BOR4STORE – DEVELOPMENT OF A BORON HYDRIDE BASED INTEGRATED SOFC – METAL HYDRIDE TANK SYSTEM

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General

- **Project funded by the European "Fuel Cells and Hydrogen Joint Undertaking"**

→ Total Budget 4.07 Mio.€, total funding 2.3 Mio. €.

→ Runtime April 2012 to September 2015

→ Development and testing of of a boron hydride based hydrogen store (materials capacity more than 8 wt.% and 80 kg H_2/m^3) integrated with a Solid Oxide Fuel Cell (SOFC)

Basic Design Considerations

- **Heat source for hydrogen release: SOFC exhaust gas**
- **Continuous operation. Start-up of SOFC ⇒ electrical heating of input air flow**

→ SOFC max. power 1.3 kW_e, η ca. 40%

→ max. H_2 supply flow ca. 20 Nl/min, air supply flow ca. 200 Nl/min (SOFC cooling!)

→ thermal power ca. 2.2 kW

→ Off-gas heat ca. 950°C after afterburner, max. ca. 200 Nl/min

- **Selected storage material: Li based Reactive Hydride Composite plus Additive**

→ dehydrogenated: 2LiH + MgB_2 plus ca. 0.02 mol of Ti based Additive ⇒ milling

→ hydrogenation ⇒ $2LiBH_4$ + MgH_2 plus $xTiB_2$ (additive converts to diboride upon cycling)

→ hydrogen release temperature of Li-RHC > ca. 250°C, better kinetics >400°C

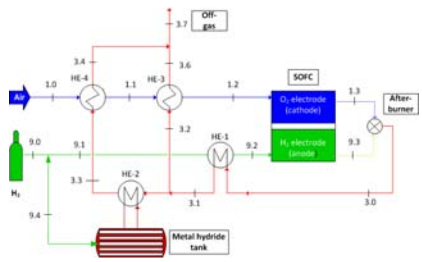
→ Dehydrogenation enthalpy ca. 32 – 45 kJ/(mol H_2)@20 Nl/min ⇒ max. ca. 0,6 kW

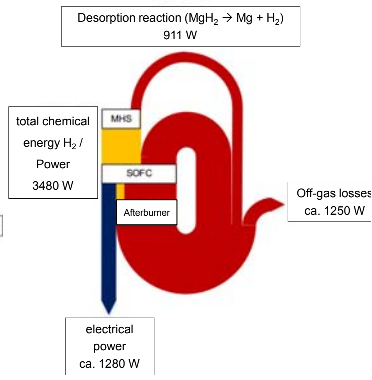
- **Tank design**

→ tubular with outer hull, containing heat transfer medium

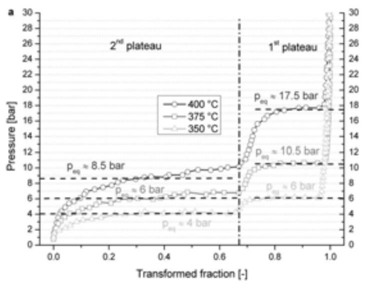
→ ca. 10 kg Li-RHC ⇒ capacity ca. 1 kg (ca. 11,000 Nl) H_2

Pinch Analysis of heat flows in integrated SOFC – MH store





Sankey diagram of heat flows in integrated system at first desorption step (MgH_2 → Mg + H_2). MHS: metal hydride store



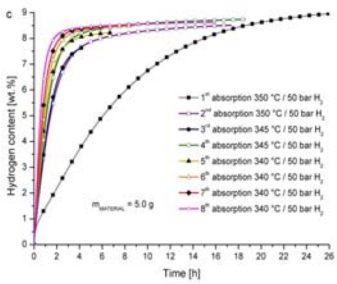
Pcl measurements of Li-RHC.

→ 1st desorption step MgH_2 → Mg + H_2: ΔH = 75 kJ/(mol H_2)

→ 2nd step $2LiBH_4$ + Mg → 2LiH + MgB_2 + $3H_2$: ΔH = 52.6 kJ/(3mol H_2)

→ Averaged ΔH = 32 kJ/(mol H_2).

[J. Jepsen, et al.; „Fundamental thermodynamic and kinetic properties of the Li-RHC system for hydrogen storage", submitted]



Improvement of hydrogen loading kinetics during cycling of Li-RHC from laboratory synthesis (Fritsch P5)

[J. Jepsen, unpublished results]

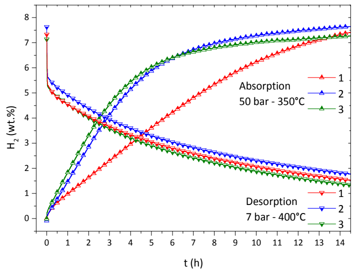
Test batch processing of the Li-RHC in a ZOZ C01 mill

→ 2 kg of grinding medium

→ Ball-to-powder ratio 13:1: 150 g of LiH – MgB_2 mixture

→ max. milling time 4 hours

→ Estimated processing cost in large scale industrial production: ca. 1 Euro/kg

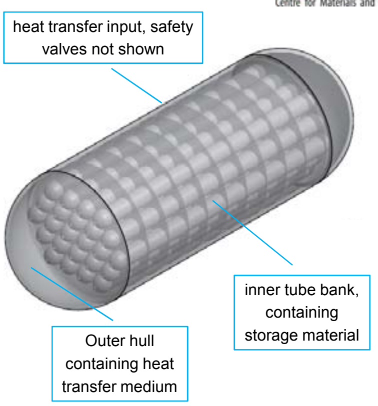


Improvement of hydrogen loading kinetics during cycling of a $2LiBH_4$-MgH_2 Reactive Hydride Composite from industrial mill (ZOZ CM08, 8l vial)

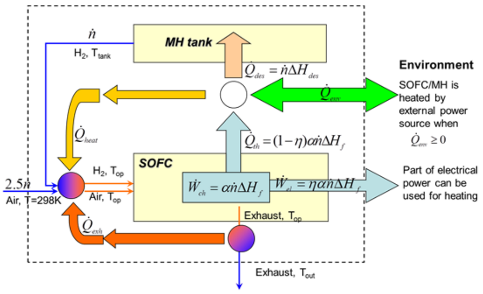
[G. Capurso, D. Yigit, N. Gupta, unpublished results]

Analysis of heat transfer

Design Draft of Tank



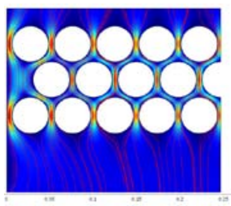
Energy balance for integrated SOFC/MH system



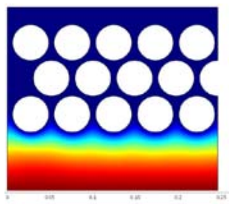
A. Yiotis et al., Journal of Power Sources 269, 440-450 (2014)

Poster: Georgia Charalambopoulou: Thermal Coupling Potential Of SOFCs with Metal Hydride Storage Tanks

Thermal Coupling w. Flow of Heat Transfer Medium@627°C (900K)



Flow Field @ u=0.03m/s



Temperature distribution

Flow field simulation shows homogeneous temperature distribution around tube bank in case of parallel input flow

Summary and Outlook

Solid state hydrogen storage prototype system based on boron hydrides

→ Target: system capacity > 40 kg H_2/m^3 , > 4 wt.% with priority on volumetric cap.

⇒ minimum requirement > 80 kg H2/m3, > 8 wt.% on materials level

→ Currently, from ALL B based storage materials, ONLY Li-RHC fulfils requirements on

→ capacity: > 8 wt.%, > 80 kg H_2/m^3 (depending on compaction)

→ loading time: ≤ 1h

→ cycling stability: pellets Δ < 7%/1000 cycles (extrapolated from ca. 20 cycles)

→ COST!: ca. 7,500 €/kg stored H_2 for storage material alone (target 500 €/kg H_2) not regarding tank and heat exchanger construction!

⇒ Well-to-tank Analysis (CAPEX + OPEX) including compression, maintenance, ….

Pinch analysis and numerical simulation of heat transfer show

→ feasibility of thermal integration, using off heat from SOFC exhaust gas alone via inert heat transfer medium

→ degree of H_2 utilisation, afterburner, heat transfer medium, tank hull materials, …

→ 1st desorption step MgH_2 → Mg + H_2: high ΔH (ca. 75 kJ/(mol H_2)) ☹

→ 2nd desorption step $2LiBH_4$ + Mg → 2LiH + MgB_2 + $6H_2$: ΔH ≤ 46 kJ/(mol H_2)) ☺!

→ Question: whole tank going through these steps consecutively, or in parallel in different regions of the tank?

→ Construction of single module test tank in progress

Potential Applications: low pressure hydrogen storage in conjunction with SOEC or H_2 supplied SOFC: energy storage, continuous power supplies (telecommunication, ..)

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