OTTO VON GUERICKE UNIVERSITÄT MAGDEBURG

Faculty for System-and Process Engineering

Literature Survey

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Solar Hydrogen Production

Lecture: Sustainability Assessment For Bio-fuels

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1. ABSTRACT

Solar power can be utilized in different ways to produce hydrogen from phtovoltanics to thermolysis and from Hybrid systems to modified reforming. In this review paper we have reviewed current research in field for the hunt of new materials and smart ways of combining different methods. Also some economic aspects have been touched so that to understand whether of not production of hydrogen through thermolysis is feasible.

2. INTRODUCTION

Energy safety is becoming increasing concern over last decades in the wake of environment crises and search for alternative to conventional fossil fuel. Lot of technologies have shown hope, and one of them is use of hydrogen- namely the hydrogen fuel cell. However use of hydrogen isn't as clean as it sounds reason being most of hydrogen production (96%) comes from fossil fuels. Where as rest is done through electrolysis, even though electrolysis can be renewable, most of the time it is not and is inefficient to convert electricity into hydrogen; however there is lot of hopes improvement.

One of the better solution is then to convert abundant solar energy directly into hydrogen, or combination of electrolysis and thermolysis to improve cost, sustainable and production. In this review paper we have studied current development, challenges and promises for the same

3. THERMOCHEMICAL PROCESSES.

There are several ways to harness solar power and store it in the form of chemical energy as hydrogen production. A figure below shows 5 ways of doing the same.

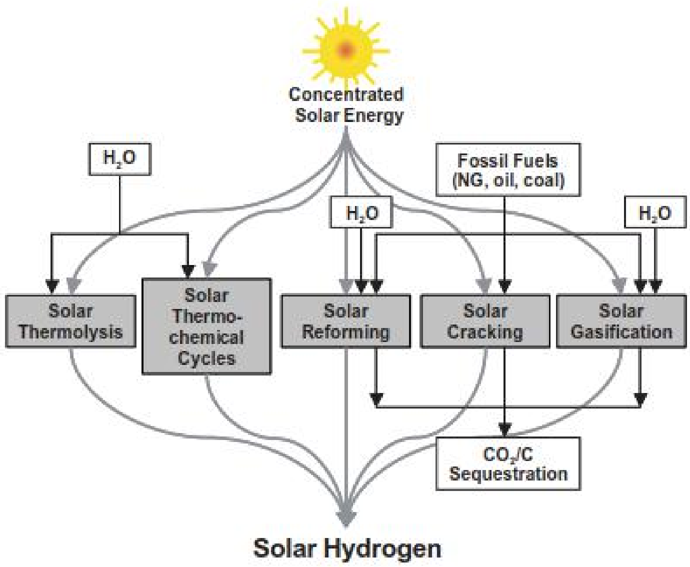

Fig 1: Different ways of producing solar Hydrogen [2]

Dissociation of water using enormous heat, and splitting (dissociation) in single-step is known as water thermolysis.

$$H_2O \rightarrow H_2 + 0.5\ O_2 \qquad (1)$$

the temperature needed for the reaction exceeds 2600K, for obtaining efficient amount. Therefor heliostats are used to to obtain high temperature through sun radiation. Although it is possible to obtain such a high temperature using solar heliostats, there are several losses to be considered. Namely Spillage factor which attributes to irradiaton losses from heliostats to receiver.

Fig 2 Solar Heliostat arrangement. [2]

Above figure 2 shows typical arrangement of heliostats and the receiver tower. This high temperature heat is then captured in various ways, from molten salt for direct evaporation of water to high temperature and pressure. Following section we will see various innovative ways to harness this high temperature radiation.

4. DISSOCIATION OF SEA WATER.

Large scale production is very much possible at through direct splitting of sea water. However chloride corrosion posses challenge. Therefore materials capable of avoiding it would solve need for fresh water for hydrogen production. Studies for the alternative material has been thus done extensively *[6] Y. Kuang et al*, .

Chloride anions are the main reason of concern when dealing with seawater. The oblivious solution is then to desalination of sea water. But to avoid the high cost corrosion resistance electrodes must be made. The authors have made NiFe/NiSx -Ni foam anode which shows some promising result by avoiding chloride corrosion. Previously IrO2 -Ti were used and tested however it was associated with high cost. Yielding to the results it shows that activated Ni anode proved it stability under various circumstances. With continuous current density. This research proves scope of new materials that can be used to improve existing technology.

5. DISSOCIATION OF PH NEUTRAL WATER

Although most of the research has been done on the water spitting, dissociation of pH neutral water is not touched much. So called artificial photosynthesis *F. A. Chowdhury* et al *[4]* can be used on the pure water to produce hydrogen and oxygen simultaneously, Photocalalytic and PEC both needs 4 photons to dissociate water. $H_2O \rightarrow H_2 + 0.5\ O_2$

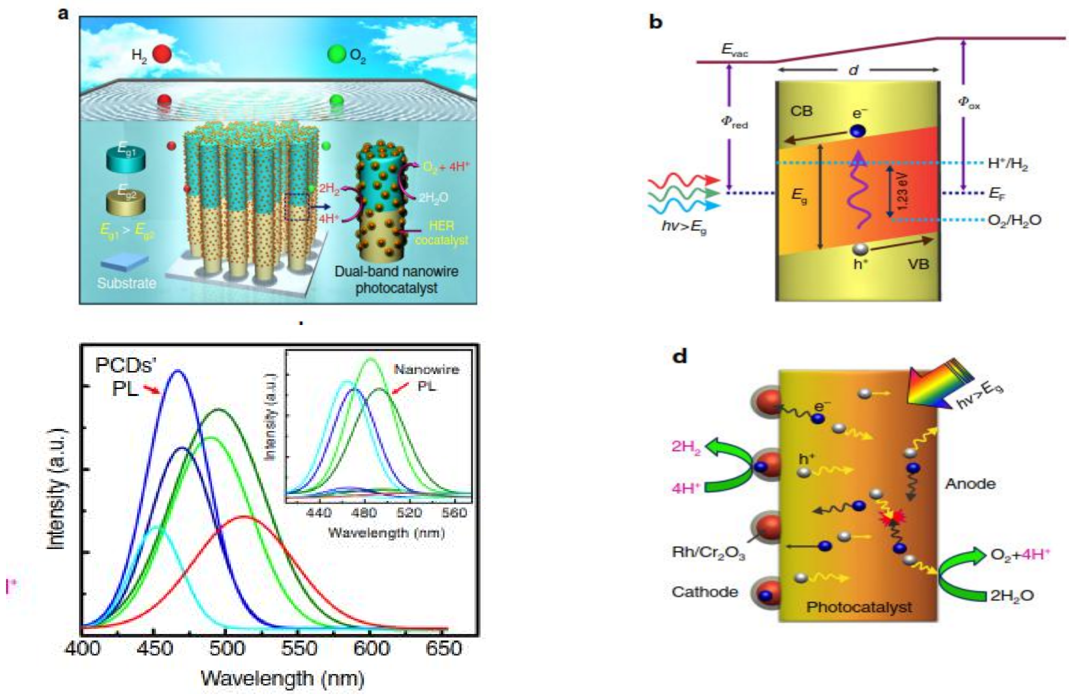

Fig 3a: Hydrogen production by artificial photosynthesis, 3b: Energy level of water molecule, 3c: Utilized wavelength spectrum of solar rays, 3d: typical reaction on nanowire catalyst [4]

The multiband GaN/InGaN nano-wire which is axially symmetric and nonostructures were randomly textured/ The photon absorption path- the energy band gap as shown in fig [3b] can further be varied along vertical direction, resulting multiband photo-catalyst which increases the efficiency of solar radiation. As shown is fig [3c] not all the part of radiation is utilized in redox reaction. So this new type of catalyst promises much higher efficiency. *F. A. Chowdhury et al [4]*

6. SOLAR THERMOCHMICAL HYDROGEN PRODUCTION-CHALLENGE OF OXYGEN PUMPING .

Solar thermochemical is yet another process for efficiently mass producing renewable hydrogen. And large improvements can be made in high temperature reduction steps, to avoid corrosion of redox material hydrogen produced must be separated and removed. But this also causes heavy load on energy efficiency of the process. Currently there are two different ways to remove the oxygen, first use of sweep gas and second vacuum pumping. But this process can further be improved. The theoretically study of main mechanism which intern predicts thermochemical oxygen pumping effect shows the same S. *Brendelberger et al* [9]. The authors experimented with different material and found CoO as optimum pumping material. It aslo matched the theoretical model that they developed showing validation of theoretical model. Oxygen pumping using materials like SrFeO3 reduces energy consumption greatly with respect to mechanical pumping. But this kind of pumping is only useful for pressure below 1 mbar. However other materials can outperform CoO like perovskites especially if probelm of efficient heat recovery is solved. Overall it seems problem of oxygen pumping can be solved using different material then using mechanical arrangements thus improving further the efficiency of solar thermal hydrogen production.

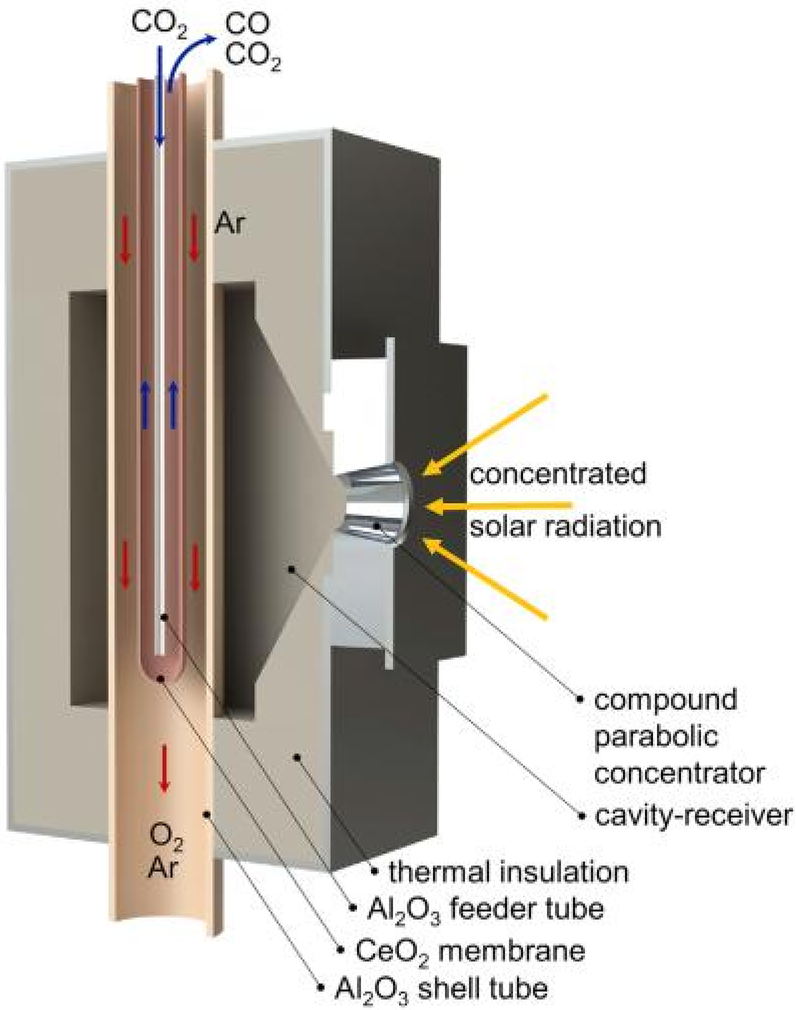

Fig 4 Solar concentrator for obtaining High temperatures for thermolysis [1]

7. OTHER WAYS OF PRODUCING HYDROGEN BY SOLAR ENERGY

Other than water splitting traditional ways of hydrogen production can be modified by introducing solar energy input for making process to reduce carbon impression of production. Fig 1 shows three of such process, solar reforming, solar cracking and solar gasification. One of the other approach *L.* is splitting of CO_2 for manufacturing of CO and O2 *Arribas et al* [3] . these research focuses on thermolysis of CO2 at high temperature and pressure. Resulting stable solar fuel production and validating use of solar energy as viable option for stable alternative for thermolysis process. Fig 4 shows implementation of setup for thermolysis of CO2. although it is not for water similar implementation are possible with obvious modifications.

Yet another implementation is combining geothermal and solar energy for reliable output of hydrogen *C. Ameur et al* [1]. combined three different types of energies- Silicon solar cells, mini-turbine and geothermal energy have been experimented *C. Ameur et al* [1]. In hybrid system temperature of water vapour are further increased using solar panels by transforming electric energy into thermal using resistors along channel. Which results into temperature increases of vapour from 310c to 622c. which is stable for production of hydrogen. Table below shows amount of hydrogen production through such hybrid system using inputs H_2SO4 and CH_4.

Table 1: Hydrogen production through Hybrid solar-Geothermal plant [1]

Cycles for Hydrogen production.	**Hydrogen Productivity MJ/KgH2**	**Amount of Hydrogen production**
H_2SO_4 $SO_2+I_2+2H_2O \rightarrow H_2SO_4+2HI$ $H_2SO_4 \rightarrow SO_2+H_2O+1/2\ O_2$ $2H \rightarrow H2+I2$	295,500 MJ/KgH2	0,51 KgH2/day
CH4 $CH4+H2O \leftrightarrow CO+3H2$ $CO+H2O \leftrightarrow CO2+H2$	165MJ/KgH2	0,939 KgH2/day

8. CONCLUSION

In this review paper different methods of implementing solar energy in the production of hydrogen are reviewed, showing us that high temperature concentrated solar radiation can be utilized for less energy intensive process of hydrogen production. Not only dissociation pure water but the sea water splitting and solar reforming are viable option. With the development of new materials for reducing oxidation of materials due to oxygen formed during the process, and modified catalyst it is possible to further reduce the cost of production, as in one case from 38.83 €/Kg to 13.06 €/ kg [2]. however investment costs are much higher with respect to traditional methane reforming. However main competitor to solar hydrogen production still remains phtovoltanics powered electrolysis, which might reach cost of production 2€/kg in coming years.

9. REFRENCE LIST

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