IV.F.10 Production of Hydrogen for Clean and Renewable Sources of Energy for Fuel Cell Vehicles*

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Contract Number: DE-FG36-05GO85025

Subcontractor:
Bowling Green State University, Bowling Green, OH

Start Date: May 1, 2005
Projected End Date: July 31, 2007

**Congressionally directed project*

Objectives

- To expand research directed to the development of clean and renewable domestic methods of producing hydrogen. This project develops and evaluates methods of producing hydrogen in an environmentally sound manner to support the use of fuel cells in vehicles and at stationary locations.
- To address DOE program objectives in the general area of renewable hydrogen production. It addresses specifically high-efficiency and low-cost production of hydrogen using photoelectrochemical (PEC) methods.

Technical Barriers

This project addresses the following technical barriers from the Hydrogen Generation by Water Electrolysis and Photoelectrochemical Hydrogen Production sections (3.1.4.2.2 and 3.1.4.2.6) of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

- I. Grid Electricity Emissions
- J. Renewable Integration
- AP. Materials Efficiency
- AQ. Materials Durability
- AR. Bulk Materials Synthesis
- AS. Device Configuration Designs

Technical Targets

Solar power is an excellent source of renewable energy generated by the conversion of sunlight into electricity via solar cells. When solar cells produce electricity, the power they produce can split water into hydrogen and oxygen. This project includes two major components: 1) a research and demonstration project wherein photovoltaic electricity drives the production of hydrogen from water in a pressurized electrolyzer, which is then stored in gas cylinders for use in powering a fuel cell delivering traction power for a small utility vehicle; and 2) a research project wherein hydrogen is produced using renewable methods including PEC generation of hydrogen from water.

Approach

Task 1. Integrated Photovoltaic (PV)-Hydrogen-Fuel Cell Facility

Demonstration of a fuel cell vehicle operating on hydrogen produced from solar power. While this task will involve some research elements, this is largely a demonstration of the integration of technologies. The task will include the installation of a 12 kW PV array installation, integration of the solar array with a pressurized electrolyzer, DC voltage regulation system for direct PV-to-electrolyzer power feed, and retrofit of an electric vehicle, including integration of all balance of plant components.

Task 2. Development of Substrate-Type PEC Cells

Development and improvement of a substrate-type photoelectrochemical cell for hydrogen generation. Areas of research activities include: encapsulation materials and process, grid configuration and installation process, effect of various cell dimensions in the oxidation and reduction compartments, improved membrane holder to prevent hydrogen and oxygen from intermixing, and electrolyte inlet and gas/electrolyte outlet configurations.

Task 3. Development of Advanced Materials for Immersion-Type PEC Cells

Areas of research include deposition of a transparent, conducting and corrosion resistant coating for PEC photoelectrodes and deposition of photoactive semiconductor as the top component cell absorber layer in a multi-junction PEC photoelectrode. This research also includes real time characterization of corrosion resistance using Mueller matrix ellipsometry and modeling of a PEC photoelectrode.

Task 4. Hydrogen Production Through Conversion of Biomass-Derived Resources

The conversion of biomass-derived resources through integrated biological and chemical processes into hydrogen primarily for use with SOFC systems will be demonstrated. This research task will evaluate rates of conversion and the levels of production that can be achieved through system optimization.

Task 5. Cost and Performance Analysis of Integrated Hydrogen Systems

An economic assessment of the cost, efficiency, and system reliabilities of integrated hydrogen production systems will be conducted. A determination of the opportunity to use PV-produced hydrogen as the sole source for fueling a fuel cell vehicle will be assessed.

Accomplishments

- Obtained approval from University of Toledo (UT) Campus Beautification Committee and UT Facilities Planning Council for installation of a 12kW PV array in front of UT's Research and Technology Building One. The construction and installation purchase order has been issued and the facility is scheduled for completion by the end of September 2005. This array will feed power at 450-500 V_{DC} to grid-connected inverters until the electrolyzer is installed and the direct, low-voltage DC (~60V) power conditioning system is completed.
- Various TiO_2 based materials were investigated as transparent, conducting and corrosion-resistant materials for a-Si based photoelectrodes

- Studied the deposition of Co-doped TiO_2 using radio frequency co-sputtering of Co and TiO_2 in an O_2/Ar environment at the deposition temperature less than 250 C.
- Studied the deposition of Zr-doped TiO_2 using radio frequency co-sputtering of Zr with TiO_2 in an O_2/Ar environment.
- Studied the deposition of TiO_2/Fe_2O_3 using co-sputtering of TiO_2 and Fe_2O_3 in an O_2/Ar environment.
- Various iron (III) oxide (Fe_2O_3) are deposited using radio frequency sputtering for use as a photoactive semiconductor.
- Studied tantalum doped Fe_2O_3 by co-sputtering Fe_2O_3 and Ta in O_2/Ar environment.
- Studied indium doped Fe_2O_3 by co-sputtering In and Fe_2O_3 and in an O_2/Ar environment.
- Thus far, Fe_2O_3 shows very good stability while being produced at low temperatures (i.e., 250°C or lower); however, photocurrent response is relatively small and needs to be improved.
- Studied electroplating of Pt and RuO_2 materials for stable electrode applications. The materials were evaluated for corrosion resistance. The performance in terms of stability and reproducibility has been investigated.