Production of Hydrogen for Clean and Renewable Sources of Energy for Fuel Cell Vehicles

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Project ID # PDP-58

Overview

Timeline

- Project start date: ~ June, 2005
- Project end date: ~ June, 2006
- Percent complete: 0%

Budget

- Total project funding
  - DOE share: $1,000,000
  - UT share: $136,000
  - ODOD share: $519,000
- Funding received in FY04 to date : 0
- Funding for FY05: $0

Overview

Barriers Addressed

- DOE MYPP Objective for Photoelectrochemical Production of Hydrogen
  - By 2015, demonstrate direct PEC water splitting with a plant-gate hydrogen production cost of $5/kg projected to commercial scale.
- Technical Targets:
  - 2010: STH Eff >9%; Durability >10,000 hours; Cost < $22/kg
  - 2015: STH Eff >14%; Durability >20,000 hours; Cost < $5/kg
- PEC Hydrogen Generation Barriers -- MYPP 3.1.4.2.3
  - M. Materials Durability
  - N. Materials and Systems Engineering
  - O. PEC efficiency

Partners

- Bowling Green State University
- Ohio Department of Development
- Midwest Optoelectronics, LLC

Objectives

- To expand a research program directed to the development of clean and renewable domestic methods of producing hydrogen. This program will provide industry with ways to produce hydrogen in an environmentally sound manner to support the use of fuel cells in vehicles and at stationary locations.

Approach - Tasks

Task 1: Integrated hydrogen facility

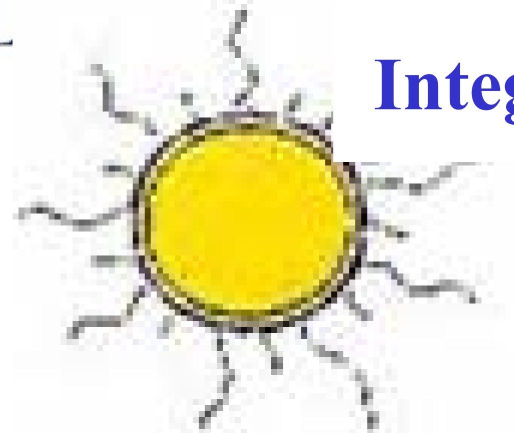
Task 2: Development of substrate-type PEC cells

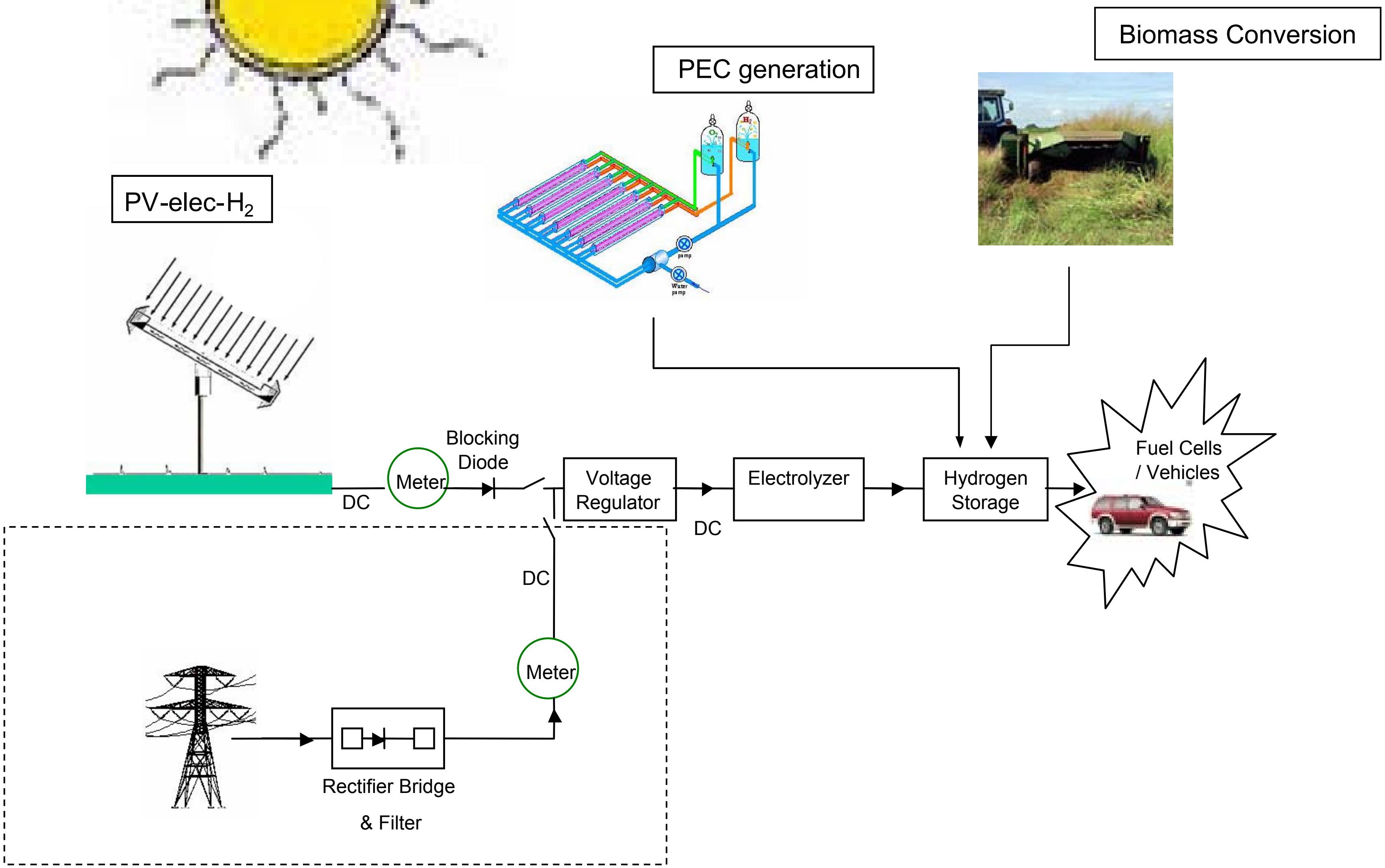
Task 3: Development of advanced materials for immersion-type PEC cells

Task 4: Hydrogen production through conversion of biomass-derived wastes

Task 5: Economic analysis of integrated system

Integrated hydrogen facility





Task 1: Integrated hydrogen facility

Demonstration of a solar-powered fuel cell vehicle. While this task will involve some research elements, this is largely a demonstration of technologies. The task will include

- 12 kW PV array installation (First Solar thin-film CdTe on glass modules)
- Integration of the solar array with a pressurized electrolyzer (or an integrated electrolyzer plus compressor)
- DC voltage regulation system for direct PV-to-electrolyzer power feed
- Hydrogen storage options include storage in carbon fiber cylinders or nickel metal hydride
- Retrofit of an electric vehicle, envisioned to be of a GEM-style, with a Ballard 5 kW liquid-cooled fuel cell, including all balance of plant components

This task is to be heavily cost shared with funds from Ohio Department of Development and from University of Toledo.

Task 2: Development of substrate-type photoelectrochemical cells

To develop and improve a substrate-type photoelectrochemical cell for hydrogen generation. In such a PEC cell, a triple-junction amorphous silicon photoelectrode deposited on a conducting substrate is integrated in a PEC cell, in which the hydrogen and oxygen compartments are both behind the photoelectrode and are separated by a membrane. Specific research activities include:

- Development of improved encapsulation materials and process
- Optimization of grid configuration and installation process
- Investigation of effect of various cell dimensions in the oxidation and reduction compartments
- Design of improved membrane holder to prevent hydrogen and oxygen from intermixing, and
- Study of various electrolyte inlet and gas/electrolyte outlet configurations

Task 3: Development of advanced materials for immersion-type photoelectrochemical cells

- Deposition of a transparent, conducting and corrosion resistant coating for PEC photoelectrode.
- Deposition of photoactive semiconductor as the top component cell absorber layer in a multi-junction PEC photoelectrode
- Characterization and modeling of PEC materials and photoelectrodes

Deposition of a transparent, conducting and corrosion resistant coating for PEC photoelectrode

The objective of this subtask is to develop a transparent, conducting and corrosion resistant (TCCR) material that can be made at low temperature (below 250°C) using a low-cost thin-film deposition technique, and in addition has the following properties: high optical transmission in the visible wavelength range, high electrochemical stability in the electrolyte, and sufficient conductivity for transport of charge carriers, such that an ohmic contact is formed with both the electrolyte and the topmost layer of the a-Si solar cell.

Materials to be studied under this task will include:

- p-type a-SiC TCCR layer
- fluorine-doped tin oxide (SnO_2:F)
- TiO_2 based alloys
- polymer nanocomposite

Deposition of photoactive semiconductor as the top component cell absorber layer in a multi-junction PEC photoelectrode

The objective of the task is to develop a photoactive semiconductor material that

1) is stable in electrolyte both in dark and under illumination,
2) forms a high-quality rectifying junction with electrolyte and an ohmic contact with the tf-Si layer underneath;
3) generates at least 7.5 mA/cm^2 current so that it can be matched with the middle and bottom component solar cells in an a-Si based triple-junction stack, and
4) is deposited at low temperature (< 250^{o}C) using a low-cost deposition method.

Materials to be studied under this task will include:

- polycrystalline CdS based II-VI compounds
- TiO_2 based materials such as $SrTiO_3$

Characterization and modeling of PEC materials and photoelectrodes

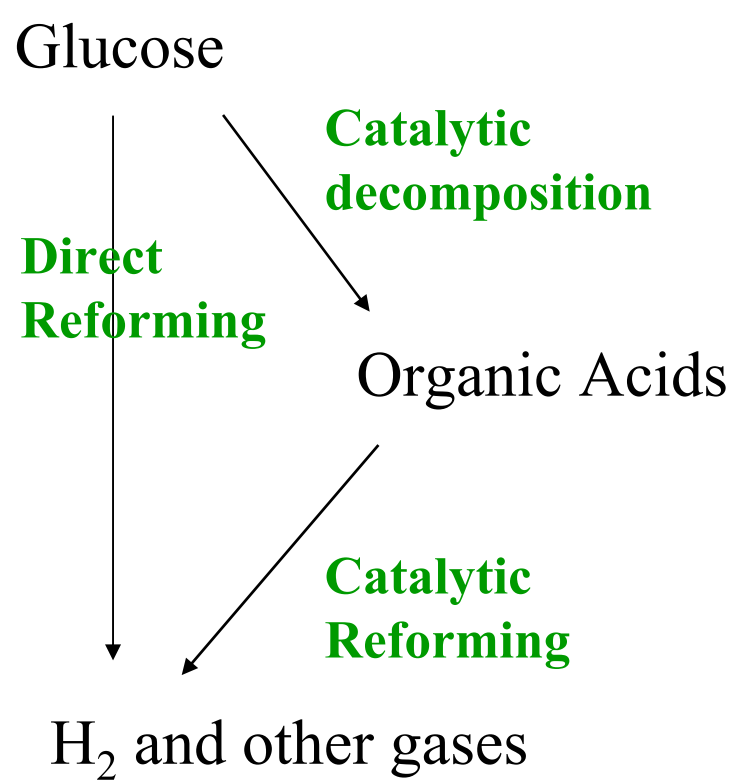
- Real time characterization of corrosion resistance using Mueller matrix ellipsometry
- Modeling of PEC photoelectrode

Task 4: Hydrogen production through conversion of biomass-derived wastes

Task 4a: Identify the products of fermentation

Task 4b: Catalytic reforming

Cellulose, Starch, or other biomass → **Pre-treatment of solubilization** → Glucose



- Direct conversion of biomass derived resources to hydrogen
- Low temperature (< 300°C)
- Pressurized, aqueous phase
- Evaluate
  - Feedstock opportunities
  - Reaction conditions
  - Catalyst stability

Task 5: Economic Analysis of Integrated System

- Cost analysis:
  - Economic analysis of different types of PEC cells
  - Operating and equipment cost at each step
  - Cost projections considering
    - Economies of scale
    - Technology advancements
- Efficiency: energy loss at each step and across the system
- System Reliability

Hydrogen Safety

The most significant hydrogen hazard associated with this project is:

- Hydrogen generated from PV/electrolyzer and PEC panels needs to be appropriately handled.

Our approach to deal with this hazard is:

- Follow related federal and state guidelines for handling the hydrogen generated in our PEC panels
- Provide safety training to all personals handling hydrogen

Other significant hazard related to this research is the handling of hazard gases such as PH_3, GeH_4, SiH_4, BF_3, H_2 during the deposition of semiconductor layers for the photoelectrodes

Have installed comprehensive safety measures for the handling of toxic gasses including

- toxic gas monitors probing various areas of deposition machines.
- gas monitor that can be accessed remotely and is monitored by police department.
- 24-hour training course provided to system operator.
- Visit by Toledo Fire department to discuss various safety issues and preventive measures.

UT Key Participants

Office of Research

- Frank Calzonetti, Vice Provost for Research, Graduate Education and Economic Development

College of Arts and Sciences

Department of Physics and Astronom

- Xunming Deng, Professor
- Alvin Compaan, Professor and Chair

Department of Chemistry

- Dean Giolando, Professor

College of Engineering

Department of Chemical and Environmental Engineering

- Martin Abraham, Professor

Department of Electrical Engineering and Computer Science

- Thomas Stuart, Professor

College of Business

Department of Information Operations and Technology Management

- Mark Vonderembse, Professor

Collaborators

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