IV.F.6 Critical Research for Cost-Effective Photoelectrochemical Production of Hydrogen

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Objectives

- To develop critical technologies required for cost-effective production of hydrogen from sunlight and water using thin film Si (tf-Si) based photoelectrodes.
- To develop and demonstrate, at the end of the 3-year program, immersion-type tf-Si based photoelectrochemical (PEC) systems with 9% solar-to-hydrogen efficiency with a lifetime of 10,000 hours and with a potential hydrogen cost below $22/kg.

Technical Barriers

This project addresses the following technical barriers from the Hydrogen Production section of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

- AP. Materials Efficiency
- AQ. Materials Durability
- AR. Bulk Materials Synthesis
- AS. Device Configuration Designs
- AT. Systems Design and Evaluation

Technical Targets

This project is focused on the development of photoelectrode materials and PEC cells that are required to achieve or exceed DOE's technical target of 8% solar-to-hydrogen efficiency and 1,000 hr durability by 2010, as stated in DOE's Multi-Year Research, Development and Demonstration Plan.

Approach

Two approaches are taken for the development of efficient and durable photoelectrodes for immersion-type photoelectrochemical cells. In the first approach, shown in Figure 1, triple-junction tf-Si based solar cells (a-Si/a-SiGe/a-SiGe or a-Si/a-SiGe/nc-Si) are used to generate the voltage bias and a transparent, conducting and corrosion resistant (TCCR) coating is deposited on top to protect the semiconductor layer from corrosion while forming an ohmic contact with the electrolyte.

In the second approach, shown in Figure 2, a hybrid structure in which two tf-Si based junctions (middle and bottom junctions of the present triple-junction tf-Si cell provide a voltage bias [around 1.1V]) and a third junction (the top junction) is a rectifying junction between a photo-active semiconductor and the electrolyte.

Five technical tasks are being performed in this project:

Task 1: TCCR coating for triple-junction tf-Si based photoelectrode

Task 2: Hybrid multi junction PEC electrode having semiconductor-electrolyte junction

Task 3: Understanding and characterization of photoelectrochemistry

Task 4: Fabrication of low-cost, durable and efficient immersion-type PEC cells and systems

Task 5: Fabrication of substrate-type PEC panels

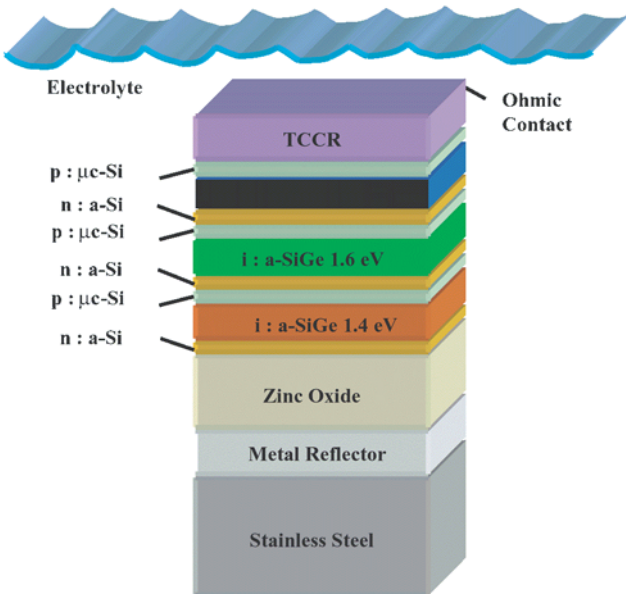

Figure 1. Schematic of PEC Electrode with TCCR Layer on Top of a-Si Triple Cell

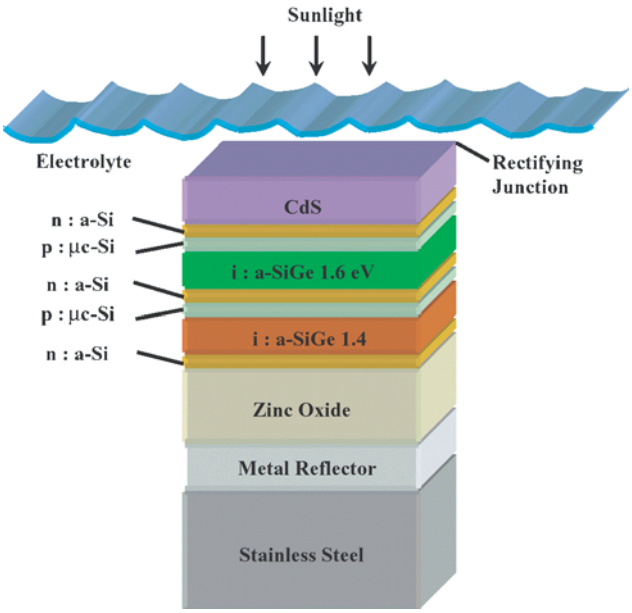

Figure 2. Schematic of Hybrid PEC Electrode with Photoactive Electrode (e.g., CdS) that Forms a Liquid Junction with Electrolyte

Accomplishments

- Studied the sputter deposition of TiO_2 based films (University of Toledo)
  - with different oxygen content
  - with different nitrogen doping
  - with different indium doping
- Performed sol-gel synthesis of zinc oxide films as TCCR material
- Completed design of a special test cell to be used for characterization of TCCR and photo-active semiconductor materials in device-like environment.
- Completed the initial design of a 4” x 12” immersion-type PEC cell
- Completed initial design of 4” x 12” substrate-type PEC cell
- Fabricated a preliminary 4” x 12” substrate-type PEC cell using triple-junction a-Si solar cell deposited on stainless steel substrate
- Explored various epoxies to avoid leak of electrolyte for substrate-type cell