CALIFORNIA STATE SCIENCE FAIR
2006 PROJECT SUMMARY

Name(s)

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Project Number

S0521

Project Title

A Novel Nanocrystalline Chlorophyll-Based Photoelectrochemical Cell:H2 Production via the Light-Driven Redox of Seawater

Abstract

Objectives/Goals

Hydrogen, a clean-burning fuel, has the potential to replace fossil fuels as the worlds# primary energy storage medium thus eliminating pollution and global warming. Current hydrogen generation systems have been unable to attain an effective balance of cost and efficiency. My aim was to develop a novel photoelectrochemical cell to cheaply and more efficiently produce hydrogen. The cell design, electron transfer mechanism, was modeled after nature#s PS I and PS II photosystems. In fact chlorophyll, designed by nature to photo-oxidize water intracellularly, was utilized as the primary light harvesting and redox molecule.

Methods/Materials

To serve as the electron transfer and reduction mechanism I formulated a procedure to coat a transparent, heat-resistant ceramic composite with conductive SnO2 glass successfully lowering the resistance to 3-5 ohms. Subsequently a TiO2 colloid was fused to the conductive glass in order to create a nanostructured TiO2 matrix. This allowed a large surface area for chlorophyll adsorption and serve as a suitable structural anchor for the chlorophyll. An orange leaf-acetone extraction produced the chlorophyll which was adsorbed to the TiO2 films. In order to determine the efficiency of the assembled photoelectrochemical cell, current and voltage were measured by the photoelectrolysis of seawater, in addition to capturing hydrogen gas via a self-built gas capture system. This was then coupled with free energy calculations and incident light intensity measurements to determine the efficiency of the cell.

Results

The data analysis revealed that the chlorophyll-based redox reaction yielded an average calculated efficiency of 17.9 % derived from eight H2 gas capture samples. Current-voltage measurements of 15 samples generated a maximum photocurrent of 1.10 mA with a maximum photovoltage of 0.541 V. Overall the highest observed solar-to-hydrogen efficiency was a respectable 0.875 %. In fact the chlorophyll-enhanced electrodes produced over 30 times the photovoltage of the TiO2 film controls.

Conclusions/Discussion

In essence, my results showed that the chlorophyll-based system produced hydrogen efficiently compared to the controls. I was able to demonstrate in a novel, self-constructed, photoelectrochemical cell (that mimics nature) that chlorophyll can be harnessed to photo-oxidize water for hydrogen production.

Summary Statement

A new chlorophyll-enhanced Ti(O)2 cermaic electrode modeled after photosynthesis was developed and successfully tested to determine its efficiency in hydrogen production by the photoelectrolysis of seawater.

Help Received

Parents helped assemble board, Mr. Figueroa and Mr. Garabedian provided equipment, Used lab equipment at California State University Fresno in Dr. Zhang lab. Creative Materials and DeGussa provided free materials