Thermochemical Energy Storage – Chemical Reactions

Storage Principles

Thermochemical energy storage (TCS) with chemical reactions is one of the most promising storage technologies of the future. The principle of TCS is a reversible gas-solid reaction consisting of two reactants. There are two basic driving forces for the reaction: a) a supply or release of thermal energy and b) an increase or decrease in the availability of the reactants.

While some reactions offer extremely high storage densities, the main characteristics of TCS systems are that the storage period is free of losses and the heat release is controllable with respect to time, temperature and power level. Furthermore, as the reaction temperature of equilibrium reactions is a function of the gas pressure, the reaction temperature is adjustable. This has major implications that allow not only thermal energy storages to be realized, but also heat pumps, heat transformers and combinations of both [1].

$$AB(s) + \Delta H \underset{\text{exothermic}}{\overset{\text{endothermic}}{\rightleftarrows}} A(s) + B(g)$$

Figure 3. Generalized reversible gas-solid reaction mechanism.

Figure 4. 100 kWh pilot plant for TCS with quicklime (DLR).

Technical Characteristics

Typical Power (MW): application-specific

Feasible size (MWh):

Energy density (kWh/m³): 100 – 400 [2]

Response time (min.): <1 [3]

Temperature range (°C): application dependent.

Efficiency (%): very high, reversible reactions can proceed almost loss-free

Maturity

Installed worldwide (GW): N/A

Installation costs (€/kWh): N/A

Technology readiness level: 2 – 3

Challenges in development

- Need for focus on application-oriented rather than just material aspects
- Integration of gaseous reactants
- Scaling from prototypes to application-relevant sizes
- Development of new materials with tunable reaction temperatures

Potential of technology

- Switchable and controllable release of thermal energy
- Adjustable reaction temperature
- Low-cost and widely available materials
- Long-term, loss-free storage that can be used seasonally

Barriers

- Low technology readiness level for all types of technology
- Available reaction temperatures are limited
- Complex reactor design

Common Applications

- Solar thermal power plants
- Industrial process heat (heat transformation)
- Building engineering
- Automotive thermal management
- Seasonal storage and peak-shifting
- Industrial waste heat
- Buffer storage in district heating
- Domestic heating, cooling and hot water

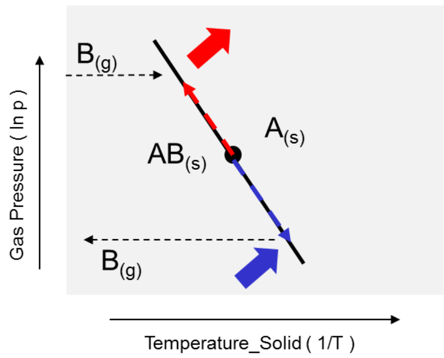

Figure 3. Reversible gas-solid reactions allow the temperature to be a function of the gas pressure.

Example Applications

1. Concentrating solar power

Thermochemical energy storages integrated in solar thermal power plants provide an improved plant capacity factor, reduced levelized cost of electricity, dispatchable power and improved energy efficiency. Quicklime a.k.a calcium hydroxide, a low-cost material widely available, can use solar heat to undergo reversible hydration reactions (with water vapour) that store the thermal energy [4].

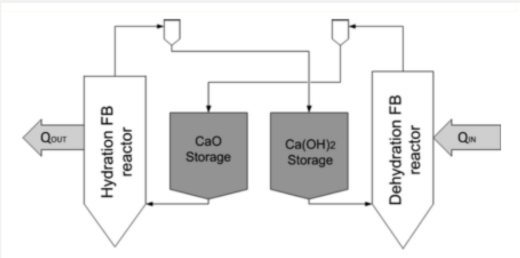

Figure 4. Basic storage system scheme [5].

2. Heat transformation in industrial processes

Heat transformation permits the storing of normally un-used waste heat at low temperatures and release at higher temperatures, with possible output temperature of over 140°C. Although similar in principle to a heat pump, a heat transformer does not require a high-grade energy source (i.e. electricity) – it is driven by low-temperature waste heat [6].

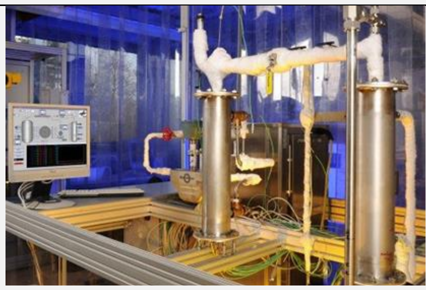

Figure 5. Test stand for thermal upgrade of waste heat at T>140 °C (DLR).

3. Thermal management in automobiles

When used with hydrogen, metal hydrides (MeH) have high power densities and fast reaction times that indicate potential for applications in automobiles. In winter, MeH devices can be used to preheat vehicle components to decrease pollutants in ICEs or improve the lifespan of fuel cells [7]. In summer, MeH devices provide cold for air conditioning that improves vehicle range [8].

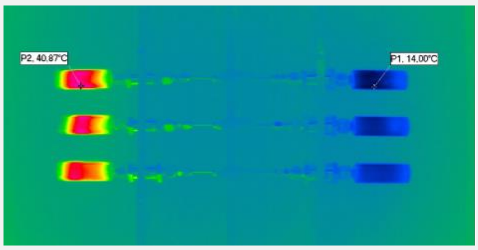

Figure 6. Experimental system with MeH.

References

1. M. Linder, (2015).
2. EASE/EERA, (2017).
3. VDI, (2017).
4. M. Schmidt, et al., (2014).
5. Y. Criado et al., (2017).
6. M. Richter et al., (2016).
7. M. Dieterich et al., (2017).
8. C. Weckerle et al., (2017).

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