



# **Materials for Energy Storage**

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# Hydrogen Production from Biomass

The capacity exists to produce hydrogen from different sources, for example: methane, propane, gasoline, light diesel, biodiesel, methanol, and ethanol, between others substances. Among the liquid sources to, in situ, produce hydrogen, ethanol is an excellent aspirant. Ethanol, a natural product produced with biomass, is a renewable, available, unproblematic to transport, biodegradable and a low toxicity source of energy. The steam reforming of ethanol is an outstanding alternative for hydrogen production, where the purpose of the process is to produce a large amount of hydrogen and carbon dioxide.

# Ethanol Steam Reforming with Zeolites

The ethanol steam reforming reaction applying Rh and Pd bifunctional ZSM-5, Y, L, mordenite catalysts is the following: firstly ethanol is converted into ethylene. Furthermore, ethylene reacts with hydrogen to form ethane. Then, ethane is steam reformed according to the following reaction:



Finally, with the help of the water shift reaction:



The produced  $CO$  is eliminated.

# Water Splitting Process with Quantum Boost

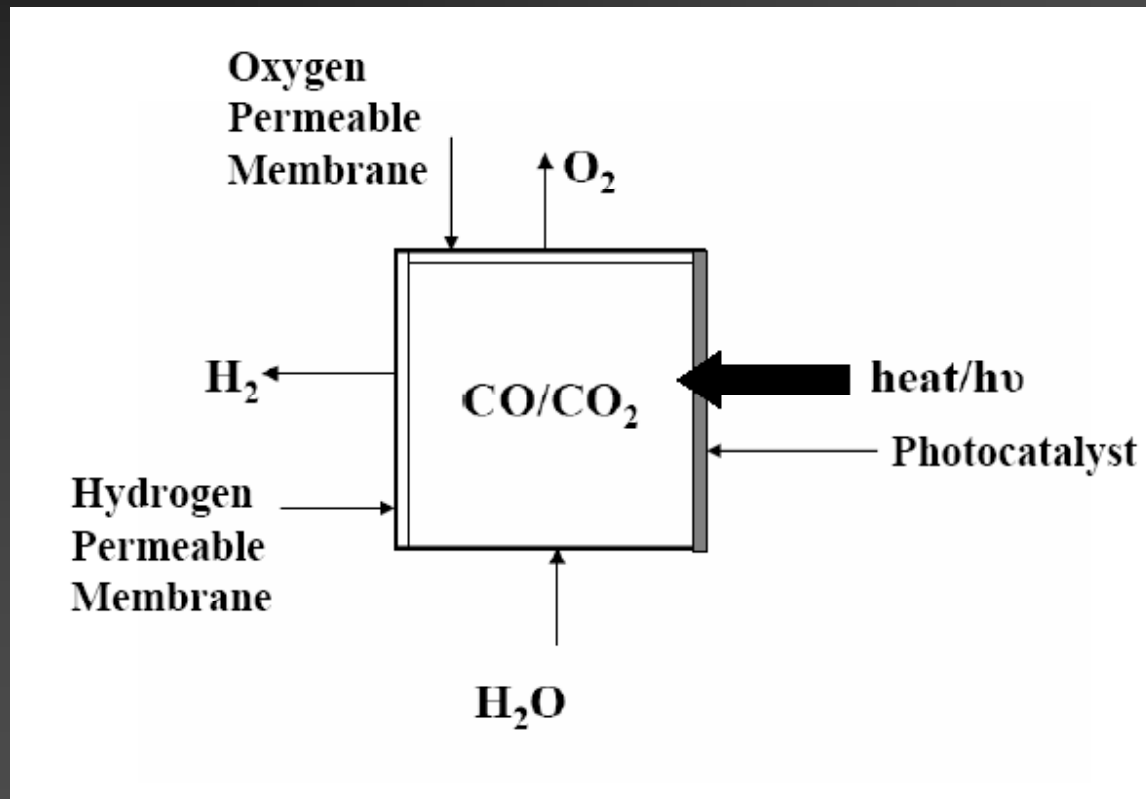
This approach is based on splitting water using a two-step high-temperature cycle that include one step utilizing solar (visible and/or near-UV) photons according to the following scheme [1]:



A quantum boost exercised by the solar near-UV and visible photons conducts to  $\text{CO}_2$  thermal dissociation at the temperature range of 1500-2500 K easily attainable by solar concentrators. In addition reaction “2” is the very well-known water gas shift reaction

1. R. Taylor, C. Mullich, A. Raissi and R. Roque-Malherbe, Solar High-Temperature Water-Splitting Cycle With Quantum Boost, Solicitation Number DE-PS36-03GO093007, to the Department of Energy Program: Hydrogen Production Using High Temperature Thermochemical Water Splitting Cycles, SAIC-FSEC-UT, 2004.

# Scheme of the System for Water Splitting with Quantum Boost



# Hydrogen Purification

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The purity of the hydrogen stream from the extraction process is an important consideration, and there are enormous technical challenges to overcome. Since lower the cost of hydrogen production is a major need

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# Hydrogen Permeable Membranes

In some oxides, during hydrogen absorption, the hydrogen molecule is first dissociated in the surface of the oxide; then, the adsorbed hydrogen atoms are ionized and incorporated directly into the material as protons and electrons, through interaction with the oxide ions and also, by another mechanism, i.e., interstitially located in the tetrahedral and octahedral sites of the perovskite unit cell [2]. The fundamental proton transport mechanism in oxides is the free migration mechanism; where the proton, moves by cation hopping or jumping between immobile host oxygen ions. That is, the proton diffuses by way of molecular orientation and proton displacement or cation (proton) hopping.

2. S. Nieto, R. Polanco and R. Roque-Malherbe, *Journal of Physical Chemistry C*, 111, (2007) 2809.

# **Synthesis and Characterization of Zeolite Based Porous Ceramic Membranes [3,4]**

**Porous membranes were synthesized using a ceramic methodology. The membranes were produced by thermal transformation of natural clinoptilolite. The membranes were further transformed by hydrothermal synthesis to obtain materials covered with an  $\text{AlPO}_4\text{-5}$  molecular sieve. Then, novel, inexpensive, strong, high permeation rate, and high temperature membranes were produced with natural clinoptilolite, a low cost and available material.**

**3. R. Roque-Malherbe, W. del Valle, F. Marquez, J. Duconge and M.F.A. Goosen, Separation Science and Technology, 41 (2006) 73.**

**4. R. Roque-Malherbe, Adsorption and Diffusion of Gases in Nanoporous Materials, CRC Press-Taylor & Francis, Boca Raton, FL, USA, 2007.**



# Hydrogen Storage

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In order to establish one of the components of the hydrogen economy, i.e., transportation, during the last years the development of transportable reversible systems for high capacity hydrogen storage had a great consideration. Hydrogen storage, in general, can be defined as its confinement for delivery, and use; this process, needs tanks for both gases, and liquids at ambient, and high pressure, and includes reversible, and irreversible systems

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# Hydrogen Storage Options

The direct techniques for hydrogen storage are liquid hydrogen at very low temperatures and gas storage at extremely high pressures, but, liquid and compressed hydrogen are dangerous, energy intensive, and requires a big tank volume. Other options has been metal-hydride systems, but this method is characterized by high cost, and weight. Hence, adsorption on nanoporous materials, such as: zeolites, metal-organic frameworks, active carbons, carbon nanotubes, mesoporous molecular sieves, pillared clays and silica, as systems for hydrogen storage could be a solution

# Development of Adsorbents for Hydrogen Storage [5-10]

We have obtained silica nanostructured materials showing extremely high specific surface area, i.e., up to 1,200 m<sup>2</sup>/g. Our results shows that these materials could adsorb about 11 wt. % of hydrogen contained in the NH<sub>3</sub> molecule. The NH<sub>3</sub> could be later decomposed into H<sub>2</sub> and N<sub>2</sub>, with commercial catalysts [4-10].

5. R. Roque-Malherbe, Physical Chemistry of Materials Energy and Environmental Applications, CRC Press, Boca Raton, FL, 2009.
6. F. Marquez and R. Roque-Malherbe, Journal of Nanoscience and Nanotechnology, 6 (2006) 1114.
7. R. Roque-Malherbe and F. Marquez, Surface and Interface Analysis 37 (2005) 393
8. R. Roque-Malherbe and F. Marquez, Materials Science in Semiconductor Processing 7 (2004) 467
9. R. Roque-Malherbe, F. Marquez, W. del Valle and M. Thommes, Journal of Nanoscience and Nanotechnology, 8 (2008) 5993
- .10. R. Roque-Malherbe and F. Marquez, Silica Mesoporous Materials, US Patent WO2006052917 – May 18, 2006. IPC: C01B33/12; C01B33/00.