Thermochemical Energy Storage Materials for Waste Heat Recycling or in Combination with Concentrated Solar Power Plants

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Introduction

Thermochemical energy storage (TCES) features long-term storage, a wide range of compatible temperatures, applicability as a heat pump system and finally, high energy storage densities. Based on these aspects, medium-temperature waste heat (up to 450 °C and extensively available from industrial processes) is perfectly suitable for TCES-systems. An attractive TCES-material for medium-temperature applications is the system $Mg(OH)_2$ / MgO with a storage temperature around 350 °C. Both $Mg(OH)_2$ and MgO are industrial base materials and are therefore available in large quantities at low prices.

Experimental

MgO obtained by calcination of $Mg(OH)_2$, $MgCO_3$ and $MgC_2O_4 \cdot 2H_2O$ was compared regarding its rehydration reactivity and cycle stability to assess its applicability in thermochemical energy storage. The three different MgO-precursors led to three MgO samples featuring different particle morphologies with identical chemical compositions. Whereas $Mg(OH)_2$- and $MgC_2O_4 \cdot 2H_2O$ resulted in reactive MgO that could be rehydrated by water vapour to $Mg(OH)_2$ directly following calcination, material originating from $MgCO_3$ resulted in no conversion on contact with water vapour. Only after rehydration in liquid water and subsequent calcination of the thus formed $Mg(OH)_2$, 84 % of the resulting material could be rehydrated by water vapour. All materials investigated showed decreased rehydration reactivity during consecutive calcination / rehydration cycles, with $MgCO_3$ derived MgO showing the smallest decline in reactivity. A regeneration step, consisting of rehydration of the spent material in liquid water over 24 h, restored the initial reactivity allowing for recycling of the material. In the case of $Mg(OH)_2$ derived material, the initial reactivity could even be improved by repeated regeneration of the material in liquid water.

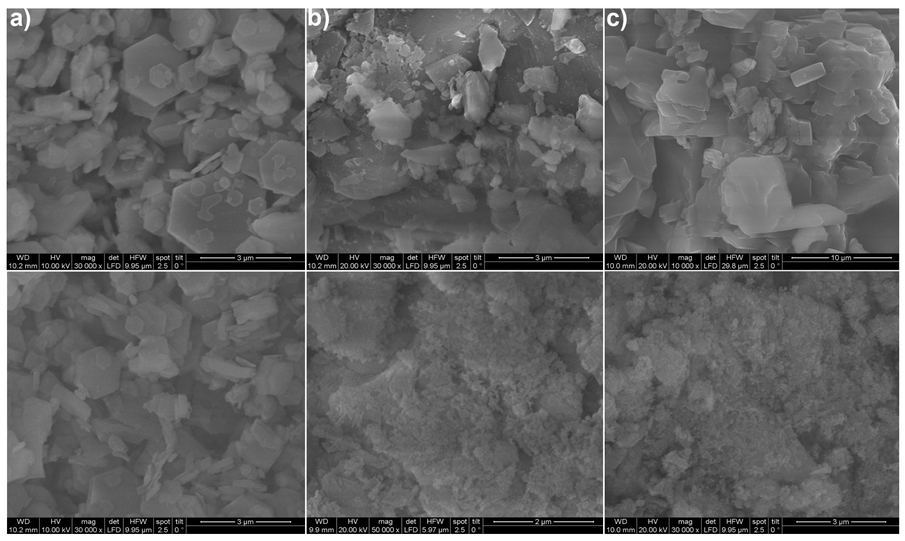

Fig. 1: SEM-pictures of (**a**) $Mg(OH)_2$, (**b**) $MgCO_3$, (**c**) $MgC_2O_4 \cdot 2\ H_2O$ before calcination (first row) and after calcination (second row)

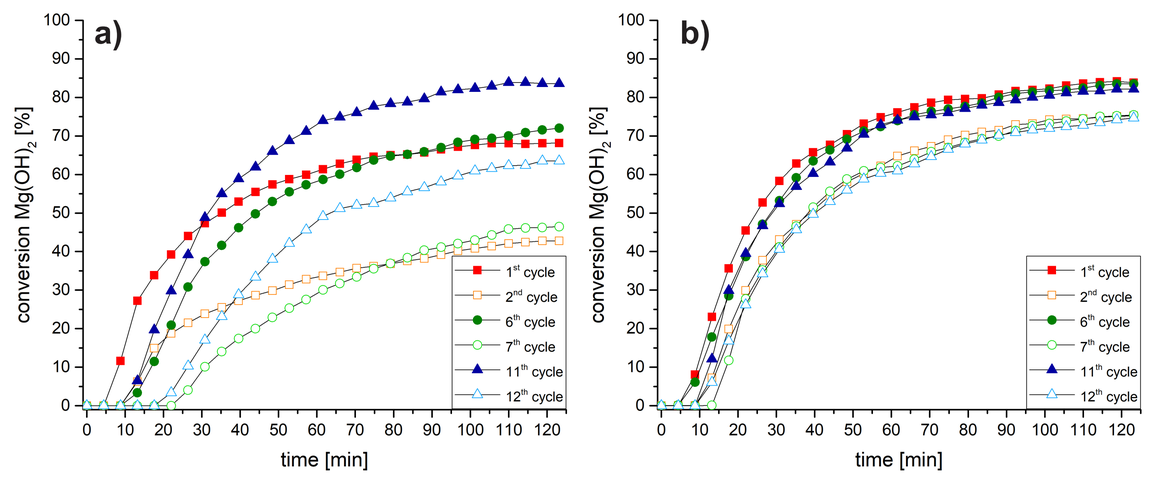

Fig. 2: Selected conversion rates from a series of 15 consecutive calcination / hydration cycles, including two regeneration steps in liquid water after the 5th and the 10th cycle. **(a)** $Mg(OH)_2$-originating MgO after regeneration **(b)** $MgCO_3$-originating MgO after regeneration

The particle morphology of the materials changes during calcination (figure 1, second row), leading to three differently textured MgO-samples. Whereas for using $Mg(OH)_2$ as the precursor material (figure 1a) calcination results in an apparently unchanged particle morphologies, the MgO crystallites obtained from both $MgCO_3$ (figure 1b) and $MgC_2O_4 \cdot 2\ H_2O$ (figure 1c) precursors are characterized by a clear surface fragmentation, which can be attributed to larger degree of structural reconstruction on the release of volatile components. In contrast, the H_2O release from $Mg(OH)_2$ to MgO follows a simple change from hcp to ccp arrangement of the octahedral subunits and hence preserves the particles in its shape to a large extent.

Conclusions

The results reported herein confirm, that the reactivity of MgO towards rehydration is strongly correlated to origin and physicochemical history of the material - an aspect so far neglected in the research on TCES materials.The correlation between chemical history and performance of storage materials may stimulate additional to coating, chemical dotation [2], etc...the considerationof a further, easily tunable parameter for the research on novel TCES materials.

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[2] D. Müller, C. Knoll, T. Ruh, W. Artner, J.M. Welch, H. Peterlik, E. Eitenberger, G. Friedbacher, M. Harasek, P. Blaha, K. Hradil, A. Werner, P. Weinberger, Adv. Sustainable Syst. (2018) 2, 1700096