Neutron insights into nickel metal hydride batteries

Marin Nikolic,[a,b] Alessia Cesarini,[a,c] Pavel Trtik,[d] Andreas Borgschulte*[a]

[a] Laboratory for Advanced Analytical Technologies, Empa - Swiss Federal Laboratories for Material Science and Technology, Überlandstrasse 129, CH-8600 Dübendorf, Switzerland

[b] Department of Chemistry, University of Zürich, Winterthurerstrasse 190, CH-8057 Zürich, Switzerland

[c] Institute for Chemical and Bioengineering, Department of Chemistry and Applied Biosciences, ETH Zürich, Vladimir-Prelog-Weg 1-5/10, CH-8093 Zürich, Switzerland

[d] Laboratory for Neutron Scattering and Imaging, Paul-Scherrer-Institute, Forschungsstrasse 111, CH-5232 Villigen, Switzerland

The transition to renewable energy sources relies on seasonal energy. Nickel metal hydride (Ni-MH) batteries, invented at the end of the last century, are established batteries without the use of precious and highly hazardous materials [1]. Despite great advantages such as high power-density and easy scale-up, NiMH battery are currently no option as seasonal storage because of various side reactions leading to great efficiency losses such as self-discharge. The latter stems from the unavoidable hydrogen background pressure of the hydride used. Furthermore, hydrogen/oxygen generation occurs during overcharging or over-discharging. For safety, a vent is installed into the battery to release the excess gas. However, the efficiency loss remains [2].

To minimize these effects, it is beneficial to know the dependence of the external parameters on the hydrogen evolution. It is important to study this on the systems and not on the materials level, because the hydrogen pressure depends on the dead volume and (catalytically active) surfaces present in the battery. We performed neutron imaging and tomography while monitoring the SoC of the battery under operating conditions to observe the reaction processes in the battery. The measurements reveal the hydrogenation states of the electrodes as well as the hydrogen back pressure in the battery in real time as a function of applied potential and current. One of the most contradictory observations is that over-discharge, i.e., the generation of hydrogen gas during discharge, depends on the charging state of the battery as well as current extracted.

References

[1] G. Bronoel, et al., *Int. J. Hydrogen Energy* **1976**, *1*, 251–254

[2] P.H.L. Notten, et al., *Chem. Ind.*, **2000**, *54 (3)*, 102-115
W. Chen, et al, *PNAS*, **2018**, *115 (46)*, 11694-11699