Hydrogen production by a two-step water-splitting cycle based on Zn/ZnO redox reactions

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PhD starting date :	**01.09.2005**	Laboratory address :	**Sonneggstrasse 3 CH-8092 Zürich**

The production of solar hydrogen via a two-step water-splitting cycle is considered, where ZnO is reduced in a first step to Zn by solar thermal energy, and hydrogen is produced in a second, non-solar step by hydrolysis of Zn. For the first step a cylindrical cavity-receiver that is subjected to concentrated solar radiative power is used. It contains a tubular absorber which serves as reaction chamber and is subjected to incoming solar radiation and thermal radiation emitted from the surrounding cavity. The reactor was tested in batch mode, where ZnO-plates were dissociated in a temperature range of 1790 K to 1975 K. Numerical heat transfer analysis is applied to the cavity receiver, employing the Monte-Carlo ray-tracing technique for the radiative flux distribution and the finite difference method for the steady-state energy equation. Simulations include batch mode as well as continuous mode processes. For the second step, which is thermodynamically favorable below 1490 K, a novel aerosol-flow reactor is used. The process encompasses formation of Zn-nanoparticles by quenching a Zn(g)-laden gas flow to reach oversaturation and thus condensation. In-situ chemical reaction releasing H_2 and forming ZnO follows. This simultaneous synthesis of H_2 and ZnO-nanoparticles is investigated experimentally. Product characterization is performed by measuring the composition of the gaseous products by gas-chromatography. Further the solid products on the reactor outlet filter and the reactor walls are analyzed by means of X-ray diffraction (XRD) and nitrogen adsorption (BET – Brunauer, Emmet and Teller surface area theory). Emphasis is placed on understanding the effect of process parameters on product characteristics and H_2 conversion efficiency.