, "Renewable

hydrogen generation from a dual-circuit redox flow battery", Energy & Environmental Science 7 (2014), p. 2350 - 2358.
[2] X. Yu, M. S. Prévot, K. Sivula, "Multiflake Thin Film Electronic Devices of Solution Processed 2D MoS2 Enabled by Sonopolymer Assisted Exfoliation and Surface Modification"Chem. Mater. (2014), ASAP doi: 10.1021/cm502378g.
[3] Z. Ö. Kocabas Atakli, E. Callini, S. Kato, A. Züttel, "Catalyzed H Sorption Mechanism in Alanates", to be submitted to J. Alloys and Compounds (2014).
[4] B. Bogdanovic, M. Schwickardi, "Ti-doped alkali metal aluminium hydrides as potential novel reversible hydrogen storage materials", J. of Alloys and Compounds 253, 1-9 (1997). and B. Bogdanovic et al., J. Alloys and Comp. 302 (2000), pp. 36 - 58
[5] S. Moret, P. J. Dyson, G. Laurenczy, "Direct Synthesis of Formic Acid from Carbon Dioxide by Hydrogenation in Acidic Media", Nature Communications 5 (2014), 4017

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Session Classification: Hydrogen Production and Storage