Solar Hydrogen Production

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Abstract
In fact, hydrogen can only be considered as an environmentally friendly and sustainable alternative if it is produced from renewable energies in large quantities without harmful pollution at reasonable costs. To establish a transition towards a „green fuel” concentrated solar energy replaces fossil fuels for heat supply at first. Thermo-chemical cycles are one of the most promising processes, so that fossil fuels will be replaced by water as feedstock additionally. From several hundred cycles reported in literature, the Hybrid-Sulphur cycle and the metal oxide based cycle have good prospects for the long-term future. Both processes are investigated within the European Projects HYTHEC, HycycleS and HYDROSOL (1+2) respectively.

1 Introduction
Hydrogen is acclaimed to be a promising energy carrier in the future. Today, it is predominantly produced as a by-product in chemical industry or refinery processes as well as by fossil fuels causing climate changing emissions. Produced from renewable energy, hydrogen is seen as a future secondary energy carrier, which can become an important substitute for fossil fuels for the next generations. If water and renewable energy, such as solar radiation, can be used for hydrogen production, then the energy cycle is closed.

2 Hydrogen production processes
Apart from the still very costly procedure of electrolysing water by means of renewable electricity, the technologies required for sustainable hydrogen production are not yet ready for use. But today, intense research work is underway. The cheapest way of transforming solar energy into hydrogen is called Solar Steam Reforming. This process uses methane and solar heat at a temperature of above 700°C, to produce hydrogen and CO. Using biogas instead of methane, this process can even be rendered CO-neutral. By using water as feedstock and by applying solar energy as the driving energy for its decomposition, the production of hydrogen becomes almost free of emissions and almost free of the consumption of fossil fuels. A mature technology in that respect is the alkaline electrolysis of water, which is environmentally benign if “renewable” electricity is used, for example from photovoltaic and solar thermal power plants. Another possibility is the splitting of water divided into thermo-chemical cycles. Water is converted into hydrogen and oxygen by a series of thermally driven chemical reactions. This takes place at temperatures of around 1000°C. In these cycles all the deployed chemicals apart from water that is transferred into hydrogen and oxygen are regained and recycled.

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Figure 1: Solar Driven Processes for Hydrogen Production and Solar Hydrogen Production scheme

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3 Thermo-chemical processes as promising option

DLR’s research is focused on two thermo-chemical cycles. One is the Hybrid-Sulphur cycle, where solar energy is used to transform $\text{H}_2\text{SO}_4$ into $\text{SO}_2$ and oxygen. $\text{SO}_2$ solved in water is electrolysed with significantly lower energy input than water itself, producing hydrogen and $\text{H}_2\text{SO}_4$ again. The other cycle uses metal oxides. These, when heated to about 800°C, split water molecules that come into contact by integrating the oxygen into their lattice. Hydrogen can be easily extracted. After saturation of the lattice the metal oxide is regenerated by heating it beyond 1000°C. DLR and its partners have successfully demonstrated this cycle in the solar furnace in Cologne.

![Figure 2: Metal oxide based and Hybrid-Sulphur thermo-chemical cycle reaction scheme](image)

4 Conclusion and Outlook

Within the second phase of the HYDROSOL project a 100 kWth pilot plant will be installed at Plataforma Solar de Almería (Spain) in 2008. All preparations at the tower platform concerning the periphery have been completed in 2007. The reactor was subjected to first Start-up tests; thermal tests will be carried out soon.

Concerning the sulphur based processes; next steps towards massive solar thermal hydrogen production are the investigation and troubleshooting concerning heat provision, suitability of materials and components as well as product separation. This work will be done within the HycycleS project, started on January 1st of 2008.

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Literatur
